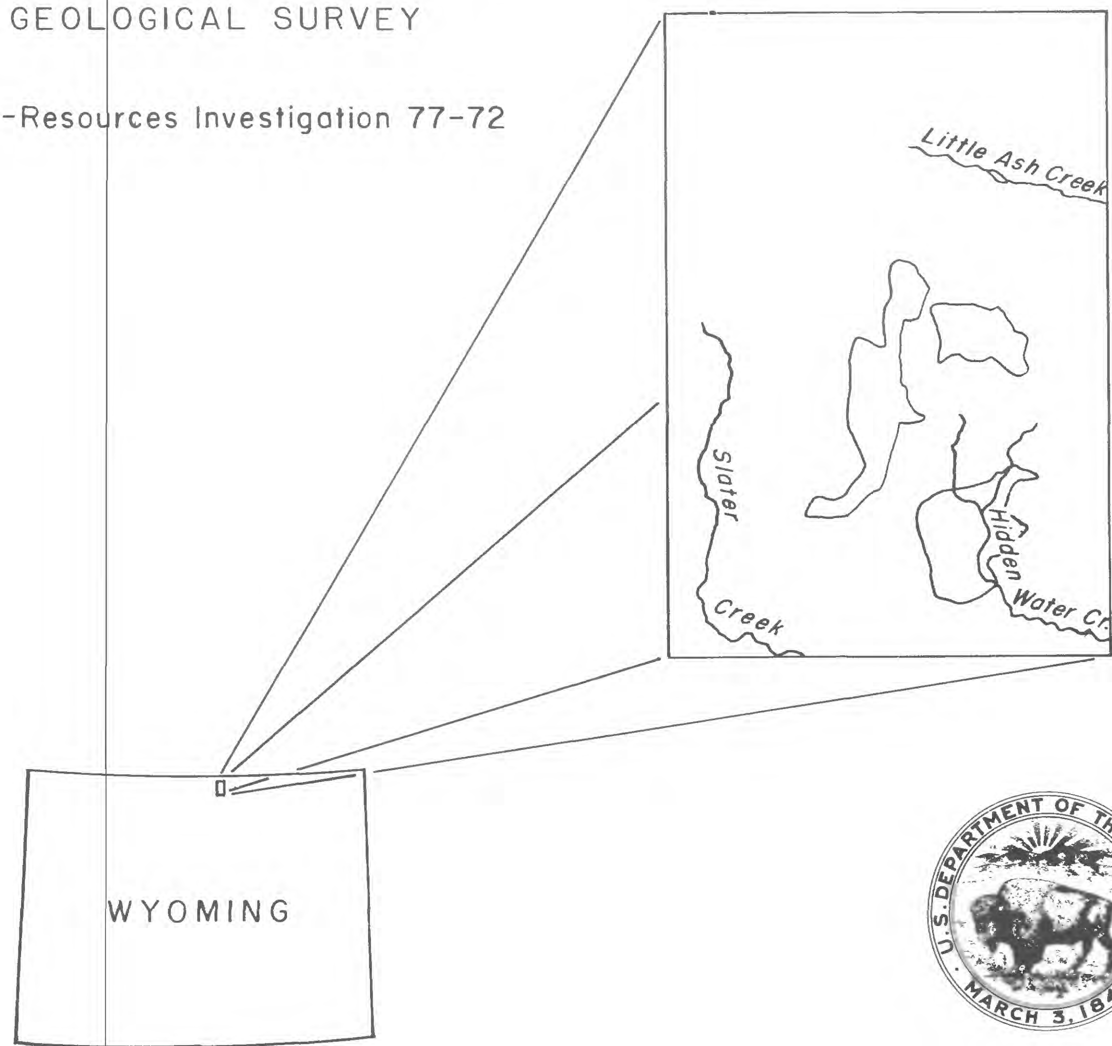
PHYSICAL, CHEMICAL, AND BIOLOGICAL RELATIONS OF FOUR PONDS IN THE HIDDEN WATER CREEK STRIP-MINE AREA, POWDER RIVER BASIN, WYOMING

U.S. GEOLOGICAL SURVEY

Water-Resources Investigation 77-72



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Dissolved oxygen concentrations were lower in the ponds within the mined area. Most of the major ions (calcium, magnesium, sulfate, and sodium) were present in greater concentrations in the ponds within the mined area. Higher concentrations of bicarbonate and total hardness were measured in the water within the mined area.

Biological communities were less diverse and chemical concentrations fluctuated more in the mined area than in the ponds outside the mined area.

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CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

For additional information write to:

U.S. Geological Survey
P.O. Box 1125
Cheyenne, Wyoming 82001

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PHYSICAL, CHEMICAL, AND BIOLOGICAL RELATIONS OF FOUR PONDS IN THE HIDDEN WATER CREEK STRIP-MINE AREA, POWDER RIVER BASIN, WYOMING

By David J. Wangsness

ABSTRACT

The Hidden Water Creek area was mined from 1944 to 1955 and was then abandoned. The open pits filled with water and pond-type ecosystems developed.

Light penetrates to greater depths within two control ponds located outside the mine area. The lower light penetration in the ponds within the mined area probably is due, in part, to the greater number of phytoplankton cells. Also, unconsolidated soil material within the mine area was observed to slough off the pond banks, which could add to the concentration of suspended sediments.

Dissolved oxygen concentrations were lower in the ponds within the mined area. Most of the major ions (calcium, magnesium, sulfate, and sodium) were present in greater concentrations in the ponds within the mined area. Higher concentrations of bicarbonate and total hardness were measured in the water within the mined area.

Biological communities were less diverse and chemical concentrations fluctuated more in the mined area than in the ponds outside the mined area.

INTRODUCTION

Coal and oil-shale extraction processes in the western United States pose a potential threat to aquatic resources. As a result of renewed interest in mining coal, the U.S. Geological Survey is presently conducting a study of the water resources of the Powder River basin (fig. 1). Included in the study is the Hidden Water Creek area, twelve miles northwest of Sheridan, Wyo., which was mined by Decker Coal Company from 1944 to 1955 when about 10 million tons of subbituminous coal were removed. The area was then abandoned, the open pits filled with water, and pond-type ecosystems developed.

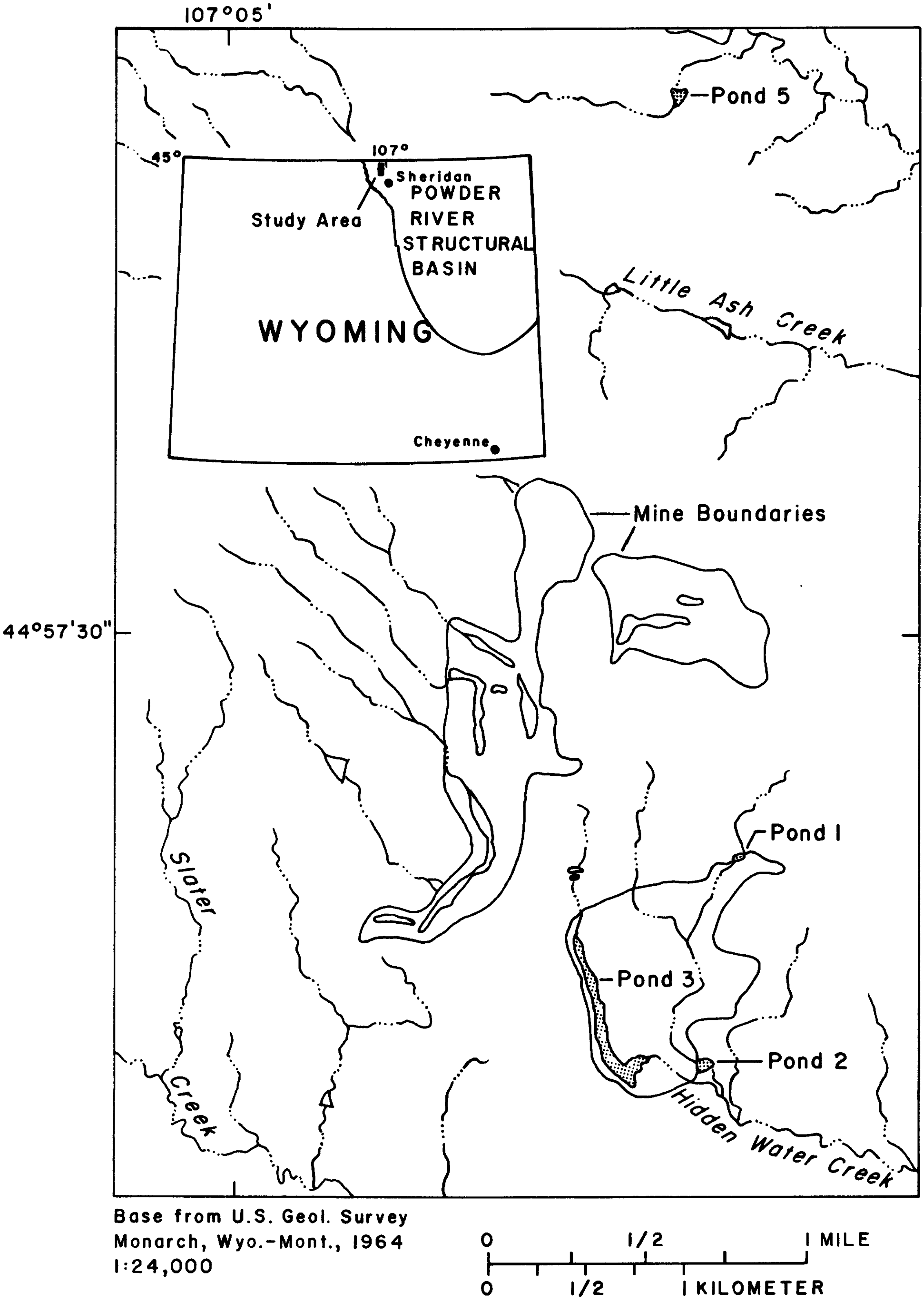

Figure 1.--Location of Powder River structural basin and Hidden Water Creek study area.

The purpose of the study was to describe the differences between ponds that developed within an abandoned mine site and in control ponds not affected by mining. Four ponds were selected and some aspects of their physical, chemical, and biological properties were studied. Three of the ponds are in or near the boundaries of the abandoned mine site (ponds 1, 2, and 3). Pond 1 is outside the mine boundary and upstream from pond 2. Pond 5 is a stock pond two miles north of the mine site. Ponds 1 and 5 were used as control ponds. The location of the ponds is shown in figure 1. It should be noted that while the study included 4 ponds their sequence of numbers in the study area is 1, 2, 3, and 5.

USE OF METRIC UNITS

The International System (SI) of units has been adopted for use in reports prepared by the Geological Survey. To assist readers of this report, measurements used in describing the well-numbering system are reported in English units and, in parentheses, SI or metric units. The English units used in this report may be converted to metric (SI) units by use of the following factors:

Multiply English units	by	To obtain metric (SI) units
Inches (in)	25.4	millimeters
Feet (ft)	.3048	meters

METHODS

The ponds were sampled seasonally (May, August, and February) during a 1-year period. The May 1975 and 1976 samples represent peak water volumes in the ponds, and the lowest (most dilute) chemical concentrations. The August 1975 and 1976 samples represent low water volumes in the ponds and the highest chemical concentrations as well as maximum water temperatures. Samples collected in February 1976 were to determine the water quality of the ponds under ice cover. Samples were collected at a point representing the deepest part of each pond.

Physical Measurements

Prior to May 1976, surface-water temperature of each pond was measured using a hand-held thermometer. Beginning in May 1976, the temperature was measured at 1-foot intervals from the surface to the bottom using the temperature probe associated with a dissolved oxygen meter.

Beginning in May 1976, an estimate of light penetration in the ponds was measured using a Secchi disc having a diameter of 8 inches as described by Schwoerbel (1970, p. 17).

Biological Sampling

Samples for phytoplankton analyses were collected from the four ponds with a PVC (polyvinylchloride) water sampler. Prior to May 1976, samples were collected only at the surface. Beginning in May 1976, samples were collected at the surface, and at the 2.5- and 5.0-foot depths. The phytoplankton samples were preserved as described by Slack and others (1973, p. 71). The organisms were counted, identified to genus, and a diversity index computed at the U.S. Geological Survey biological laboratory in Doraville, Georgia.

Samples for periphyton analyses were collected from the four ponds by scraping the attached material from natural substratum. The samples were preserved as described for phytoplankton. Organisms were indentified to genus and classified as dominant or observed taxa at the biological laboratory in Doraville.

Benthic invertebrate samples were collected qualitatively from the littoral zone of the ponds using a nylon dip net with a mesh opening of 210 microns. The samples were sorted and preserved with 40 percent isopropyl alcohol according to Slack and others (1973, p. 129) and sent to the Doraville laboratory for counting and identification to family.

Water samples for the determination of algal growth potential (AGP) were collected at the surface, 2.5- and 5.0-foot depths and composited in an effort to represent the average conditions of each pond. A liter of water from the composite sample was filtered through a 0.22 micron filter. The filtered sample was chilled to 4°C and shipped to the U.S. Geological Survey biological laboratory in Doraville, Georgia, where AGP was determined using the methods described by Shoaf and Lium (written commun., 1975).

Chemical Sampling

Field determinations of dissolved oxygen, specific conductance, and pH were made at each pond during each visit. Prior to May 1976, the determinations were made at the surface of each pond with field meters. After May 1976, the dissolved oxygen was measured at 1-foot intervals from the surface to the bottom of the ponds. All field meters were calibrated in the field using the techniques described by Brown and others (1970).

Water samples were collected at several depths with a PVC sampler and combined into a composite sample. The water samples were analyzed for dissolved and total major and minor elements, and the nutrients, nitrogen and phosphorus. Samples to be analyzed for dissolved constituents were passed through a 0.45 micron filter using nitrogen pressure. Samples analyzed for minor elements were acidified with double distilled nitric acid to a pH of 3 or less (Brown and others, 1970, p. 16). Samples analyzed for major elements and nutrients were appropriately acidified or chilled. All chemical analyses were made at the U.S. Geological Survey Central Laboratory in Arvada, Colo.

Field measurements of dissolved oxygen, pH, temperature, and water-sample collection for laboratory analysis of chemical and biological constituents took place during daylight hours and therefore did not represent diel conditions.

RESULTS

Physical Characteristics

Water Temperature

Temperature is an important factor in biological processes; chemical reaction rates and many physical events in the aquatic environment are temperature controlled. The water temperature in the four study ponds varied both seasonally, and between ponds in the same season.

Pond 1 ranged from near 0°C during February 1976 to 19 degrees at the surface in August. Figures 2 and 3 show the temperature gradient for May and August 1976. The temperature maximum was reached early in the year and did not fluctuate from the 18- to 19-degree range until cooling began in the autumn.

The temperature characteristics of pond 2 were similar to pond 1 with two exceptions. Pond 2 warmed more slowly and less uniformly than did pond 1 due to its slightly larger volume, and reached a uniform temperature in August that was two degrees warmer than pond 1 (figs. 2 and 3).

