6-1-1977

Buffalo National River Ecosystem - Part III

M. D. Springer

E. B. Smith

D. G. Parker

R. L. Meyer

E. E. Dale

See next page for additional authors

Citation

Springer, M. D.; Smith, E. B.; Parker, D. G.; Meyer, R. L.; Dale, E. E.; and Babcock, R. E.. 1977. Buffalo National River Ecosystem - Part III. Arkansas Water Resources Center, Fayetteville, AR. PUB049A. 97
https://scholarworks.uark.edu/awrctr/92

Authors

M. D. Springer, E. B. Smith, D. G. Parker, R. L. Meyer, E. E. Dale, and R. E. Babcock

BUFFALO NATIONAL RIVER ECOSYSTEMS
PART III

CONTRIBUTING AUTHORS

M. D. SPRINGER
E. B. SMITH
D. G. PARKER
R. L. MEYER
E. E. DALE
R. E. BABCOCK

Water Resources Research Center

Publication No. 49-A

University of Arkansas

Fayetteville

1977

FINAL REPORT

BUFFALO NATIONAL RIVER ECOSYSTEMS PART III

1 April 1976 - 31 May 1977

Submitted by:

Project Director: R. E. Babcock

on Behalf of

Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

for the Office of Natural Sciences,
Southwest Region, National Park
Service, Santa Fe, New Mexico
under Contract Number CX-02960157

ACKNOWLEDGEMENT

This study was supported in part by funds provided by the Office of Natural Sciences, Southwest Region, National Park Service, U.S. Department of the Interior in cooperation with the University of Arkansas at Fayetteville.

Appreciation is also expressed to the following graduate assistants for their dedication to the task:

Robert Andersen
Neil Woomer
Sharon McBride
Bobby Keeland
Ray Strain
Laura L. Rippey

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

WATER QUALITY MONITORING AND ANALYSIS

Richard L. Meyer, Principal Investigator
Robert Andersen, Graduate Assistant
Neil Woomer, Graduate Assistant
Laura Rippey, Graduate Assistant

Samples for water quality analyses and phycological studies were taken from the nine standard sampling locations on the Buffalo River nine times during the period from March 1976 through February 1977. The April-June 1976 samples represent nearly identical conditions throughout the spring period; therefore, emphasis was placed on taxonomic research. As the early January sample was considered sufficiently reflective of stable winter conditions, the December and February periods were used for detailed microscopic examination of the rich and diverse diatom flora that was found in the river this year. A total of 273 taxa of diatoms were identified from the 75 samples collected, including 123 new additions to the diatom flora of the Buffalo River. Details of this study, including the breakdown of many species into varieties, will be presented in a separate paper. A list of the new species found and a general discussion are included in this report.

The water samples were analyzed for the same chemical and physical parameters as those listed in last year's report, plus pH and total alkalinity, which were added in June. Dissolved oxygen, calculated as percent of saturation at ambient water temperature, also is presented in the tables and graphs.

Methods of collection and analysis are essentially unchanged from those given in previous reports. Total alkalinity and pH were measured by the electrometric method given in Standard Methods. A Corning Model 7 pH meter was used. The procedure for chlorophylls was altered somewhat in the June through January samples. A known volume of sample was filtered through an 0.45 Millipore filter in the field, and the filter then was dissolved in a known volume of acetone which had been saturated previously with magnesium carbonate to prevent deterioration of the chlorophylls. These samples were maintained at or below O C in the dark until analysis was performed by the glass fiber filter technique as previously described.

DISCUSSION

In general, water quality, as reflected in the parameters measured, changed little from that found in recent years. Most of the differences noted can be related to changes in flow patterns, particularly the persistence of base flow conditions through fall and early winter. The physical-chemical data are presented in Table 1.

The seasonal trends for temperature, turbidity, specific conductance, and total alkalinity are shown in Figure 1. Trends for pH, silica, nitrate, dissolved oxygen, percent saturation, and orthophosphate are shown in Figure 2. Upstream-downstream trends for these parameters are shown in Figures 3 and 4. The seasonal cycle of temperature was as expected. An unusually cold period occurred in December and January, and a thick ice cover persisted on the quiet water areas for several weeks. Water temperatures ranged from 0 C beneath the ice in January to 30 C at several stations in July. There appears to be a slight increase in mean temperature in the downstream direction but, because sampling usually is done at the upstream stations early in the day and at the downstream stations later in the day, much of the apparent increase is undoubtedly due to normal diurnal warming of the water as the day progresses.

The relationship of turbidity to surface runoff is illustrated in Figure 1, which shows a rapid dropoff from the March samples, taken during a period of flooding, to the June samples, taken when the river was falling rapidly after a rise, to a base level of extraordinarily clear water in July that persisted for the rest of the year in the absence of any significant surface runoff. Mean turbidity was also slightly higher in a downstream direction, as would be expected (Figure 3). Turbudity readings ranged from a high of 43 NTU at Rush in March to a low of 0.6 NTU at Rush in January.

Conductivity, pH, and total alkalinity are related parameters, at least in the Buffalo River (pH trends are shown in Figure 2). Conductivity is related to total dissolved solids (TDS), alkalinity is a measure of the basic or proton-accepting ions in water, and pH is a

Table 1. Buffalo National River Physical and Chemical Data (March 1976-January 1977)

Survey Date 11 March 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley	--	--	--	--	--	--	--	--	--	--
Ponca	10°	13	10.2	90.2	45	3.77	0.241	0.031	--	--
Jasper	13°	12	9.6	90.5	70	3.55	0.300	0.012	--	--
Pruitt	11°	18	9.6	90.6	75	3.74	0.260	0.035	--	--
Hasty	15°	13	8.2	80.4	100	4.98	1.219	0.034	--	--
Gilbert	11°	17	16.2	145.0	85	4.13	0.400	0.018	--	--
Highway 14	10.5°	22	9.5	84.8	90	4.28	0.420	0.013	--	--
Buffalo Pt.	10°	40	10.0	88.5	90	4.05	0.050	0.022	--	--
Rush	10.5°	43	10.0	89.3	90	4.27	0.201	0.004	--	--
Mean	11.4°	22.3	10.4	94.9	83.0	4.09	0.386	0.021	--	--

Survey Date 30 April 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley	12.5°	--	8.2	76.6	40	2.28	0.178	0.004	--	--
Ponca	12.2°	--	8.0	74.1	50	3.18	0.099	0.004	--	--
Jasper	14.0°	--	7.9	76.0	70	3.20	0.099	0.004	--	--
Pruitt	13.2°	--	7.7	72.2	60	3.39	0.099	0.004	--	--
Hasty	14.5°	--	7.2	69.9	130	3.30	0.138	0.005	--	--
Gilbert	15.5°	--	7.8	77.2	115	3.30	0.138	0.007	--	--
Highway 14	16.8°	--	8.0	82.5	125	3.48	0.138	0.005	--	--
Buffalo Pt.	16.2°	--	8.0	80.1	130	3.02	0.178	0.005	--	--
Rush	15.0°	--	8.0	78.4	130	3.30	0.099	0.004	--	--
Mean	14.4°	--	7.86	76.4	94.4	3.16	0.129	0.005	--	--

Survey Date 30 June 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley	19.5°	6.3	--	--	70	7.58	0.224	0.001	7.8	32
Ponca	19.5°	4.6	--	--	92	7.54	0.263	0.174	7.5	50
Jasper	20.0°	4.3	--	--	132	8.42	0.361	0.122	7.8	77
Pruitt	22.5°	4.1	--	--	152	6.87	0.263	0.001	7.9	82
Hasty	22.5°	4.5	--	--	162	8.20	0.420	0.010	8.0	94
Gilbert	22.0°	4.75	--	--	180	8.31	0.813	0.010	8.05	96
Highway 14	26.0°	4.75	--	--	185	8.71	0.420	0.001	8.2	98
Buffalo Pt.	25.5°	4.75	--	--	172	8.09	0.420	0.001	8.1	98
Rush	25.0°	5.7	--	--	172	9.08	0.499	0.001	8.15	98
Mean	22.5°	4.86	--	--	143	8.08	0.409	0.035	7.89	80.6

Table 1 (cont.)

Survey Date 15 July 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley	20.2°	2.0	10.3	112.0	89	7.41	0.116	0.000	7.8	44
Ponca	20°	1.5	9.7	105.4	125	6.78	0.116	0.000	7.7	68
Jasper	26°	1.6	9.9	120.7	170	6.88	0.200	0.008	8.0	100
Pruitt	26°	2.1	9.5	115.9	165	6.57	0.116	0.006	7.9	94
Hasty	26.5°	2.0	9.3	113.4	200	6.78	0.158	0.007	7.95	110
Gilbert	29°	2.2	11.0	141.0	200	4.78	0.158	0.007	8.1	108
Highway 14	30°	1.4	11.6	152.6	210	6.46	0.116	0.011	8.25	112
Buffalo Pt.	30°	1.4	11.0	144.7	210	5.10	0.200	0.006	8.2	112
Rush	30°	1.5	9.8	128.9	222	6.67	0.241	0.000	8.2	112
Mean	25.9°	1.7	10.2	122.7	176.8	6.38	0.157	0.005	7.97	95.6

Survey Date 18 August 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley*	--	--	--	--	--	--	--	--	--	--
Ponca	24°	2.0	6.95	81.8	160	5.65	0.307	0.000	7.4	86
Jasper	26.5°	2.4	9.4	116.8	180	6.76	0.225	0.000	7.65	113
Pruitt	26°	3.0	8.4	102.4	190	5.35	0.083	0.000	7.8	110
Hasty	26.5°	2.8	8.45	105.0	205	6.66	0.103	0.000	7.8	120
Gilbert	28.5°	1.8	10.05	128.0	205	6.86	0.042	0.000	8.0	108
Highway 14	29.5°	2.2	10.6	137.7	202	7.65	0.083	0.000	8.2	105
Buffalo Pt.	29°	2.7	10.3	132.1	200	7.37	0.042	0.000	8.2	103
Rush	29°	3.5	12.83	164.5	190	7.77	0.002	0.000	8.5	93
Mean	27.4°	2.55	9.63	121.0	191.5	6.76	0.110	0.000	7.83	104.8

Survey Date 16-18 September 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley*	--	--	--	--	--	--	--	--	--	--
Ponca	20.8°	2.8	8.0	88.9	160	4.71	0.119	0.000	7.4	113
Jasper	22°	3.2	8.9	101.1	200	5.78	0.099	0.000	7.8	126
Pruitt	19.9°	2.7	8.5	92.4	199	4.71	0.099	0.017	7.7	126
Hasty	20.6°	2.8	8.9	97.8	200	6.72	0.021	0.002	7.65	128
Gilbert	24°	1.8	9.0	105.9	200	7.53	0.021	0.000	7.8	116
Highway	24.8°	1.1	10.6	126.2	200	7.79	0.041	0.000	8.1	126
Buffalo Pt.	21.5°	1.2	8.5	95.5	185	7.66	0.061	0.000	7.9	126
Rush	25°	0.8	10.6	126.2	198	6.72	0.119	0.000	7.9	120
Mean	22.3°	2.1	9.1	104.3	192.8	6.45	0.072	0.003	7.74	123.3

Table 1 (cont.)

Survey Date 16-17 October 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley*	--	--	--	--	--	--	--	--	--	--
Ponca	18°	1.6	10.2	107.4	150	6.30	0.148	0.004	8.0	124
Jasper	18°	1.5	10.2	107.4	162	5.90	0.203	0.009	7.8	134
Pruitt	16.5°	3.7	9.8	99.5	171	4.88	0.166	0.055	7.9	132
Hasty	16.2°	2.3	9.7	97.0	171	5.80	0.166	0.010	8.0	136
Gilbert	15.5°	1.3	10.5	104.0	160	5.80	0.148	0.008	7.8	134
Highway 14	16.0°	1.1	10.9	109.0	149	5.69	0.148	0.008	8.1	122
Buffalo Pt.	14.5°	1.7	9.6	95.0	159	5.59	0.166	0.000	7.9	122
Rush	13.5°	1.7	8.6	81.9	142	5.31	0.166	0.000	7.9	124
Mean	16.0°	1.9	9.9	100.2	158	5.66	0.163	0.012	7.91	128.5

Survey Date 19 November 1976

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley*	--	--	--	--	--	--	--	--	--	--
Ponca	9	0.9	11.4	98.3	130	4.09	0.061	0.022	7.85	118
Jasper	10	0.9	10.8	95.6	160	4.57	0.061	0.018	7.9	128
Pruitt	8	1.3	11.4	95.8	159	4.57	0.137	0.012	7.9	130
Hasty	8.5	1.2	11.7	99.6	165	4.57	0.157	0.012	7.95	136
Gilbert	10	1.0	11.5	101.8	150	4.79	0.309	0.015	8.15	126
Highway 14	6.5	1.0	10.0	81	151	4.79	0.157	0.000	8.0	134
Buffalo Pt.	7.9	1.2	11.5	96.6	154	4.68	0.157	0.002	8.0	132
Rush	7	0.8	11.5	94.3	150	4.63	0.061	0.000	8.15	134
Mean	8.4	1.9	11.2	95.4	152	4.58	0.137	0.007	7.97	130

Survey Date 4 January 1977

Station	Temp.	Turb.	D.O.	% Sat.	Cond.	Silica	Nitrate	Ortho-Phos.	pH	ALK.
Boxley*	--	--	--	--	--	--	--	--	--	--
Ponca	2	0.8	11.5	83.3	83	3.34	0.079	0.029	7.7	68
Jasper	4	0.6	12.3	97.7	119	3.34	0.173	0.022	7.9	108
Pruitt	1	1.3	12.9	90.8	115	3.88	0.079	0.039	7.8	96
Hasty	2	1.5	13.2	95.7	122	3.22	0.135	0.038	8.0	112
Gilbert	4	0.9	12.6	92.6	117	3.34	0.079	0.056	8.0	102
Highway	1	1.0	13.4	94.4	115	3.27	0.098	0.010	8.0	112
Buffalo Pt.	0	0.7	13.5	92.5	120	3.09	0.173	0.002	8.1	111
Rush	0	0.6	13.5	92.5	114	2.85	0.117	0.019	8.1	112
Mean	1.8	0.9	12.9	92.4	113	3.29	0.116	0.026	7.93	103

FIG. 1 SEASONAL TRENDS FOR TEMPERATURE, TURBIDITY, CONDUCTANCE, AND TOTAL ALKALINITY (MEAN VALUES vs. TIME).

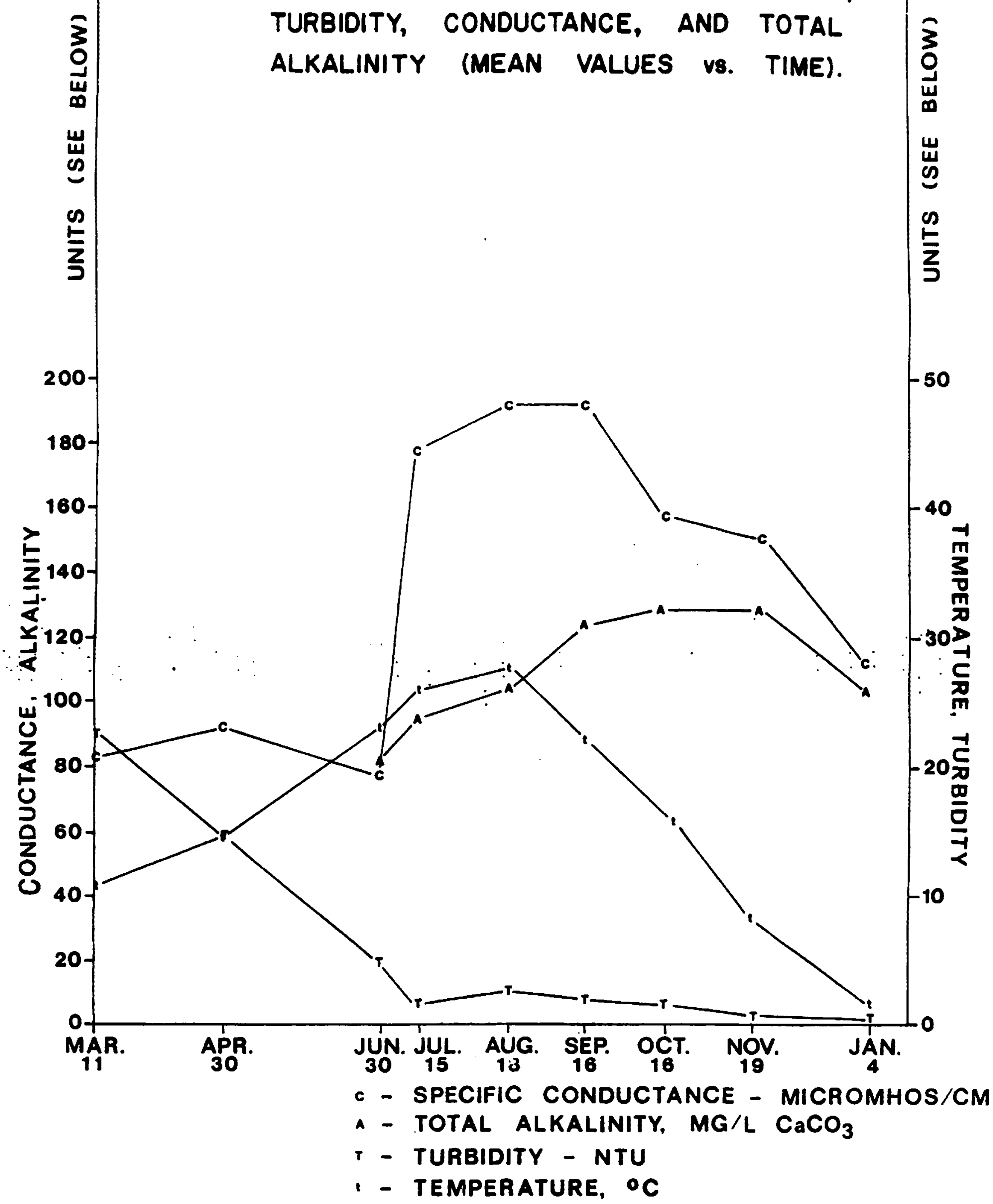


FIG. 2 SEASONAL TRENDS FOR pH, SILICA, PHOSPHATE, NITRATE, DISSOLVED OXYGEN, AND OXYGEN SATURATION (MEAN VALUES vs. TIME).

