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SOME RELATIONSHIPS IN THE WATER QUALITY AND LIFE FORMS OF FIELD TILE EFFLUENTS AND DOWNSTREAM WATER

(TITLE)

BY

JOSEPH C. SIDWELL

THESIS

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YEAR

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SOME RELATIONSHIPS IN THE WATER QUALITY AND LIFE FORMS OF FIELD TILE EFFLUENTS AND DOWNSTREAM WATER

JOSEPH C. SIDWELL

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INTRODUCTION

In recent years there has been a critical need to understand the relationship between the quality of ground water and downstream water in drainage systems. As a public utility, this downstream water often directly affects additional thousands of people. As a recreational source and aesthetic value, it indirectly affects additional thousands of persons who wade in it, fish or swim in it, or just look at it. To determine the cause of what is right or wrong with water, one must look upstreams to the source. Except for a few hours following a rain shower, the source for any existing stream is ground water. This water, moving through the soil, dissolves organic and inorganic constituents, moves toward the lower levels of the water table, and gets to the surface of the ground. Here it seeps or flows out to become part of the flowing watershed..

When field tile exist beneath the surface of the water table, this process is speeded up. Agricultural economics, which demand greater productivity from existing acreage, create the need for greater drainage efficiency. Increased drainage efficiency encourages cultivation of slopes that might otherwise have been pastured or left fallow. It also encourages the farmer to plant cash crops that require intensive fertilization. These soils are left bare longer and are more subject to erosion. The resulting soil and nutrient loss from fields end up as sediment and nutrient loading in lakes and streams. This end result is a lower quality of water for aquatic life and public use.

Since 1945 surface waters in various Illinois rivers have been measured monthly on a five year basis by the Illinois State Water Survey. Since 1956 the waters in the state have been increasing in NO_3-N concentration. Harmeson et al. (1973)reported that none of the rivers monitored before 1956 had exceeded the United States Public Health Service (USPHS) Drinking Water Standard (DWS) of 45 mg/l. However, in the five years following, 9 of 19 streams sampled exceeded the DWS. Continued monitoring of these rivers shows considerable variability from year to year (Harmeson et al. 1973). Nutrient concentrations from agricultural runoff results from an interaction of many factors. These factors include soil fertility, types of crops, conservation practices, amount and distribution of precipitation, soil infiltration and percolation characteristics, and the size of the watershed (Keup 1968).

Inorganic fertilizers have long been suspect as a primary source of NO_3 in water (Welch 1952; Harmeson et al. 1973). Algal blooms and winter fish die-offs in lakes have been attributed to inorganic fertilizers. Other more natural sources do occur. In Israel, Avnimelech and Raveh (1974) reported that rapid decomposition in muck from drained lake sediments was leaching unacceptable levels of NO_3 into the Jordan River. Accurate estimates of nitrates in the soil and in plants can be made. Harmeson et al. (1971) estimated that corn stalks contributed about 21%, soils 36%, rainfall 2%, and fertilizers 41% of the total nitrogen in a study area in Champaign County, Illinois. Of the total amount calculated to exist as a residual, about 20% was lost yearly from one field tile. In a controlled experiment, Timmons et al. (1970) showed that alfalfa and bluegrass also add a large percentage (77%) of their dry weight to the soil. Of this a significant amount was lost by leaching. In Kentucky, Thomas and Crutchfield (1974) observed higher NO_3 and PO_4 concentrations in water draining from a bluegrass pasture than from adjacent fertilized fields.

Tillage practices have a direct effect on the No_3 and PO_4 concentrations in runoff water. Romkens et al. (1972) found that lower concentrations in runoff resulted from minimum tillage practices. Holt et al. (1970) found less phosphate was lost when it was deeply incorporated in application. Nitrate-nitrogen concentrations were found to be higher under cultivated fields than under adjacent wetter sites (Boswell and Anderson 1964; Gilliam 1974). Well-drained soils obviously leach greater amounts of NO_3 and PO_4 into the drainage system than poorly drained soils. Jackson et al. (1974) found a greater subsurface flow of NO_3-N than in surface flow in a Georgia Cowarts loamy sand. In study wells, Harmeson et al. (1971) found nitrates concentrating three to five feet below the soil surface in prairie loam. Johnston et al. (1965) found large percentages of nitrates in field tile effluents from silty clay loam. Johnston feels that the phosphorus compounds are fixed in the soil and, being bound to the sediments, are not well represented in runoff. Römkens and Nelson (1974) found decreased phosphorus in sediments with increasing rainfall. During dry spells the phosphorus was thought to be drawn toward the surface by capillary action. The initial rain after the dry spell causes heavier losses than later more continuous rains.

The amount of phosphorus in flowing or standing waters is not very large, but it does seem to play a limiting role in lake and stream eutrophication. The control of phosphate levels in water is considered more important than of nitrates in maintaining stream and lake quality (Sawyer 1968).

In Illinois the Illinois State Water Survey is conducting monthly, biweekly, and hourly studies on some watersheds (Harmeson 1971). In Macon County, the Macon County Public Health Department (MCPHD) has monitored various local streams and Lake Decatur during the summer months since 1967(Wait 1968, 1969a, 1969b, 1970a, 1970b, 1971). Lake Decatur is the water supply source for Decatur and several surrounding communities. The nitrate levels in the lake have exceeded the EPA standard 45PPM several times in 1974-75 (interview September 1974 with Dr. Fred Grosz, Department of Chemistry, Millikin University, Decatur, Illinois). The streams that empty into Lake Decatur have also been observed to exceed the 45 PPM nitrate level (Grosz 1971) as well as have high fecal coliform counts >30,000 (Wait 1970a). Of the streams emptying into Lake

Decatur, Big Creek and Long Creek have been proposed as future reservoir sites by the Macon County Regional Planning Commission (MCRPC 1969;1970). The sampling of water from these streams has been spotty and confined to the summer months only. The feasibility of such proposals should be based on a knowledge of the water quality parameters of these two streams.