Ponds 3 and 5 had thermal stratification profiles typical of a temperate zone lake (figs. 2 and 3). Temperature differences between surface and bottom waters in ponds 3 and 5 were small in May 1976, and the temperature profile of each of the two ponds was almost vertical. Temperature differences between surface and bottom water increased by autumn with an abrupt change in gradient just below the surface. It is this difference, the warmer surface water abruptly separated from the cooler, deeper water, that thermally differenciates ponds 3 and 5 from ponds 1 and 2.

Light Penetration

Light is an important factor in the photosynthetic processes of green plants and is therefore a controlling factor for the biological processes in the ponds. The depth of light penetration in a pond can be used to estimate that depth to which photosynthesis can occur.

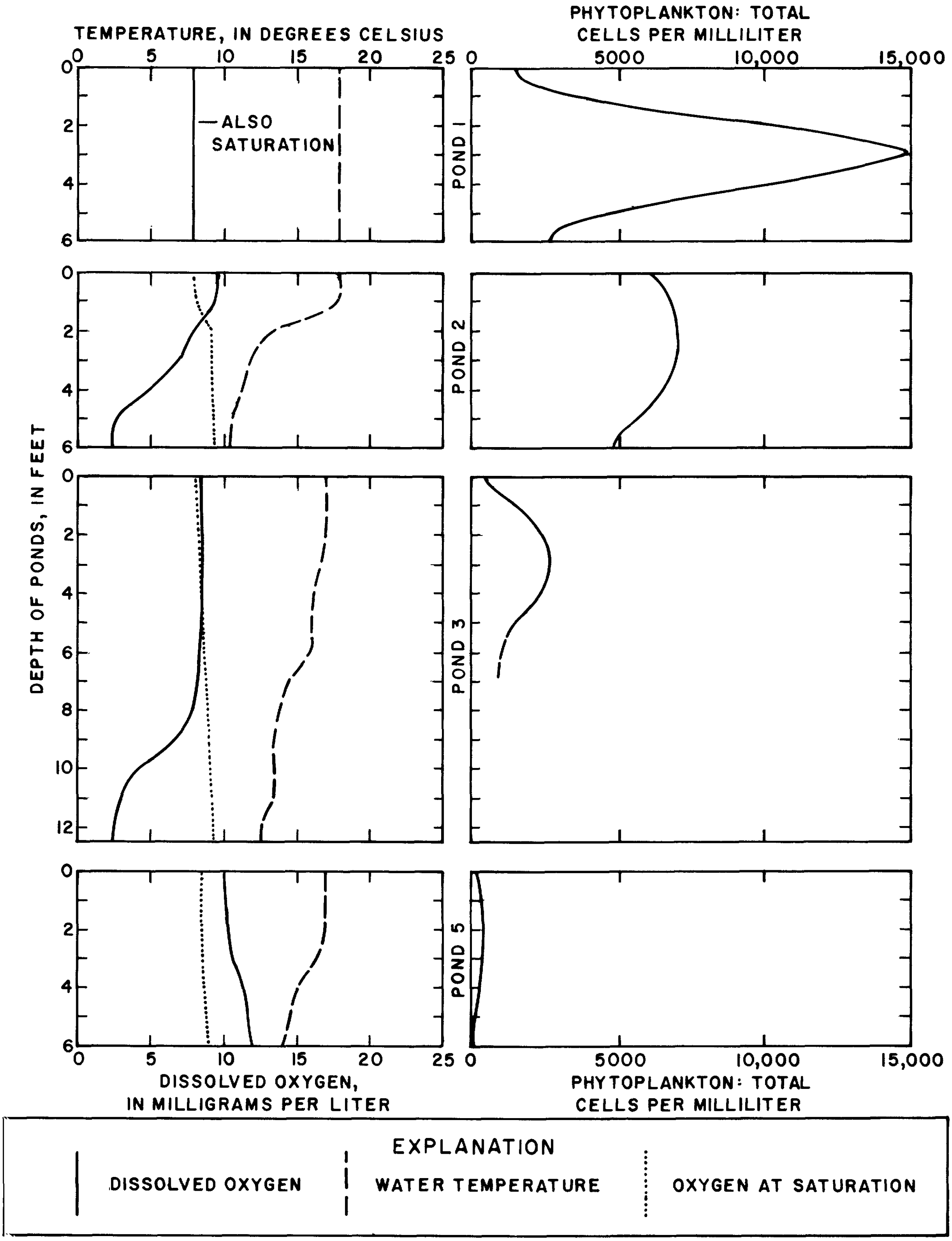

Figure 2.--Dissolved oxygen, temperature, and phytoplankton profiles for May 1976.

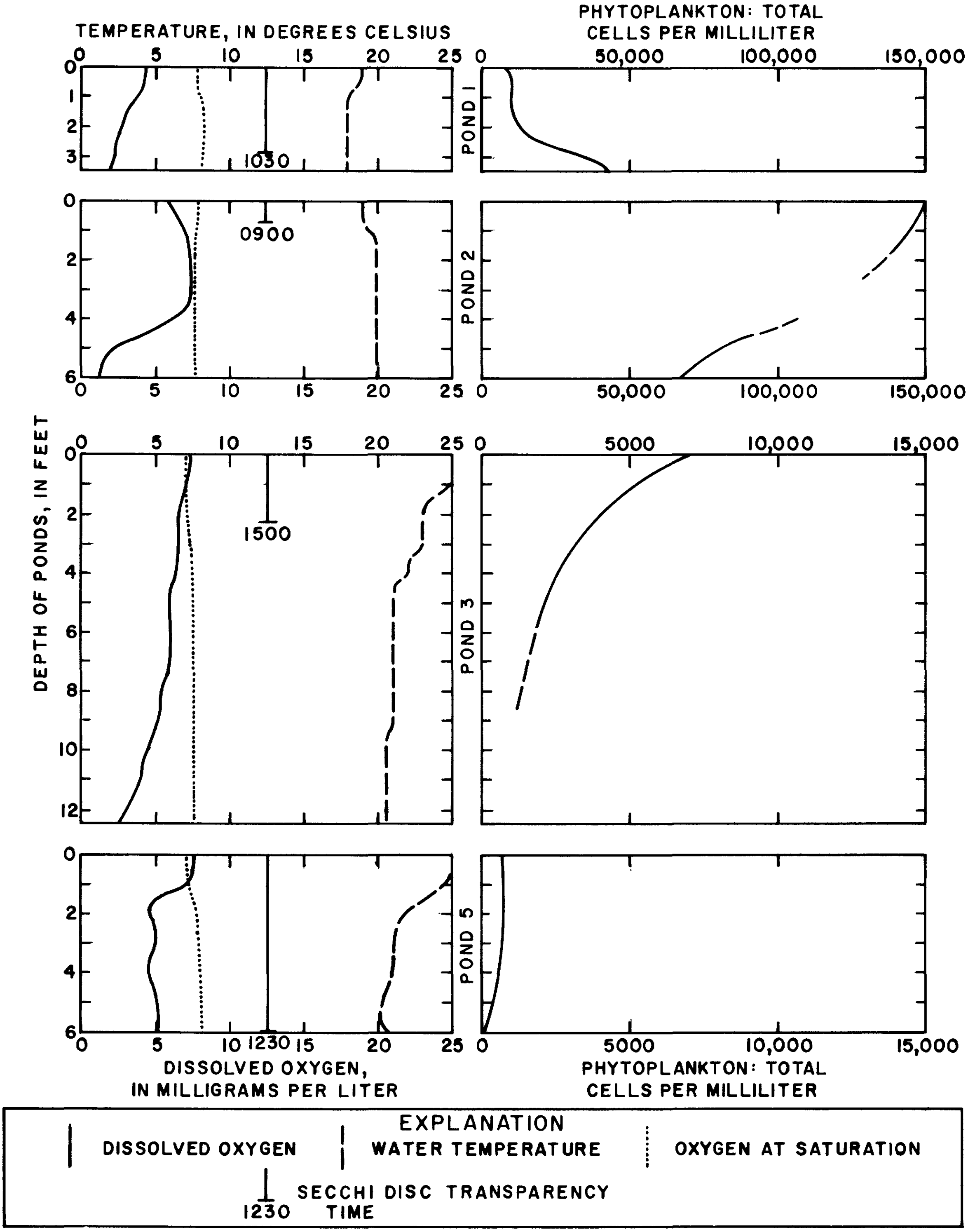

Figure 3.--Dissolved oxygen, temperature, and phytoplankton profiles and Secchi disc transparency for August 1976.

Light penetration was estimated in August 1976 with a Secchi disc (fig. 3). In pond 5 the Secchi disc could be seen on the bottom, a depth of 6.0 feet. The Secchi disc reading in pond 2 was only 0.75 feet. Ponds 1 and 3 had Secchi disc readings of 2.65 feet and 2.35 feet, respectively. Multiplying the Secchi disc reading by a factor of five gives an approximation of the lower limit or compensation level of the euphotic (photosynthetic) zone (Verduin, 1956). The euphotic zone is where there is sufficient light for photosynthesis. Pond 2 had an euphotic zone to a depth of 3.75 feet. Ponds 1 and 5 had euphotic zones throughout their depths and the euphotic zone of pond 3 reached a depth of 11.75 feet, almost its maximum depth (12.5 ft).

Biological Characteristics

Phytoplankton

Phytoplankton are primary producers in the aquatic food chain. The variability of phytoplankton cells is controlled by the physical, chemical, and biological characteristics of the ponds. In turn, the phytoplankton affect physical, chemical, and biological properties of the aquatic ecosystem.

Pond 2 had the greatest number of phytoplankton cells at the surface on all sample dates (table 1). However, when the vertical samples (May 1976) are considered, pond 1 had more than twice the number of cells than pond 2 at the 2.5-foot depth. In each of the four ponds, the 2.5-foot sample depth resulted in greater numbers of phytoplankton cells per milliliter than did the surface sample (figs. 2 and 3).

The dominant genera (15 percent or greater in abundance) representing the phytoplankton of the ponds varied considerably (figs. 4A and 4B). In the August samples, flagellates (Sub-Phylum Chrysophyceae), euglenoids (Phylum Euglenophyta), and diatoms (Sub-Phylum Bacillariophyceae) were the dominant organisms in pond 1. The dominant genera were *Dinobryon*, *Euglena*, and *Melosira* (table 2). Pond 2 was dominated by green algae (Phylum Chlorophyta) and represented by two genera, *Ankistrodemus*, and *Dictyosphaerium*. *Trachelomonas* (euglenoid) dominated pond 3 in August and *Fragilaria* (diatom) dominated pond 5.

A variety of phytoplankton were dominant in the February samples. In pond 1 the blue-green alga *Anabaena* (Phylum Cyanophyta), was the dominant organism. Pond 2 was dominated by *Uroglendopsis* (flagellate) and pond 3 by *Trachelomonas*. The diatoms *Fragilaria* and *Diatoma* dominated the February samples from pond 5.

Table 1.--Phytoplankton counts, number of genera and diversity index

PHYTOPLANKTON	POND 1			POND 2			POND 3			POND 5		
CELLS PER MILLILITER	0 ft	2½ ft	5 ft	0 ft	2½ ft	5 ft	0 ft	2½ ft	5 ft	0 ft	2½ ft	5 ft
AUGUST 1975												
Total count	589	-----	-----	5810	-----	-----	462	-----	-----	299	-----	-----
Green algae	82	-----	-----	3200	-----	-----	0	-----	-----	24	-----	-----
Blue-green algae	14	-----	-----	0	-----	-----	0	-----	-----	95	-----	-----
Diatoms	137	-----	-----	830	-----	-----	46	-----	-----	156	-----	-----
Euglenoids	151	-----	-----	1640	-----	-----	370	-----	-----	0	-----	-----
Flagellates	150	-----	-----	0	-----	-----	0	-----	-----	0	-----	-----
Dinoflagellates	55	-----	-----	140	-----	-----	46	-----	-----	24	-----	-----
Number of genera	13	-----	-----	11	-----	-----	4	-----	-----	9	-----	-----
Diversity index	2.848	-----	-----	2.545	-----	-----	0.922	-----	-----	2.195	-----	-----
FEBRUARY 1976												
Total count	1139	-----	-----	14500	-----	-----	326	-----	-----	437	-----	-----
Green algae	256	-----	-----	0	-----	-----	36	-----	-----	0	-----	-----
Blue-green algae	700	-----	-----	0	-----	-----	0	-----	-----	0	-----	-----
Diatoms	92	-----	-----	0	-----	-----	0	-----	-----	437	-----	-----
Englenoids	73	-----	-----	0	-----	-----	290	-----	-----	0	-----	-----
Flagellates	0	-----	-----	13000	-----	-----	0	-----	-----	0	-----	-----
Dinoflagellates	18	-----	-----	1500	-----	-----	0	-----	-----	0	-----	-----
Number of genera	7	-----	-----	3	-----	-----	2	-----	-----	3	-----	-----
Diversity index	1.913	-----	-----	0.474	-----	-----	0.503	-----	-----	1.190	-----	-----
MAY 1976												
Total count	1716	15577	3004	6570	7100	5361	777	2670	1396	261	304	59
Green algae	0	0	0	4030	1380	1674	507	1960	591	0	0	8
Blue-green algae	0	0	680	500	0	1100	0	0	0	0	31	0
Diatoms	71	0	137	610	1610	980	250	710	272	87	133	51
Euglenoids	95	77	27	330	460	307	20	0	21	152	140	0
Flagellates	1550	15500	2160	1100	3420	1300	0	0	491	22	0	0
Dinoflagellates	0	0	0	0	230	0	0	0	21	0	0	0
Number of genera	4	5	6	20	11	15	7	6	10	6	9	5
Diversity index	1.432	0.736	1.800	3.340	2.944	3.182	1.835	2.131	2.327	1.980	2.684	1.559
AUGUST 1976												
Total count	9986	10220	37510	156120		70570	5918	3087	2040	534	537	106
Green algae	790	0	0	0		34870	1630	0	136	0	4	0
Blue-green algae	0	0	0	150000		34000	4100	2620	1500	56	310	0
Diatoms	3230	110	23510	5200		0	31	172	23	133	38	56
Euglenoids	5966	10110	14000	920		1700	31	0	290	345	85	50
Flagellates	0	0	0	0		0	63	85	0	0	100	0
Dinoflagellates	0	0	0	0		0	63	210	91	0	0	0
Number of genera	6	3	3	5		5	8	6	6	7	7	6
Diversity index	1.392	0.171	1.041	0.267		1.370	1.952	1.436	1.315	2.043	1.816	2.048