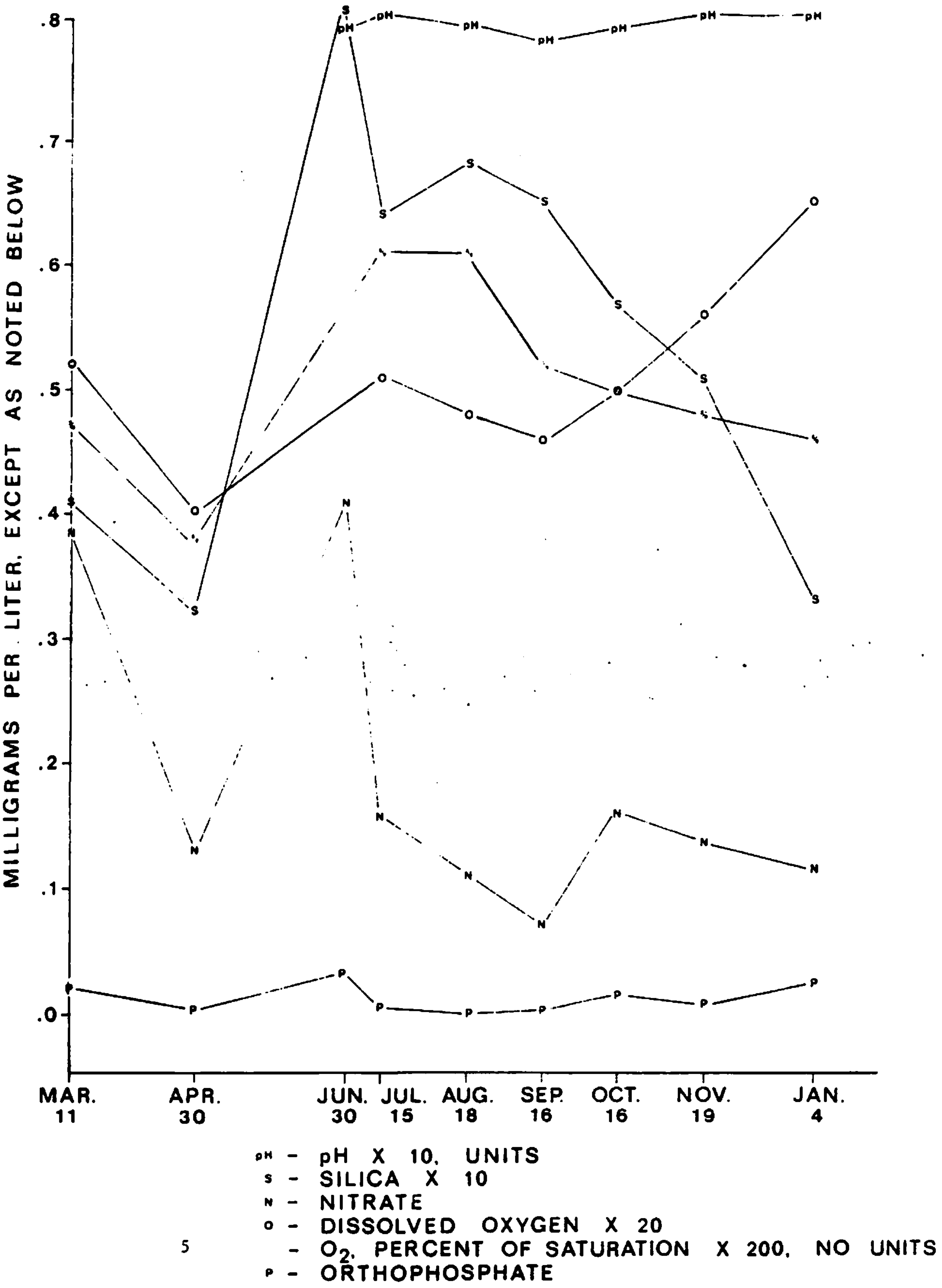
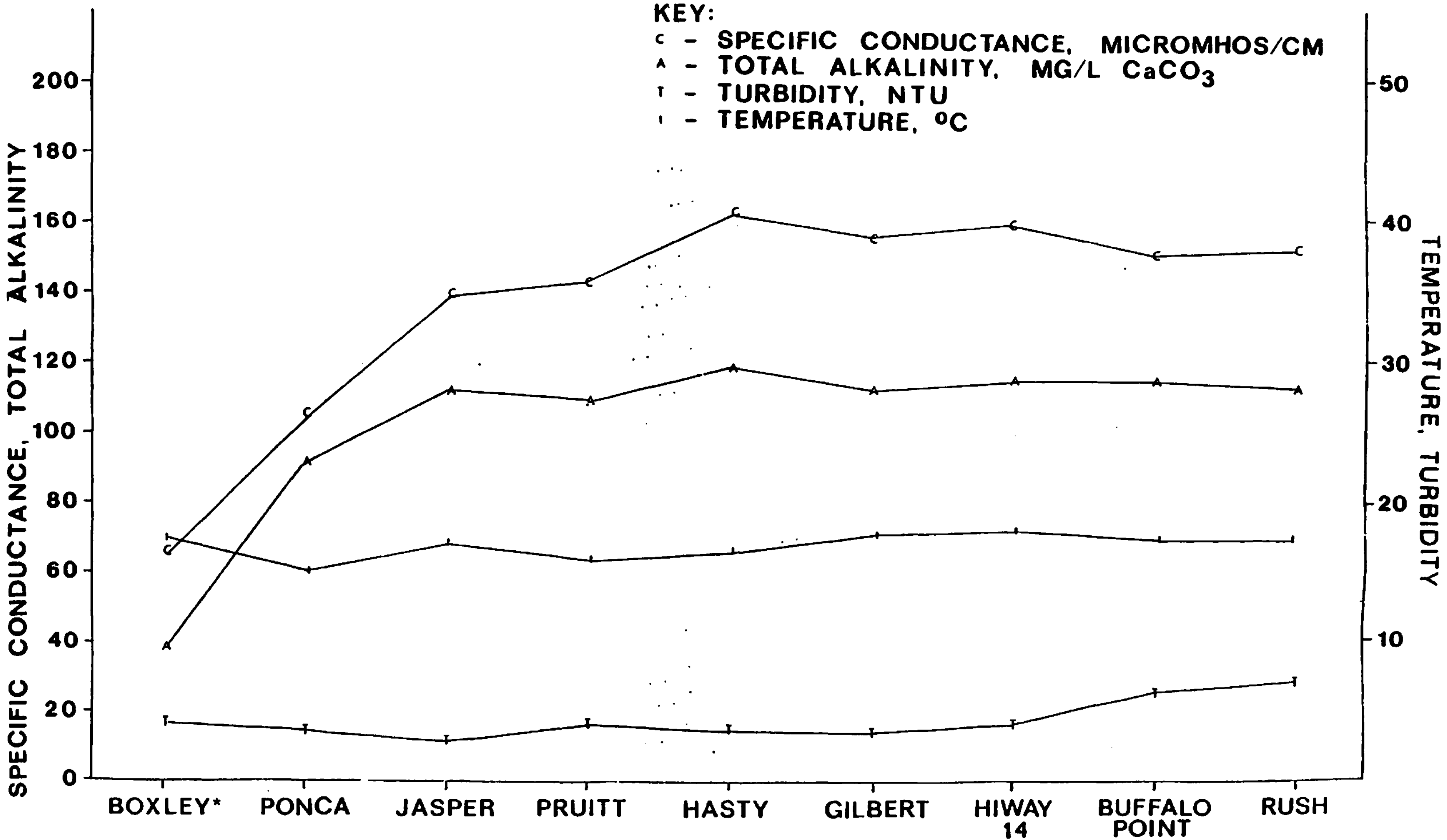


FIG. 3 UPSTREAM - DOWNSTREAM TRENDS FOR TEMPERATURE, TURBIDITY, CONDUCTANCE, AND TOTAL ALKALINITY (MEAN VALUES vs. SAMPLING STATION).



*3 SAMPLES ONLY (APRIL, JUNE, JULY)

measure of the hydrogen ion activity. Bicarbonate is the primary ion contributing to total alkalinity in the Buffalo River, as well as the primary component of the total dissolved solids.

During low flow periods most of the river's flow is contributed by groundwater, which is high in alkalinity and TDS because of dissolution of carbonate from underground limestone. In addition, solids continuously leached from the stream sediments and bedrock contribute to the high in alkalinity. In the absence of diluting runoff, these parameters (and consequently pH as well, because carbonate is a hydrogen ion acceptor) tend to increase. Such a pattern was evident in the Buffalo during 1976. The initial June alkalinity readings, after a high rise, were lowest, and they increased steadily to a high in November (Figure l). Mean pH remained in the 7.8 to 8.0 range throughout the last half of the year (Figure 2). Total alkalinity ranged from a high of 136 mg/l at Boxley in June.

Conductivity showed a similar pattern (Figure 1). Lowest readings were obtained during spring and early summer when rain was relatively abundant and a larger percentage of the flow was derived from runoff. For the next six months the river was essentially at base flow with little or no runoff, and conductivity doubled before falling off in January with the onset of snow. These results are consistent with the assertion that the carbonate, silicate, and other dissolved solids load derives primarily from groundwater and stream bed leaching and that total dissolved solids are diluted by surface runoff.

Figure 2 shows the trends over time for pH, dissolved oxygen, percent oxygen saturation, silica, nitrate, and orthophosphate. It continues to be evident that no significant problems related to organic or other high oxygen-demanding substances are occurring in the Buffalo. Dissolved oxygen levels were consistently above 7 mg/l and near or above saturation at all times with the exception of some anomalous April readings. Oxygen levels as percent of saturation are included in the graphs and tables this year. Oxygen solubility in water varies inversely with temperature, so relatively low values obtained during summer, when primary production is highest, may actually represent supersaturation, where similar or even higher values obtained during winter may be below saturation and indicative of significant oxygen depletion. Several of the samples taken in January were well below saturation because the thick ice cover impeded diffusion of oxygen into the water from the atmosphere. The ice cover also reduces the intensity of insolation reaching the algal population and thereby reduces the amount of surplus oxygen produced above the ambient respiration requirements. In addition, the ice may reduce the periphyton standing crop by mechanical removal through scouring.

Mean dissolved oxygen values from the Gilbert station downstream are higher than those from the upstream stations (see Figure 4). This difference reflects the higher primary productivity in the downstream zone of the river during the summer when the photosynthetic activity of *Spirogyra* drives dissolved oxygen concentrations to more than 150% of saturation. The *Spirogyra* bloom, as pointed out previously, generally does not occur in the upper zone of the river above Gilbert. Work planned for the summer of 1977 is designed to investigate this and other aspects of ecological zonation in the river.

The reported April dissolved oxygen values ranged from 7.2 to 8.2 mg/l and from 69.9 to 82.5% of saturation. Concentrations this low are expected during hot summer months, but values as much as 30% below saturation in the spring, when flows and natural oxygenation are both normally high, and difficult to explain. The April values were obtained by use of the dissolved oxygen meter, and possibly they are in error because of an undetected malfunction of the meter. Subsequent D. O. tests were made by the Winkler titrametric method.

Studies were made on two occasions to determine diel oxygen profiles. Dissolved oxygen and temperature readings were made at 1 to 1½-hour intervals for a 24-hour period. Such studies were done in midsummer at Rush and midautumn at Buffalo Point. The results are plotted in Figure 5, and the patterns obtained are almost identical with those from similar studies in last year's report. In summer, when productivity is high, the diel oxygen range is greater; maximum values occur during mid-to-late afternoon, when the photosynthesis to respiration ratio is highest, and minimum values occur around dawn when this ratio is lowest. The same pattern occurs in cold weather, but productivity is lower and thus the D. O. range is narrower. The range of D. O. values was 2.0 mg/l in July and 1.2 mg/l in November.

Silica levels showed a classic pattern, rising as the predominant algal component changed in spring from diatoms to green algae and other forms, and dropping dramatically

FIG. 4 UPSTREAM - DOWNSTREAM TRENDS FOR pH, SILICA, PHOSPHATE, NITRATE, DISSOLVED OXYGEN, AND OXYGEN SATURATION (MEAN VALUES vs. SAMPLING STATION).

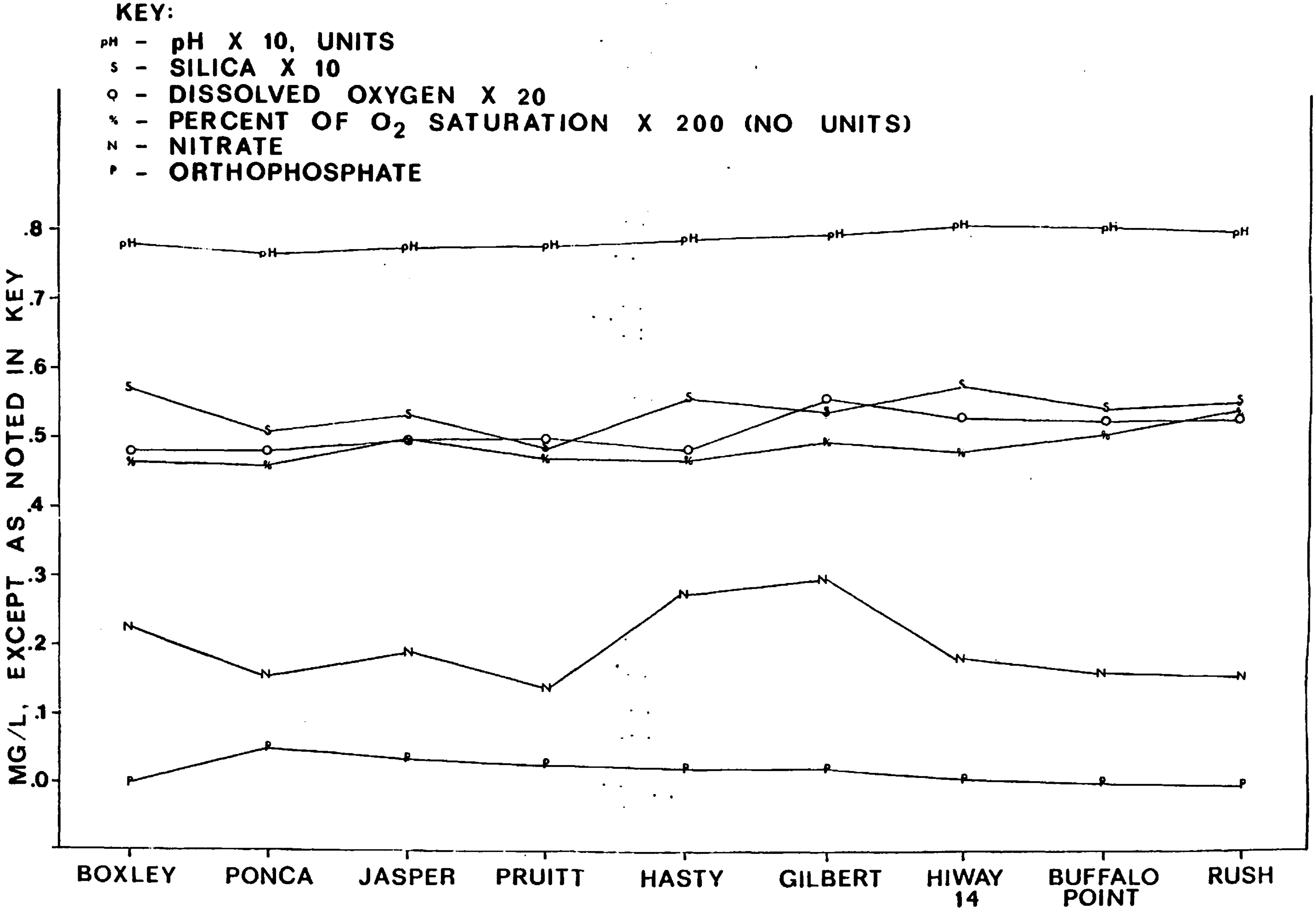
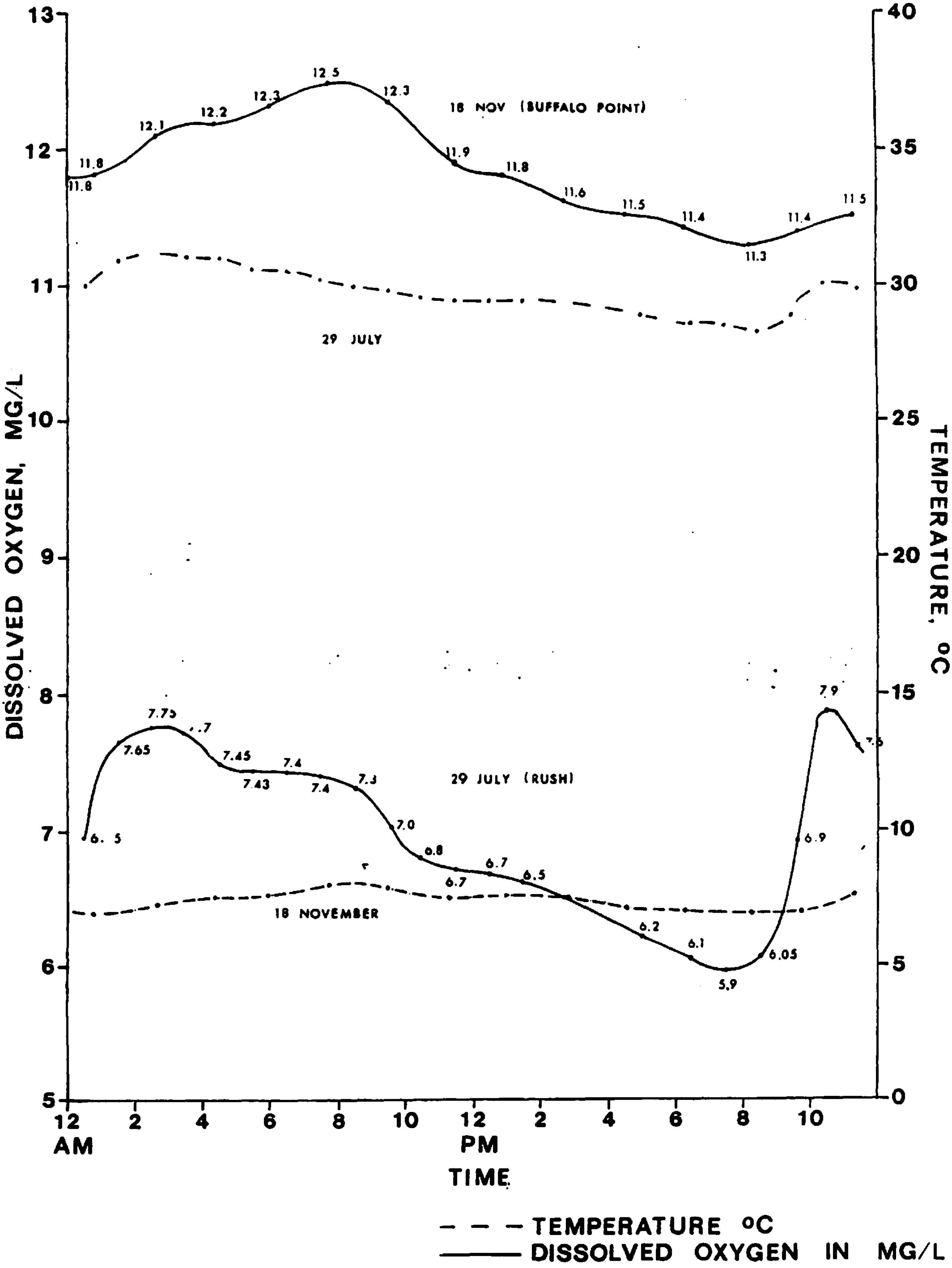


FIG. 5

SEASONAL DIEL OXYGEN PROFILES



as diatoms became re-established as the water temperature dropped in late fall and early winter. The drop seen in mean silica levels in Figure 2 between November and January coincided with the formation of a thick gelatinous coating of expilithic diatoms (predominately *Diatoma vulgare*) which was not visible in November but was very evident in January. The mean silica values found from July through October are significantly higher than those reported in previous years, and this increase perhaps is related to the particularly high diatom populations and species diversity that were evidenced by the addition of 123 new species of diatoms to the Buffalo River list this year. Silica levels ranged from a high of 8.71 mg/l at Highway 14 in June to a low of 2.85 mg/l at Rush in January.

Nitrate and orthophosphate, the so-called nutrient substances, tended to follow the patterns that have been established in past years. Orthophosphate has always been present in very low concentrations and, as can be seen in Figure 2, this year's results are no exception. The small peaks are generally correlated with periods of high surface runoff. Nitrate peaks occurred in the March and June samples, both of which were taken during or immediately after heavy runoff. This finding tends to confirm previous assertions that nitrate loading is directly related to runoff.

Orthophosphate ranged from a high of 0.174 mg/l at Ponca in June to below detectable limits in about a third of the samples collected. Swimmers were present at Ponca in June, and the relatively high phosphate concentration is very possibly related to their use of soap. Nitrate levels ranged from 1.219 mg/l at Hasty in March to 0.002 mg/l at Rush in August. As can be seen in Figure 4, there is again no evidence of downstream loading of either nitrate or orthophosphate. In fact, orthophosphate shows a definite decline in mean values in a downstream direction.

These results illustrate generally that established patterns of water chemistry and water qaulity are being maintained in the Buffalo River. When degradation of certain water quality parameters such as turbidity and nutrients did occur, it was invariably associated with periods of high surface runoff. It is especially significant that uniformly high water quality was observed throughout the length of the river for the entire last half of the year, when precipitation was abnormally low and the river remained at or near base flow for the entire period. It is during these low flow periods that the effects of possible pollution other than surface runoff would be expected to be detected if present. That such effects were not detected is strong indication that significant water quality degradation from point source pollution or recreational usage is not occurring in the Buffalo River at this time.