The purpose of this paper is to establish the relationship between the water quality parameters of the sources of these two streams (field tile effluents) and the quality of downstream water.

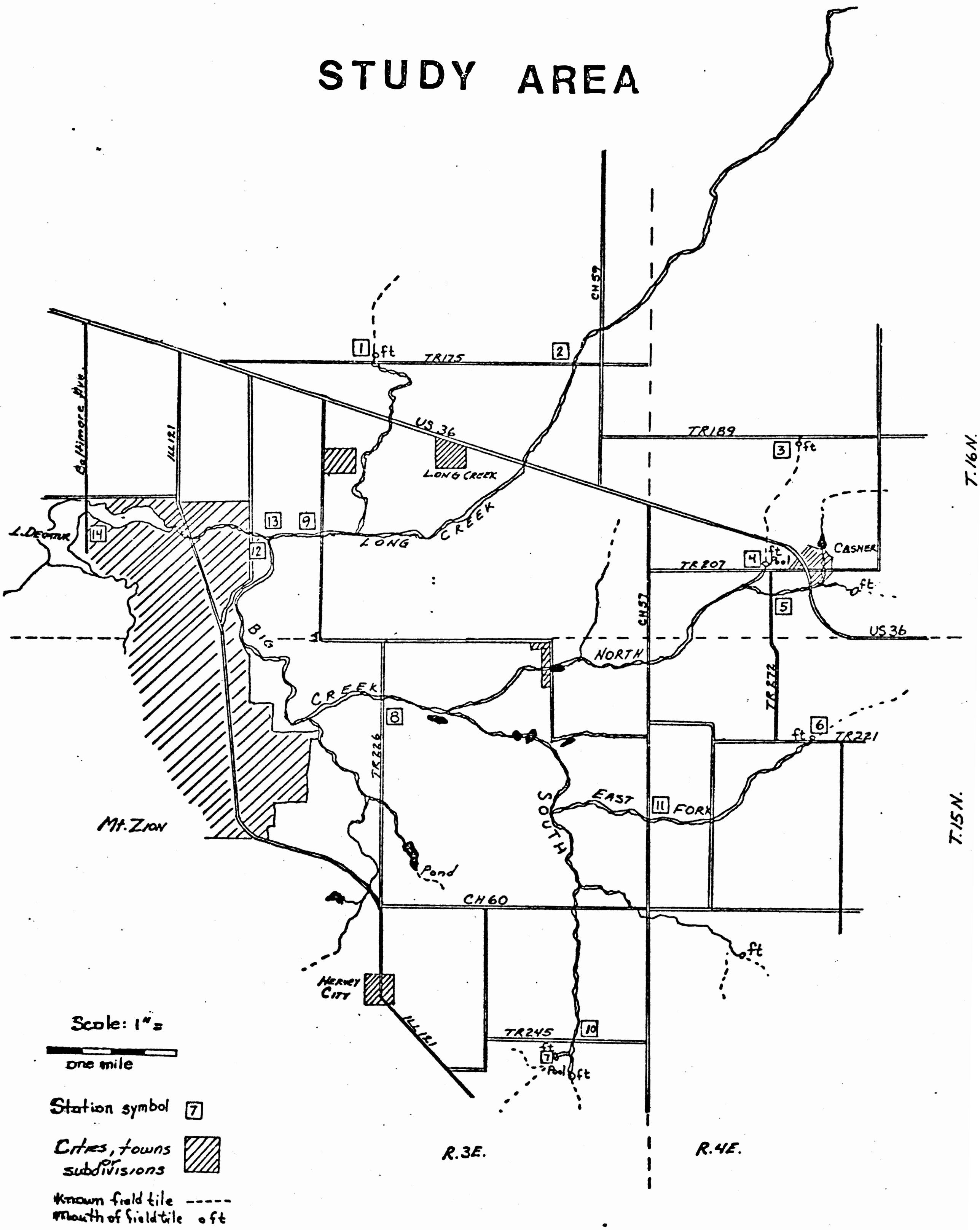


Fig. 1. Map of study area.