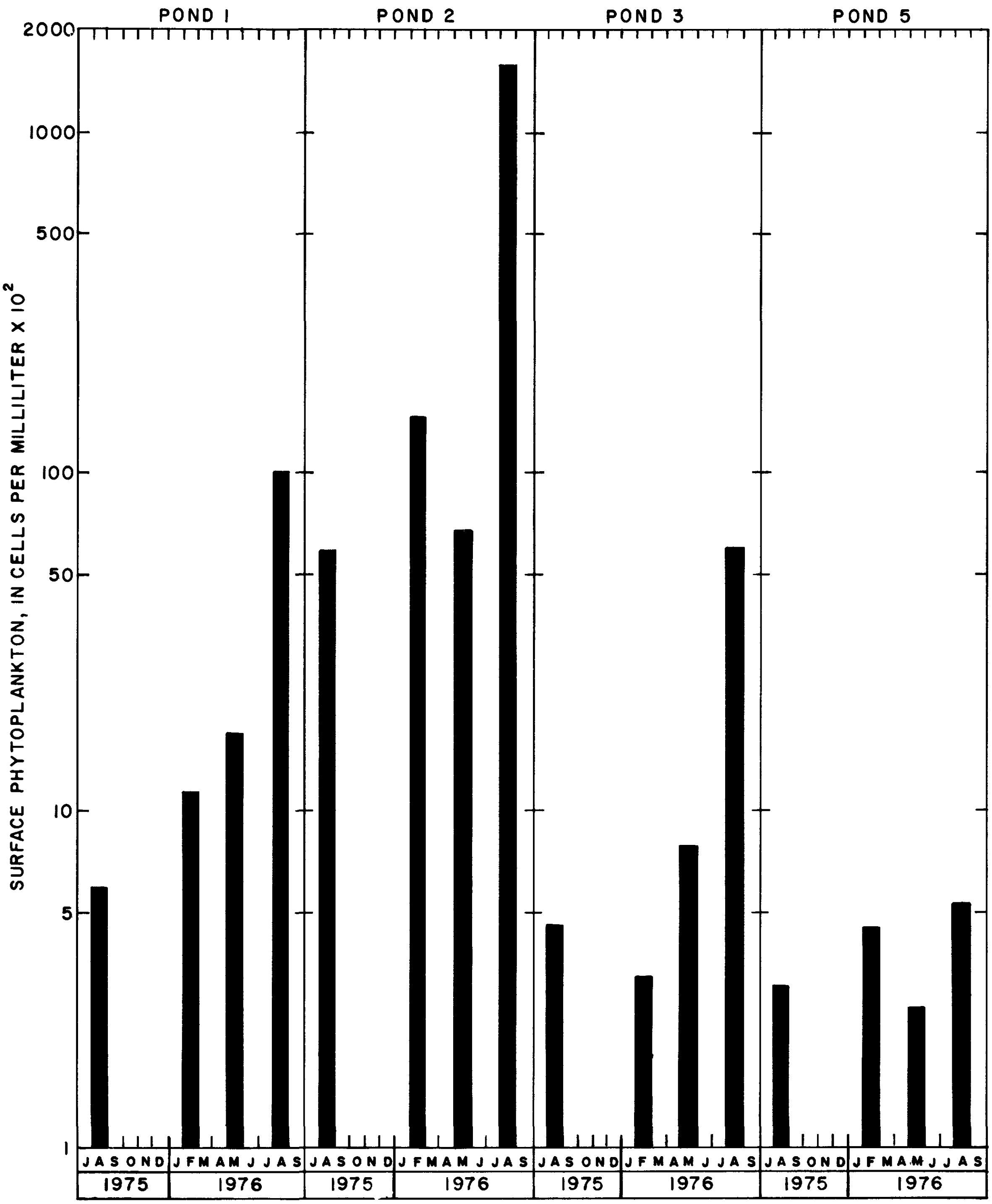

Figure 4A.--Surface phytoplankton contents.

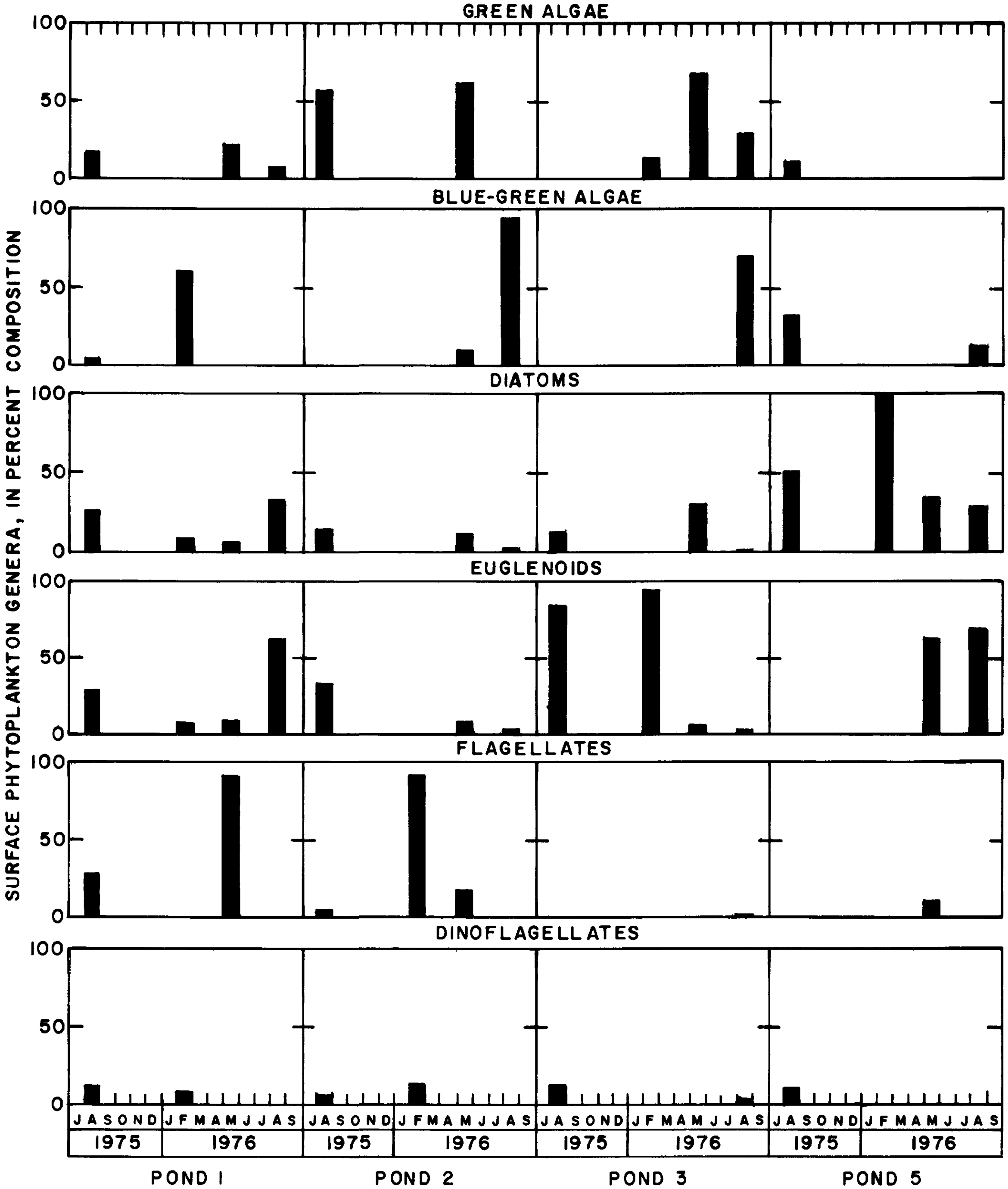

Figure 4B.--Surface phytoplankton genera in percent of composition.

Table 2.--Phytoplankton communities, in percent, in August 1975 and February, May, and August 1976.

ORGANISMS	POND 1				POND 2				POND 3				POND 5			
BY GENERA	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG
Clamydomonas	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Staurastrum	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tribonema	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Anacystis	2	---	---	---	---	---	---	---	---	---	---	51	---	---	---	---
Rhopalodia	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Eudorina	14	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Melosira	16	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Gonium	---	---	---	8	---	---	---	---	---	---	---	---	---	---	---	---
Dinobryon	26	---	54	---	---	---	---	---	---	---	---	---	---	---	---	---
Oedogonium	---	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ochromonus	---	---	36	---	---	---	---	---	---	---	---	1	---	---	---	---
Anabaena	---	61	---	---	---	---	8	---	---	---	---	---	---	---	---	10
Euglena	16	6	---	1	26	---	4	---	---	---	1	---	---	---	---	---
Oocystis	---	6	---	---	---	---	9	---	---	---	---	13	---	---	---	---
Gymnodinum	---	2	---	---	---	10	---	---	---	---	---	---	---	---	---	---
Cryptomonas	---	---	6	---	2	---	---	---	---	---	---	---	---	---	8	7
Trachelomonas	9	---	---	59	2	---	1	1	80	89	2	1	---	---	---	---
Peridinium	9	---	---	---	2	---	1	---	10	---	---	1	---	---	---	---
Nitzschia	5	8	4	---	7	---	1	---	10	---	30	---	4	---	25	8
Ankistrodesmus	---	6	---	---	26	---	12	---	---	11	50	---	4	---	---	---
Gomphonema	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---
Kirchneriella	---	---	---	---	---	---	17	---	---	---	10	---	---	---	---	---
Scenedesmus	---	---	---	---	---	---	6	---	---	---	5	---	---	---	---	---
Dictyosphaerium	---	---	---	---	28	---	16	---	---	---	---	15	---	---	---	---
Aphonizominon	---	---	---	---	---	---	---	96	---	---	---	---	---	---	---	---
Uroglendopsis	---	---	---	---	---	90	---	---	---	---	---	---	---	---	---	---
Cyclotella	---	---	---	---	---	---	5	3	---	---	---	---	---	---	---	---
Neidium	---	---	---	---	2	---	1	---	---	---	---	---	---	---	---	---
Amphiprora	---	---	---	---	1	---	2	---	---	---	---	---	---	---	---	---
Oscillatoria	---	---	---	---	---	---	1	---	---	---	---	19	---	---	---	---
Navicula	---	---	---	1	2	---	2	---	---	---	---	1	---	---	4	5
Chrysococcus	---	---	---	---	---	---	16	---	---	---	---	---	---	---	8	---
Achnanthes	---	---	---	---	2	---	---	---	---	---	---	---	8	11	---	4
Ceratium	---	---	---	---	---	---	---	1	---	---	---	---	8	---	---	---
Phacotus	---	---	---	---	---	---	---	---	---	---	---	---	4	---	---	---
Gomphosphaeria	---	---	---	---	---	---	---	---	---	---	---	---	32	---	---	---
Fragilaria	---	---	---	31	---	---	---	---	---	---	---	---	40	21	---	---
Diatoma	---	---	---	---	---	---	---	---	---	---	---	---	---	68	---	---
Chroomonas	---	---	---	---	---	---	---	---	---	---	---	---	---	---	50	58
Cymbella	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4	---
Cocconeis	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8

Dinobryon was again dominant in pond 1 in the May 1976 sample along with another flagellate, Ochromonas. Ankistrodesmus and Dictyosphaerium, which were dominant in August 1976, were again dominant in pond 2 in May 1976. The flagellate, Chrysococcus, shared dominance in pond 2 with the above two green algae. Ankistrodesmus was also dominant in pond 3 during May. In pond 5 Chroomonas (euglenoid) dominated the phytoplankton collected at the surface and at 2.5 feet below the surface, but was not found in the samples collected at the 5-foot depth. At the 5-foot depth the dominant alga was Nitzschia (diatom) (figs. 5A and 5B).

Periphyton

The periphytic (attached) algae, like the phytoplankton, are an important part of the food chain in a pond. They act upon and react to their physical and chemical surroundings just as do the phytoplankton. The major difference is that the periphyton are attached to a natural substratum and are not free to move about the pond with the currents, or move vertically with the changes in water density.

The periphyton community was made up largely of blue-green algae early in the year, as shown in the May 1975 sample (table 3). Anabaena, Lyngbya, and the flagellate Tribonema shared dominance in pond 1. Navicula (diatom) and Tribonema dominated pond 2. Oscillatoria, another blue-green algae, dominated the periphyton sample from pond 3 while Ulothorix (green algae) was the dominant organism in pond 5.

In August 1975, diatoms dominated many of the samples except the sample collected from pond 1. Tribonema and the blue-green algae Plectonema dominated the August sample from pond 1. Achnanthes and Nitzschia dominated the sample from pond 2. Fifteen genera of diatoms were identified in the sample collected from pond 2 in August 1975, and 12 diatom genera were reported in the sample from pond 3. Amphipleura, Rhopalodia, and Synedra shared dominance in this sample. Of the 11 diatom genera identified in the sample from pond 5, Fragilaria and Synedra were dominant.

Green algae, diatoms, and blue-green algae were codominant in many of the samples collected in February. Oedogonium (green algae) and Fragilaria were codominant in pond 1. Rhizoclonium (green algae), Lyngbya (blue-green algae), and Synedra dominated the February sample in pond 2. The same organisms that dominated ponds 1 and 2, plus Achnanthes, were dominant in pond 3. Unfortunately, the container of the sample from pond 5 in February was broken in transit.

A spring diatom increase occured in ponds, 2, 3, and 5 in May 1976. Anabaena and Oscillatoria dominated the May 1976 sample from pond 1. Nitzschia and Stauroneis increased in May but were not abundant enough to be considered dominant. Sixteen diatom genera were identified in pond 2; dominant representatives were Diatoma, Navicula, and Nitzschia. Nitzschia also was the dominant genera in pond 3. The number of genera of green algae increased in pond 5 but the diatoms remained dominant. Achnanthes, Diatoma, Fragilaria, and Nitzschia were the codominant diatoms in the sample collected from pond 5.