PHYCOLOGICAL STUDIES

Sampling and analysis of algal communities at the nine standard stations continued during the past year in much the same way as reported previously. The most significant difference was the much greater emphasis placed upon identification and classification of many of the less common species and varieties of all the algae, but particularly the Bacillariophyceae. Table 2 is a list of the new algal species found in the river this year. A total of 253 species not previously reported are listed, including 123 species of diatoms. Further identification of these diatom species resulted in 169 varieties being found. For example, four varieties of *Achnanthes lanceolata* and *Fragilaria brevistriata* were identified, and five varieties of *Synedra ulna*. This detailed taxonomic work will be the subject of a future publication on the diatoms of the Buffalo River.

A detailed duscussion of the spatial and temporal distribution patterns of the common species of algae in the Buffalo River is contained in the M. S. thesis of a previous participant in this study (Rippey, 1976). Last year's Buffalo National River report also contained a lengthy discussion of the general patterns of occurrence of the various communities and subcommunities of algae and their relation to specific water quality parameters. A detailed description of the temporal and spatial compartments which have been identified has been read to, and is to be published in the Proceedings of, the National Park Service Symposium on Scientific Research in the National Parks. (A copy of this paper is included in the Appendix). The patterns noted in this year's analysis indicate that little change has occurred in the broad distributional patterns of Buffalo River algae, so these discussions need not be repeated. It is sufficient here to touch upon some of the new facts or patterns that have emerged from another year's investigation.

The most unique feature of the Buffalo River in 1976 was the abnormally low flow patterns that persisted through fall and early winter. Rippey (1976) concluded among other

Table 2. Additions to the Algal Flora of the Buffalo River

- Chlorophyceae
    - Volvocales
        - Chlamydomonas spp.
        - Chlamydomonas incerta
        - Gonium pectorale
        - Pandorina morum
        - Platymonas elliptica
    - Tetrasporales
        - Gloeocystis ampla
        - Gloeocystis gigas
        - Sphaerocystis schroeteri
    - Chlorococcales
        - Ankistrodesmus convolutus
        - Ankistrodesmus spiralis
        - Characium eniforme
        - Characium strictum
        - Coelastrum cambricum
        - Coelastrum microporum
        - Coelastrum scabrum
        - Crucigenia quadrata
        - Dictyosphaerium ehrenbergium
        - Dictyosphaerium pulchellum
        - Golenkinia radiata
        - Oocystis borgei
        - Oocystis pusilla
        - Oocystis submarina
        - Pediastrum integrum
        - Pediastrum sculptatum
        - Scenedesmus armatus
        - Scenedlesmus longus

        - Scenedesmus quadricauda
        - Scenedemus serratus
        - Tetraedron minimum
    - Ulotrichales
        - Geminella sp.
        - Geminella mutabilis
        - Microspora tumidula
        - Schizomeris sp.
        - Ulothrix subconstricta
        - Ulothrix subtilissima
        - Ulothrix tenerrima
    - Chaetophorales
        - Chaetophera elegans
        - Chaetophora pisiformis
        - Draparnaldia glomerata
        - Stigeoclonium polymorphum
        - Stigeoclonium protensum
    - Oedogoniales
        - Oedogonium reinschii
    - Cladophorales
        - Cladophora basiramosa
        - Rhizoclonium crispum
- Conjugatophyceae
    - Zygnematales
        - Spirogyra neglecta
        - Zygnema spp.
    - Desmidiales
        - Hyalotheca dissiliens
        - Penium marginatum
        - Staruastrum alternans
        - Staurastrum arachne

- Staurastrum cingulum
- Staurastrum orbiculare
- Staurastrum turgescens

Euglenophyceae
- Euglenales
  - Lepocinclis sp.
  - Peronema sp.
  - Phacus sp.
  - Phacus swirenkoi
  - Phacus tortus
  - Trachelomonas creba
  - Trachelomonas volvocina

Pyrrophyceae
- Peridiniales
  - Glenodinium sp.
- Dinococcales
  - Cystodinium steinii

Xanthophyceae
- Heterococcales
  - Ophiocytium capitatum
  - Ophiocytium parvulum
- Heterosiphonales
  - Vaucheria sp.

Chrysophyceae
- Chrysomonadales
  - Chromulina sp.
  - Chrysocossus sp.
  - Chrysocossus minutus
  - Dinobryon bavaricum
  - Dinobryon sertularia
  - Mallomonas spp.

            Mallomonas caudta
        Ochromonas sp.
        Synura spp.
        Synura curtispina
Cryptophyceae
        Chroomonas sp.
        Cryptomonas spp.
Cyanophyceae
    Chroococales
        Aphanothece microscopica
        Aphanothece nidulans
        Aphanothece saxicola
        Chroococcus dispersus
        Chroococcus minor
        Chroococcus minutus
        Chroocoddus turgidus
        Coccochloris stagnina
        Coelosphaerium kuetzingianum
        Gloeocapsa aeruginosa
        Gloeocapsa plurocapsoides
        Gomphosphaeria aponina
        Gomphosphaeria lacustris
        Holopedium irregulare
        Microcystis aeruginosa
        Microcystis pulverea
        Synechococcus cedrorum
        Synechococcus elongatus
    Chamaesiphonales
        Chamaesiphon africanus
        Chamaesiphon cylindricum
        Stichosiphon regularis
    Oscillatoriales

Anabaena minuta
Dictothrix meneghiniana
Gloeotrichia echinulata
Homeothrix juliana
Lyngbya aerugineo-caerulea
Lyngbya aestuarii
Lyngbya latissima
Lyngbya magnifica
Lyngbya nana
Microcoleus annulatus
Nostoc paludosum
Oscillatoria aghardii
Oscillatoria amoena
Oscillatoria chalybea
Oscillatoria foreaui
Oscillatoria nigra
Oscillatoria ornata
Oscillatoria prolifica
Phormidium foveolarum
Phormidium frigidum
Phormidium tenue
Phormidium truncicola
Plectonema nostocorum
Plectonema notatum
Pseudanabaena minutus
Pseudanabaena schmidlii
Rivularia beccariana
Schizothrix hyalina
Schizothrix rivularis
Schizothrix symplocoides

- Spirulina laxa
- Spirulina nordstedii

Bacillariophyceae

- Centrales
  - Cyclotella comensis
  - Cyclotella kuetzingianum
  - Cyclotella meneghiniana
  - Cyclotella stelligera
- Pennales
  - Achnanthes clevei
  - Achnanthes deflexa
  - Achnanthes ambigua
  - Achnanthes exigua
  - Achnanthes linearis
  - Achnanthes microcephala
  - Amphora ovalis
  - Caloneis bacillum
  - Caloneis lewisii
  - Caloneis schumanniana
  - Capartogramma crucicula
  - Cocconeis japonica
  - Cymbella acuta
  - Cymbella aspera
  - Cymbella Brehmii
  - Cymbella cistula
  - Cymbella cymbiformis
  - Cymbella hauckii
  - Cymbella hustedtii
  - Cymbella lanceolata
  - Cymbella microcephala
  - Cymbella parva

Cymbella tumidula

Cymbella turgidula

Diatoma anceps

Diatoma elongatus

Diploneis elliptica

Diploneis oblongella

Diploneis oculata

Diploneis subovalis

Epithemia intermedia

Epithemia reicheltii

Epithemia zebra

Eunotia curvata

Eunotia incisa

Eunotia quaternaria

Eunotia tenella

Eunotia valida

Fragilaria construens

Fragilaria leptostauron

Fragilaria pinnata

Fragilaria vaucheri

Gomphocymbella ancyli

Gomphonema abbreviatum

Gomphonema gracile

Gomphonema intermedia

Gomphonema intricatum

Gomphonema lanceolatum

Gomphonema longiceps

Gomphonema parvulum

Gomphonema Sphaerophorum

Gomphonema ventricosum

Gyrosigma exilis

Gyrosigma obtusatum
Gyrosigma sciotense
Navicula affinis
Navicula agma
Navicula americana
Navicula cincta
Navicula confervacea
Navicula contraria
Navicula cuspidata
Navicula decussis
Navicula disputans
Navicula elginensis
Navicula elmorei
Navicula explanata
Navicula festiva
Navicula gregaria
Navicula hambergii
Navicula hasta
Navicula laevissima
Navicula linearis
Navicula lucidula
Navicula menisculus
Navicula minima
Navicula minuscula
Navicula muralis
Navicula mutica
Navicula notha
Navicula odiosa
Navicula pseudoreinhardii
Navicula pupula
Navicula rhynchocephala

Navicula subhalophila
Navicula subhamulata
Navicula tripunctata
Neidium binode
Neidium bisulcata
Neidium iridis
Nitzschia acicularis
Nitzschia acuta
Nitzschia amphibia
Nitzschia angustata
Nitzschia apiculata
Nitzschia capitellata
Nitzschia clausii
Nitzschia dissipata
Nitzschia frustulum
Nitzschia gracilis
Nitzschia kuetzingianum
Nitzschia linearis
Nitzschia microcephala
Nitzschia sigma
Nitzschia sinuata
Nitzschia sublinearis
Peronia erinacea
Pinnularia interrupta
Pinnularia legumen
Pinnularia maior
Pinnularia mesogongyla
Pinnularia mesolepta
Pinnularia nodulosa
Rhoicosphenia curvata
Stauroneis anceps

Surirella elegans

Surirella linearis

Surirella suecica

Synedra affinis

Synedra amphicephala

Synedra delicatissima

Synedra filiformis

Synedra goulardii

Synedra incisa

Synedra minuscula

Synedra ostenfeldii

Synedra radians

Synedra rumpens

Synedra socia

things that algal distribution was most clearly determined by water level, flow rate, and flooding. Though this conclusion is certainly true it is interesting to note that even with the abnormally low flow patterns, most of the previously described cyclic algal phenomena still occured. *Spirogyra* disappeared for the most part by midautumn, even without the scouring usually associated with high fall flows. Also, the normal wintertime epilithic diatom population appeared as in the past in December in perhaps even greater profusion than is normal.

Though true planktonic communities have not been observed to develop to any appreciable extent in the Buffalo River, small numbers of euplankters have been observed in stagnant pools in summer and early fall when flow is low, and it had been suspected that these populations might persist as long as flushing does not occur. But euplanktonic algae disappeared almost completely without flushing after the onset of cold weather in November, as evidenced by both the chlorophyll date (Table 3) and direct observation of plankton tow samples. A greater number of normally euplanktonic flagellates were found during cold weather; they were not collected from open water as plankton but were found to be associated with the metaphyton. These include such genera as *Dinobryon, Mallomonas, Ochromonas,* and *Synura* among the Chrysophyceae, *Euglena* and *Trachelomonas* among the Euglenophyceae, and *Chlamydomonas* and *Platymonas* among the Chlorophyceae.

Table 3 gives the chlorophyll data for the past year, and as can be seen, previous trends are continued. Chlorophylls a, b, and c concentrations are mostly near or below the limits of detectability. The sample taken on March 11, 1976, contained the highest concentrations of chlorophylls b and c, particularly the latter. This sample was taken near the peak of a high rise following heavy local rains. The high chlorophyll c values probably are associated with the scouring and consequent suspension of the winter diatom populations.

With the exception of March, and to a lesser extent August, chlorophyll concentrations were in general vanishingly small. During the months of November and January values were below detectable limits at all stations. This finding corresponds with observations of plankton tows, which revealed virtually no planktonic algae, and with turbidity data, which showed water of remarkable clarity during those two months.

The same is true of the July samples when no significant amounts of chlorophyll were found in water collected at any of the Buffalo River stations. Chlorophylls were found at

Table 3. Chlorophyll Data (results in micrograms/liter)

Station	11 March 76 Chlorophyll			30 April 76 Chlorophyll		
	a	b	c	a	b	c
Boxley	--	--	--	0.00	0.03	0.79
Ponca	0.26	2.10	5.23	0.00	0.89	3.42
Jasper	0.00	0.98	2.32	0.78	0.31	0.77
Pruitt	0.88	3.08	3.98	0.00	0.00	17.03
Hasty	0.00	0.80	4.52	0.00	0.33	0.77
Gilbert	0.09	1.54	3.78	0.00	0.41	0.00
Highway 14	0.67	2.58	6.60	0.00	1.98	0.00
Buffalo Pt.	0.51	0.94	13.77	0.00	0.83	0.00
Rush	0.00	4.44	15.92	0.00	0.00	0.00

Station	15 July 76 Chlorophyll			30 April 76 Chlorophyll		
	a	b	c	a	b	c
Boxley	0.08	0.22	0.00	--	--	--
Ponca	0.00	0.00	0.00	2.18	0.74	2.94
Jasper	1.09	0.37	1.47	0.52	0.81	0.00
Pruitt	0.00	0.00	0.00	2.04	2.59	4.06
Hasty	0.00	0.00	0.00	1.02	1.41	0.66
Gilbert	0.00	0.00	0.00	0.52	0.81	0.00
Highway 14	0.00	0.00	0.00	2.49	4.44	2.20
Buffalo Pt.	0.00	0.00	0.00	0.52	0.81	0.00
Rush	0.00	0.00	0.00	0.00	0.00	0.00

Station	16, 18 September 76 Chlorophyll			16-17 October 76 Chlorophyll		
	a	b	c	a	b	c
Boxley	--	--	--	--	--	--
Ponca	0.26	0.39	0.00	0.00	0.00	0.00
Jasper	1.29	1.61	0.30	1.74	0.00	0.00
Pruitt	0.13	0.61	0.00	0.00	0.00	0.00
Hasty	1.64	2.45	0.00	2.77	0.46	0.00
Gilbert	0.02	0.00	0.00	0.00	0.00	0.00
Highway 14	0.07	0.00	0.00	0.00	0.00	0.00
Buffalo Pt.	0.10	0.00	0.00	0.00	0.00	0.00
Rush	0.00	0.12	0.00	0.00	0.00	0.00

Table 3 (cont.)

Station	19 November 76 Chlorophyll			16-17 October 76 Chlorophyll		
	a	b	c	a	b	c
Boxley	--	--	--	--	--	--
Ponca	0.00	0.00	0.00	0.00	0.00	0.00
Jasper	0.00	0.00	0.00	0.00	0.00	0.00
Pruitt	0.00	0.00	0.00	0.00	0.00	0.00
Hasty	0.00	0.00	0.00	0.00	0.00	0.00
Gilbert	0.00	0.00	0.00	0.00	0.00	0.00
Highway 14	0.00	0.00	0.00	0.00	0.00	0.00
Buffalo Pt.	0.00	0.00	0.00	0.00	0.00	0.00
Rush	0.00	0.00	0.00	0.00	0.00	0.00

in the Little Buffalo, where floating mats of sloughed-off *Spirogyra* filaments were noted. In the Buffalo River itself, no significant growths of *Spirogyra* were noted at any station, nor were any truly planktonic algae identified. It is evident that, in the absence of true plankton, the presence of chlorophyll in the water column is limited mainly to times of heavy runoff and high flows when scouring of substrates causes periphyton to become dislodged and suspended in the flowing water. Flow had been low and runoff slight for several weeks before the July sample, and suspended algae had been removed by simple sedimentation. Turbidity data indicate very clean water at that time.

It is clear that the development of significant populations of true plankton is a rarity in the Buffalo River, and chlorophyll concentrations in the water can be expected to be very small during times when scouring or sloughing-off of periphyton is not occurring.

Several other general and more or less random observations were made with regard to the occurrence and distribution of algae in the Buffalo River. It is notable, for example, that the summer *Spirogyra* populations did not appear to be as great as in past years, at least not in the vicinity of the nine sampling stations. Floating mats of this alga were not observed to the extent noted in previous years.

The winter epilithic diatom population was profuse in January of 1977, covering the rocks and bottom with a thick golden-brown coat. *Diatoma vulgare* was by far the predominant species in this population.

Several other examples of seasonal occurrence of algae were noted. The Conjugatophycean genus *Zygnema*, which has not been reported previously from the Buffalo, was found at both upstream and downstream locations, but only during the cold months. It appeared at three stations in January.

The filamentous desmid *Hyalotheca dissiliens* was found to be a prominent member of the winter assemblage at several upstream stations, particularly Ponca. This organism also has not been reported previously from the Buffalo, and was seen only in January when water temperatures were near the freezing point.

Two species of diatoms exhibited striking patterns of seasonal occurrence. *Fragilaria capucina* was found in 12 of 16 samples taken during November and January, but only once during the rest of the year. Other species of *Fragilaria* also appear to be more common in winter. *Gomphonema constrictum* shows a striking restriction to fall and winter conditions.

It was found in 16 of 24 samples taken in October through January, but only two of all the others.

Some interesting spatial distributional patterns were noted. The red alga *Chroodactylon ramosum*, for example, was found in 25 of the 32 samples taken at and below Gilbert, and in only three of the 35 samples taken above Gilbert.

The species *Rhizoclonium hieroglyphicum*, a member of the Cladophorales, appeared in 17 samples of which 14 were taken below Hasty. Because this is a heavily epiphytized filamemtous form, certain epiphytic algae consequently are also restricted to the lower zones of the river. An example is the blue-green alga *Stichosiphon regularis*, which was found six times, all as an epiphyte on *R. hieroglyphicum*.

The only species of *Pediastrum* present to any significant degree below Hasty was *P. boryanum*, which was found there seven times. Six other species of *Pediastrum* were found in 37 samples, of which 34 were taken at or above Hasty. *Pediastrum tetras* appeared 10 times above Hasty and not at all below that point.

Two diatoms showed marked spatial zonation. *Epithemia turgida* appears to be found primarily in the downstream zones, 21 of 25 appearances being at or below Hasty. *Achananthes lanceolata* is an ubiquitous species at all locations and all times; however, one variety of this species, var. *apiculata*, seems to be present only in the downstream zone below Gilbert.

HUMAN CARRYING CAPACITY STUDY

Edward E. Dale, Jr., Principal Investigator
Bobby D. Keeland, Graduate Assistant

A better knowledge of how many people can use wild or scenic river areas without adversely affecting the natural environment is becoming increasingly important for proper management. Several human carrying capacity studies have been published on lakes, rivers, and river systems elsewhere in the United States, such as in the Boundary Waters Canoe area of Minnesota (Lime, 1972), in Oregon (Pfister and Frenkel, 1975), and in Utah (Hoagland, Iverson, and Davis, 1976), but studies have not been made in Arkansas.

The objectives of this study were to: (1) identify criteria indicative of human overuse of a deciduous forest ecosystem and (2) devise a rating system using those criteria suitable for indicating the effects of different intensities of visitor use in the Buffalo National River area.

METHODS

Work during the first part of the study consisted of library research. More than 65 professional publications on human carrying capacity and the effects of human use on natural ecosystems were examined, and abstracts were made of the more pertinent articles. Also, much valuable information was obtained at the annual meeting of the Ecological Society of America in June 1976, and at the First Conference on Scientific Research in the National Parks in November 1976.

A tentative rating system was devised on the basis of the library research and other information, and forms were prepared for making field studies.

Field work was started in June 1976, and continued periodically throughout the summer and early fall. A total of 34 areas were rated by means of the system. Because the Buffalo National River has a limited number of campgrounds and a larger sample was desired, camping areas near lakes and rivers in the Ozarks and Ouachitas maintained by the Arkansas Department of Parks and Tourism, U.S. Forest Service, or Corps of Engineers were examined also. The information was compiled and the method of rating the different areas was modified on the basis of field experience.

RESULTS AND DISCUSSION

In using the proposed rating system, a decision should be made first as to what consitutes the ideal campground condition or what conditions meet acceptable management goals. Then campgrounds can be rated with this standard as a basis for management procedures.

Some vegetation types can be safely used more intensively for camping than others and should be rated accordingly. For example, a gravel bar containing a few willow trees is less likely to be damaged by heavy visitor use than an oak or pine forest. Also, campgrounds established in one vegetation type should be compared with those in the same vegetation type if possible.

Finally, even in campgrounds and campsites in excellent condition certain areas will be overused and other sections underused. Bare soil is likely to be found around picnic tables, tent sites, and cooking areas in a campsite and near interpretive areas, comfort stations, water hydrants, and other places that are used intensively. Generally a "bullseye" type of use pattern develops around most campsites, with symptoms of heavy use near the center of visitor activity which decrease progressively at greater distances. Because an understanding of conditions in the campground area as a whole is necessary for proper management planning, the rating system should be based on an assessment of the total area.