MATERIALS AND METHODS

The study was begun 4 September 1974 and concluded 15 May 1975. Initially eight water sampling stations were established with seven on Big Creek and one on Long Creek. This arrangement was changed 11 December 1974. Stations 1, 2, 4, 6, 7, and 9 were added while stations 11, 12, 13, and 14 were deleted. Fig. 1 shows the arrangement of these stations in the study area. The second arrangement increased the number of stations at field tiles from one to five and deleted stations downstream from station 8. Water samples were collected between 0430 and 0630 usually on Tuesday or Wednesday of each week. BOD and DO samples were collected in 300 ml BOD bottles. Temperatures were measured with the alcohol Celsius thermometer provided in the Hach DR-EL Kit which was used to analyze the samples for nitrate and phosphate (Hach 1973). Those samples were collected in 275 ml sterile glass bottles with screw caps. The bottle was held beneath the surface of stream water and unscrewed allowing the bottle to fill. At field tile stations, the bottles were uncapped and held in the current for several seconds before recapping. These samples were analyzed at the MCPHD for nitrate, orthophosphate, pH, and fecal coliform. The BOD bottles were filled using the apparatus shown in Fig. 2 to prevent aeration of the sample. Dissolved oxygen (mg/l) and biochemical oxygen demand (mg/l) were determined according to <u>Standard Methods</u> (APHA 1965) at the Mt. Zion Sewage Treatment Plant. Samples to be tested for dissolved oxygen were treated at the station site with 2 ml manganese sulfate and 2 ml alkalai-iodide-azide. Within one hour, samples were refrigerated until they could be further tested at the treatment plant four hours later. pH was measured using a PORTO-matic pH meter. Fecal coliform counts (counts/100 ml) were made using the Millipore filter method (Millipore Corp. 1973). Starting 25 September 1974, dilutions of 1:100 were made on all samples. Volume of flow (cfs) were made starting 26 December 1974 using two methods. The first method utilized a bent glass tube and attached funnel (Fig. 3) aimed upstream (Andrews 1972). The height of the resulting column of water was used to calculate the velocity of the flow in field tile. Once velocity is known, it is multiplied by the cross-sectional area of the water in the field tile. The second method involved a modification of the method described by Robins and Crawford (1954). This method involves timing a float as it passes through a known distance and over three different segments of stream width. Since field tile are uniform in depth and width, only the center flow line was used for the test. This method is intended for larger streams and was of limited use in the smaller inaccessible field tile at station 6. The float was tossed into each tile a known distance and timed with a stopwatch as it floated out. The average velocity of three trials was multiplied by the area of the tile opening, occupied by water, to get the volume in cubic feet/second. In both meth-

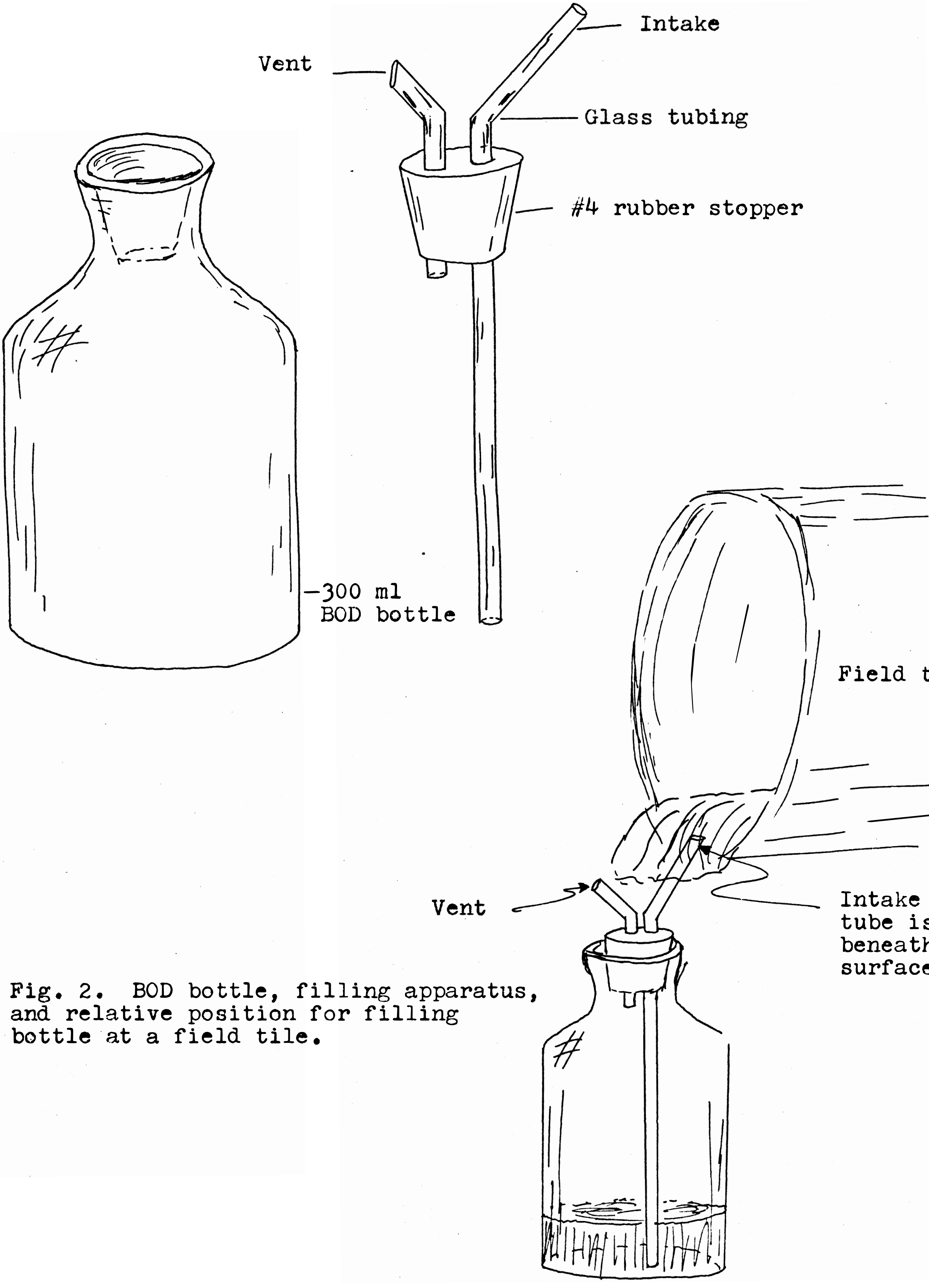
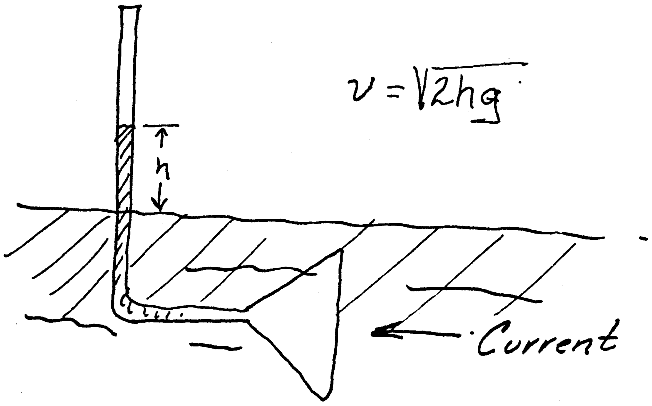


Fig. 2. BOD bottle, filling apparatus, and relative position for filling bottle at a field tile.