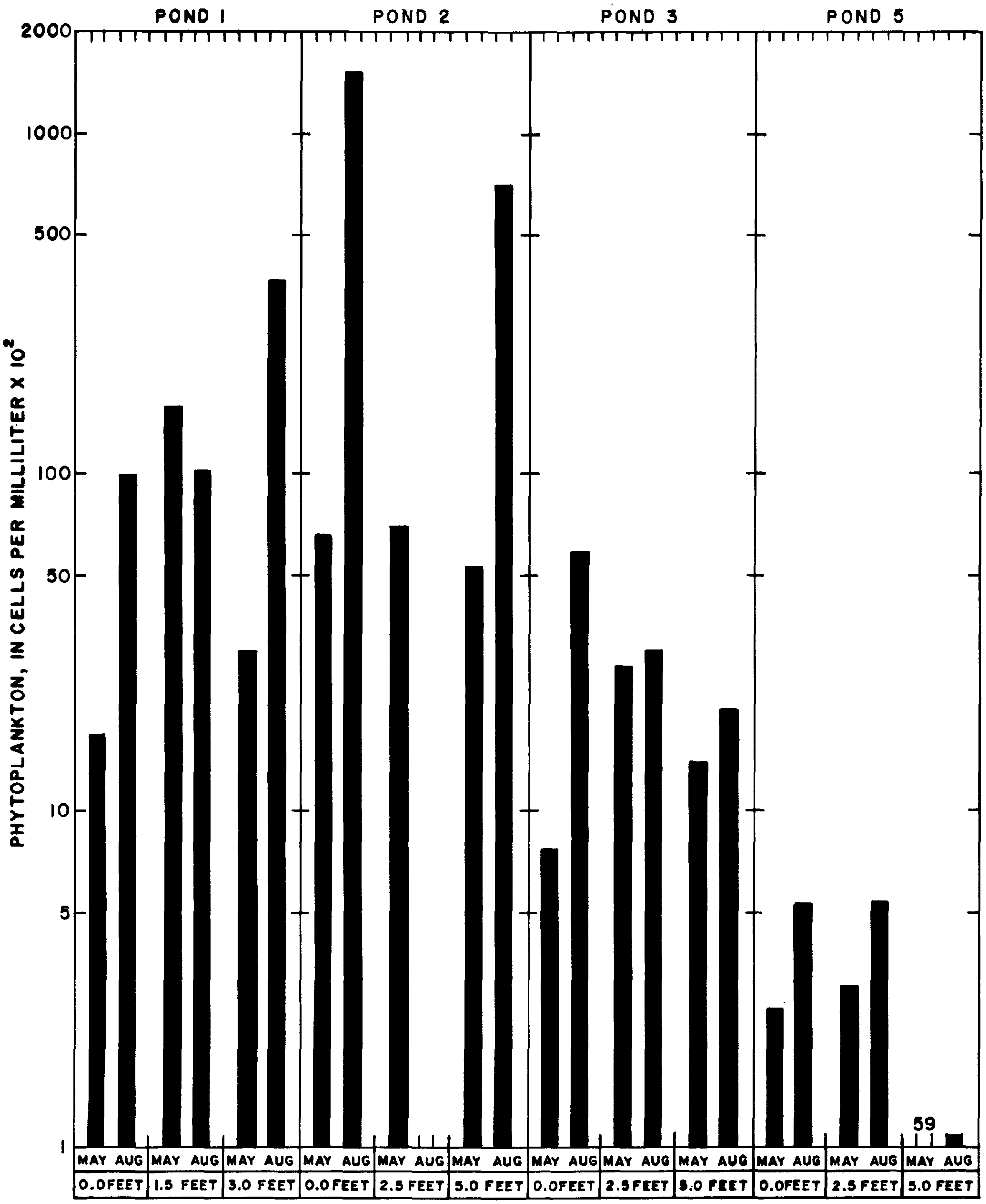

Figure 5A.--Phytoplankton counts at three depths for May and August 1976.

Table 3.--Periphyton communities[1/], May and August 1975 and February, May, and August 1976.

ORGANISMS BY GENERA	POND 1					POND 2					POND 3					POND 5				
	MAY	AUG	FEB	MAY	AUG	MAY	AUG	FEB	MAY	AUG	MAY	AUG	FEB	MAY	AUG	MAY	AUG	FEB	MAY	AUG
Epipyxis----------	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tetraspora--------	X	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Elakatothrix------	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Staurastrum-------	---	X	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cylindrospermum---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Dinobryon---------	---	X	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tetraedron--------	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Arthrospira-------	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Colacium----------	X	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Peridinium--------	---	---	---	X	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---
Cylindrocapsa-----	X	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Eudorina----------	---	X	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---
Microspora--------	---	---	---	X	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---
Plectonema--------	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Stauroneis--------	---	X	---	0	X	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tribonema---------	0	0	---	X	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Oedogonium--------	X	X	0	X	X	---	X	X	---	---	---	X	X	---	X	X	---	---	X	0
Anabaena----------	0	---	X	0	0	X	X	---	---	---	X	X	---	---	---	---	---	---	---	0
Lyngbya-----------	0	---	---	---	X	---	X	0	---	0	---	---	0	---	---	X	X	---	---	X
Oscillatoria------	X	X	---	0	X	X	---	---	X	X	0	---	---	X	---	X	X	---	X	X
Nitzschia---------	X	X	---	0	X	X	0	X	0	X	X	X	X	0	X	---	X	---	0	X
Fragilaria--------	---	X	0	X	0	---	X	---	---	---	---	---	---	---	---	---	0	---	0	X
Navicula----------	---	X	X	X	X	0	X	X	0	X	X	X	X	X	X	---	X	---	X	X
Synedra-----------	---	---	X	X	X	X	X	0	X	X	---	0	0	X	X	X	0	---	X	0
Achnanthes--------	---	---	---	---	---	---	0	X	---	---	---	X	0	---	---	X	X	---	0	X
Rhopalodia--------	---	X	X	X	X	---	X	X	X	X	---	0	X	X	X	---	X	---	X	X
Rhizoclonium------	X	---	---	---	---	---	---	0	---	---	---	---	0	---	---	---	---	---	---	---
Diatoma-----------	---	---	---	---	---	X	---	X	0	---	---	---	---	X	---	---	X	---	0	---
Amphipleura-------	---	---	---	---	---	---	X	X	---	---	---	0	---	---	---	---	X	---	---	X
Ulothrix----------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	---	---	---	---
Caloneis----------	---	---	---	X	---	X	---	---	X	X	---	---	X	---	---	---	---	---	---	---
Trachelomonas-----	---	X	X	X	X	---	X	X	---	---	---	X	---	---	---	---	---	---	---	---
Mastogloia--------	---	---	X	---	---	---	X	X	X	0	---	X	X	X	---	---	---	---	---	X
Cosmarium---------	---	---	---	X	X	---	X	---	X	---	---	X	---	---	X	---	X	---	X	X
Scenedesmus-------	---	X	---	---	X	---	X	---	---	---	---	X	---	X	---	---	---	---	X	X
Anacystis---------	X	X	---	X	---	---	X	---	---	---	---	X	---	---	---	---	X	---	---	X
Cyclotella--------	---	X	---	---	---	---	X	---	X	X	---	X	---	---	---	X	---	---	---	X
Cymbella----------	---	X	---	---	X	---	X	X	X	X	---	X	X	X	---	---	X	---	X	X
Hantzschia--------	X	---	---	---	---	---	---	---	X	---	X	---	---	X	---	X	---	---	---	---
Pinnularia--------	---	---	---	X	---	X	---	X	X	X	---	---	---	X	---	X	---	---	---	---
Euglena-----------	---	---	X	---	X	---	X	---	X	---	---	---	---	X	---	---	---	---	X	---
Epithemia---------	---	X	---	---	0	---	---	---	---	---	---	---	X	X	X	---	---	---	---	X
Gyrosigma---------	---	---	---	---	---	X	X	---	X	X	---	---	X	---	X	---	X	---	X	---
Closterium--------	---	---	---	X	X	---	---	---	---	---	---	---	---	---	X	---	---	---	X	---
Mougeotia---------	---	X	---	---	X	---	---	---	---	---	---	---	---	---	---	---	X	---	X	---
Zygonema----------	X	X	---	X	X	---	---	---	---	---	---	---	---	---	---	---	X	---	X	---
Cocconeis---------	---	---	---	---	X	---	---	X	---	X	---	X	---	X	0	---	---	---	X	0
Asterionella------	---	---	---	---	---	---	---	---	X	---	---	---	---	X	---	---	---	---	X	---
Agmenellum--------	---	---	---	---	---	---	X	---	---	---	---	X	---	---	X	---	X	---	X	X
Amphiprora--------	---	---	---	---	---	X	X	X	X	X	---	X	X	---	---	---	---	---	---	---
Gomphonema--------	---	---	---	---	---	X	X	X	X	---	---	---	---	---	X	---	---	---	X	---
Surirella---------	---	---	---	---	---	X	X	---	X	X	---	---	---	---	X	X	X	---	---	---
Dictyosphaerium---	---	---	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---
Stigeoclonium-----	---	---	---	---	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---
Denticula---------	---	---	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---
Eunotia-----------	---	---	---	---	---	---	---	---	---	---	---	X	---	---	---	---	---	---	---	---
Diploneis---------	---	---	---	---	---	---	---	---	---	X	---	X	---	---	---	---	---	---	---	X
Amphithrix--------	---	---	---	---	---	---	---	---	---	---	---	---	X	---	---	---	---	---	---	---
Aulosira----------	---	---	---	---	---	---	---	---	---	---	---	---	X	---	---	---	---	---	---	---
Bulbochaete-------	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	X	---
Oocystis----------	---	---	---	---	X	---	---	---	---	---	---	---	---	---	X	---	X	---	---	---
Spirogyra---------	---	---	---	---	X	---	---	---	---	---	---	---	---	---	---	---	---	---	X	---
Chara-------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X
Botryococcus------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X
Amphora-----------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X
Cymatopleura------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X
Spirulina---------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	X

[1/] 0, dominant; X, present.

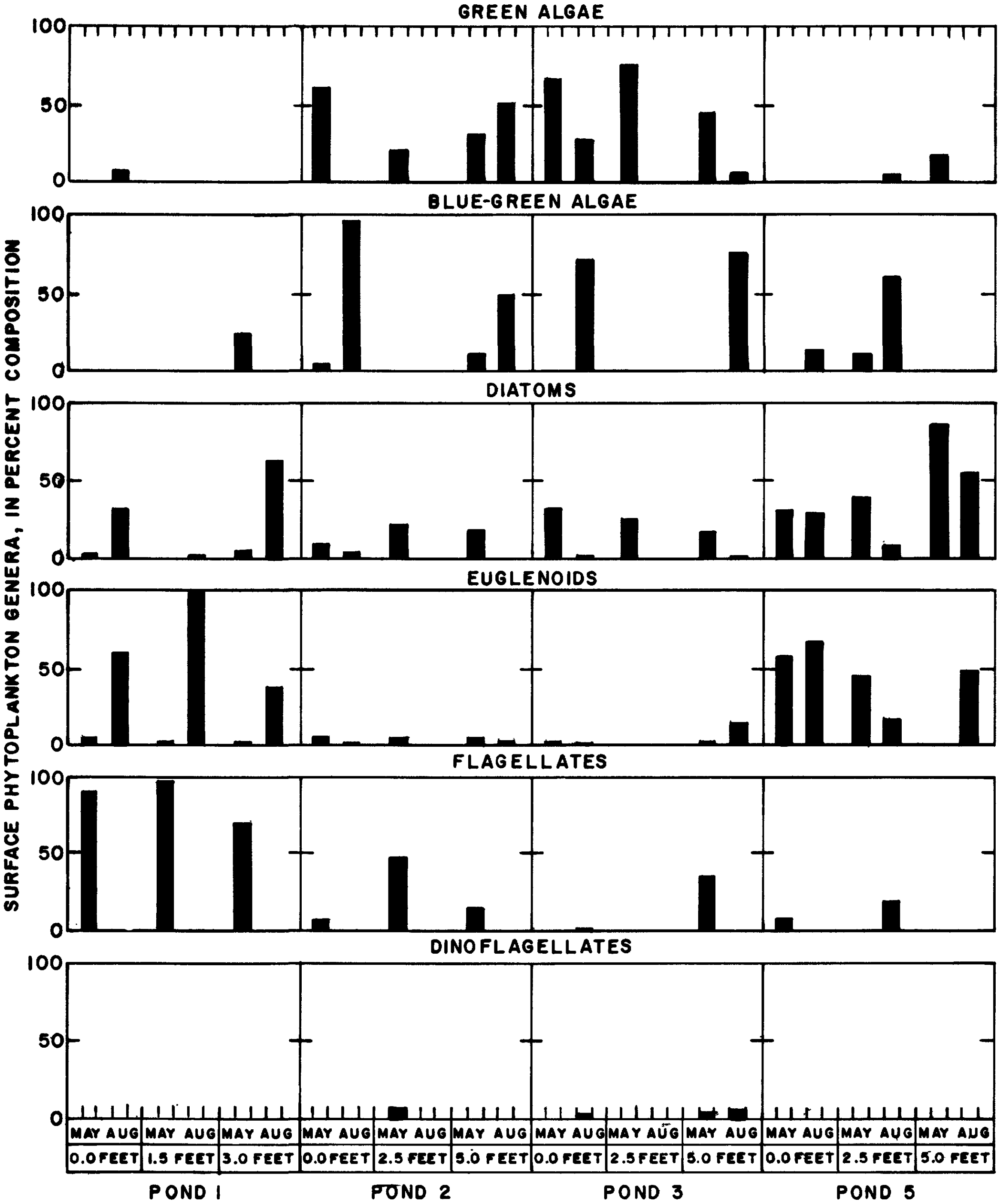

Figure 5B.--Percent composition of phytoplankton genera at three depths for May and August 1976.

Invertebrates

Aquatic invertebrates live in the water or on natural substrates including the bottom sediments of a pond. They may be represented by large numbers of organisms, depending upon the physical and chemical conditions in the aquatic environment. Invertebrate samples and results are strictly qualitative and any reference to quantity is relative to the amount of time spent in the collection of organisms. Sampling relative to area or volume were not carried out in this study.

The four ponds supported a variety of immature and mature invertebrates and molluscs (table 4). However, ponds 1 and 5 had a greater variety of organisms than did ponds 2 and 3. In the samples collected from pond 1, 20 families were identified. Chaoboridae (phantom midge larva) and Gyrinidae (whirligig beetle) were most frequently found in the samples. Baetidae (mayfly larva) and Dytiscidae (predaceous diving beetle) were present in the littoral zone of pond 1 along with Lestidae (damselfly larva) and Limnephilidae (caddisfly larva). Perlodidae (stonefly larva) and Tabanidae (horsefly larva) were only found in pond 1. Glossiphoniidae (leeches) were found only in ponds 1 and 5.

Ten invertebrate families were collected in pond 2. The Baetidae (mayfly), Chironomidae (midge larva), and Hydracarina (water mites) were the most abundant. Physidae (pouch snails) were frequently found in the sample but usually not in excessive numbers. The Hydrophilidae (water scavenger) was found only in pond 2. Of particular interest is that in February, three sites were sampled in pond 2, but no organisms were captured.

Pond 3 usually had high numbers of zooplankton, free floating microscopic invertebrates, such as Cyclopidae (cyclops), Daphnidae (daphnia) and Diaptomidae (copopods) which were most abundant in the May 1976 sample. Invertebrates such as Talitridae (side swimmers) were captured in large numbers as were Physidae and Chironomidae larva. The Caenidae (mayfly numphs) were captured in relative abundance along with Lestidae and Hydracarina. Ceratopogonidae (biting midge larva) were captured only in pond 3.

Nineteen invertebrate families and zooplanktors were captured in pond 5. Several mayfly nymphs and damselfly nymphs were collected but the Talitridae (side swimmers) were captured most frequently. Pouch snails and water mites were also numerous in the samples. The Chydoridae (water flea) was collected in large numbers in February 1976. This organism also was found in pond 2, but not in abundance. The Lymnaeidae (pond snail) and the Leptoceridae (caddisfly larva) were found only in pond 5.

Table 4.--Invertebrate communities in pond water, August 1975 and February, May, and August 1976.