There are many different criteria indicating human use, but only those considered most applicable to the Buffalo National River area are included. Also, the use of fewer criteria simplifies the system and makes it easier to apply. In the final analysis, any system is subjective at least in part and there is no substitute for reasonable judgment.

Rating System

A. Ground Cover in terms of kind of ecosystem present:

1. Ground cover thick.
2. Ground cover generally thick, but with a few thin patches present.
3. Ground cover generally thin.
4. Ground cover thin with extensive bare areas.
5. Ground cover almost entirely absent.

B. Litter-Trash

1. No litter.
2. Widely scattered litter.
3. Scarce litter, mostly around campsites.
4. Litter concentrated around campsites.
5. Litter nearly everywhere.

C. Species Present

1. Some rare species or species intolerant to trampling present.
2. No rare or intolerant species, but many native forbs and grasses present.
3. Mostly grasses present and some forbs. Grasses native or introduced, many species tolerant to trampling, such as bermuda *(Cynodon dactylon)*, goose grass *(Eleusine indica)* poor-jo *(Diodia teres)* etc.
4. Mostly grasses and forbs tolerant of trampling, some poison ivy *(Rhus radicans)*, catbrier *(Smilax spp.)* or other undesirable vines or shrubs present.
5. All species present herbaceous weeds tolerant of trampling or undesirable vines or shrubs.

D. Soil erosion

1. No soil erosion.
2. Soil erosion near areas of heavy use only.
3. Some soil erosion evident over most of areas.
4. Much soil erosion, some exposed tree roots.
5. Extensive soil erosion, many tree roots exposed.

E. Paths

1. No unauthorized paths.
2. Some unauthorized paths in heavily used areas, some ground cover and little compaction.

3. Several unauthorized paths in areas behind and between campgrounds.
4. Numerous paths and trails, some made by 4-wheel drive vehicles and motorcycles.
5. Extensive paths and trails made by vehicles.

F. Forest litter
   1. Deep, well distributed forest litter.
   2. Well distributed forest litter, but thin in some places because of human activity.
   3. Well distributed but thin forest litter.
   4. Litter in protected places only, such as under shrubs, etc.
   5. Little or no litter present.

G. Screening (small trees and shrubs) between campsites
   1. Excellent screening between camps, tables, etc.
   2. Good screening, thin in places, a few paths between campsites.
   3. Fairly well screened, numerous paths or openings between campsites.
   4. Not well screened, a few small trees between campsites, extensive removal of vegetation.
   5. No or little screening.

Campground Rating Form

Name of Area ____________________ Date Visited ______________

Location of Area ____________________ Years in Public Service_____

Vegetation Type ____

	Rating Scale				
	1	2	3	4	5
A. Ground Cover					
B. Litter					
C. Species Present					
D. Erosion					
E. Paths					
F. Forest Litter					
G. Screening					

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments:

Table 4. Summary of Campgrounds Evaluated

Name	Location	Total Rating Pts. (A-G)
(Private Campground) Savoy Bridge	10 miles west of Fayetteville	19
Lost Bridge Valley Area 1	Southeast of Garfield, near Beaver Lake	26
Lost Bridge Valley Area 2	Southeast of Garfield, near Beaver Lake	19
Shady Lake Loop A	Ouachita N.F.	26
Shady Lake Loop E	Ouachita N.F.	11
Crystal Camp	Ouachita N.F.	24
Camping Area A	Petit Jean State Park	22
Rush Camping Area	Buffalo National River	16
Campground below restaurant	Buffalo National River	25
Gilbert	Gravel Bar near Gilbert	17

* Lowest number indicates least disturbed areas.

RECOMMENDATIONS

It is recommended that different camping areas in the same vegetation type that range from heavily to lightly used be located and assessed periodically during the summer of 1977. Information gained from ratings of the areas should be supplemented with photographs and accurate counts of the number of visitors using the areas. The data then should be compiled with the objective of determining what will happen to the physical characteristics of an area with light, intermediate or heavy use.

ANALYSIS OF CANOE DENSITY

Melvin D. Springer, Principal Investigator

R. E. Babcock, Principal Investigator

Sharon McBride, Graduate Assistant

The objectives of the study were threefold:

1. To determine the relative effect of certain relevant variables on the density of canoes at selected points on the Buffalo River.
2. To obtain regression functions for estimating (predicting) the number of canoes as a function of certain relevant variables. Specifically, the variables originally considered were:
    - (a) date (day of year)
    - (b) weekday,
    - (c) temperature,
    - (d) holiday,
    - (e) water level,
    - (f) weekend,
    - (g) rainfall.
3. To obtain numerical estimates of canoe densities at selected river reaches.

Data were obtained by mounting cameras at three locations: Ponca, on the top of the dining hall at Buffalo Point, and a bluff at Buffalo Point. The data covered the months of June and August, and parts of May and September. Because of technical difficulties, no data were obtained from the film used during July.

Two separate multivariate normal regression models were used: one for the months of May and June when the trend for the canoe density was described very well by a multivariate linear function involving from three to five variables, and another for the months of July, August, and September when the canoe density was described very well by a multivariate linear function of the same independent variables. The use of a multivariate regression model enables one to make confidence statements for the estimated density (number) of canoes during a given time period (usually canoes per day).

ANALYSIS

The analysis of the canoe density on the Buffalo River included several variables with the canoe density as the dependent variable. Eight independent variables originally were considered. The data was represented by the day of the year (1-365). The day of the week has values 1-7 with Saturday as one and Friday as seven. High temperature for the day, low temperature, and the average temperature were included originally, but all were interrelated and actually a measure of the same variable. Because canoe density was slightly more correlated with low temperature than with the other two, low temperature was kept as a variable and high and average temperature were dropped. Only one holiday observation was available last year and so this variable was left out, but it will be included more extensively next year. Water level is measured in two different ways. At Ponca the water level is measured as inches of air space under a low water bridge. A large value of this variable therefore represents low water conditions. At Buffalo Point the water level is measured as feet and inches above sea level. This variable was coded by subtracting 400 feet from the actual measurement. The other variable originally considered was rainfall. Later, the variable "day of the week" was replaced by a variable called "weekend" which had a value of one for Saturday and Sunday and a value of zero for any other day. A multivariate norman regression model was chosen to analyze the data because a high value of the multiple correlation coefficient R indicated the relevance of such a model, and because this model enables one to associate a confidence interval with an estimate of canoe density.

Statistical analysis was carried out on three subsets of the data, one for each camera location. The set collected at Ponca contains 16 complete observations made from May 29 to June 23. Other observations were included in the set which did not have a canoe count but which did have values for all other variables. These observations were used to estimate the canoe density once regression equations were found. The second set consists of observations made by a camera mounted on the dining hall at Buffalo Point. This set has 41 complete observations dated from July 30 to September 21.

Regression functions for each camera location were obtained by SAS procedures. The best regression model was chosen in which each variable was significant at least at the 0.20 level. At Ponca, this regression function is given by:

$$Y = -276.06 + 2.58X_1 - 76.35X_2 - 15.55X_3 + 3.28X_4 \qquad (1)$$

where Y is the canoe density, X_1 is the date, X_2 is the rainfall, X_3 is the air space under the low water bridge, and X_4 is the low temperature. The correlation coefficient for this model is 0.82. The mean number of canoes for these 16 days was 41 and the standard deviation was 21.3. The estimated number of canoes to pass this camera location from May 28 until June 25 was 1528 with 90% confidence that it was between 1359 and 1737.

The beta coefficients for this model are given by the coefficients of the variables in the equation:

$$Y = +.664X_1 - .860X_2 - 1.56X_3 + .503X_4$$

where again Y is the canoe density, X_1 is the date, X_2 is the rainfall, X_3 is the air space under the bridge, and X_4 is the low temperature. These coefficients were found by standardizing all the variables to remove the effects of the different units involved. The beta coefficients represent the relative importance of the independent variables. For instance, an increase of one standard deviation in the air space (X_3) would decrease the number of canoes by 1.56 standard deviations. Because water level is related inversely to air space, an increase in the water level of one standard deviation would increase the canoe density by 1.56 standard deviations). An increase of one standard deviation in the low temperature (X_4) however, would increase the canoe density by only 0.503 standard deviations. Variation in the air space (water level) thus has the largest effect on the canoe density of these four variables and the low temperature the least effect.

The regression function for the camera location on the dining hall at Buffalo Point in which each variable is significant at the 0.20 level or better is given by:

$$Y = 320.34 - 1.18X_1 - 83.93X_2 + 48.30X_5 \tag{2}$$

where X_1 is the date, X_2 is the rainfall, and X_5 represents whether or not an observation occurs on a weekend. In this model, all variables turned out to be significant at the 0.01 level. The correlation coefficient for this model is 0.82. The mean number of canoes per day at this location was 29.5 and the standard deviation was 21.17. The estimated number of canoes at this location from June 26 until September 30 was 6072 with 90% confidence that it was between 5730 and 6414. The beta coefficients for this model were obtained as the coefficients in the equation

$$Y = .617X_1 - .278X_2 + .640X_5$$

and are interpreted as previously explained.

For the data collected at the second camera location at Buffalo Point the regression function is:

$$Y = 318.63 - 1.24X_1 - 45.49X_2 - 35.43X_5$$

where the variables are the same as in the previous model. All variables are significant at the .05 level. The correlation coefficient for this model is 0.88. The beta coefficients are given by the coefficients in the equation:

$$Y = .626X_1 - .224X_2 + .608X_5$$

The mean number of canoes at this location was 29.54 and the standard deviation was 14.87. From June 26 until September 21, the predicted number of canoes at this location was 4530 with 90% confidence that it was between 4301 and 4759.

For the entire summer, the average number of canoes observed per day was 41.6. The average number predicted was 53.38 per day. The predicted number was higher because it included July which the regression functions indicated had a higher canoe density than the other months. The sum of all canoes predicted for the entire period at all of the camera locations was 12,492 with 90% confidence that it was between 12,039 and 12,946.

When the results of the three analyses are compared, it is found that the canoe density increases linearly in accordance with a multiple linear regression function during May and June, and decreases linearly in accordance with such a function during July-September. The variables for water level, rainfall, weekend or weekday, and low temperature also have a significant effect on the canoe density but are not equal in importance. Their relative importance is discussed in the analyses and is indicated in Table 5. Water level was found significant at Ponca but not at Buffalo Point. The weekend-week variable was not found significant at Ponca, but the observations were concentrated on the weekends and a better distribution of date might show that it was significant.

Table 5. Relative Importance of the Variables on Canoe Density at Three Locations on the Buffalo River

Time Period	Location	Variable	Rank*	Beta Coefficient
May-June	Ponca	Air space (X_3)**	1	-1.56***
		Rainfall (X_2)	2	-0.860
		Date (X_1)	3	0.664
		Low temperature (X_4)	4	0.503
July-September	Buffalo Point (dining hall)	Weekend (X_5)	1	0.640
		Date (X_1)	2	-0.617
		Rainfall (X_2)	3	-0.278
July-September	Buffalo Point (bluff)	Weekend (X_5)	1	0.608
		Date (X_1)	2	-0.626
		Rainfall (X_2)	3	-0.224

---

*The most influential variable is given a rank of 1.

**Water level varies inversly with air space.

***A negative Beta coefficient indicates that the variable multiplied by that coefficient varies inversely with canoe density.

Four graphs are included in the analysis (figures 6-9). In three of these graphs (Figures 6-8) the number of canoes is plotted versus date for each of the three locations. The fourth graph (Figure 9) is a plot of the number of canoes versus water level at the Ponca location.

A word of caution is in order at this point lest the graphs be misinterpreted. Consider, for example, the graphs of number of canoes versus date. The linear trend does not appear to be nearly as strong as one would expect for a correlation coefficient of the order of $R = 0.82$. However, one must remember that the other variables (water level, rainfall, low temperature), although they do not appear per se on the graph, exert a hidden influence on the canoe density. Thus, if the effect of each of the other variables were held constant, the linear trend of canoe density versus date (or any other single variable) would be much more striking, in view of the fact that the multiple linear correlation is high. In fact, this is what the multivariate normal model does for the analyst. It first makes possible the determination of which independent variables have a significant effect upon canoe density, and then leads to the multiple linear function (1) which gives the best estimate of Y (canoe density) by simultaneously using these variables ($X_1 X_2 X_3$, and X_4). The validity of this estimate is indicated by the value of the multiple correlation coefficient R, which can range from zero to one. The value $R = 0.82$. reaveals the relevance of the multivariate normal model is appropriate, if sufficient data were available (which is usually not the case) and one were to hold all but one of the variables constant and vary the remaining one, the corresponding graph would reveal a linear trend. However, the best estimate of the number of canoes is obtained by using all the relevant variables to estimate Y via equation (1). Similar statements hold with regard to equations (2) and (3). In short, the point of these remarks is to emphasize that the graphs of canoe density versus a single variable cannot be taken at face value, in that they shed no light upon the effect of that single variable upon canoe density. At best, they give a numerical accounting of the boat density for the dates considered. Interpretation of results must be obtained by using the appropriate analytical model, which enables one to separate the relative effect of each independent variable upon canoe density, and to estimate the canoe density with a stated confidence level, for a given set of values of the relevant individual variables.

FIG. 6 CANOE DENSITY vs. DATE AT PONCA.

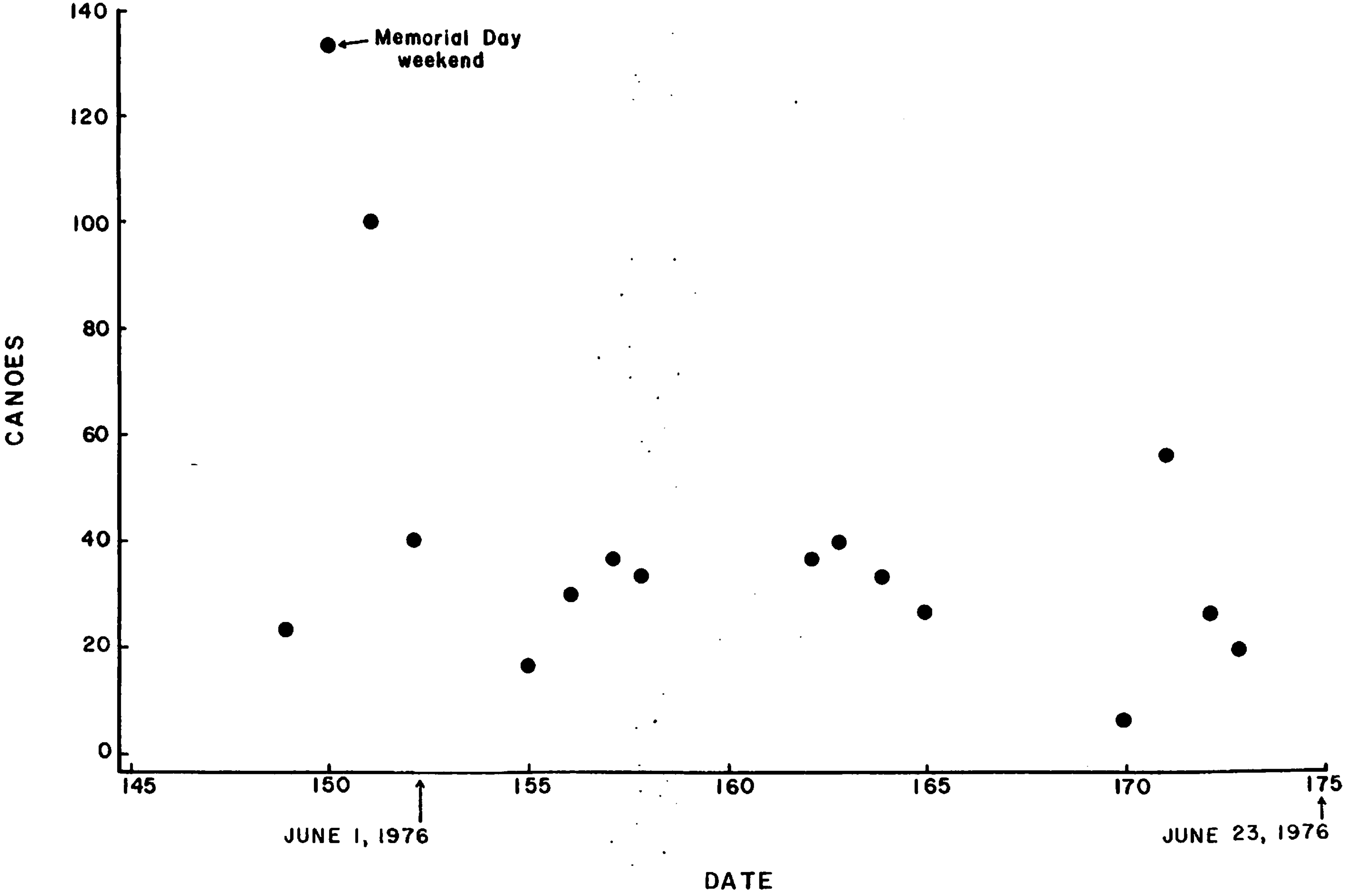


FIG. 7 CANOE DENSITY vs. DATE AT BUFFALO POINT (DINING HALL).

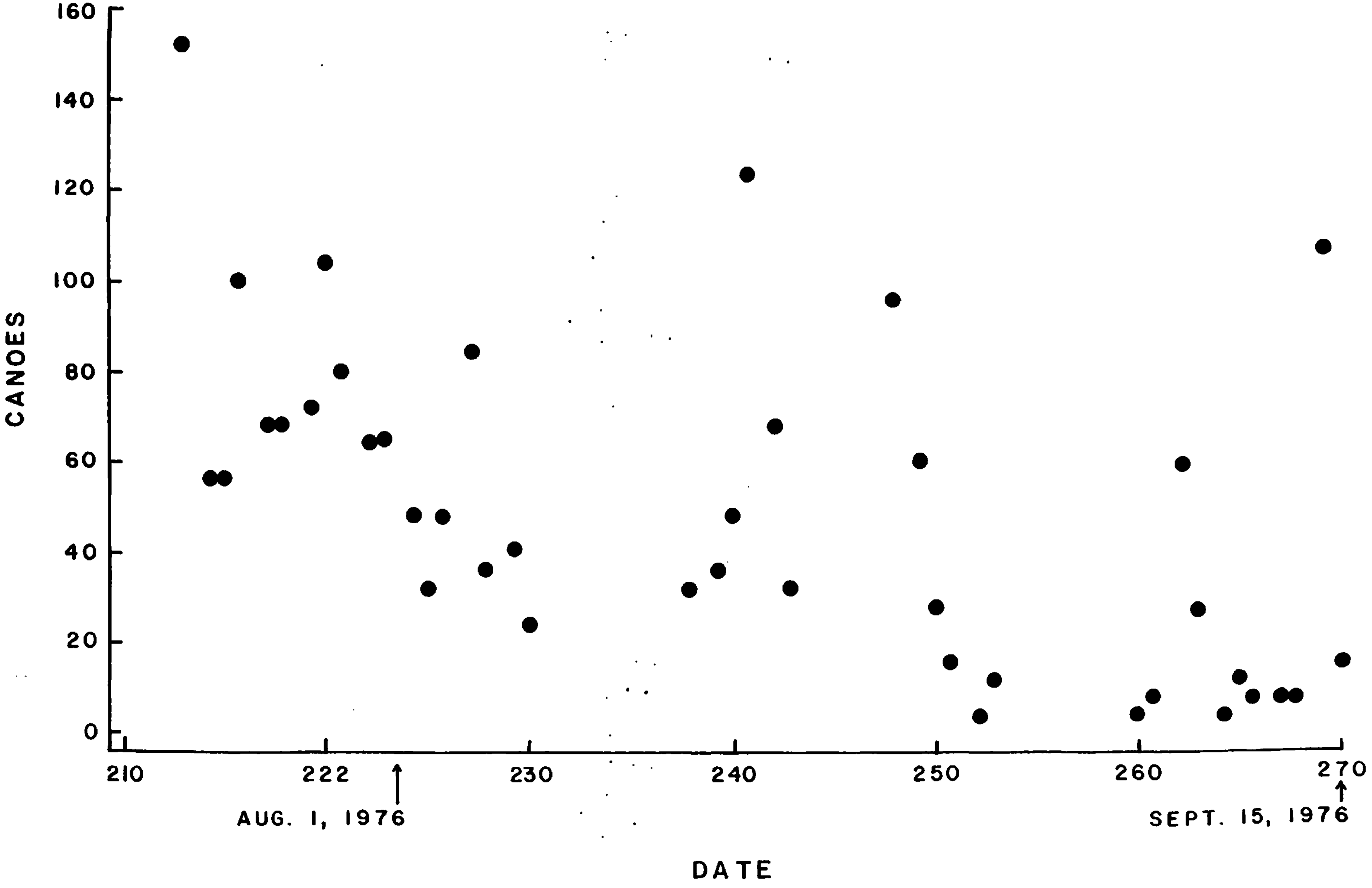


FIG. 8 CANOE DENSITY vs. DATE AT BUFFALO POINT (BLUFF).