$v \equiv$ velocity in ft/s
$h \equiv$ heighth of column in feet
$g =$ acceleration of gravity

Fig. 3. Funnel apparatus for determining velocity of shallow streams and field tile effluents.

ods the area was calculated using the following trigonometric formulae: $A = 1/2 \cdot r^2(\theta \sin \theta)$, where $\theta = 2 \sin^{-1} C(2r)^{-1}$, where A is the area of the water in square feet, r is the radius in feet, θ is the angle in radians enclosed by chord C in feet. The limitations of the first method are that the apparatus is fragile and does not measure velocities below one foot/second. The second method requires that the surface of the water be accessible. In connection with this project, isopods and amphipods were collected at the mouths of field tiles at stations 3, 6, and 7. Fishes were seined at stations 6, 7, 8, 9, and 10 with a 1/4 inch mesh nylon seine. Approximately 100 feet of stream at each station were seined and fishes counted and representative species were preserved in formalin.

Data Analysis

The data for seven parameters for stations 1-10 were subjected to Student's "t" test for significance between monthly means for the nine months. Stations 3, 5, 8, and 10 had N=35; the other stations had N=22. The computer facilities of Eastern Illinois University were used to compute Student's "t" and the associated p values. Pearson correlation coefficients were computed using a computer program designed by Dave Schaub, programmer at the EIU Computer Services Center. Pearson correlation coefficients were used to correlate the parameters of downstream station 8 with the parameters of each upstream station. In this correlation, all weekly data for each parameter at station 8 are compared with the same parameter at each upstream station. Correlation was conducted first for the entire study period. However when a seasonal pattern was noticed, the data were separated into two sets. The first set was of 13 weeks, so that the second set was 22 weeks. Correlation coefficients of .801 are very significient with $p < .001$ and .684 with $p < .01$ for the first set. For the second, correlation coefficients of .652 and .537 have $p < .001$ and .01 respectively. There is a better correlation or relationship between stations having higher correlation coefficients than with stations having smaller correlation coefficients. The relationship of upstream water to downstream water can be determined,in part, by comparing the size of the correlation coefficients of the parameters along the stream. In the t test, monthly means of each parameter at each station were compared with the monthly means of the same parameter at each of the other stations. P values of 1.0 mean that the two stations had identical values and there is no difference between them. Very low p values $< .01$ indicate that there is a very significant difference between the two means. These p values are plotted on Fig. 4.

DESCRIPTION OF THE STUDY AREA

The study area occupies 73 square miles of southeastern Macon County, Illinois. The drainage area includes two streams, Big Creek and Long Creek, which are part of the Sangamon River Drainage System. Thornbury (1954) suggested using topographic maps to determine stream order. In determining stream order, extreme headwater streams, intermittent or permanent, are ranked 1st. order. The union of two such streams forms a stream of the 2nd. order. Whenever two streams of the same order join, they form a next higher order stream. This "Horton classification" (Kuehne 1962) was developed by Horton (1945) and later refined by Strahler (1954, 1957). Big Creek is a third order stream and Long Creek is a second order stream. The drainage density of both streams is less than 1.0, indicating that the area is well drained (Horton 1945). At the mouths of many field tiles a stream may originate at the second order. or higher, so that actual stream order numbers for both of these streams are probably at least two orders higher. Big Creek is 10.9 miles long and falls at an average 11.4 feet per mile with a drainage area of 53 square miles. Long Creek is 9.8 miles long and falls at a rate of 10.4 feet per mile, with a drainage area of 20 square miles (Corps. of Engineers 1971). Both streams originate in the low Cerro Gordo Moraine of the Woodfordian Glacier (Willman and Frye 1970). This area contains relatively flat rich soils used for intensive agriculture.

As the streams widen and slopes increase, fields give way to woodland borders and pastures interspersed with subdivisions.

Station Description

Sta 1: a 27" clay field tile opening in the concrete wall 15 feet north of Township Road 175 (TR175) in SE¼, SE¼, SE¼, SEC 22, T16N, R3E, 3PM.

Sta 2: mid-stream (Long Creek) 20 feet north of bridge on TR175 in SE¼, SE¼, SE¼, SEC 22, T16N, R3E, 3PM.

Sta 3: 20" clay field tile wash out 5 feet wouth of TR189 in SW¼, SE¼, NE¼, SEC 30, T16N, R4E, 3PM.

Sta 4: mid-pool formed by 27"+ clay field tile, artesian, 50 feet north of bridge on TR207 in SE¼, SW¼, NW¼, SEC 31, T16N, R4E, 3PM.

Sta 5: midstream Big Creek North 20 feet east of bridge on TR272 in NW¼, NE¼, SW¼, SEC 31, T16N, R4E, 3PM.

Sta 6: 17" cast iron pipe in wall of concrete culvert, 10 feet north of TR221 in SE¼, SE¼, NW¼,SEC 15, T15N, R4E, 3PM.