ORGANISMS BY FAMILY	POND 1				POND 2				POND 3				POND 5			
	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG
Oligochaeta (Segmented Worm)	--	--	13	3	--	--	--	--	--	--	--	--	--	--	--	--
Perlodidae (Stone Fly)	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Tabanidae (Horse Fly)	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Unknown (Seed Shrimp)	--	600	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gyrinidae (Whirligig Beetle)	2	--	3	--	--	--	--	--	--	--	--	--	2	--	--	--
Chaoboridae (Phantom Midge)	--	454	24	--	--	--	--	--	--	1	--	--	--	--	--	--
Elmidae (Riffle Beetle)	1	--	--	2	1	--	--	--	--	--	--	--	--	--	--	1
Corixidae (Water Boatman)	--	--	9	5	2	--	--	2	--	--	1	--	--	--	--	--
Baetidae (May Fly)	1	1	--	25	94	--	--	15	--	--	--	--	--	26	--	--
Hydracarina (Water Mite)	--	--	12	15	3	--	7	6	2	--	13	12	--	--	26	60
Aeschnidae (Dragon Fly)	--	2	--	3	--	--	--	1	--	3	--	2	--	16	--	--
Chydoridae (Water Flea)	--	--	--	--	3	--	--	--	--	--	--	--	--	51	--	--
Physidae (Pouch Snail)	--	--	2	--	3	--	3	3	49	1	--	3	14	--	2	1
Talitridae (Side Swimmer)	--	1	--	4	--	--	--	--	--	14	2	2	18	24	16	10
Chironomidae (Midge)	--	--	9	2	6	--	3	--	1	11	2	5	--	9	2	--
Lestidae (Damsel Fly)	--	--	5	6	--	--	3	4	--	--	26	3	--	--	9	4
Cyclopidae (Cyclops)	--	30	--	--	--	--	--	--	--	1	500	--	--	9	--	50
Daphnidae (Daphnia)	--	--	10	--	--	--	--	--	--	--	500	--	--	9	10	50
Diaptomidae (Copopod)	--	--	--	--	--	--	--	--	--	--	500	--	--	3	3	30
Caenidae (May Fly)	--	--	--	--	--	--	--	--	3	--	26	32	--	1	15	--
Dytiscidae (Predaceous Diving Bettle)	--	4	12	3	--	--	--	--	--	--	1	--	--	1	--	--
Culicidae (Mosquitoe)	--	--	13	--	--	--	--	--	--	--	--	--	1	--	--	--
Glossiphoniidae (Leech)	--	--	2	2	--	--	--	--	--	--	--	--	--	--	2	--
Limnophilidae (Caddis Fly)	--	--	1	--	--	--	--	--	--	--	--	--	--	2	--	4
Leptoceridae (Caddis Fly)	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Lymnaeidae (Pond Snail)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Agrionidae (Dansel Fly)	--	--	--	--	6	--	--	--	--	--	--	--	3	--	--	--
Hydrophilidae (Water Scavenger)	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--
Haliplidae (Crawling Water Beetle)	--	--	--	15	--	--	--	--	--	--	1	--	--	--	--	--
Ceratopogonidae (Biting Midge)	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--
Planorbiidae (Orb Snails)	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	15
Ancylidae (Limpets)	--	--	--	100	--	--	--	--	--	--	--	10	--	--	--	--

Similarity Index

When the biological communities were compared using an index of community similarity, as listed in table 5A, it was noted that ponds 1 and 5 were more often similar than ponds 2 and 3. This was expressed in the phytoplankton data for May 1976, but during other times of the year any given pond may have been more similar to any other pond. For example, in August 1975, pond 1 and 3 had the most similar communities. However, the similarity index in August was lower than that index in May 1976. The May similarity index was consistently higher, and the best similarity was that between ponds 1 and 5 and ponds 2 and 3. The periphyton data showed nearly the same relation as the phytoplanton data except that while pond 1 was more similar to pond 5, pond 5 showed a greater similarity to ponds 2 and 3. The greatest similarity within the periphyton community was not necessarily found during the spring sample period. Ponds 2 and 3 had similar invertebrate communities, but ponds 1 and 5 also showed their greatest similarity to ponds 2 and 3. This may indicate that a universal group of organisms with wide ranges of habitat and large tolerance ranges are characteristic of the study ponds. However, ponds 1 and 5 have formed more diverse habitats than ponds 2 and 3 (table 5B). The results indicate very low community similarities in the phytoplankton and invertebrate communities when compared to the periphyton community. Tables 6 and 7 list all the organisms that were identified from the study area during the period of study.

Table 5A.--Similarity indices[1/] of phytoplankton, periphyton, and invertebrate populations, between ponds

		PHYTOPLANKTON				PERIPHYTON				INVERTEBRATES			
		POND 1	POND 2	POND 3	POND 5	POND 1	POND 2	POND 3	POND 5	POND 1	POND 2	POND 3	POND 5
	May 1975	([2])	0.273	0.133	0.200	([2])	0.414	0.421	0.333	-----	-----	-----	-----
	Aug 1975	([2])	.333	.353	.091	([2])	.417	.429	.390	([2])	0.364	0.333	0.000
POND 1	Feb 1976	([2])	.200	.222	.000	([2])	.429	.385	-----	([2])	.429	.000	.421
	May 1976	([2])	.083	.182	.400	([2])	.381	-----	.465	([2])	.421	.462	.400
	Aug 1976	([2])	.250	.308	.167	([2])	.390	.513	.314	([2])	.526	.545	.333
	May 1975	0.273	([2])	.286	.385	0.414	([2])	.400	.320	-----	-----	-----	-----
	Aug 1975	.333	([2])	.400	.300	.417	([2])	.739	.622	0.364	([2])	.615	.286
POND 2	Feb 1976	.200	([2])	.000	.000	.429	([2])	.647	-----	.429	([2])	.000	.421
	May 1976	.083	([2])	.444	.231	.381	([2])	.316	.512	.421	([2])	.400	.571
	Aug 1976	.250	([2])	.182	.000	.390	([2])	.467	.524	.526	([2])	.533	.235
	May 1975	.133	.286	([2])	.316	.421	.400	([2])	.267	-----	-----	-----	-----
	Aug 1975	.353	.400	([2])	.308	.429	.739	([2])	.513	.333	.615	([2])	.222
POND 3	Feb 1976	.222	.000	([2])	.000	.385	.647	([2])	-----	.000	.000	([2])	.000
	May 1976	.182	.444	([2])	.154	-----	.316	([2])	.609	.462	.400	([2])	.667
	Aug 1976	.308	.182	([2])	.133	.513	.467	([2])	.450	.545	.533	([2])	.400
	May 1975	.200	.385	.316	([2])	.333	.320	.267	([2])	-----	-----	-----	-----
	Aug 1975	.091	.300	.308	([2])	.390	.622	.513	([2])	.000	.286	.222	([2])
POND 5	Feb 1976	.000	.000	.000	([2])	-----	-----	-----	-----	.421	.421	.000	([2])
	May 1976	.400	.231	.154	([2])	.465	.512	.609	([2])	.400	.571	.667	([2])
	Aug 1976	.167	.000	.133	([2])	.314	.524	.450	([2])	.333	.235	.400	([2])

[1/] Similarity Index (S)=2C÷A+B Where: C=Number of Common Genera
A=Number of Genera in First Pond
B=Number of Genera in Second Pond

([2]) See table 7B for similarity index, within ponds.
[Similarity Index within ponds is computed by having A equal the number of genera on **the first date and B equal the number of genera on the second date.** The results are listed in Table 7B.]

Table 5B.--Similarity indices of phytoplankton, periphyton, and invertebrate populations, within ponds

	PHYTOPLANKTON				PERIPHYTON				INVERTEBRATES			
	POND 1	POND 2	POND 3	POND 5	POND 1	POND 2	POND 3	POND 5	POND 1	POND 2	POND 3	POND 5
May 1975-Aug 1975	0.190	0.160	0.182	0.286	0.278	0.390	0.240	0.345	-----	-----	-----	-----
Aug 1975-Feb 1976	.200	.000	.333	.333	.312	.591	.500	-----	0.222	0.375	0.000	0.118
Feb 1976-May 1976	.182	.000	.444	.000	.452	.513	.320	-----	.000	.364	.000	.364
May 1976-Aug 1976	.000	.210	.133	.615	.553	.703	.414	.531	.500	.600	.500	.667
May 1975-May 1976	.167	.176	.286	.333	.400	.611	.286	.250	-----	-----	-----	-----
Aug 1975-Aug 1976	.235	.143	.333	.286	.596	.524	.470	.578	.250	.533	.615	.250

Table 6. Phytoplankton[1/] and periphyton[2/] identified during the study.

Organisms by genera: Green algae			Organisms by genera: Diatoms		
Ankistrodesmus	A	B	Achnanthes	A	B
Botryococcus		B	Amphipleura		B
Bulbochaete		B	Amphiprora	A	B
Carteria	A		Amphora		B
Chara		B	Anomoeoneis		B
Characium		B	Asterionella	A	
Chlamydomonas	A	B	Caloneis		B
Chodatella	A		Chaetoceros	A	
Closterium		B	Cocconeis	A	B
Cosmarium		B	Cyclotella	A	B
Crucigenia	A		Cymatopleura	A	B
Cylindrocapsa		B	Cymbella	A	B
Distyosphaerium	A	B	Denticula	A	B
Elaktothrix		B	Diatoma	A	B
Eudorina	A	B	Diploneis		B
Eunotia		B	Epithemia		B
Gonium	A		Fragilaria	A	B
Kirchneriella	A		Gomphonema	A	B
Microspora		B	Gyrosigma	A	B
Mougeotia		B	Hantzschia	A	B
Nephrocytium		B	Mastogloia	A	B
Oedocladium		B	Melosira	A	
Oedogonium	A	B	Meridion	A	
Oocystis	A	B	Navicula	A	B
Phacotus	A	B	Neidium	A	
Rhizoclonium		B	Nitzschia	A	B
Scenedesmus	A	B	Pinnularia		B
Sphaerocystis	A		Rhoiocosphenia	A	B
Spirogyra		B	Rhopalodia	A	B
Staurastrum	A	B	Stauroneis	A	B
Stigeoclonium		B	Surirella	A	B
Tetraedron		B	Synedra	A	B
Tetrastrum	A		Tabellaria	A	
Tetraspora		B			
Ulothrix		B			
Zygnema		B			

1/ A = Organisms identified as phytoplankton.

2/ B = Organisms identified as periphyton.

Table 6. Phytoplankton[1/] and periphyton[2/] identified during the study--continued

Organisms by genera			Organisms by genera		
Blue-green algae			**Euglenoids**		
Agmenellum		B	Colacium		B
Amphithrix		B	Croomonas	A	
Anabaena	A	B	Cryptomonas	A	
Anacystis	A	B	Euglena	A	B
Aphanizomenon	A		Phacus	A	B
Arthrospira		B	Trachelomonas	A	B
Aulosira		B			
Cylindrospermum		B	**Flagellates**		
Gloeotrichia		B			
Gomphosphaeria	A		Chrysococcus	A	B
Lyngbya	A		Dinobryon	A	B
Nostoc	A	B	Epipyxis		B
Oscillatoria	A	B	Ochromonas	A	
Plectonema		B	Tribonema	A	B
Spirulina		B	Uroglendopsis	A	
Dinoflagellates					
Ceratium	A				
Glenodinium	A				
Gymonodinium	A				
Peridium	A	B			

1/ A = Organisms identified as phytoplankton.

2/ B = Organisms identified as periphyton.

Table 7.--Invertebrates identified during the study

Organisms listed by family

Aeschnidae (Dragonfly)
Agrionidae (Damselfly)
Ancylidae (Limpets)
Baetidae (Mayfly)
Caenidae (Mayfly)
Ceratopogonidae (Biting Midge)
Chaoboridae (Phantom Midge)
Chironomidae (Midge)
Chydoridae (Water Flea)
Corixidae (Water Boatman)
Culicidae (Mosquitoe)
Cyclopidae (Cyclops)
Daphnidae (Daphnia)
Diaptomidae (Copopod)
Dytiscidae (Predaceous Diving Beetle)
Elmidae (Riffle Beetle)
Glossiphoniidae (leech)
Gyrinidae (Whirligig Beetle)
Haliplidae (Crawling Water Beetle)
Hydracarina (Water Mite)
Hydrophilidae (Water Scavenger)
Leptoceridae (Caddisfly)
Lestidae (Damselfly)
Limnephilidae (Caddisfly)
Lymnaeidae (Pond Snail)
Oligochaeta (Segmented Worm)
Perlodidae (Stonefly)
Physidae (Pouch Snail)
Planorbiidae (Orb Snail)
Tabanidae (Horsefly)
Talitridae (Side Swimmer)

Algal Growth Potential

Algal growth is controlled by light, water temperature, carbon dioxide, the presence of algal cells, and the availability of plant nutrients dissolved in the euphotic zone of the pond. In an essentially closed system, nutrients become most available during the spring overturn which results in the mixing of the pond waters. An increase in diatoms often occurs in the spring, resulting in a temporary decrease in the availability of dissolved nutrients. The nutrients are incorporated into the plant cell, and remain there until the plant dies and its cellular material released by bacterial oxidation. Since bacterial oxidation of cellular material and nutrient release usually occurs at or near the bottom of the pond, the nutrients are often not available to organisms near the surface until another complete mixing of the pond occurs.

Algal growth potential (AGP) is a measure of growth potential of a test algae (*Selenastrum capricornutum*) in dissolved constituents of the water sample. When the nutrients are present in solution, as prior to the spring overturn, the AGP is usually higher than during the rest of the year when the nutrients are not available in the upper levels of the ponds because of thermal stratification or sorption on bottom sediments. This finding that nutrients were not available is most obvious in ponds 2 and 5 (table 8). The potential for algal growth in the May 1976 sample was 3 to 4 times the potential in samples collected in August or February. In pond 3, the May sample had a considerably higher AGP than the February sample, but was about the same as the August 1975 sample. Pond 1 had a higher potential for algal growth in February 1976 than did the other ponds but by May 1976 the AGP was within the range established for the other ponds.

Table 8.--Values of algal growth potential in pond water

	Algal growth potential in milligrams per liter			
	AUG 1975	FEB 1976	MAY 1976	AUG 1976
Pond 1	----	17.00	2.70	0.40
Pond 2	0.60	.70	2.70	.20
Pond 3	1.10	.40	1.20	.20
Pond 5	.50	.50	.40	.30

Chemical Characteristics

Water samples were analyzed for dissolved and total major and minor elements and the nutrients nitrogen and phosphorus. The results are listed in tables 9A and 9B.

Dissolved Oxygen

Dissolved oxygen is essential to aerobic aquatic organisms. In unproductive ponds, the dissolved-oxygen concentration is usually uniform throughout and near saturation. In enriched ponds, the concentration of dissolved oxygen can be high, even to the point of supersaturation, or it can be very low if respiration and oxidation of organic matter are rapidly taking place (Dong, 1974, p. 19).

The dissolved oxygen measured at the surface of each pond indicated that pond 5 had the most uniform values ranging from 7.3 to 10.0 mg/L. A mimimum dissolved-oxygen concentration of 1.2 mg/L was measured during the winter in pond 1. The maximum dissolved-oxygen concentration, 14.2 mg/L, was measured in pond 3, also during the winter.

Beginning in May 1976, the dissolved oxygen was measured vertically throughout each pond and the results indicated ponds 1 and 5 had a more even distribution of oxygen throughout their depths. The oxygen profiles for May and August 1976 are shown in figure 3.