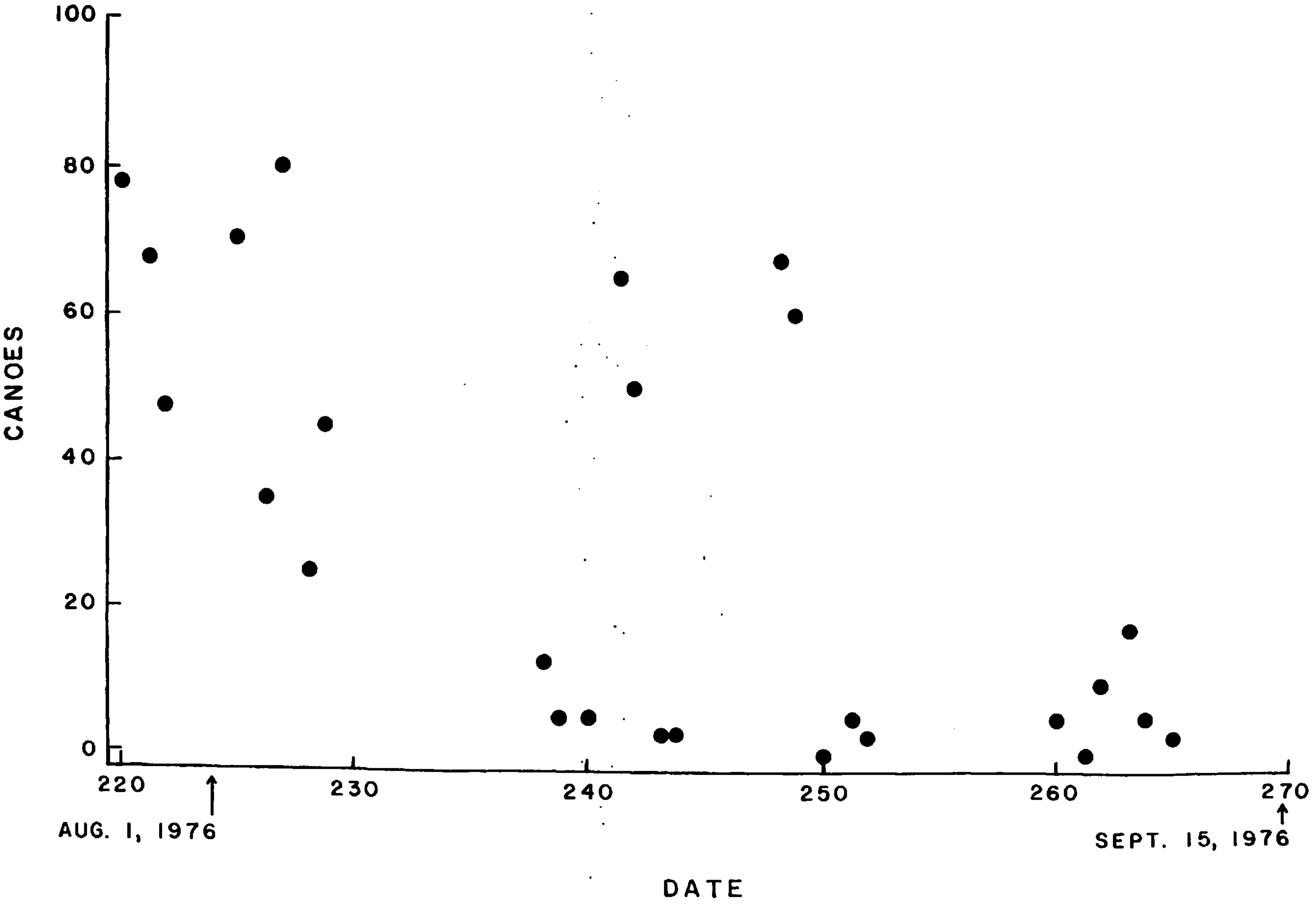
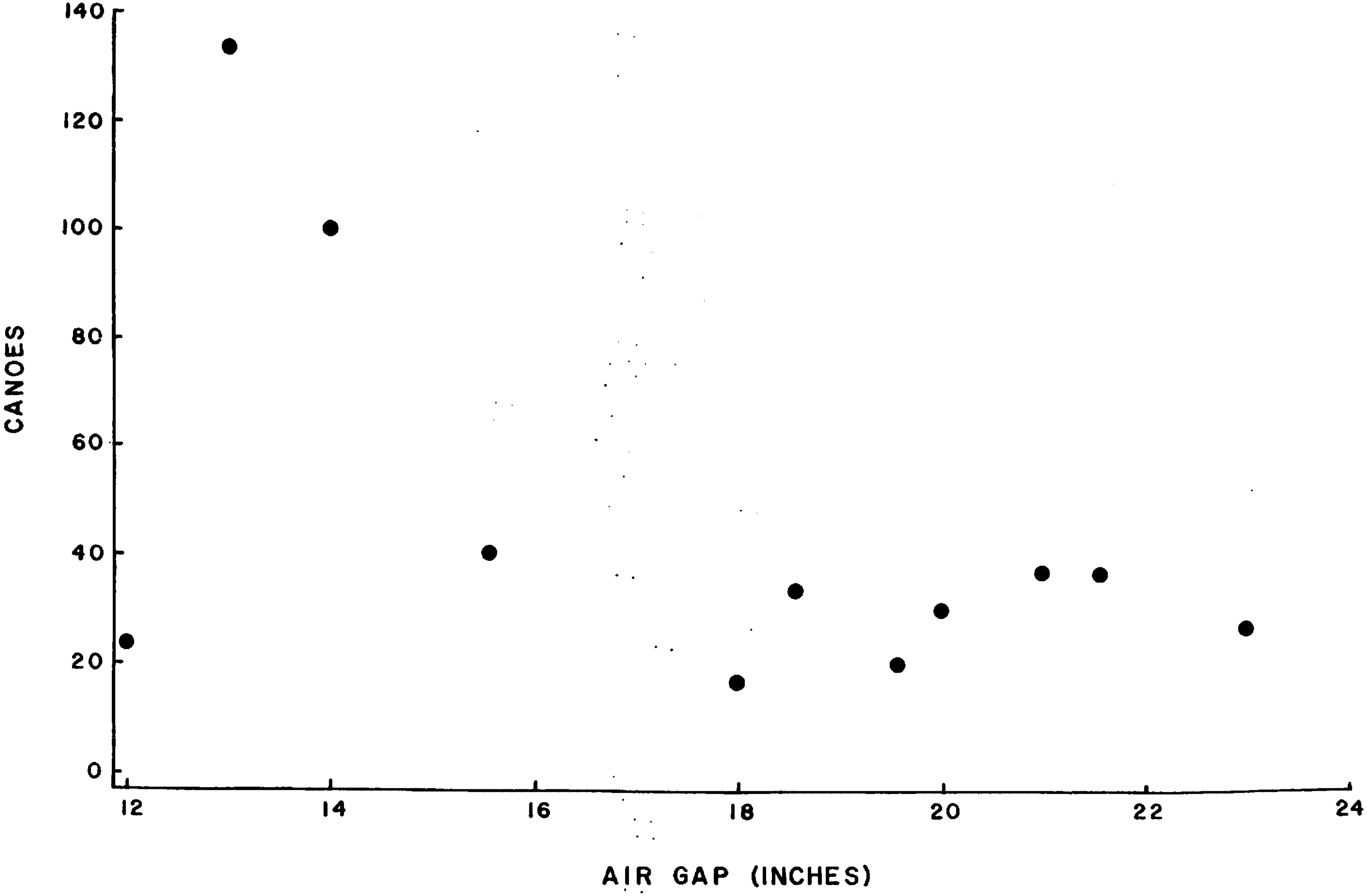


FIG. 9 CANOE DENSITY vs. WATER LEVEL AT PONCA.



CONCLUSIONS

1. The canoe density can be estimated (predicted) reasonably accurately as a linear function of date (day of year), rainfall, and weekend at the dining hall and bluff locations. Water level was not indicated to be significant in the analysis, probably because there was relatively little variation in the water level at these two location.
2. The canoe denisty at Ponca can be estimated reasonably accurately as a linear function of date, rainfall, water level, and low temperature. Of these variables, low temperature was the least significant.
3. The canoe density increases during May and June, and decreases during July, August, and September.
4. Though all the variables considered had a significant effect upon canoe density at one place or another, low temperature and water level were not significant at the dining hall and bluff locations. At Ponca, weekend was not significant, and low temperature was the least significant of the other variables.
5. The relative importance of the variables used at each of the locations is summarized in Table 5, where the independent variables are ranked in order of their influence upon canoe density. The most influential variable of those considered is given a rank of one, the second most influential variable a rank of two, etc. A relative comparision can be made by comparing the beta coefficients. It should be remembered that water level varies inversely with air space at Ponca. Also, a negative beta coefficient indicates that the variable multiplied by that coefficient varies inversely with canoe density.
6. The total number of canoes traveling the Buffalo River at the aforementioned locations during the months of May through September was estimated to be 12,492, with 90% confidence that the true number was between 12,039 and 12,946.
7. The power of the present analysis is considerably limited because of a substantial number of missing data. More specifically, the width of the 90% confidence interval for the average and total number of canoes would probably have been appreciably narrower had the data for July not been missing.

RARE, THREATENED, AND ENDANGERED VASCULAR PLANTS

Edwin B. Smith, Principal Investigator
Burnetta Hinterthuer, Graduate Assistant

The objective of this study is to bring together a list of all vascular plants of the Buffalo National River area that are rare, threatened, or endangered. The determination of the status of particular species is not always easy because of generally inadequate collecting in Arkansas. If the number of collections is very low for a particular species, it is assumed to be rare (it could be more common but simply not collected). Some species are rare in the Buffalo National River area but are common in other parts of Arkansas, or in other parts of the United States; these generally have been included in the list. Introduced plants (e.g. European weeds) have been excluded from the list.

For clarity, the terms rare, threatened, and endangered are defined much as they were in the Endangered Species Act of 1973 (House of Representatives Report No. 93-740. Dec. 19, 1973) and in Tucker (1974)

RARE: A species that occurs in small numbers of specialized habitats, seldom found in large populations; not in immediate danger of extinction. In general (in this study), present in four or fewer known to be declining in numbers.

THREATENENED: A species which is likely to become endangered within the forseeable future throughout or nearly throughout its range. Species not in immediate danger of extinction, but in greater jeopardy than the rare species. The Park Service should consider protecting these species, for without protection they may disappear.

ENDANGERED: A species which is in danger of extinction throughout or nearly throughout its range. Species in this category are in immediate danger of extinction. Often they are present in only one or a very few sites. The Park Service should protect these species and their habitats, for without protection they will very likely disappear.

MATERIALS AND METHODS

Eight primary sites in the Buffalo National River area were selected for the study:

Newton County
  1. Lost Valley
  2. Leatherwood Creek
  3. Indian Creek
  4. Sneed Creek
  5. Big Bluff
  6. Hemmed-in-Hollow

Marion County
  7. The Rush area

Searcy County
  8. Bluff area near Gilbert

Several additional (secondary) sites were visited: Boxley, Shaddox, Jasper, Hasty, the bridge area near Highway 14, Buffalo Point, Richland Creek, Terrapin Branch Creek, and the Henry Koen Forest.

Field trips to each of the eight primary sites were made at least once by the principal investigator or by the assistant. A total of more than 14 sites along the Buffalo were visited last summer and six this spring. During the field trips, suspected rare plants were collected for pressing and mounting. Vouchers of these species will be sent to the Park Headquarters Herbarium in Harrison. Determination of status (rare, threatened, endangered) was made by comparing the suspected rare species with the material on file in the University of Arkansas Fayetteville Herbarium.

A survey of the 60,000+ specimens at the University of Arkansas Fayetteville Herbarium was undertaken to establish a list of potentially rare plants of the Buffalo River area. This survey has nearly been completed, and has added several species to the Buffalo River list. Completion of the survey will require additional work.

A survey of the literature for reports of rare plants of the Buffalo River area has been started. The survey is not expected to reveal many additional species for the area, and other work has hampered the literature survey. A search has been made through only about four years of the past literature, but plans are to work back to at least 1963 (the year of publication of Steyermark's *Flora of Missouri)* before completion of the project in fiscal 1978.

RESULTS

Table 6 is a list of the known rare, threatened, and endangered vascular plants of the Buffalo National River area. Probably at least a few additions to the list will be made on the basis of continued work on the project in fiscal 1978. The following columns are used in the table.

Scientific Name:
The plants are arranged by family in phylogenetic order according to Fernald (1950). Within families, the genera and species are arranged alphabetically.

Common Name: The vernacular name, as listed in Steyermark (1963), Correll and Johnston (1970), or other manuals, is given in quotation marks is available. If a species lacks a common name, the common name of the genus is given. In one case (*Diarrhena americana)*, neither the species nor the genus has a common name.

Arkansas Counties:
The number of counties of Arkansas in which the species is known to be present is indicated. If the species is present in a single county in the state, that county is listed.

Status in Buffalo:
The status in the Buffalo National River area is indicated. R = rare; T = threatened; E = endangered. If Tucker (1974) listed a species for Arkansas, this fact is indicated. T:PE = Tucker, possible endangered; T:E = Tucker, endangered. The investigators agree with the status assigned by Tucker. Note that the status assigned is for the ***Buffalo National River area,*** and does not apply for Arkansas in general or for the United States.

N.A. Distribution:
The distribution in North America (outside Arkansas) is indicated, based on the ranges given in the standard manuals.

Table 6. Known Rare, Threatened, and Endangered Vascular Plants of Selected Areas of the Buffalo National River.

Scientific Name	Common Name	Arkansas Counties	Status in Buffalo	N. A. Distribution
CUPRESSACEAE - Cypress Family				
Juniperus ashei Buchholz	"Ashe's Juniper"	14	R	Texas, Okla., Mo.
GRAMINEAE - Grass Family				
Diarrhena americana Beauv.		3	R	SE 1/3 of U.S.
CYPERACEAE - Sedge Family				
Carex albursina Sheldon	"Sedge" (genus)	4	R	Quebec; NE 1/3 of U.S.
Carex careyana Torr.	"Sedge" (genus)	1 (Newton)	E	Ontario; NE 1/4 of U.S.
Carex communis Bailey	"Sedge" (genus)	1 (Newton)	E (T:PE)	E Canada; NE 1/3 of U.S
Carex festucacea Schkuhr var. brevior (Dewey) Fern.	"Sedge" (genus)	1 (Newton)	E	Canada; N & W U.S.
Carex jamesii Schwein.	"Sedge" (genus)	1 (Newton)	E (T:PE)	Ontario; NE 1/4 U.S.
Cyperus refractus Engelm.	"Umbrella Sedge" (genus)	3	R	NE 1/3 of U.S.
Eleocharis smallii Britt.	"Spike Rush" (genus)	1 (Newton)	E	E Canada; NE 1/3 of U.S
COMMELINACEAE - Spiderwort Family				
Tradescantia ozarkana Anderson & Woodson	"Spiderwort" (genus)	9	R (T:E)	SW Mo. & E (endemic to Ozarks & Ouachitas)
LILIACEAE - Lily Family				
Trillium pusillum Michx. var. ozarkanum (Palmer & Steyerm.) Stererm.	"Ozark Trillium"	7	T (T:E)	S. Mo. (endemic to Ozarks)
ORCHIDACEAE - Orchid Family				
Cypripedium calceolus L. var. parviflorum (Salisb.) Fern.	"Small Yellow Lady-slipper"	7	T	Canada; E and C U.S.
Goodyera pubescens (Willd.) R. Br.	"Rattlesnake Orchid"	5	T (T:PE)	E Canada; E 1/2 of U.S.
Orchis spectabilis L.	"Showy Orchis"	7	T (T:E)	E Canada; E 1/2 of U.S.

Table 6. (Cont.)

FAGACEAE - Beech Family				
Castanea pumila Mill. var. *ozarkensis* (Ashe) Tucker	"Ozark Chinquapin"	31	E (T:E)[1]	SW Mo. & NE Okla. (endemic to Ozarks)
CARYOPHYLLACEAE - Pink Family				
Cerastium arvense L. var. *villosum* (Muhl.) Hollick & Britt.	"Mouse-ear Chickweed" (genus)	1 (Newton)	E	Ontario; N 1/2 of U.S.
RANUNCULACEAE - Buttercup Family				
Delphinium newtonianum D. M. Moore	"Larkspur" (genus)	4	E (T:E)	None (Endemic to Ark.)
PAPAVERACEAE - Poppy Family				
Stylophorum diphyllum (Michx.) Nutt.	"Wood Poppy"	3	T (T:PE)	NE 1/4 of U.S.
CRUCIFERAE - Mustard Family				
Arabis shortii (Fern.) Gl. var. *shortii*	"Rock Cress" (genus)	1 (Marion)	E	NE 1/4 of U.S.
SAXIFRAGACEAE - Saxifrage Family				
Heuchera villosa Michx.	"Alum Root" (genus)	4	R	SE 1/4 of U.S.
ROSACEAE - Rose Family				
Neviusia alabamensis A. Gray	"Snow Wreath"	4	E (T:E)	Ala. & Mo.
ANACARDIACEAE - Cashew Family				
Cotinus obovatus Raf.	"American Smoke Tree"	12	R (T:E)	Tex. to Ala., Tenn. & Mo.
ARALIACEAE - Ginseng Family				
Panax quinquefolium L.	"Ginseng"	12	T (T:E)	E 1/2 of U.S.

Table 6. (cont.)

MALVACEAE - Mallow Family				
Abutilon incanum (Link) Sweet	"Pelotazo"	3	E (T:E)	Mexico; W. Tex. to Ariz. (disjunct by about 500 miles!)
POLEMONIACEAE - Phlox Family				
Phlox bifida Beck var. *bifida*	"Sand Phlox"	2	E (T:PE)	NE 1/3 of U.S.
BORAGINACEAE - Borage Family				
Lithospermum latifolium Michx.	"Gromwell" (genus)	4	T (T:PE)	NE 1/4 of U.S.
SCROPHULARIACEAE - Figwort Family				
Mimulus floribundus Dougl.	"Yellow Monkeyflower"	6	E (T:E)	W Canada; Cal. to Mont., Colo. & Ariz. (disjunct by about 700 miles!)
COMPOSITAE - Sunflower Family				
Eupatorium sessilifolium L.	"Upland Boneset"	6	R	NE 1/4 of U.S.
Brickellia grandiflora (hook.) Nutt.	"Tassel Flower"	4	R	SE 1/4 of u.s., and Texas to Cal.

---

[1] This variety (as *Castanea ozarkensis*) is listed as endangered in the Federal Register (Vol. 41, No. 117, Pt. 4; June 16, 1976). *Castanea ozarkensis* was reduced to a variety of *C. pumila* by G. E. Tucker (Tucker, 1975).

[2] This glabrous calyx form of *H. villosa* var. *villosa* is known only from Arkansas.

SUMMARY AND DISCUSSION

A total of 31 species of vascular plants are known to be rare, threatened, or endangered in the Buffalo National River area. Many of these are species that have a more general distribution in the northeastern United States and Canada, and are on the southwesternmost margin of their range along the Buffalo River in Arkansas. Two represent long disjuncts with their general distribution in the western or southwestern parts of the United States. Three are regional endemics, limited to the Ozarks and Ouachitas, and one (Delphinium newtonianum) is endimic to Arkansas. The Snow Wreath *(Neviusia alabamensis)* in one of the rarest shrubs in North America; it is known from four counties in Alabama, one county in Missouri, and four counties in Arkansas.