Sta 7: 24" clay field tile in field 100 yards south of TR245 at fence row in NE¼, SW¼, SEC 13, T15N, R3E, 3PM.

Sta 8: south bank of Big Creek 10 feet west of bridge on TR226 in NW¼, SW¼, NW¼ SEC 2, T15N, R3E, 3PM.

Sta 9: North bank of Long Creek, 10 feet west of bridge on TR226 in S½, NW¼, NW¼, SEC 34, T16N, R3E, 3PM.

Sta10: west bank of Big Creek South, 3 feet north of 60" culvert on TR245, in NE¼, SW¼, SEC 13, T15N, R3E, 3PM.

Sta11: north bank of east fork Big Creek South, 10 feet east of bridge on County Highway 57, in SW¼, SW¼, SEC1, T15N, R3E, 3PM.

Sta12: midstream of Big Creek, 50 yards east of bridge at Twin Bridges, 10 feet above confluence of Big Creek and Long Creek, in SW¼, NE¼, SEC 34, T16N, R3E, 3PM.

Sta 13: midstream of Long Creek, 10 feet above confluence with Big Creek, in SW¼, NE¼, SEC 34, T16N, R3E, 3PM.

Sta 14: south bank of Big Creek mouth at Lake Decatur, 20 feet east of bridge on Baltimore Avenue, in NE¼, SW¼, SEC 32, T16N, R3E, 3PM.

RESULTS

The water quality parameters of air and water temperature, nitrate-nitrogen, orthophosphate, pH, fecal coliform, dissolved oxygen (DO), and BOD were collected for 35 weeks. High, low, and mean values for all data except air temperature are listed in Tables 1-14. Air temperature is plotted with water temperatures in Fig. 5A. No data were collected in the weeks of 16 October 1974 and 10 April 1975. Stations 5, 7, and 10 were not sampled 23 April 1975 due to severe weather conditions.

The species of fishes collected and identified at the various stations are listed in Table 15.

The amphipods and isopods collected and identified are listed in Table 16.

Table 1. High, low, and mean values for Station 1.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	11.0	10.0	10.40	64.9	36.3	45.4	0.33	0.11	0.20	7.2	6.70	6.95
Jan.	4	9.0	8.0	8.50	40.7	36.7	38.8	0.28	0.08	0.17	7.2	6.80	7.05
Feb.	4	8.0	5.0	6.75	42.9	34.1	39.6	0.53	0.11	0.27	7.3	6.85	7.76
Mar.	5	7.0	6.5	6.80	43.4	34.1	39.9	0.28	0.18	0.20	7.4	6.75	7.08
Apr.	3	9.0	8.0	8.67	47.3	41.8	43.6	0.20	0.18	0.19	7.0	6.90	6.95
May	2	11.0	11.0	11.00	52.8	42.9	47.9	0.25	0.14	0.20	6.9	6.90	6.90

		Fecal (#/100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	150	50	100	10.2	9.6	9.9
Jan.	4	450	50	150	10.4	9.3	10.0
Feb.	4	150	50	75	10.6	7.4	9.7
Mar.	5	2950	50	990	11.2	10.5	11.0
Apr.	3	1150	250	680	10.6	10.0	10.3
May	2	750	450	600	9.0	8.2	8.6

Table 2. High, low, and mean values for Station 2.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	7.5	6.0	6.63	48.4	27.5	33.6	0.28	0.15	0.21	7.5	7.10	7.36
Jan.	4	9.5	4.5	6.50	37.4	29.7	33.6	0.22	0.08	0.17	7.5	7.20	7.25
Feb.	4	6.0	4.0	5.00	39.6	34.1	35.8	0.35	0.11	0.22	7.2	7.11	7.15
Mar.	5	7.0	3.0	4.80	38.5	31.8	35.8	0.22	0.15	0.18	7.55	7.15	7.33
Apr.	2	9.5	8.0	8.75	35.2	34.1	34.7	0.19	0.15	0.17	7.4	7.20	7.30
May	2	12.0	12.0	12.00	31.9	49.5	40.7	0.18	0.18	0.18	7.1	6.90	7.00

		Fecal (#/100 ml)			Do (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	350	150	250	11.2	10.4	10.8
Jan.	4	1450	150	800	11.4	9.4	10.6
Feb.	4	550	150	825	11.2	10.3	10.9
Mar.	5	3150	50	1330	11.8	10.8	11.4
Apr,	2	250	150	200	9.6	9.5	9.6
May	2	1550	650	1100	8.6	8.6	8.6

Table 3. High, low, and mean values for Station 3.

		Water T.(°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	19.0	16.0	18.25	44.	27.5	34.4	2.20	0.40	1.10	7.95	6.90	7.38
Oct.	4	17.0	15.0	16.50	47.3	35.2	37.7	0.60	0.20	0.30	7.7	6.85	7.43
Nov.	4	16.0	13.0	14.50	36.3	29.7	32.7	0.20	0.05	0.15	8.0	6.70	7.30
Dec.	5	12.0	9.0	10.50	75.8	33.	46.8	0.24	0.07	0.14	7.6	7.00	7.22
Jan.	4	9.0	7.5	8.13	46.2	38.5	41.7	0.15	0.09	0.12	7.5	6.80	7.17
Feb.	4	7.0	4.0	5.88	48.4	32.5	40.0	0.42	0.11	0.20	7.1	7.00	7.03
Mar.	5	7.0	5.0	5.90	45.1	34.1	38.4	0.22	0.13	0.17	7.32	7.10	7.21
Apr.	3	9.5	8.0	8.83	51.7	39.6	46.2	0.18	0.16	0.17	7.15	7.05	7.10
May	2	11.0	10.5	10.75	44.0	44.0	44.0	0.20	0.18	0.19	6.95	6.85	6.90