Table 9A.--Dissolved (Diss) and total (Tot) chemical constituents in pond water, August 1975 and February, May, and August 1976

CHEMICAL PARAMETER	POND 1				POND 2				POND 3				POND 5			
	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG
Alkalinity($CaCO_3$) mg/L	216	60	126	117	299	321	349	230	207	181	237	181	126	135	153	95
Aluminum(Diss) µg/L	10	60	30	0	20	0	20	49	70	0	20	10	10	10	80	10
Aluminum(Tot) µg/L	80	840	80	120	130	80	1200	450	10	50	200	250	50	960	550	80
Antimony(Diss) µg/L	0	0	---	---	0	0	---	---	0	0	---	---	0	0	---	---
Antimony(Tot) µg/L	1	0	---	---	0	0	---	---	1	0	---	---	0	0	---	---
Arsenic(Diss) µg/L	3	3	1	3	2	0	1	5	1	1	0	1	0	0	1	3
Arsenic(Tot) µg/L	3	3	1	3	3	0	1	5	1	1	0	2	0	1	1	3
Beryllium(Diss) µg/L	10	10	20	0	10	10	0	0	---	10	0	0	10	0	10	0
Beryllium(Tot) µg/L	10	0	0	0	10	10	0	10	10	10	0	0	10	0	0	0
Bicarbonate mg/L	263	73	154	143	---	391	426	280	252	221	289	213	109	165	186	79
Boron(Diss) µg/L	130	---	80	90	900	---	740	770	400	---	380	420	190	---	190	230
Cadmium(Diss) µg/L	0	1	0	0	3	0	1	0	0	1	1	0	0	1	0	0
Cadmium(Tot) µg/L	10	10	10	10	30	0	10	10	10	10	10	10	10	10	10	10
Calcium(Diss) mg/L	45	18	31	22	320	280	310	280	130	97	140	130	60	56	27	55
Carbonate mg/L	0	0	---	0	---	0	---	0	0	0	---	4	22	0	---	18
Chloride(Diss) mg/L	4.4	3.1	2.7	.8	20	18	19	19	18	14	22	21	24	13	16	21
Chromium(Diss) µg/L	0	0	0	0	10	0	10	0	0	0	10	0	0	0	0	0
Chromium(Tot) µg/L	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0
Copper (Diss) µg/L	2	3	2	1	1	1	2	2	2	2	4	2	3	4	7	3
Copper(Tot) µg/L	10	10	20	10	10	10	40	10	10	10	20	10	10	10	10	10
Fluoride(Diss) mg/L	.6	.2	.3	.4	.5	.4	.4	.4	.7	.6	.7	.8	.5	.4	.4	.5
Hardness(NonCarb) mg/L	16	6	0	0	---	1800	2100	2100	860	560	890	970	290	190	170	280
Hardness(Tot) mg/L	230	66	120	110	2700	2100	2500	2300	1100	740	1100	1100	410	330	330	380
Iron(Diss) µg/L	30	150	350	150	20	40	60	40	0	0	20	10	0	20	20	30
Iron(Tot) µg/L	170	760	420	1200	190	40	2000	580	50	140	230	160	20	910	640	20
Lead(Diss) µg/L	3	1	3	1	0	2	3	1	0	2	5	0	0	2	6	1
Lead(Tot) µg/L	100	100	100	100	200	100	100	100	100	100	100	100	100	100	100	100
Lithium(Diss) µg/L	20	0	10	10	260	190	220	250	190	130	190	240	80	60	80	90
Lithium(Tot) µg/L	10	10	10	10	180	190	250	270	130	140	220	240	60	70	90	100
Magnesium(Diss) mg/L	29	5.1	11	14	460	340	410	400	180	120	190	200	64	46	63	58
Manganese(Diss) µg/L	0	160	50	20	60	290	30	260	---	10	30	30	10	10	30	10
Manganese(Tot) µg/L	90	170	50	120	130	390	340	230	40	40	60	50	20	130	30	10
Mercury(Diss) µg/L	0	0	.2	0	0	0	0	0	.1	0	0	.2	0	0	0	0
Mercury(Tot) µg/L	0	0	.6	.3	0	0	.3	0	---	0	.1	.3	0	0	.1	1.4
Molybdenum(Diss) µg/L	0	1	0	0	1	1	0	1	3	1	2	3	1	0	1	1
Molybdenum(Tot) µg/L	1	2	1	0	1	2	1	1	3	2	4	3	1	2	1	0
Nickel(Diss) µg/L	0	3	4	2	9	13	13	13	2	4	10	4	5	11	11	6
Nickel(Tot) µg/L	50	50	50	50	50	50	100	50	50	50	50	50	50	50	50	50
Nitrogen NH_4-N(Tot) mg/L	0	---	.05	0	.01	.04	.04	0	0	.04	.05	0	0	.15	.05	0
Nitrogen NH_4-N(Diss) mg/L	---	---	.01	0	---	---	.05	.06	---	---	.05	.01	---	---	.21	.02

Table 9A.--Dissolved (Diss) and total (Tot) chemical constituents in pond water, August 1975 and February, May, and August 1976--continued

CHEMICAL PARAMETER	POND 1				POND 2				POND 3				POND 5			
	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG
Nitrogen Total as N mg/L	1.2	1.3	1.1	1.4	1.4	1.9	1.5	1.3	0.70	0.84	0.64	0.64	0.97	1.70	0.78	0.74
Nitrogen Tot as NO_3 mg/L	5.3	5.8	4.9	6.2	6.2	8.5	6.7	5.8	3.1	3.7	2.8	2.8	4.3	7.6	3.5	3.3
N Diss as Org-N mg/L	---	---	.99	1.2	---	---	.96	1.3	---	---	.71	.77	---	---	.94	.74
N Tot as Org-N mg/L	1.2	---	1.1	1.4	1.4	1.3	1.5	1.2	.67	.74	.58	.63	.96	1.2	.68	.73
KJD Nitrogen(Diss) mg/L	---	---	1.0	1.2	---	---	1.0	1.4	---	---	.75	.78	---	---	1.1	.76
KJD Nitrogen (Tot) mg/L	1.2	1.3	1.1	1.4	1.4	1.3	1.5	1.2	.67	.78	.63	.63	.96	1.3	.73	.73
NO_2+NO_3 Diss as N mg/L	---	---	.05	.02	---	---	.04	.16	---	---	.02	.04	---	---	.07	.03
NO_2+NO_3 Tot as N mg/L	0	.02	.31	0	.01	.61	.30	.11	.03	.06	.18	.01	.01	.41	.32	.01
Diss. Oxygen(Surface) mg/L	8	1.2	8.4	4.3	5.2	12.1	9.6	6.3	6.6	14.2	8.7	7.2	9.2	7.3	10.0	7.3
pH (Field)	7.8	6.7	7.3	8.5	8.3	7.5	8.2	8.4	8.6	8.1	8.3	8.4	9.2	6.9	8.7	9.4
Phosphorus(Diss) mg/L	---	---	.04	.03	---	---	.02	.01	---	---	.02	0	---	---	.02	0
Phosphorus(Tot) mg/L	.08	.28	.04	.01	.01	.03	.02	.08	0	.02	.01	.02	0	.08	.01	.02
Potassium(Diss) mg/L	9.2	9.2	10	8.8	27	20	25	25	26	21	25	28	9.1	7.7	8.9	10
Diss.Solids (Calulated Sum) mg/L	1294	93	150	137	---	3150	3510	3670	1830	1250	1780	2070	636	493	568	584
Residue:Diss Ton/Ac-Ft	.4	.13	.20	.19	---	4.28	4.77	4.99	2.49	1.7	2.42	2.82	.87	.67	.77	.79
Sodium Adsorption Ratio	.5	.1	.2	.2	1.9	1.7	1.9	1.8	2	1.6	2.1	2.3	.9	.7	1	.9
Selenium(Diss) µg/L	1	0	0	0	1	0	1	1	1	1	1	1	5	2	2	1
Selenium(Tot) µg/L	1	0	0	0	1	0	1	1	1	1	1	1	5	2	2	1
Silica(Diss) mg/L	1	5.3	2.3	.4	13	18	11	7.7	2.2	6	2.7	1.3	.7	8.8	.8	.4
Sodium(Diss) mg/L	19	2.7	4.9	5.5	230	180	220	200	150	100	160	180	42	30	40	42
Spec.Cond. (Field) µmhos	460	160	320	225	3800	3600	4200	2760	2000	1650	2600	2200	900	700	930	855
Sulfate(Diss) mg/L	56	13	11	14	2700	2100	2300	2600	1200	780	1100	1400	360	250	320	340
Turbidity JTU	5	20	1	5	---	3	55	20	---	6	2	9	2	40	35	2
Vanadium(Diss) µg/L	1.4	3.8	0	---	2.2	1.9	0	---	1.1	1.2	0	---	1.3	1.8	0	---
Water Temp (Celsius)	19	0	18	19	21	0	17	19	22	0	15	26	21	1	17	25
Zinc(Diss) µg/L	0	10	0	0	20	20	0	10	10	0	10	0	10	10	0	0
Zinc (Tot) µg/L	10	10	90	10	20	180	90	30	10	20	90	10	0	30	90	10

Table 9B.--Dissolved concentrations of major cations and anions in pond water, in milliequivalents per liter, August 1975 and February, May, and August 1976

CHEMICAL	POND 1				POND 2				POND 3				POND 5			
PARAMETER	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG	AUG	FEB	MAY	AUG
Cations																
Calcium	2.25	0.90	1.55	1.10	15.97	13.97	15.47	13.97	6.49	4.84	6.99	6.49	2.99	2.80	1.35	2.74
Magnesium	2.39	.42	.90	1.15	37.84	27.97	33.73	32.90	14.81	9.87	15.63	16.45	5.26	3.78	5.18	4.77
Potassium	.24	.24	.26	.23	.69	.51	.64	.64	.66	.54	.64	.72	.23	.20	.23	.26
Sodium	.83	.12	.21	.24	10.00	7.83	9.57	8.70	6.52	4.35	6.96	7.83	1.83	1.30	1.74	1.83
Total	5.71	1.68	2.92	2.72	64.50	50.28	59.41	56.21	28.48	19.60	30.22	31.49	10.31	8.08	8.50	9.60
Anions																
Bicarbonate	4.31	1.20	2.52	2.34	-----	6.41	6.98	4.59	4.13	3.62	4.74	3.49	1.79	2.70	3.05	1.30
Carbonate	0	0	----	0	-----	0	-----	0	-----	0	-----	.13	.73	0	----	.60
Chloride	.12	.09	.08	.02	.56	.51	.54	.54	.51	.40	.62	.59	.68	.37	.45	.59
Fluoride	.03	.01	.02	.02	.03	.02	.02	.02	.04	.03	.04	.04	.03	.02	.02	.03
Sulfate	1.12	.27	.23	.29	56.21	43.72	47.89	54.13	24.98	16.24	22.90	29.15	7.50	5.20	6.66	7.08
Total	5.58	1.57	2.85	2.67	56.80	50.66	55.43	59.28	29.66	20.29	28.90	33.40	10.73	8.29	10.18	9.59
Percent difference	0.53	3.25	1.31	0.62		-0.37	3.47	-2.02	-2.02	-1.73	3.28	-2.97	-1.90	-1.32	-9.03	0.02

Carbonate, Bicarbonate, and pH

The process of photosynthesis in green plants utilizes carbon dioxide in the synthesis of carbon compounds within the cell. One source of carbon dioxide in the aquatic system is the bicarbonate ion. Water high in bicarbonate alkalinity often is more productive than water low in bicarbonate alkalinity (National Acadamy of Sciences 1972, p. 195). The pH also is related to productivity and may be used as an indicator (fig. 6). Carbon dioxide is used in the photosynthetic process and a hydroxol ion is given off during the reaction, thus increasing the pH. During respiration carbon dioxide is released, hydroxol ions are taken up, and an excess of hydrogen ions results in a decrease in the pH.

In pond 5, the pH reached 9.2 by August 1975 and 22 mg/L of carbonate was measured (fig. 7A). At no other time was carbonate measured in solution.

Ponds 1 and 5 were the lowest in measurable bicarbonate alkalinity (fig. 7A). The lowest value (73 mg/L) was measured in February in pond 1. The August 1975 sample from pond 5 had a low value of bicarbonate alkalinity (109 mg/L). Pond 3 had bicarbonate alkalinity values which were relatively uniform throughout the year. The values ranged from a low of 213 mg/L in the August 1976 sample to 289 mg/L in the May sample. Pond 2 had the highest bicarbonate values with a maximum of 426 mg/L in the May sample.

The pH values in ponds 2 and 3 were consistently high and somewhat uniform throughout the year. The lowest value was 7.5 in February in pond 2. The highest pH was measured in pond 3 in August 1975. Ponds 1 and 5 had the greatest change in pH, with a range from 6.7 units in February to 9.4 units in August 1976.

Major Elements

In addition to the major plant nutrients, phosphorus and nitrogen, many elements and compounds play an important biochemical role in the pond. Sulfate, formed in this study area by oxidation of sulfides in coal, is important in promoting the formation of chlorophyll but is not a part of the final product. A concentration range of 3 to 30 mg/L may be considered normal (Hutchinson, 1957), with the highest values usually occurring in the spring and the lowest in the fall (Reid, 1976). In this study the sulfate concentration in the ponds (fig. 7A) was much higher than normal and the seasonal distribution was opposite that given by Reid and Wood (1976).