The preponderance of sedges in the list probably reflects a lack of adequate collecting in this group, rather than actual rarity. The sedges are an extremely difficult group taxonomically, and many collectors avoid them. Many of these infrequently collected sedges are present in cool moist valleys of creeks feeding into the Buffalo River (Sneed Creek, Indian Creek, etc.) that are difficult to sample.

A total of 13 species are classified as endangered in the Buffalo National River area. These species need protection by the Park Service, if possible, for their continued maintenance in the area. Most of the endangered species are known from only 1-4 counties in Arkansas; two are present in more than 4 counties. *Mimulas floribundus* (in 6 counties) requires a moist but rocky habitat, with adequate shade and proper seepage. The habitat is fragile and easily disturbed. *Castanea pumila* var. *ozarkensis* (31 counties) is known from most of northwestern Arkansas, but is declining rapidly from a blight similar to the one that has devastated the American Chestnut. It will probably continue to decline.

The most critically endangered species are those known from a single area (county) in Arkansas, or endemic to Arkansas. Therefore those species (and their known habitats) of the Buffalo National River area that are most desperately in need of protection are listed.

EFFECT OF CATTLE GRAZING ON FECAL BACTERIA (INTERIM REPORT) CONTAMINATION

David G. Parker, Principal Investigator
Ray Strain, Graduate Assistant

The objective of this study is to monitor several tributaries of the Buffalo National River in order to evaluate the effect of cattle grazing on water quality over a two-year period.

To date, a total of 13 trips have been taken including four site selection trips. The streams sampled are Adds, Clark, Leatherwood, and Whitley creeks and an unnamed branch of Mill Creek. (See Figure 10 for sample locations.)

The parameters measured were fecal bacteria, dissolved oxygen, BOD, nitrogen, phosphorous, temperature, and turbidity. With the exception of the fecal bacteria, no trends in the data are apparent at this stage of the research. Only fecal coliform data are presented in this report to illustrate apparent trends. Conclusions drawn from the data should be considered tentative because the sampling program has not been completed.

Table 7 shows fecal coliform concentrations in samples collected at different stations on four different creeks. The stations were ranked according to an estimate of the potential for contamination of the sample site by cattle. The factors used in the ranking were the ease of access of cattle to the stream directly upstream from the sample site and the number of cattle involved. (This ranking procedure will be reviewed at the end of the project but it is considered to be adequate for this preliminary report.)

Also included in the table is a breakdown of the dry weather flow and the wet weather flow. (The wet weather flow is considered to be flow in the stream which is still influenced by runoff from a rainfall within three days prior to the sampling.)

An analysis of the data in the Table 7 led to some tentative conclusions about the potential for contamination of surface water by cattle grazing in the Buffalo River Valley.

First, the ease of direct access of cattle to the creek and the number of cattle involved seem to influence the contamination in the creek. Second, rainfall within three days prior to sampling tends to increase the contamination at any sample point in the creek.

A complete presentation of all the data collected and an analysis of these data will be presented in the final report.

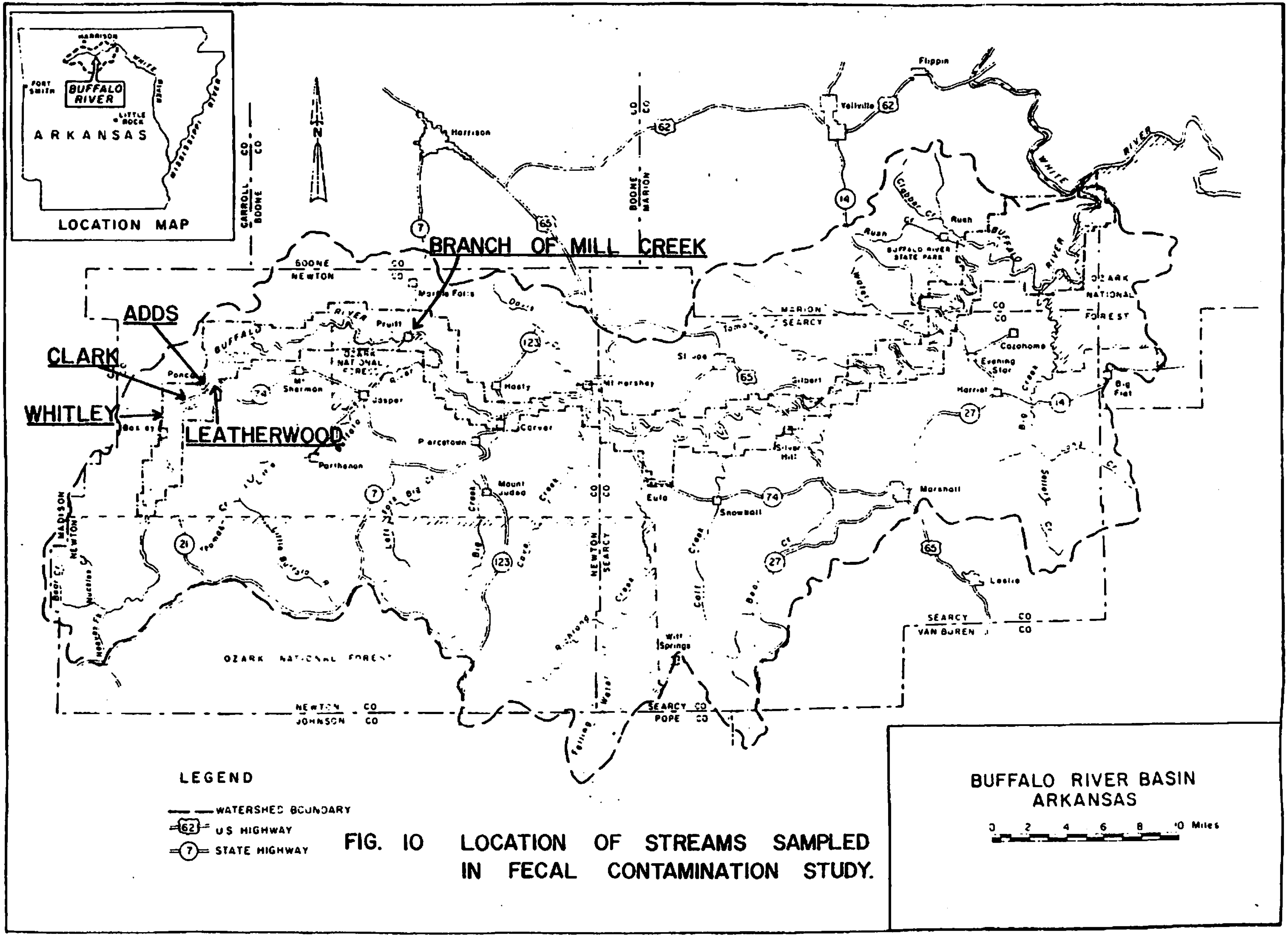


FIG. 10 LOCATION OF STREAMS SAMPLED IN FECAL CONTAMINATION STUDY.

Table 7. Fecal Coliform Concentration

Station	Ease of Access of Cattle to Creek	No. of Cattle	Rank	Fecal Coliform Concentration Log Mean Average of Organisms Per 100 ml	
				Dry Weather Flow	Wet Weather Flow
C3	very good	10	High Potential for Contamination	34	2000
C1	good	30		17	1000
W3	fair	80		19	1100
W1	good	30		35	860
W2	good	30		7	550
W7	good	8		56	142
				Average 27	Average 940
W5	medium	15	Low Potential for Contamination	3	27
W4	medium	15		20	26
W6	medium	8		2	--
C5	cattle grazing on riges in headwater regions	--		3	30
W8		--		--	24
L1		--		0	22
				Average 6	Average 26
U1	no cattle drainage area			1	5

APPENDIX I

SELECTED BIBLIOGRAPHY

LITERATURE CITED

Correll, D. S. and M. C. Johnston 1970. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Tex.

Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. Amer. Book Co., N.Y.

Hoagland, John F., D. C. Iverson and L. S. Davis. 1976. Methods for Determining Recreational, Environmental, and Economic Consequences of Alternative Development Programs for the Bear Lake Area. Department of Forestry and Outdoor Recreation. College of Natural Resources. Utah State University. Logan, Utah 84322.

Lime, David W. 1972. Large groups in the Boundary Waters Canoe area: Their Numbers, Characteristics, and Impact. U.S.D.A. Forest Research Note NC-142. North Central Forest Experiment Station. St. Paul, Minn.

Pfister, Robert E., and R. E. Frenkel. 1975. The Concept of Carrying Capacity: Its Application for Management of Oregon's Scenic Waterway System. Rogue River Study--Report 2. Oregon State Marine Board, Salem, Oregon, and Water Resources Research Institute. Oregon State University, Corvallis, Oregon.

Rippey, Laura L. 1976. Spatial and Temporal Distribution of Algae and Selected Water Quality Parameters in the Buffalo River, Arkansas. Master Thesis, University of Arkansas, Fayetteville. Arkansas Water Resources Research Center Thesis and Dissertation Series Report No. 1.

Steyermark, J. A. 1963. Flora of Missouri. Iowa State U. Press, Ames.

Tucker, G. E. 1974. Threatened Native Plants of Arkansas. pp 39-65 _in_ Arkansas Natural Area Plan. Ark. Dept. Planning, Little Rock, Arkansas.

__________. 1975. _Castanea pumila_ var. _ozarkensis_ (Ashe) Tucker, comb. nov. Proc. Ark. Acad. Sci. 29:67-69.

SELECTED BIBLIOGRAPHY

Brandborg, S. 1963. On the carrying capacity of wilderness. Living Wilderness 82:28-33.

Burke, Hubert D. 1969. Wilderness engenders new management traditions. The Living Wilderness 33:9-13.

Cieslinski, Thomas J., and J. Allen Wagar. 1970. Predicting the durability of forest recreation sites in northern Utah. Preliminary results. USDA For. Serv. Res. Note INT-117.

Clawson, M. 1968. Philmont Scout Ranch: An intensively managed wilderness. American Forest. Maryland.

Dotzenko, A. D., N. I. Papamichos and D. S. Romine. 1967. Effects of recreational use on soil and moisture conditions in Rocky Mountain National Park. Jour. Soil and Water Conservation 22:196-197.

Frissell, Sidney S., Jr., and Donald P. Duncan. 1965. Campsite preference and deterioration. Jour. Forestry 63:256-260.

Heinsleman, Miron L. 1965. Vegetation management in wilderness areas and primitive parks. Jour. Forestry 63:440-445.

Herrington, Roscoe B., and Wendell G. Beardsley. 1970. Improvement and maintenance of campground vegetation in central Idaho. USDA Forest Service Research Paper. INT-87.

Hoagland, John F., D. C. Iverson and L. S. Davis. 1976. Methods for determining recreational, environmental, and economic consequences of alternative development programs for the Bear Lake area. Department of Forestry and Outdoor Recreation. College of Natural Resources. Utah State University. Logan, Utah 84322.

Lepage, W. F. 1967. Some observations on campground trampling and ground cover response. USDA Forest Service Research Paper N.E. - 68.

Lime, David W. 1971. Factors influencing campground use in the Superior National Forest of Minnesota. North Central For. Exp. Sta., St. Paul, Minn. USDA Forest Service Research Paper NC-60.

Lime, David W. 1972. Large groups in the Boundary Waters Canoe area: Their numbers, characteristics, and impact. U.S.D.A. Forest Research Note NC-142. North Central Forest Experiment Station. St. Paul, Minn.

Lucas, Robert C. 1970. User evaluation of campgrounds on two Michigan National Forests. North Central Forestry Exp. Sta. St. Paul, Minn. USDA Forest Service Research Paper NC-44.

Magill, Arthur W. 1970. Five California campgrounds--conditions improve after 5 years recreation use. USDA Forest Service Research Paper PSW-62.

Moorhead, Bruce B., and Edward S. Schreiner. 1976. Instructions for use of human impact inventory: a campsite survey method in National parks of the Pacific northwest. Unpublished mimeo. Bruce B. Moorhead, Olmypia National Park, 600 E. Park Ave., Port Angeles, Washington 98362

Pfister, Robert E., and R. E. Frenkel. 1975. The concept of carrying capacity: its application for management of Oregon's scenic waterway system. Pogue River Study--Report 2. Oregon State Marine Board, Salem, Oregon, and Water Resources Research Institute. Oregon State University, Corvallis, Oregon.

Pfister, Robert E., and R. E. Frenkel. 1976. Abstracts. First Conference on Scientific Research in the National Parks. 9-13 November, 1976. New Orleans, La. National Park Service. United States Department of The Interior.

Setergrew, C. D., and D. M. Cole. 1970. Recreation effects on soil and vegetation in the Missouri Ozarks. Jour. Forestry 68:231-233.

Stankey, George H., and David W. Lime. 1973. Recreational carrying capacity: an annotated bibliography. USDA Forest Service General Technical Report INT-3. Intermountain Forest and Range Experiment Station. Odgen, Utah 84401

APPENDIX II

EXAMPLES OF CAMPGROUND RATING SHEETS

Campground Rating Form

Name of Area (Private Campground) Savoy Bridge Date Visited 7/7/76

Location of Area 10 Miles W. Fayetteville Years in Public Service ____

Vegetation Type Willow (Gravel bar)

Rating Scale

	1	2	3	4	5
A. Ground Cover			✓		
B. Litter			✓		
C. Species Present			✓		
D. Erosion		✓			
E. Paths		✓			
F. Forest Litter			✓		
G. Screening			✓		

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: Total Area approx 2 acres, heavily used area approx 1/4 acre - litter concentrated in heavily used area. Vegetation, litter & screening sparze, but about average for areas of this type. This type typically weedy - (Crabgrass, poorjo, fescue, etc.)

Campground Rating Form

Name of Area Lost Bridge Valley Area 2 Date Visited 7/26/76

Location of Area S.E. of Garfield, Near Beaver Lake Years in Public Service 10 (?)

Vegetation Type Cleared area - mostly bermuda grass scattered overstory, oak-elm-hickory

Rating Scale

	1	2	3	4	5
A. Ground Cover				✓	
B. Litter			✓		
C. Species Present				✓	
D. Erosion		✓			
E. Paths			✓		
F. Forest Litter					✓
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: Most common species - bermuda grass, broomsedge and Japanese clover. Area heavily used

Campground Rating Form

Name of Area Lost Bridge Valley, Area 2 Date Visited 7/26/76

Location of Area S.E. of Garfield, Beaver Lake Years in Public Service

Vegetation Type Cedar glade

Rating Scale

	1	2	3	4	5
A. Ground Cover		✓			
B. Litter		✓			
C. Species Present			✓		
D. Erosion		✓			
E. Paths		✓			
F. Forest Litter				✓	
G. Screening				✓	

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

<u>Comments</u>: Glade sites frequently have little screening vegetation present even when relatively undisturbed.

Campground Rating Form

Name of Area Shady lake Loop A Date Visited 8/11/76

Location of Area Ouachita N F Years in Public Service ____

Vegetation Type oak - pine

Rating Scale

	1	2	3	4	5
A. Ground Cover				✓	
B. Litter	✓				
C. Species Present				✓	
D. Erosion				✓	
E. Paths				✓	
F. Forest Litter				✓	
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: Area heavily used at one time, well kept. Campground Near lake, moved away from lake Shore to nerby woods

Campground Rating Form

Name of Area Shady Lake, Loop E Date Visited 8/11/76

Location of Area Ouachita NF Years in Public Service ___

Vegetation Type pine-oak

Rating Scale

	1	2	3	4	5
A. Ground Cover	✓				
B. Litter	✓				
C. Species Present		✓			
D. Erosion		✓			
E. Paths		✓			
F. Forest Litter		✓			
G. Screening	✓				

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: mostly pine in campsite area. Screening actually fairly thin, but rated as excellent for this type of habitat.

Campground Rating Form

Name of Area Crystal Camp Date Visited 8/11/76

Location of Area Ouachita NF Years in Public Service ____

Vegetation Type Mixed - upper floodplain - mesic upland hardwoods

Rating Scale

		1	2	3	4	5
A.	Ground Cover			✓		
B.	Litter	✓				
C.	Species Present				✓	
D.	Erosion			✓		
E.	Paths				✓	
F.	Forest Litter				✓	
G.	Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale. Assume that 3 is average.

Comments: Area apparently heavily used, but well kept. very little brush, forest floor areas mostly mixed grasses

Campground Rating Form

Name of Area Camping Area A Date Visited 8/12/76

Location of Area Petit Jean State Park Years in Public Service ____

Vegetation Type Pine forest

Rating Scale

	1	2	3	4	5
A. Ground Cover			✓		
B. Litter	✓				
C. Species Present			✓		
D. Erosion			✓		
E. Paths				✓	
F. Forest Litter			✓		
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: Forest floor with heavy cover of needles, but about average for forests of this type. Forest floor vegetation scattered grasses. Area heavily used. no screening between Campsites with few exceptions, However, forests of this type frequently have low brush cover and few saplings.

Campground Rating Form

Name of Area Rush Camping Area Date Visited 7/15/76

Location of Area Buffalo Nat'l River Years in Public Service ____

Vegetation Type Bermuda grass.

Rating Scale

	1	2	3	4	5
A. Ground Cover		✓			
B. Litter		✓			
C. Species Present			✓		
D. Erosion		✓			
E. Paths		✓			
F. Forest Litter	Not applicable				
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: Vegetation surrounding area disturbed, Mixed hardwood forest, but camp area proper mostly bermuda. Campsites in open area, thus No screening. Area not developed. Area in overall good condition for camp areas of this type. Apparently the area not frequently used as much as other campgrounds

Campground Rating Form

Name of Area Campground below restaurant* Date Visited 7/15/76

Location of Area Buffalo Nat'l River Years in Public Service Many

Vegetation Type Floodplain Forest (Elm- Ash- Maple)

Rating Scale

	1	2	3	4	5
A. Ground Cover				✓	
B. Litter	✓				
C. Species Present				✓	
D. Erosion			✓		
E. Paths				✓	
F. Forest Litter				✓	
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

<u>Comments</u>: Area heavily overused for many years, forest floor in camp area mostly species tolerant of trampling (goose grass, bitterweed, bermuda grass, etc). Erosion between campsites and along paths to river.

* Campground near river.

Campground Rating Form

Name of Area Gilbert

Date Visited 7-19-76

Location of Area Gravel bar near Gilbert

Years in Public Service

Vegetation Type Willow (Gravel bar)

Rating Scale

	1	2	3	4	5
A. Ground Cover		✓			
B. Litter		✓			
C. Species Present			✓		
D. Erosion			✓		
E. Paths		✓			
F. Forest Litter	Not applicable				
G. Screening					✓

Check applicable item using the 1 (excellent) to 5 (very poor) scale.

Assume that 3 is average.

Comments: No established campsites. Much sand and gravel removed, area weedy (Ragweed, sorrel, smartweed, ponjo), but weeds typical of this site

APPENDIX III

Paper Presented at First Conference
on Scientific Research
in the National Parks

SPATIAL AND TEMPORAL DISTRIBUTION OF ALGAE AND SELECTED WATER QUALITY PARAMETERS IN THE BUFFALO RIVER, ARKANSAS

The Buffalo National River rises in the Boston Mountains and courses eastward 148 miles through narrow valleys of the Ozark Plateau until it enters the White River. The Buffalo River watershed is primarily an upland oak-hickory deciduous forest interspersed with pastoral lands. The terrain of the region is rugged and the valleys are typically narrow with tall vertical bluffs.

Along the 110 miles of river within the area of study the river changes gradient significantly. In the upper third of the river, slope is 16 feet per mile in the headwaters area of Boxley to Ponca and 13 feet per mile from Ponca to Pruitt. In the central third, Pruitt to Tyler Bend, the gradient averages 5 feet per mile, and a shallow slope of 3 feet per mile typifies the lower reaches. In the headwaters region the stream is narrow and meanders through a flood plain forest. This section is characterized by broad riffle areas with pools which undergo a transition to isolated pools before the stream dries from late June until September. The riffle and pool margins are invaded by beds of vascular phaenerogams, predominantly *Justicia americana* (Water Willow) (Rippey, 1976). The central part has typically a low flow rate, expecially in the summer when languid pools are formed. The bottoms of the large pools are principally silt covered with a few large boulders exposed. The interconnecting areas are extensive gravel bars. Densely wooded steep bluffs surround the stream and *Salix* spp. grow on the gravel bars. The lowermost section has an aspect very different from that of the steeper portions. Here the river bed is silty with little exposed gravel. The valley widens and forms a sluggish pool with the banks shaded by large *Populas deltoides* (Cottonwood) trees.