		Fecal (#100 ml)			DO (mg/l)			BOD (mg/l)		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	300	1	853	.8	0.0	8.3	.8	.2	.3
Oct.	4	3150	250	1050	9.7	9.3	9.5	1.8	.3	.9
Nov.	4	350	50	125	9.3	8.4	8.8	1.5	.6	1.2
Dec.	5	150	50	70	10.0	9.3	9.8	1.5	--	1.5
Jan.	4	50	50	50	10.0	9.7	9.8			
Feb.	4	50	50	50	10.6	9.7	10.2			
Mar.	5	50	50	50	11.7	10.8	11.3			
Apr.	3	150	50	83	10.6	9.6	10.2			
May	2	150	150	150	8.8	8.1	8.5			

Table 4. High, low, and mean values for Station 4.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	11.0	9.0	9.88	68.2	38.5	49.0	0.23	0.08	0.19	7.4	7.00	7.15
Jan.	4	9.0	7.0	8.00	42.9	37.4	40.4	0.32	0.16	0.24	7.25	6.90	7.06
Feb.	4	7.0	4.0	20.5	44.0	34.1	38.5	0.42	0.05	0.23	7.2	6.80	6.95
Mar.	5	6.5	5.0	6.0	47.3	40.7	43.6	0.28	0.10	0.14	7.45	6.90	7.11
Apr.	3	9.0	8.0	8.7	47.3	44.	55.1	0.18	0.07	0.12	7.3	7.05	7.18
May	2	12.0	11.5	11.8	47.3	39.6	43.5	0.38	0.22	0.30	6.95	6.85	6.90

		Fecal (#100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	50	50	50	10.4	9.8	10.0
Jan.	4	50	50	50	10.6	10.1	10.2
Feb.	4	50	50	50	10.9	10.	10.5
Mar.	5	50	50	50	11.5	10.5	11.2
Apr.	3	50	50	50	10.6	10.0	10.3
May	2	350	150	250	9.0	8.1	8.6

Table 5. High, low, and mean values for Station 5.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	22.0	10.0	15.4	30.8	19.8	25.3	0.9	0.8	0.80	8.00	6.90	7.40
Oct.	4	16.0	4.0	10.0	29.7	15.4	23.9	0.9	0.3	0.61	7.50	7.00	7.35
Nov.	4	12.0	7.0	10.0	40.7	31.9	36.0	0.4	0.2	0.29	7.90	7.00	7.64
Dec.	5	7.5	3.0	6.0	51.7	37.4	49.0	0.23	0.15	0.16	7.90	7.30	7.56
Jan.	4	10.0	3.0	6.3	40.7	36.3	39.3	0.25	0.16	0.21	7.48	7.15	7.25
Feb.	4	6.0	3.0	4.6	41.5	30.8	37.9	0.51	0.20	0.30	7.45	6.95	7.16
Mar.	5	6.0	2.0	4.1	44.0	38.5	39.8	0.65	0.14	0.29	7.65	7.1	7.42
Apr.	2	9.0	7.5	8.2	41.8	33.0	37.4	0.12	0.11	0.12	7.6	7.3	7.45
May	2	13.0	12.0	12.8	47.3	47.3	47.3	0.45	0.20	0.33	7.25	6.85	7.05

		Fecal (#/100 ml)			DO (mg/l)			BOD (mg/l)		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	16150	350	5000	7.6	5.3	7.5	3.2	2.6	2.8
Oct.	4	950	150	600	8.8	5.8	7.6	4.3	3.0	3.6
Nov.	4	2150	650	1100	10.6	8.0	9.5	2.4	1.3	1.9
Dec.	5	550	150	310	11.5	10.7	11.1			
Jan.	4	1750	50	475	10.9	10.3	11.1			
Feb.	4	150	50	75	11.7	11.2	11.5			
Mar.	5	150	50	70	12.5	10.9	11.8			
Apr.	2	950	250	600	10.1	9.7	9.9			
May	2	1150	450	800	9.4	8.9	9.0			

Table 6. High, low, and mean values for Station 6.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	10.5	9.0	9.5	88.0	41.8	57.5	0.14	0.08	0.10	7.50	7.00	7.18
Jan.	4	9.0	7.5	8.3	49.5	44.1	46.8	0.15	0.06	0.13	7.60	7.05	7.33
Feb.	4	7.0	6.0	6.6	57.2	44.0	49.0	0.31	0.08	0.14	7.30	6.70	6.95
Mar.	5	7.0	6.0	6.4	57.0	39.6	50.3	0.29	0.10	0.18	7.20	6.90	7.21
Apr.	3	9.5	8.0	8.8	80.3	48.4	62.0	0.19	0.10	0.14	7.40	7.10	7.22
May	2	12.0	11.5	11.8	57.2	55.0	56.1	0.32	0.15	0.24	7.0	6.90	6.95

		Fecal (#/100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	50	150	100	10.2	9.1	9.7
Jan.	4	50	50	50	10.5	9.4	10.0
Feb.	4	50	50	50	10.7	8.7	9.9
Mar.	5	150	50	70	11.3	10.3	11.0
Apr.	3	50	50	50	10.3	9.5	10.0
May	2	250	50	150	8.8	7.4	8.1