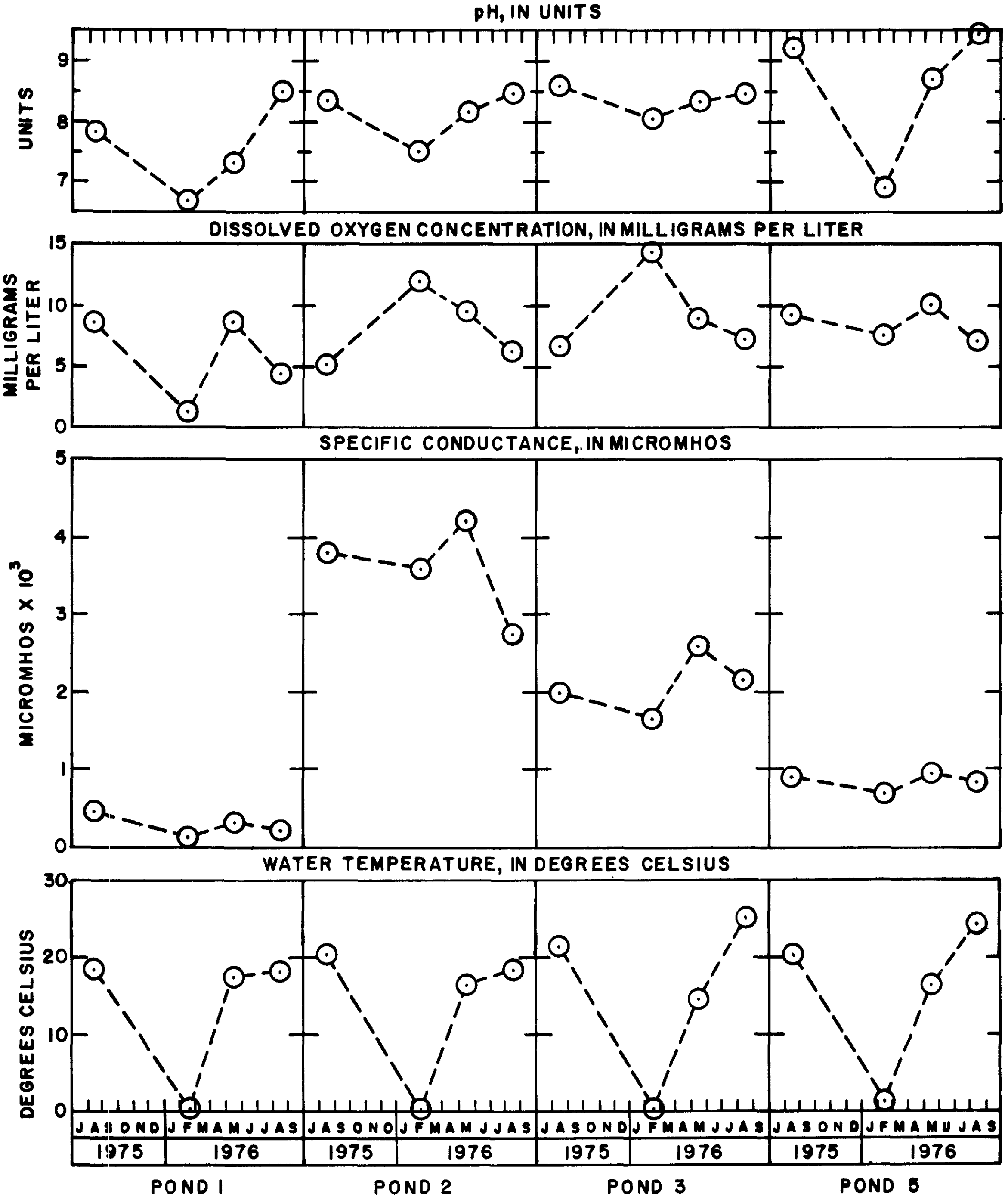

Figure 6.--Seasonal fluctuations of pH, dissolved oxygen, conductance, and temperature.

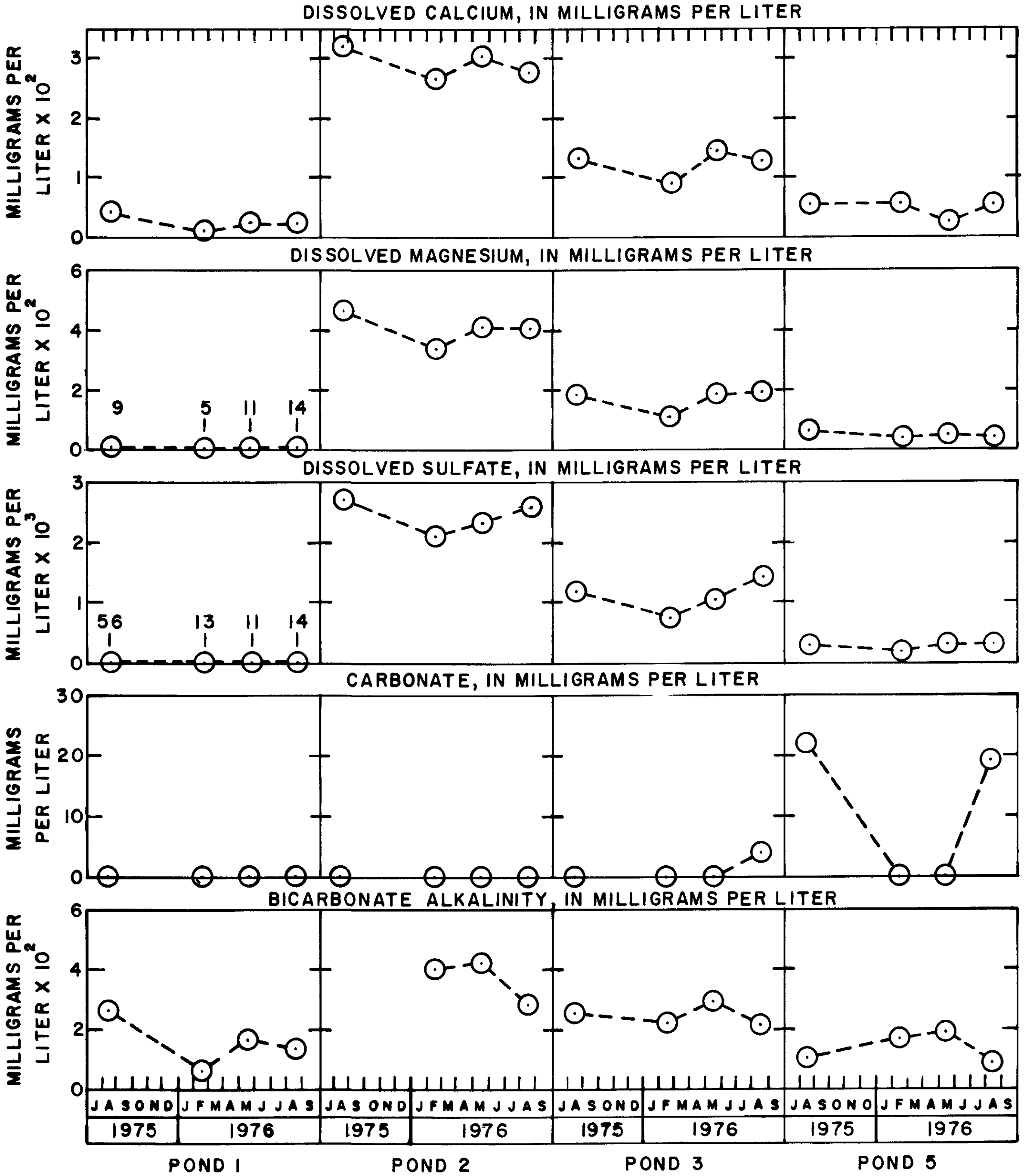

Figure 7A.--Seasonal relationships of common chemical constituents: Calcium, magnesium, sulfate, carbonate, and bicarbonate.

Manganese is necessary in small amounts as an enzyme activator in the photosynthetic process. Amounts often greater than 1 mg/L have been reported in coal mining areas (Hem, 1970). Manganese values for the ponds in this study were well below that figure (fig. 7B).

Potassium (fig. 7B) acts as a catalyst in the process of photosynthesis. Values greater than 30 mg/L are considered high in most waters (Hem, 1970). Sodium also is an essential element for biological processes and may replace potassium when potassium is limiting. Iron is another element that aids in the formation of the chlorophyll molecule. Free iron is seldom found in detectable amounts in solution when the oxygen level is high, unless incomplete precipitation results in a supersaturated solution. All study ponds had dissolved iron in their waters during at least part of the year (fig. 7B).

Calcium and magnesium are the major cause for hardness in water (fig. 7A). The concentrations of the two elements should be similar, with calcium generally being slightly greater. If calcium nears saturation, it precipitates as calcite, causing magnesium to be in greater concentration. This is an unusual situation according to Hem (1970), yet in three of four ponds the magnesium concentration is greater than the calcium concentration. Magnesium is an essential part of the chlorophyll molecule and its concentration therefore is important in photosynthesis. Snails and some crustacea need a minimum of 20 mg/L calcium for the formation of their outer coverings (Coker, 1968). Waters having greater than 25 mg/L calcium are considered rich in that element (Reid and Wood, 1976).

The suspended solids in a pond play more of a physical role by affecting the light penetration and the surface water temperatures (fig. 7C). Settleable solids may interfer with the respiration of fish by abraiding their gills. Settleable solids also may absorb trace elements and settle to the bottom of the pond, acting as a sink.

All ponds except pond 1 were characteristically of the magnesium-calcium-bicarbonate type. Pond 1 was a calcium-magnesium-bicarbonate type. Most chemical constituents varied seasonally and also between ponds. The highest concentrations were most often measured in the August sample than the May sample. The February samples characteristically had the lowest concentrations measured. Ponds 2 and 3 were higher than ponds 1 and 5 in potassium, sulfate, chloride, boron, calcium, silica, magnesium, sodium, and dissolved solids, often by a factor of ten or more. The total hardness (fig. 7C) of the water and the specific conductance (fig. 6) in ponds 2 and 3 was much greater than in ponds 1 and 5. Iron was the highest in pond 1, reaching 350 μg/L in the May 1976 sample. The highest value of manganese was 290 μg/L and was measured in pond 2 in the February sample.

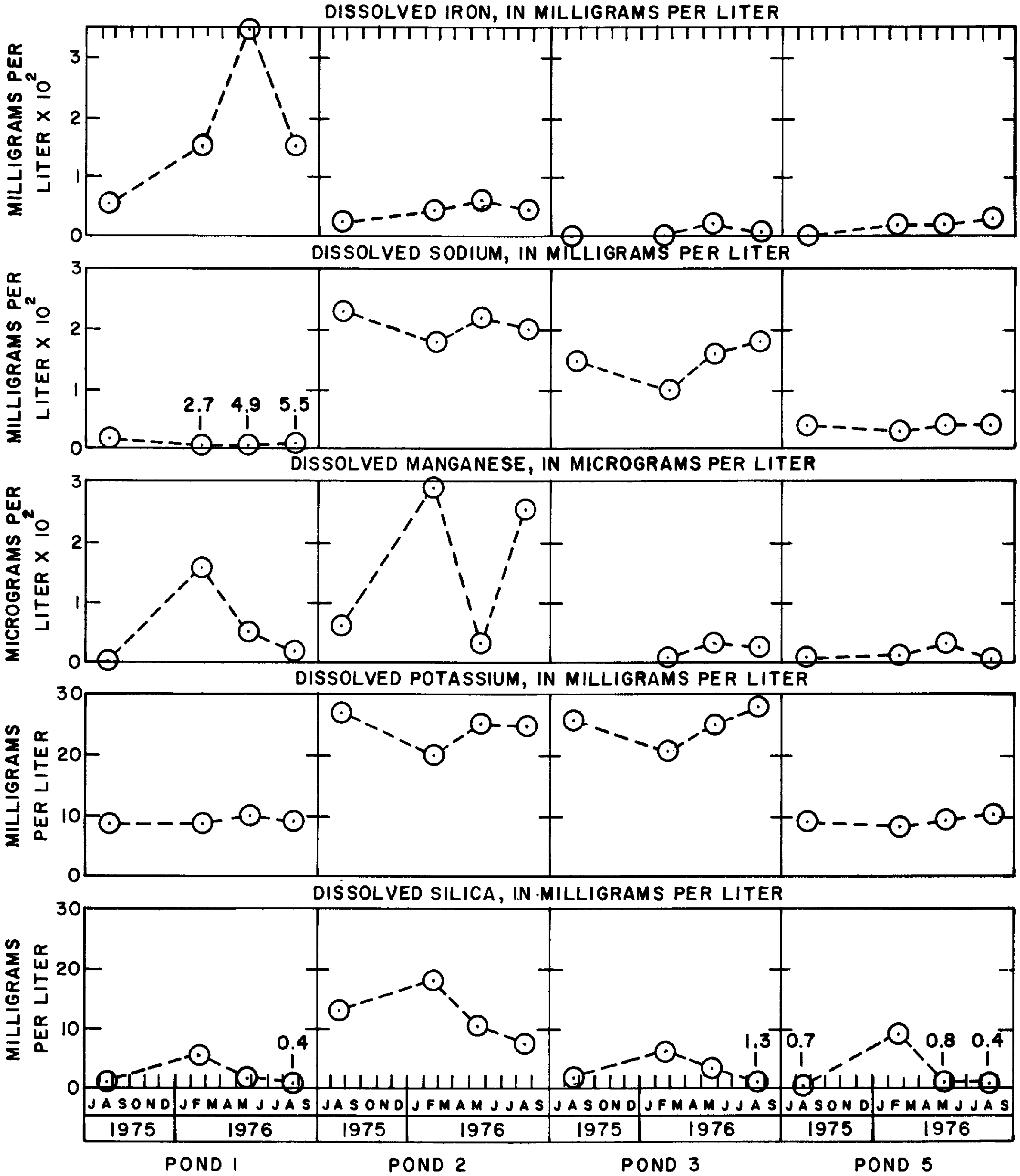

Figure 7B.--Seasonal relationships of common chemical constituents: Iron, sodium, manganese, potassium, and silica.

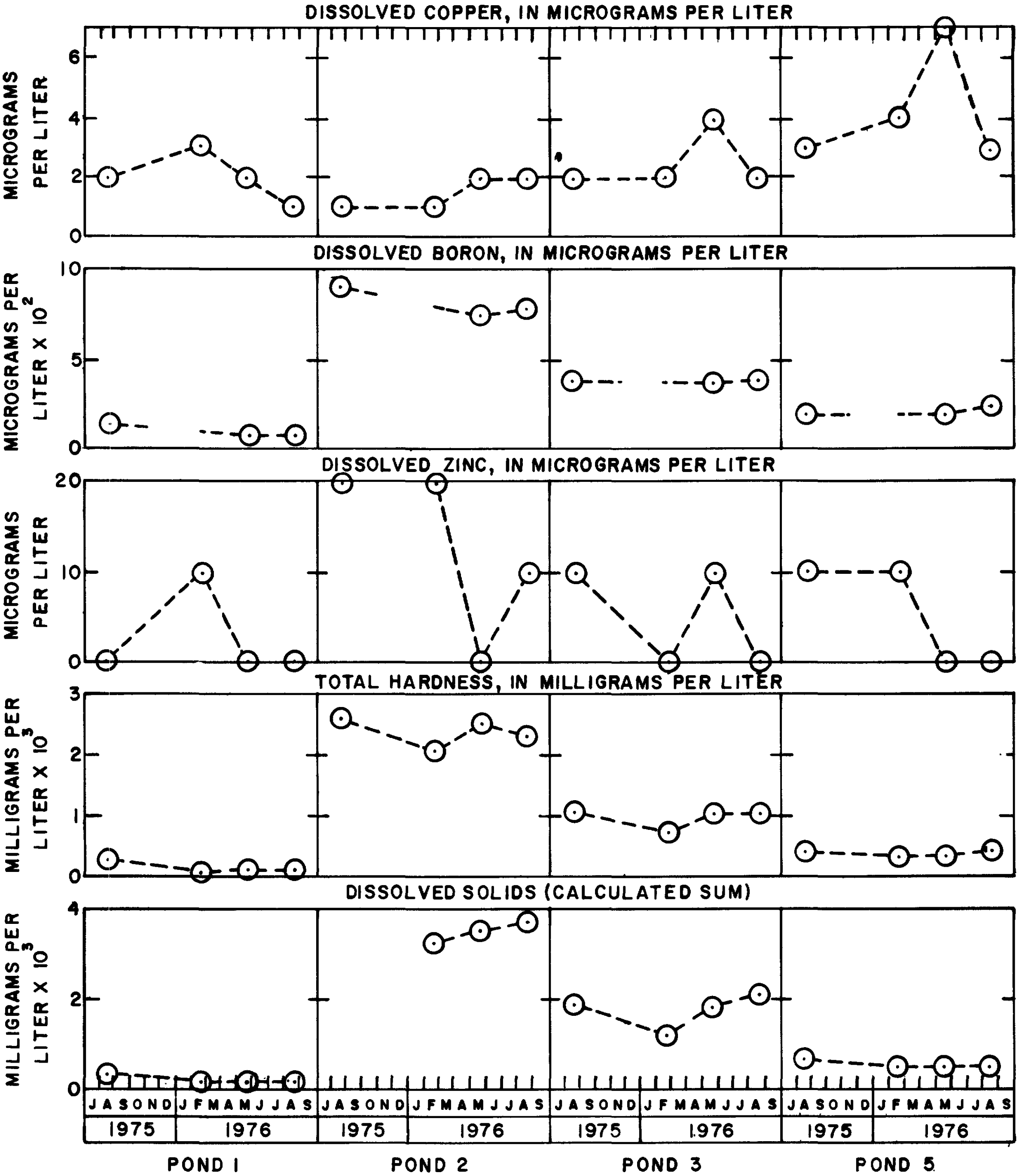

Figure 7C.--Seasonal relationships of common chemical constituents: Copper, boron, zinc, hardness, and dissolved solids.