Research on lotic ecosystems in the United States was initiated in the 1900s with a study of the Illinois River by Kofoid in 1908. The early studies were confined to summer months and larger organisms (Blum, 1956a). Annual studies of algae along an entire river's course are limited and none are known for the Ozark Highlands. Algae of the rivers are of primary types, planktonic and attached. The planktonic organisms are either rheoplankton or tychoplankton. Rheoplankton usually are found only in slowly moving rivers. Their abundance is inversely proportional to the stream gradient (Blum, 1956b). Streams may lack an annual plankton but develop seasonal rheoplankton in pools during low flow periods. Prior studies on the Buffalo River described the development of these populations during the summer when euplanktonic species were present and chlorophyll values were higher. In other seasons temporary or tychoplankters were derived from the several periphyton subcommunities, but continued to reproduce in a planktonic state (Meyer, 1975).

Meyer (1975) has shown that the principal algal component of the Buffalo National River is the Periphyton. These organisms were shown to develop assemblages in the epilithic, epiphytic, epizoic, epipelic, and metaphyton subcommunities. The development of these subcommunities is associated with variations in flow rate around the substrate units which provide diverse niches. Although the causal factors are not completely known there is an inherent "current demand" (Whitford and Schumacher, 1961). Ruttner (1964) suggested that streams are physiologically rich because zones of depletion do not form in the microhabitat surrounding the periphyton. Douglas (1958) demonstrated that low flow was adverse to growth of diatom assemblages. The effect of current has been clearly demonstrated by comparison of algal populations in adjacent pools and riffles with similar oxygen, temperature, and nutrient levels. The differential distribution of algae between these zones can be interpreted in terms of a current demand. However, maximum as well as minimum flow rates must be considered as scouring may remove algae from the substrate.

Collections of phytoplankton and periphyton at regular time intervals demonstrate a definite algal periodicity. Temporal distribution is generally accepted for plankton but distribution of periphyton may follow two patterns. In certain systems the species composition is relatively constant but abundance varies seasonally. Butcher (1940) observed this pattern in the River Hull. In other streams or regions of streams there may be a constant reappearance of algal associations in a particular season; e.g., the summer *Spirogyra* bloom in the lower Buffalo National River (Rippey and Meyer, 1975). It should be noted that the occurrence of an algal species is more dependent on the chemical and physical characteristics of the water and the structure of the river basin than on previous sequences of algal species (Patrick, 1971).

The reported research, conducted from September 1974 through September 1975, was designed to provide a description of the Buffalo National River's spatial and temporal distribution of the algal flora and selected water quality parameters. Emphasis was placed on gaining insight into major biogeographical zones and seasonal seccession, and determining which physico-chemical parameters may affect algal distribution.

MATERIALS AND METHODS

Algal and physico-chemical samples were collected at monthly intervals at nine stations (Figure 1). Periphyton grab samples from each subcommunity and phytoplankton tows were preserved in M_3 fixative (Meyer, 1971). Diatoms were acid cleaned and Hyrax mounted before examination.

Temperature was measured *in situ* and oxygen concentration was determined by azide modification of the Winkler titration APHA, 1971. Turbidity was determined on unfiltered water samples by a Hach Turbidimeter Model 2100A. Analyses were performed on filtered water samples for determination of orthophosphate, nitrate, and silica. Determination of orthophosphate was by the stannous chloride procedure, nitrate by the ultraviolet technique, and silica by the heteropolyblue method APHA, 1971).

RESULTS AND DISCUSSION

The results presented are a summation of more detailed analysis by Rippey and Meter (1975, 1976) and Rippey (1976). A generalized spatial distribution of the algal flora and temporal distribution patterns are described. Similar generalizations are given for temporal and spatial fluctuations of selected physico-chemical parameters.

The mean seasonal temperature profile is a smooth sinusoidal curve with a maximum of 32° in early September 1975. The lowest water temperature recorded was 5° in December

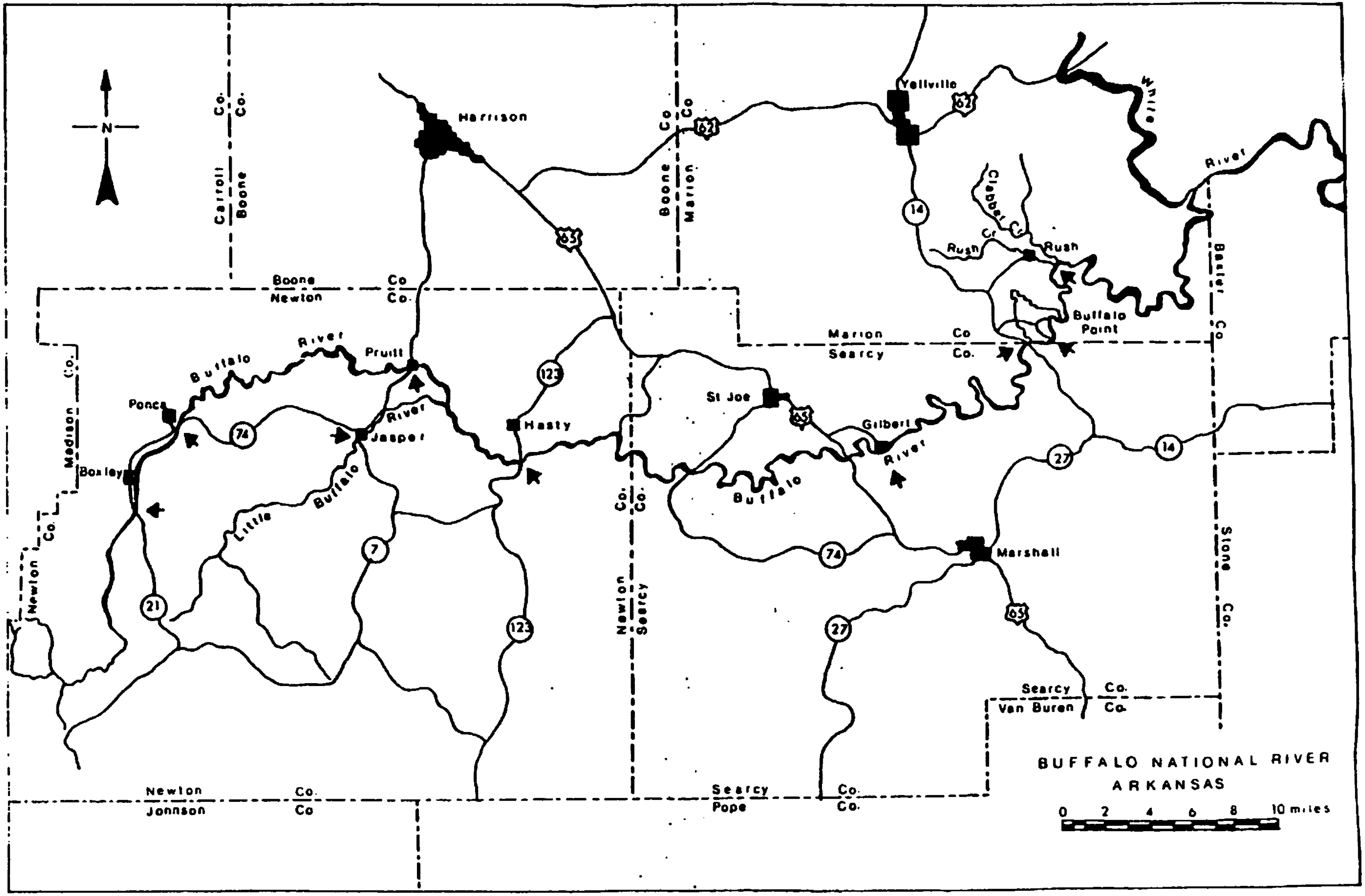


Figure 1. Buffalo National River. Arrows indicate sampling stations.

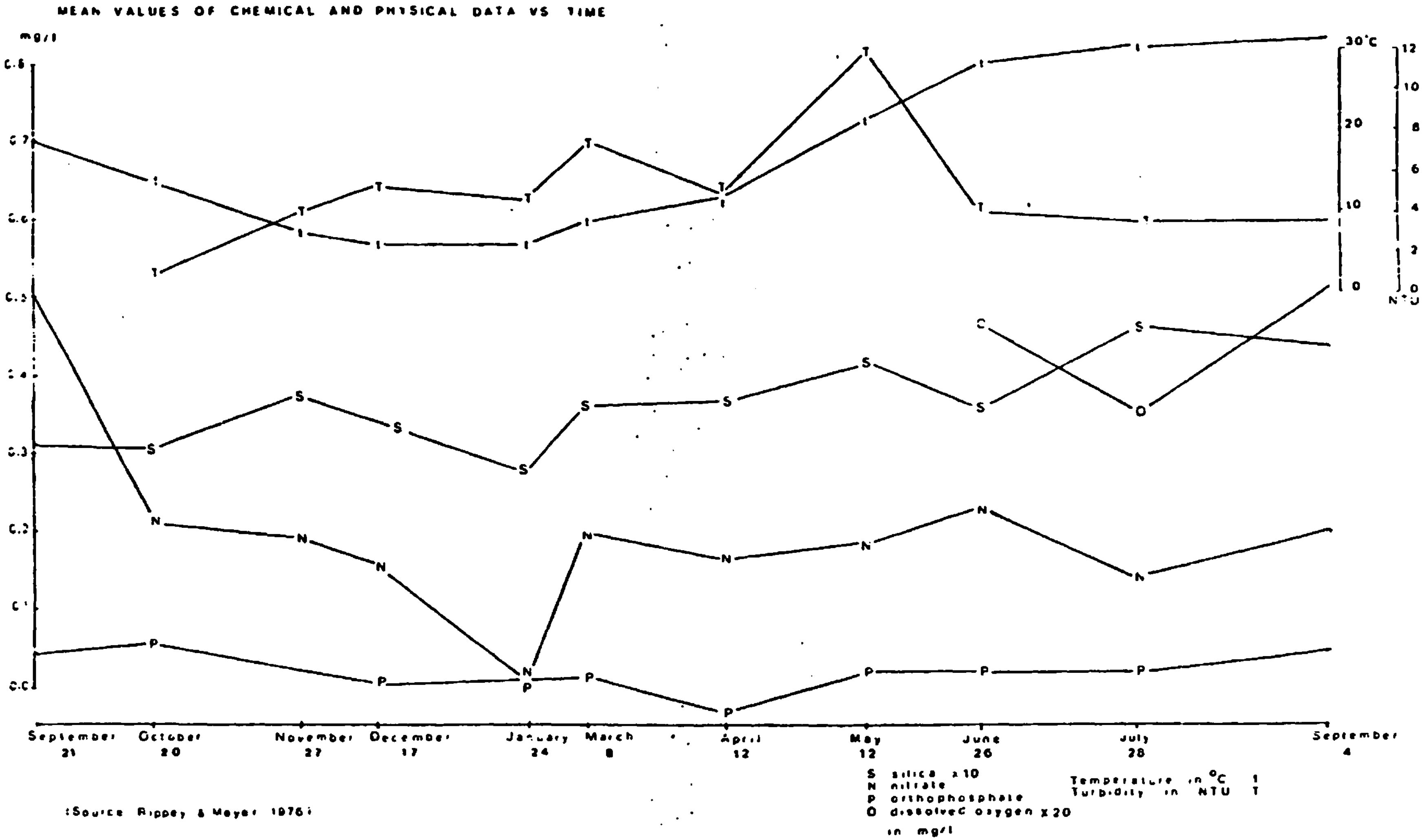
1974. The stream was spatially cooler in the headwater with a maximum of a 2° rise along the 110-mile study area (Figure 2). The minimal change in temperature is probably the result of the inflow of numerous springs and the large volume of water passing through the gravel substrate.

Dissolved oxygen is subject to diurnal and spatial fluctuations. The magnitude of the diurnal change varies seasonally according to algal productivity. Rippey and Meyer (1976) reported that marked changes in oxygen production versus respiration were dependent upon the composition and density of the standing crop as well as insolation. The mean values for mid-day dissolved oxygen ranged from 4.1 to 12.6 mg/1 from June to September (Figure 2). Later research indicated that oxygen concentrations were near saturation. Similar results have been reported by Nix (1973). These data suggest there is probably no organic overloading.

Rippey and Meyer (1975, 1976) have shown that oxygen concentrations are affected by temperature, flow rate, and productivity. The minimum concentration of 4.1 mg/1 in July can be accounted for by reduced flow, which results in a reduction of reaeration, elevated water temperatures, and high respiration associated with a large standing crop.

Turbidity values which represent the total amount of organic and inorganic suspended materials ranged from 0.29 to 19.0 NTU. Summer and autumnal turbidity values were low; the maximum values were recorded in the spring during high runoff (Figure 2). However, all of the variation could not be accounted for by flow. Disturbance in the watershed was also an important factor. During high flow the turbidity produced by flooding or man-made perturbation usually returns to norman levels within 24 hours. Flooding generally affects the entire stream system and typically results in a twofold increase. Man-made disturbances result in higher values but affect a shorter stream segment.

Previous studies have suggested nitrate loading in May and June (Parker, 1975) because of a slight increase in concentration downstream. It is generally assumed that there is a downstream accumulation of nutrients from runoff and ion exchange with the substrate. An inverse relationship was observed by Cushing (1964) in the Montreal River, Saskatchewan. He attributed this reduction to nutrient assimilation by large autotrophic assemblages.



(Source Rippey & Meyer 1976)

Figure 2. Temporal distribution of mean values for selected physico-chemical parameters.

A review of the temporal and spatial data during the study period reveals distinct seasonal periodicity, but minimal change along the river (Figure 3). The most important source of nitrate is agricultural runoff and discharge of wastes. The correlation coefficient between nitrate and turbidity showed a significant positive correlation. Nix (1973) found a maximum near river mile 80 with submaxima at river miles 70 and 50. The reduced nitrate concentrations and high turbidity values in January are the result of a flooding event. The dilution of a certain parameter while others increase during high runoff has been observed on other Arkansas streams, i.e., the Caddo River (Nix, 1973).

The nitrate concentrations along the Buffalo River are typical for the Ozark Plateau with a range from 0.03 to 0.77 mg/l, the highest concentration in the autumn tends to be higher as a result of a general increase in flow. The flow increase appeared to be associated with abscission layer formation in the trees which resulted in reduced transpiration and increased groundwater flow.

Orthophosphate concentrations tend to be stable throughout the temporal cycle with mean value ranging from 0.002 to 0.07 mg/1 (Figure 2). Spatial distribution of this ion indicates that orthophosphate is nearly constant along the river except for slightly higher concentrations at Hasty (Figure 4). The sorbtion on silt particles during periods of high runoff and on the substrate reduces the availability of this ion. The rapid uptake by the algal standing crop is an important facotr in the reduction of orhtophosphate concentration. The rapid turnover rate of phosphorus permits a large standing crop although low concentrations of available phosphorus are reported.

The concentrations of silica tend to increase during the annual cycle and attain a maximum in late summer (Figure 2). There was a slight tendency for silica concentrations to increase downstream.

Silica has been suggested by Lund (1965) to be the limiting factor when concentrations are below 0.3 mg/1. If that is indeed the limiting concentration, silica levels on the Buffalo River never are limiting. Silica concentrations of 1.55 to 6.47 mg/1 are comparable to those recorded for other streams of the Ozark Highlands (rice, 1974; Meyer, 1975). The presence of high silica concentrations suggests that the seasonal periodicity of diatoms in the Buffalo

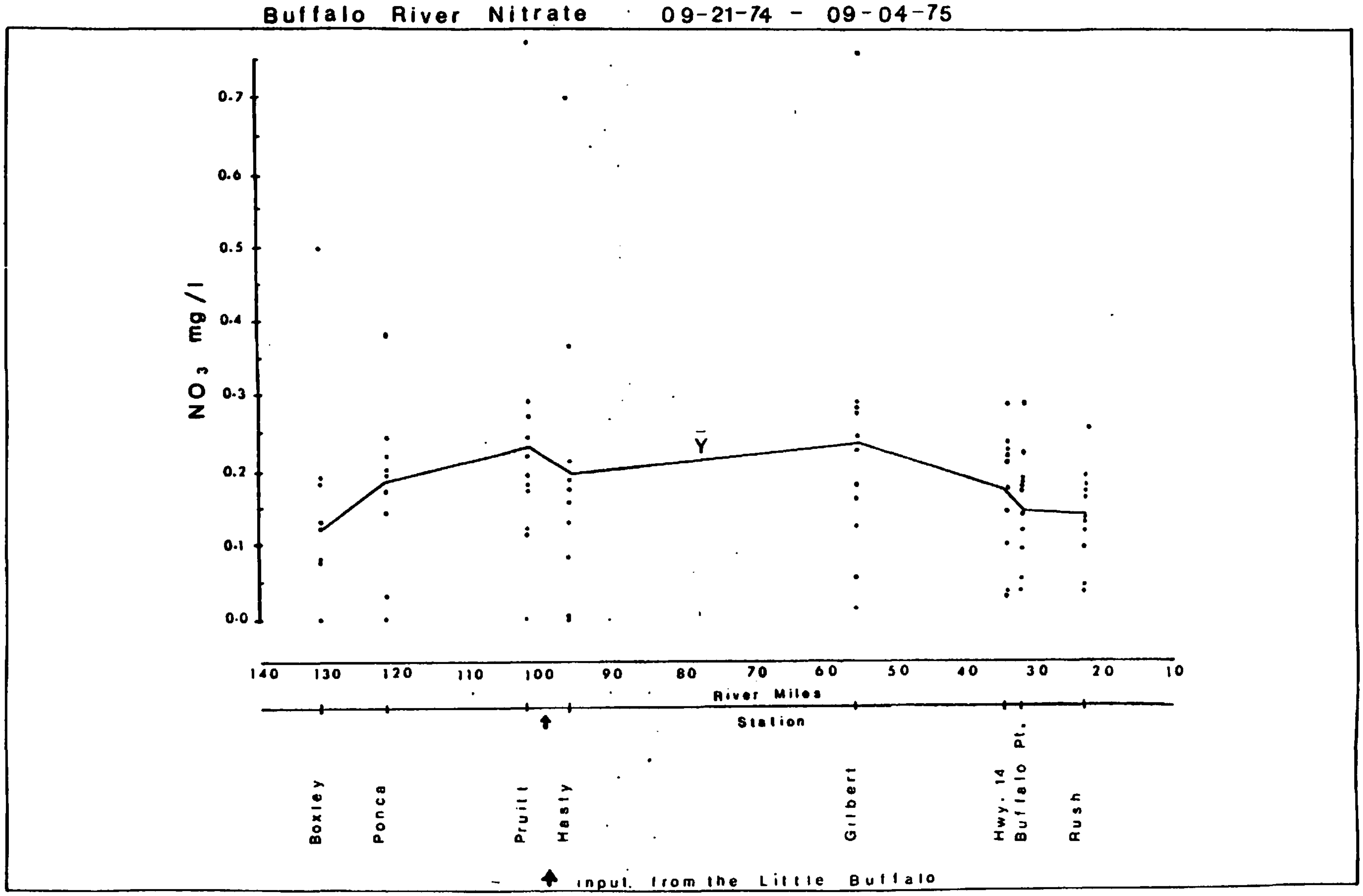


Figure 3. Buffalo River nitrate data. Concentration vs. river mile (line represents the mean value).