Table 7. High, low, and mean values for Station 7.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	11.0	10.0	10.4	79.2	39.6	53.9	0.20	0.10	0.17	7.50	7.10	7.24
Jan.	4	9.5	8.0	8.8	46.2	41.8	44.0	0.20	0.14	0.18	7.45	7.00	7.24
Feb.	4	8.0	5.5	7.1	50.6	36.3	43.7	0.6	0.15	0.30	7.00	6.60	6.84
Mar.	5	7.0	6.0	6.8	51.7	41.8	45.8	0.26	0.15	0.19	7.65	6.80	7.20
Apr.	2	9.0	8.0	8.5	54.9	45.1	50.0	0.16	0.13	0.15	7.30	7.05	7.18
May	2	11.0	10.0	10.5	52.8	46.2	50.0	0.12	0.10	0.11	7.10	6.95	7.03

		Fecal (#/100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	550	150	325	10.3	8.9	9.9
Jan.	4	1750	50	550	10.7	8.8	10.0
Feb.	4	450	150	250	10.6	8.9	9.8
Mar.	5	850	350	270	11.4	9.5	10.7
Apr.	2	650	550	600	10.3	9.1	9.7
May	2	150	50	100	9.4	8.9	9.2

Table 8. High, low, and mean values for Station 8.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	23.0	10.0	14.50	20.9	12.1	16.2	0.60	0.20	0.34	7.80	7.10	7.40
Oct.	4	15.5	9.0	10.4	12.1	2.2	7.2	1.90	0.15	0.69	7.50	6.75	7.23
Nov.	4	12.0	5.0	9.0	37.4	28.6	33.0	0.37	0.15	0.28	8.00	7.25	7.70
Dec.	5	6.5	2.0	4.1	58.3	29.7	40.0	0.14	0.09	0.11	7.80	7.60	7.67
Jan.	4	9.0	3.0	5.8	45.1	33.1	38.8	0.18	0.05	0.11	7.65	7.3	7.48
Feb.	4	5.0	3.0	4.3	47.3	31.9	39.1	0.28	0.10	0.19	7.40	6.6	7.12
Mar.	5	8.0	2.0	4.2	39.6	33.0	36.7	0.39	0.10	0.20	7.80	7.0	7.49
Apr.	3	15.0	9.0	11.7	50.6	37.4	42.1	0.20	0.04	0.13	7.65	7.45	7.53
May	2	14.0	13.5	13.8	45.1	36.3	40.0	0.20	0.11	0.16	7.70	7.10	7.40

		Fecal (#/100 ml)			DO (mg/l)			BOD (mg/l)		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	1650	336	947	7.1	5.4	6.5	3.1	2.2	2.6
Oct.	4	450	50	300	8.2	3.0	6.2	5.5	2.8	4.2
Nov.	4	850	50	400	11.0	8.5	9.5	3.0	1.9	2.4
Dec.	5	850	50	410	11.9	10.8	11.3			
Jan.	4	350	250	275	12.9	9.8	11.3			
Feb.	4	650	250	375	12.0	11.5	11.8			
Mar.	5	450	50	250	12.4	10.7	11.8			
Apr.	3	650	350	516	9.7	7.8	8.9			
May	2	1450	450	950	9.0	8.0	8.5			

Table 9. High, low, and mean values for Station 9.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Dec.	4	6.5	4.0	4.9	52.0	30.8	38.2	0.12	0.05	0.08	7.85	7.65	7.71
Jan.	4	9.0	3.0	5.6	36.3	29.7	32.7	0.14	0.05	0.10	7.70	7.45	7.54
Feb.	4	5.0	3.0	4.3	42.9	37.4	40.4	0.23	0.07	0.13	7.45	7.25	7.15
Mar.	5	8.0	2.0	4.2	38.5	33.0	36.1	0.09	0.05	0.06	7.70	7.15	7.53
Apr.	3	13.5	9.0	11.2	39.6	33.0	34.1	0.18	0.05	0.10	7.70	7.50	7.58
May	2	14.0	14.0	14.0	38.5	36.3	37.4	0.21	0.10	0.16	7.65	7.13	7.39

		Fecal (#/100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Dec.	4	550	50	325	12.0	10.9	11.4
Jan.	4	250	50	125	11.8	9.8	11.0
Feb.	4	1150	350	750	12.0	11.7	11.8
Mar.	5	1550	50	530	12.4	10.8	11.7
Apr.	3	1450	750	883	9.4	8.1	8.9
May	2	2250	850	1550	8.8	8.6	8.7

Table 10. High, low, and mean values for Station 10.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	23.0	10.0	15.5	33.0	15.4	21.5	0.5	0.20	0.35	8.00	7.10	7.40
Oct.	4	15.5	6.0	10.4	22.0	6.6	13.5	1.9	0.25	0.84	7.50	7.30	7.41
Nov.	4	13.5	8.0	11.1	38.5	29.7	34.1	0.45	0.10	0.32	7.60	7.11	7.45
Dec.	5	10.0	9.0	9.4	71.5	36.3	44.8	0.17	0.10	0.13	7.60	7.20	7.44
Jan.	4	9.5	8.0	8.6	48.4	35.2	41.5	0.43	0.11	0.23	7.50	7.00	7.26
Feb.	4	8.0	5.5	6.9	47.3	34.1	41.3	0.56	0.09	0.29	7.30	6.90	6.95
Mar.	5	7.0	6.0	6.4	47.4	36.3	40.9	0.25	0.08	0.15	7.60	7.15	7.27
Apr.	2	9.0	8.0	8.5	45.1	38.5	41.8	0.11	0.10	0.11	7.40	7.00	7.25
May	2	11.5	11.0	11.2	49.5	45.1	51.1	0.12	0.11	0.13	7.0	6.90	6.95