The sulfate concentration in pond 2 was the highest found in any of the ponds with the August 1975 sample having 2,700 mg/L dissolved sulfate (fig. 7A). Pond 3 also was high with 1,400 mg/L in August 1976. The lowest sulfate value was 11 mg/L in pond 1 and was measured in May 1976.

Calcium, magnesium, and sodium concentrations also were highest in pond 2, in the August 1975 sample. Calcium reached a high of 320 mg/L and magnesium reached a maximum of 460 mg/L (fig. 7A). Sodium followed a similar pattern with 230 mg/L the highest value, measured in August 1975, in pond 2 (fig. 7B).

Pond 2 usually had the highest values for major elements, followed by pond 3. Ponds 1 and 5 were characterized by low major element concentrations with pond 1 always being the lowest. This same pattern was apparent in samples of dissolved solids, total hardness, and specific conductance. The dissolved solids were 3,670 mg/L in the August 1976 sample from pond 2 (fig. 7C). Pond 2 had the hardest water (2,100 to 2,700 mg/L), but pond 3 also was quite hard, having a total hardness range of 740 to 1,100 mg/L (fig. 7C). The specific conductance showed a wide range of values from the highest of 2,760 to 4,200 micromhos in pond 2 to the lowest range of 160 to 460 micromhos in pond 1. It was unusual to find the highest values occuring in the May 1976 sample, since this sample also represented the maximum volumes in the ponds. The highest values of conductance would normally be expected during the autumn of the year when the volumes are lowest and the total dissolved solids are the highest.

Nitrogen and Phosphorus

Nitrogen and phosphorus are two of the major plant nutrients. In many cases nitrogen and phosphorus can be growth limiting, but this is dependent on the type of organism and its physiological state. Nitrate is the nitrogen form utilized most readily by green plants but some organisms can utilize nitrogen in other forms. Diatoms seem to utilize the ammonium ion more readily than other forms of nitrogen. Some types of bacteria and blue-green algae can utilize atmospheric nitrogen. Phosphorus is generally preferred in the form of orthophosphate for the formation of compounds which are energy carriers in plant cells.

Only limited dissolved nutrient data are available but the sample collected in May 1976 indicates pond 5 to have considerably more dissolved ammonia nitrogen than do the other ponds (fig. 8). Pond 5 also had the highest value of nitrate nitrogen in its dissolved form. Pond 1 had a very small amount of ammonia nitrogen in comparison to the other ponds and an equally low amount of nitrite plus nitrate nitrogen. Phosphorus in the dissolved form ranged in all ponds from 0.02 to 0.04 mg/L, which is low, but not limiting.

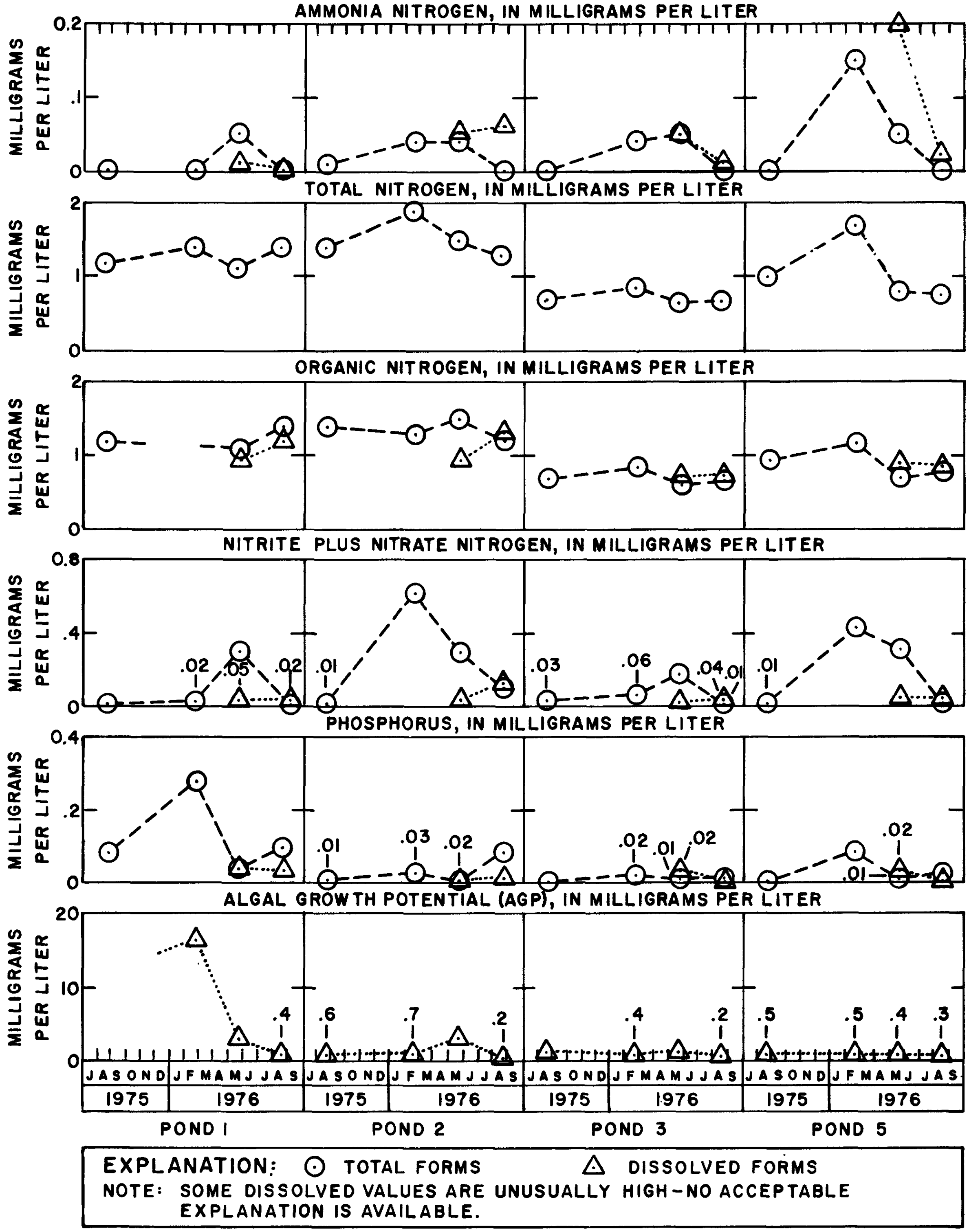

Figure 8.--Seasonal relationships of nitrogen, phosphorus, and algal growth potential.

DISCUSSION

Seasonal changes of water temperature possibly indicate an influx of ground water to the ponds. This statement is supported by the visual observations of low surface-water inflow or outflow. In pond 1 very little change in temperature was measured between May and August (figs. 2 and 3). The only change appeared to be a slight surface fluctuation. The other ponds were not as uniform and the vertical variation in temperature could be explained by daily fluctuations. The fact that the entire water mass did not remain thermally uniform from top to bottom between May and August can be explained by the greater depth and volume of pond 3 and the greater volume of pond 5, which allowed them to stratify thermally.

Light penetration as measured with a Secchi disc indicated transmittance to greater depths in ponds 1 and 5 (fig. 3). The water in ponds 1 and 5 was much clearer for several possible reasons. First, the greater number of phytoplankton cells found in pond 2 could limit light penetration. Secondly, ponds 2 and 3, within the mine area, were formed within or were immediately downstream from unconsolidated, fine soil materials (spoil piles) which had been observed to slough off the pond banks due to wave action or be transported by surface flow during spring runoff. The spoil material adds to the concentration of suspended sediments which, in turn, could cause a decrease in the depth to which light may penetrate. This was noted especially in pond 3.

Dissolved oxygen concentrations were lower in ponds 2 and 3. This may possibly be due to the strong reducing environment created in the coal areas because of high concentrations of magnesium, calcium, and sodium. In May 1975 and 1976, pond 5 had a large population of macrophytes which covered the entire bottom of the pond. This could account for the dissolved oxygen increase toward the bottom of the pond. Phytoplankton contributed to the saturation or near saturation of dissolved oxygen in the surface waters of most of the ponds. Pond 1 was sampled at 10:30 a.m. in August 1976 and therefore may have been recovering from a nighttime dissolved oxygen deficit created by respiration.

In general, the greater the fluctuation in concentration of dissolved oxygen the greater the production by photosynthetic organisms in the pond. Conversely, if the dissolved oxygen concentration fluctuates very little, it is often an indication of low photosynthetic activity. Ponds 2 and 3 had greater fluctuations of dissolved oxygen than did ponds 1 and 5 (fig. 6).

The pH, which also varies significantly with increases and decreases in photosynthesis and respiration, may be used as an indicator of relative production within a pond. As photosynthesis increases so does the pH and as photosynthesis decreases the pH generally decreases. No diel data are available but it was interesting to look at the annual fluctuations of the ponds. Ponds 2 and 3 fluctuated less than ponds 1 and 5, an indication that ponds 1 and 5 were more productive of photosynthetic organisms, particularly pond 5. The phytoplankton data did not indicate pond 5 to be very productive, but the large numbers of rooted aquatic plants that were observed could explain the pH fluctuations. Also, ponds 2 and 3 were higher in dissolved solids and consequently had a higher specific conductance. This indicated that ponds 2 and 3 were more highly buffered, with regard to pH, than pond 5. Pond 1 was was not as well buffered as the other ponds, but, at the time of sampling, it had the highest phytoplankton concentration (fig. 2). The more uniformly high phytoplankton population (fig. 4A) of pond 2 may explain its minor pH fluctuation. The macrophytes could explain the fluctuations in pH in ponds 1 and 5. Also, pond 1 had high populations of phytoplankton.

Often, hard waters contribute to a greater number of organisms and a lower diversity of the community within the pond, whereas in soft water the population will contain fewer members but will be more diverse (Reid and Wood, 1976, p. 218). These findings were supported by this study. Ponds 1 and 5 had a much more diverse population than did ponds 2 and 3. No quantitative data are available at this time for population comparisons.

The concentrations of most of the major ions were higher in ponds 2 and 3 than in ponds 1 and 5 but, according to Hem (1970), the concentrations are neither great enough to be considered toxic nor low enough to limit production. The higher concentrations of major constituents are probably due to the high concentrations of these constituents in ground water in the coal area. The processes of soil leaching through precipitation and evaporation could also act to concentrate major ions in the ponds. Regardless, the nutrients do not appear high enough to show nutrient enrichment or low enough to limit aquatic growth.

Values of algal growth potential (AGP) were low (less than 1 mg/L) in all ponds except pond 1. This can be explained by noting that total phosphorus concentration in pond 1 responded in the same way as did the AGP. However, a high concentration of iron was also present in pond 1 which could have formed a compound with the phosphorus and precipitated from solution when the dissolved-oxygen concentrations were high (Ruttner 1971, p. 91). The dissolved oxygen in February was low (1.2 mg/L) and may have permitted the iron and phosphorus to stay in solution, allowing for a high potential for growth of algae. However, high algal concentrations were not found in the February sample from pond 1 probably due to low temperatures and snow cover over the ice which allowed for very little light to enter the system. The nutrient potential was there but the physical requirements were lacking.

The organisms listed in tables 2, 3, and 4 are ranked in such a way as to present them in dominant groups. The dominant groups of organisms are here viewed from the standpoint of indicators of biological water quality, according to the criteria established by Lowe (1974). Pond 1 was dominated by genera of blue-green algae and diatoms, which Lowe (1974) considers to be indicative of low-water quality. Pond 5 was dominated by fewer blue-green algae but the majority of diatoms present were recognized as being indicators of lesser water quality than ponds 2 and 3 (Lowe, 1974). Ponds 2 and 3 were dominated by green algae and diatoms, recognized by Lowe (1974) as being more indicative of clean water conditions, and euglenoids, which were probably present because of the high concentrations of organic compounds usually associated with coal. This interpretation does not, however, correlate well with the diversity data. Generally, waters of low quality will have large numbers of organisms belonging to a small number of taxa, and hence a low diversity. Clean waters are characterized by relatively large numbers of taxa each with fewer organisms and having a high diversity. Ponds 1 and 5 had relatively high but, more importantly, stable diversity indices (table 1). Pond 2, however, had the highest diversity and lowest diversity, indicating an unstable system. The instability of the community indicated a lower quality of the aquatic environment from the standpoint of phytoplankton. The diversity of pond 3 was uniformly lower than the other ponds. These data demonstrate that pond 3 had the lowest water quality, followed by pond 2, and that ponds 1 and 5 contained clean water. This interpretation indicates that more data are needed in order to use Lowe's classification system for the ponds considered in this study.

Invertebrate diversity was described earlier as being higher in ponds 1 and 5. This could be due partly to the clarity of the water, since many of the predaceous organisms present must see their prey in order to feed. Also, ponds 1 and 5 had a greater population of rooted aquatic plants, especially pond 5. This would provide a more diverse habitat, and account in part for a more diverse population of invertebrates. The greater the fluctuation of the physical and chemical properties the lower the diversity of the community of ponds 2 and 3. More diverse, and more stable communities, develop in systems which are more physically and chemically stable.

The periphyton communities are more stable and probably play an important role as oxygen producers during periods of the year when phytoplankton numbers are low. The less stable phytoplankton community is a result of natural cycles of particular groups, which are dependent upon available nutrients, temperature, light intensity, and other physical and chemical characteristics of the environment. Invertebrates pass through life cycles from eggs and adults, which in many cases emerge and are lost to the pond. Thus, the instability of the phytoplankton and invertebrate communities is natural.

In summary, the control ponds (ponds 1 and 5) are quite different from the experimental ponds (ponds 2 and 3) physically, chemically, and biologically. Additional work is necessary to describe precisely why these differences occur.

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