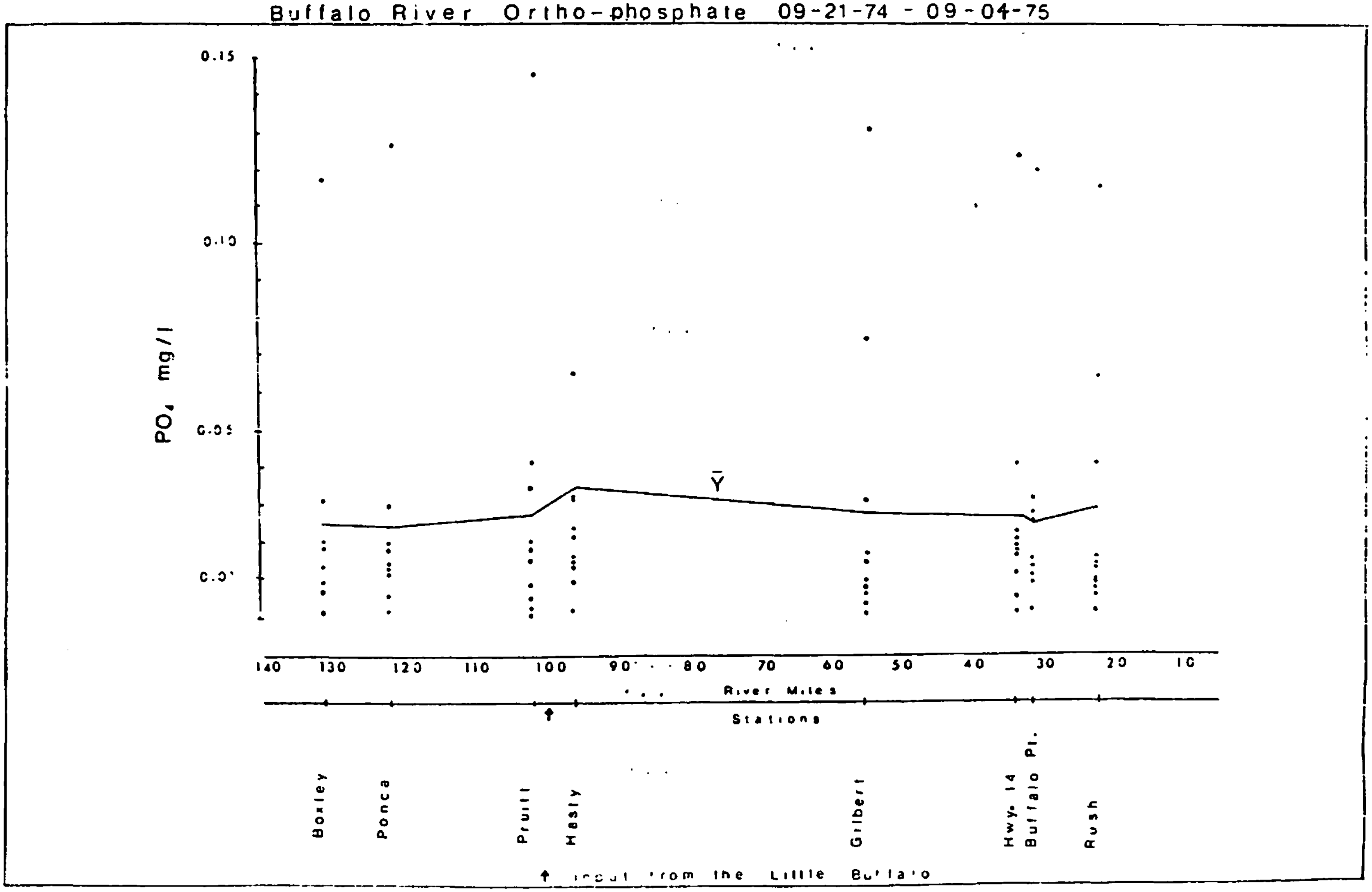


Figure 4. Buffalo River phosphate data. Concentration vs. river mile (line represents mean value).

River must be attributed to other factors.

The 270 members of the algal flora of the Buffalo National River show a marked spatial and temporal dustribution of species. Spatially the stream can be subdivided into three major segments: an ephemeral segment from the headwaters to beyond Ponca, a central portion with a continuously inundated gravel substrate, and a segment having alternately gravel and silt substrate in the riffles and pools, respectively. The last segment is also continuously inundated. The algae in the upper segment can be present only during periods of inundation, e.g., October through May. The forms present are those which can withstand desication and/or produce a resistant structure. The organisms are present during the period of high runoff and rapid flow. These conditions tend to select for organisms which are epilithic, i.e., sessile Rhodophyceae, filamentous greens, coccoid and filamentous blue-greens, and pennate diatoms. The central segment contains a diverse flora which includes the species present in the upper segment plus epiphytic, metaphytic, and euplanktonic species. Stands of *Justicia americana* develop in the pool margins and serve as a substrate for *Oedogonium, Bulbochaete, Cylindrocapsa, Oscillatoris, Lyngbya,* and the algal epiphytes *Chamaesiphon, Gomphonema,* and *Cocconeis.* A metaphyton subcommunity containing coccoid greens, desmids, and miscellaneous flagellates is associated with the vascular phaenerogams. Epizooic blue-green algae and *Gongrosira debaryana* are present on snails. The pools may contain euplanktonic as well as tychoplanktonic species derived from the metaphyton population. The true planktonic forms, *Mallomonas, Dinobryon, Eudorina, Kirchneriella, Scenedesmus,* produce minor, temporary populations. A more permanent pool resident is *Spirogyra.*

The lower river segment includes upstream organisms with the addition of epipelic and embedded species. The epipelic algae *Oscillatoria, Phormiduim, Spirulina, Vaucheria,* and naviculoid diatoms produce a pellicle at the silt-water interface of the quiet pool. These languid pools often contain stands of *Chara* embedded in the bottom. The deeper pockets are filled with floating masses of *Spirogyra.* The euplanktonic component is similar to the control segments flora but contains the euglenoids *Euglena* and *Phacus.*

Substrate composition and period of inundation tend to control spatial distribution of

The riffle areas and gravel margins of pools contain the same assemblages of algae throughout the stream's length. The algae at the soil-water interface and true plankton are substrate associated. Differences seem to be due largely to substrate availability rather than nutrient differences.

Temporal variations in species composition can be described for the Buffalo River. In contrast, the sessile algae of the Hull River did not demonstrate seasonal periodicity (Butcher, 1940). The distribution of the Buffalo River algal flora with time tends to be by major taxonomic level. A summation of the seasonal variation in occurrence of species within major taxa at each of the nine sampling stations is present in Figure 5.

The Rhodophyceae (red algae) were restricted to the epilithic subcommunity. *Batrachospermum* and most other genera of red algae occur in habitats with clean, cool, rapidly running water in eastern piedmont streams (Minckley and Tindall, 1963). *Batrachospermum, Audouinella,* and *Lemanea* showed no well defined temporal periodicity in the Buffalo River. They were found at every station, with the exception of Jasper and Buffalo Point, although they were never very common.

Flagellates are a composite grouping composed of the Volvacales, Euglenophyceae, Pyrrhophyceae, and Chrysophyceae. Their occurrence probably was related directly to flow rate and the presence of sluggish pools because they were found only during the summer and fall. As soon as flow rate exceeds swimming rate and reproductive rate, the taxa are washed from the system. These usually were found as euplankton although they also may occur as metaphyton.

Within the Chlorophyceae (green algae) there are several distributional patterns. Chlorococcales, represented by *Scenedesmus, Kirchneriella, Pediastrum,* etc., was present in varying numbers throughout the study period. These nonmotile unattached forms were often found in plankton tows taken during the summer, but they were found more frequently as metaphyton in close association with periphytic communties.

The filamentous Ulotrichales were present from December until June. They were totally absent from the summer population. *Ulothrix* and *Cylindrocapsa* grow best in cool, well-oxygenated waters with maxima in late winter and in the spring. In more northern

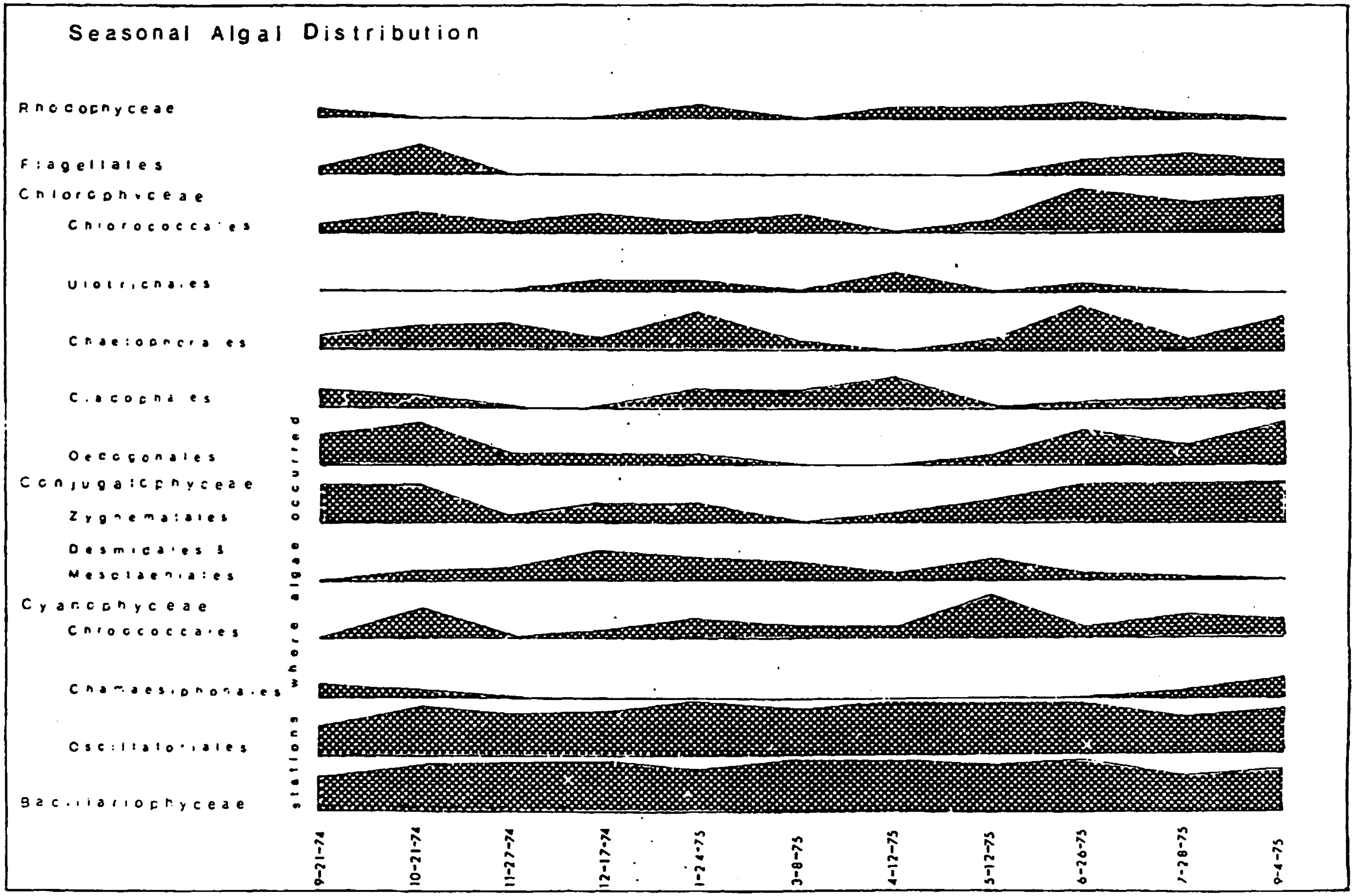


Figure 5. Seasonal algal distribution based on occurrence at nine sampling stations.

streams the seasonal occurrence is delayed approximately two months (Blue, 1960).

Representatives of the Chaetophorales were found in both epiphytic habitats, e.g. *Coleochaete*, and epilithic habitats, e.g. *Gomontia* and *Stigeoclonium*. Stigeoclonium was more prevalent during the winter (November through April), when it developed in the exposed sunny rapids, although it was found in quiet pools. In contrast, Blum (1960) reported that *Stigeoclonium* of northern streams displayed peak growth during the summer in swiftly flowing waters.

Cladophorales, of which *Cladophora* was the most prominent member, was found more frequently in the winter. This distribution probably was influenced by both temperature and flow rate. *Cladophora* has been shown to lack tolerance to summer increases (Dillard, 1969). Whitton (1970) concurred by noting a decrease in *Cladophora* when water temperatures were above 24° C.

Dillard (1969) reported that in a North Carolina piedmont stream the summer community was composed of several species of *Spirogyra* associated with *Oedogonium*. This situation parallels the warm weather aspect of the Buffalo River where *Oedogonium* and *Bulbochaete* were predominant in the rapids and high velocity zones during the summer. *Spirogyra* was present within the same time period as *Oedogonium* and *Bulbochaete*, but they were spatially separated.

Of the Conjugatophyceae, the Zygnematales were more common during the summer and fall. *Spirogyra* was represented by several species which were found floating in large masses during the summer as tychoplankton in the quiet pools. *Mougeotia*, also a member of the Zygnematales, was present predominantly during the winter and spring. Desmids *Cosmarium*, *Closterium*, *Penium*, and *Staurodesmus* were important as metaphyton and were present mainly from November through May.

The seasonal distribution of the Cyanophyceae is less well defined. Blue-greens in the Buffalo River were the second most predominant encrusted epilithic algae. These diverse encrusting forms have certain features in common. They have a compact habit with a broad surface of contact with the substrate leaving very little surface exposed to the current. Chroococcalian blue-green algae, such as *Aphanocapsa*, *Chroococcus*, *Gloeocapsa* and *Merismopedia*, were an important component in the encrusting epilithic subcommunity, as well as in the epipelic layer. The appearance of the spiphyte *Chamaesiphon* corresponded with the period when its most frequent host *Oedongonium* was most abundant. Oscillatoriales was common throughout the study period. Common representatives, including *Lynbgya, Oscillatoria,* and *Phormidium,* were usually epilithic.

By far the most abundant and diverse algal taxon represented on the river was the Bacillariophyceae. Epilithic diatoms of the littoral zone of lakes show a well-defined seasonal succession, with only a few genera such as *Gomphomena, Cymbella,* and Achnanthes present the year round (Stockner and Armstrong, 1971). The seasonal distribution of diatoms in the Buffalo River was not so well defined; many genera observed had sporadic distributions and others were present throughout the study period. *Achnanthes, Cocconeis, Cymbella, Navicula, Nitzchia, Surirella,* and *Synedra* were found frequently along the river on each sampling date. Some of these diatom genera, including *Achnanthes, Cocconeis,Cymbella,* and *Gomphonema,* are especially suited to fast flowing streams because of their ability to affix themselves firmly to the substrate (Fox et al., 1969). The presence of some genera of Bacillariophyceae in the Buffalo River apparently is restricted to rapid flow; these are *Amphipleura, Cymatopleura, Frustulia, Gyrosigma, Pinnularia, Rhophalodia, Stauroneis,* and *Cyclotella.* This effect may be due to substrate availability, as well as disturbance due to stream disturbance and/or rapid flow. For example, *Cymatopleura* and other diatoma live on silt banks which are unstable in rapid currents (Blum, 1956b). A few genera in the Buffalo showed a temporal distribution that may be related to seasonal changes. *Diatoma, Fragilaria, Meridion,* and *Pleurosigma* were more common during the winter.

The data provide a baseline from which specific, concise patterns emerge and are a standard from which clearly defined questions can be addressed. These studies have shown that the Buffalo National River is a unique system. That is, it contains three major habitat types with intergradations with an associate flora. The flora is not only spatially diverse but also shows seasonal variation. These spatial and temporal patterns are evident in each of the subcommunties.

It conserved, the Buffalo National River ecosystem can provide an excellent series of study sites for reaching an understanding of the impact of natural and man-generated perturbations. For example, the upper stream segment, the ephemeral segment, is a naturally distrubed region which is recolonized and becomes productive soon after inundation. An analysis of this response would provide insight into the potential recovery of "use" disturbed areas and lead to the development of a management plan. The diversity within this one stream system provides the National Park Service on opportunity and an obligation to preserve an important ecosystem.

LITERATURE CITED

American Public Health Association. 1971. Standard methods for the examination of water and waste water. 13th ed. N.Y. 769 p.

Blum, J. L. 1956a. The application of the climax concept to algal communities of streams. Ecology. 37:603-604.

Blum, J. L. 1956b. The ecology of river algae. Bot. Rev. 22:291-341.

Blum, J. L. 1960. Algal populations in flowing waters. p. 11-21. In: The ecology of algae. Pymatuning Laboratory of Field Biology. Spec. Publ. No. 2. University of Pittsburgh. 96 p.

Butcher, R. W. 1940. Studies in the ecology of rivers IV. Observations on the growth and distribution of the sessile algae in the River Hull, Yorkshire. J. Ecol. 28:210-223.

Cushing, C. E. 1964. Plankton and water chemistry in Montreal River lake-stream system, Saskatchewan. Ecology. 45:306-313.

Dillard, G. E. 1969. The benthic algal communities of a North Carolina Piedmont stream. Nova Hedwigia. 18:9-29.

Douglas, B. 1958. The ecology of the attached diatoms and other algae in a small stony stream. J. Ecol. 46:295-322.

Fox, J. L., T. O. Odlaug, and T. A. Olson. 1969. The ecology of periphyton in western Lake Superior. Part I. Taxonomy and distribution. Water Resources Research Center. Minneapolis, Minnesota. 127 p.

Lund, J. W. G. 1965. The ecology of freshwater phytoplankton. Biol. Rev. 40:271-293.

Meyer, R. L. 1971. A study of phytoplankton dynamics in Lake Fayetteville as a means of assessing water quality. Water Resources Research Center Publ. No. 10. University of Arkansas, Fayetteville. 59 p.

Meyer, R. L. 1975. Biochrome analysis as a method for assessing phytoplankton dynamics Phase II. Water Resources Research Center Publ. No. 32. University of Arkansas, Fayetteville. 58 p.

Minckley, W. L., and D. R. Tindall. 1963. Ecology of Batrachospermum sp. (Rhodophyceae) in Doe Run, Meade County, Kentucky. Bull. Torrey Bot. Club. 90(6):391-400.

Nix, J. 1973. Intensive "one shot" survey. In: Preliminary reconnaissance water quality survey of the Buffalo National River. Babcock, R. E., and H. C. MacDonald (eds.). Water Resources Research Center Publ. No. 19. University of Arkansas, Fayetteville. 147 p.

Parker, D. G. 1975. Seasonal water quality analysis. In: Buffalo National River ecosystems Part I. Babcock, R. E., and H. C. MacDonald (eds.). Water Resources Research Center Publ. No. 34. University of Arkansas, Fayetteville. 228 p.

Patrick, R. 1971. The effects of increasing light and temperature on the structure of diatom communities. Limnol. Oceanogr. 16(2):405-421.

Rice, R. G. 1974. Water chemistry and algal studies. pp.16-34. In: A preliminary study of the water quality of the Illinois River, Arkansas. Final report to the Illinois River Property Owners of Arkansas, Inc. 158 p.

Rippey, L. L. 1976. Spatial and Temporal Distribution of Algae and Selected Water Quality Parameters in the Buffalo River, Arkansas. Arkansas Water Resources Research Center. Thesis and Dissertation Series Report No. 1. University of Arkansas, Fayetteville. 91 p.

Rippey, L. L., and R. L. Meyer. 1975. Spatial and temporal distribution of algae and associated parameters. p. 103-115. In: Buffalo National River Ecosystems Part I. Babcock, R. E., and H. C. MacDonald (eds.). Water Resources Research Center Publ. No. 34. University of Arkansas, Fayetteville. 228 p.

Rippey, L. L., and R. L. Meyer. 1976. Spatial and temporal distribution of algae and associated parameters. In: Buffalo National River Ecosystems Part II. Babcock, R. E., and H. C. MacDonald (eds.). Water Resources Research Center Publ. No. 38. University of Arkansas, Fayetteville.

Ruttner, F. 1964. Fundamentals of Limnology. University of Toronto Press, 295 p.

Stockner, J. G., and F. A. J. Armstrong. 1971. Periphyton of the experimental lakes area, northwestern Ontario. J. Fish Res. Board Canada. 28:215-229.

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

Whitton, B. A. 1970. Biology of Cladophora in fresh waters, a review paper. Water Research. 4:457-476. Pergamon Press, N.Y.