		Fecal (#100 ml)			DO (mg/l)		
	N	High	Low	Mean	High	Low	Mean
Sept.	4	250	--	250			
Oct.	4	250	50	125			
Nov.	4	350	250	275			
Dec.	5	1450	50	410	10.4	--	
Jan.	4	1050	50	300	10.6	9.3	
Feb.	4	650	50	400	10.8	8.7	
Mar.	5	150	50	90	11.2	9.9	
Apr.	2	1150	250	700	10.2	9.5	
May	2	150	50	100	9.0	8.7	

Table 11. High, low, and mean values for Station 11.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	23.0	10.0	13.1	27.5	17.6	20.4	0.90	0.4	0.60	8.1	7.2	7.48
Oct.	4	16.0	6.0	11.0	13.2	9.9	12.4	1.90	0.1	0.62	7.5	7.3	7.43
Nov.	4	11.0	8.0	9.9	34.1	27.0	31.3	0.30	0.15	0.21	7.9	7.1	7.62
Dec.	1	3.0	--	3.0	29.7	--	29.7	0.11	--	0.11	7.6	--	7.60

		Fecal (#100 ml)		
	N	High	Low	Mean
Sept.	1	550	--	550
Oct.	4	250	50	125
Nov.	4	350	150	225
Dec.	1	150	--	150

Table 12. High, low, and mean values for Station 12.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	3	23.0	10.0	13.1	23.1	10.0	15.4	0.5	0.20	0.28	7.7	7.5	7.50
Oct.	4	16.0	6.0	11.0	15.4	3.3	7.70	1.4	0.18	0.58	7.7	7.5	7.46
Nov.	4	11.0	5.0	8.8	32.5	26.4	29.3	0.24	0.15	0.53	8.0	7.31	7.73
Dec.	1	1.0	--	1.0	30.8	--	30.8	0.18	--	0.18	7.65	--	7.65

		Fecal (#100 ml)		
	N	High	Low	Mean
Sept.	4	350	79	193
Oct.	4	550	50	200
Nov.	4	750	250	450
Dec.	3	250	--	250

Table 13. High, low, and mean values for Station 13.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	2	17.0	10.0	13.5	11.0	11.0	11.0	0.4	0.2	0.3	7.5	7.5	7.50
Oct.	4	15.5	6.0	10.1	8.8	5.5	7.2	0.4	0.2	0.27	7.6	7.4	7.49
Nov.	4	8.5	4.0	7.5	25.3	20.9	23.5	0.27	0.15	0.21	7.95	7.4	7.77
Dec.	4	1.0	--	1.0	25.3	--	25.3	0.17	--	0.17	7.65	--	7.65

		Fecal (#/100 ml)		
	N	High	Low	Mean
Sept.	2	350	150	250
Oct.	4	650	50	250
Nov.	4	550	150	383
Dec.	4	950	--	950

Table 14. High, low, and mean values for Station 14.

		Water T. (°C)			NO_3 (mg/l)			PO_4 (mg/l)			pH		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	23.0	10.0	16.5	25.3	7.7	13.3	0.4	0.1	0.33	7.70	6.80	7.45
Oct.	4	16.0	10.0	12.80	6.6	4.4	5.5	0.60	0.1	0.33	7.60	7.40	7.50
Nov.	4	11.0	4.0	8.5	34.1	25.3	28.6	0.28	0.20	0.25	8.00	7.50	7.76
Dec.	1	0.0	--	0.0	27.5	--	27.5	0.12	--	0.12	7.75	--	7.75

		Fecal (#/100 ml)			DO (mg/l)			BOD (mg/l)		
	N	High	Low	Mean	High	Low	Mean	High	Low	Mean
Sept.	4	650	150	338	12.0	2.6	8.20	6.8	3.4	5.4
Oct.	4	350	50	225	10.6	4.2	7.2	8.7	3.4	5.2
Nov.	4	950	250	625	11.3	9.5	9.40	3.0	1.3	2.4
Dec.	1	150	--	150	13.3	--	13.3			

Table 15. Fishes collected at stations 6, 7, 8, 9, and 10 and their occurrence.

	6	7	8	9	10
Family Cyprinidae					
1. *Campostoma anomalum* (Rafinesque)	X	X	X		
2. *Nocomis biguttatus* (Kirtland)			X		
3. *Notropis chrysocephalus* (Rafinesque)			X	X	
4. *Notropis hudsonius* (Clinton)				X	
5. *Notropis spilopterus* (Cope)		X			
6. *Notropis stramineus* (Cope)		X	X	X	X
7. *Pimephales notatus* (Rafinesque)			X		X
8. *Pimephales vigilax* (Baird & Girard)	X				
Family Catostomidae					
1. *Catostomus commersoni*(Lacepede)					X
Family Cyprinodontidae					
1. *Fundulus notatus* (Rafinesque)				X	
Family Centrarchidae					
1. *Lepomis cyanellus* (Rafinesque)				X	
2. *Lepomis macrochirus* (Rafinesque)				X	
Family Percidae					
1. *Etheostoma spectabile* (Agassiz)		X			X

Table 16. Isopods and amphipods collected and tentatively identified.

ISOPODA
  Asellidae
    <u>Ascellus communis</u> (Say 1818)
      at stations 3, 4, 6, 7, and 10.

    <u>Ascellus kendeighi</u> (Steeves and Seidenberg 1971)
      at stations 3, 4, 6, and 7.

AMPHIPODA
  Gammaridae
    <u>Bactrurus mucronatus</u> (Forbes 1876)
      at stations 3, 4, 6, and 7

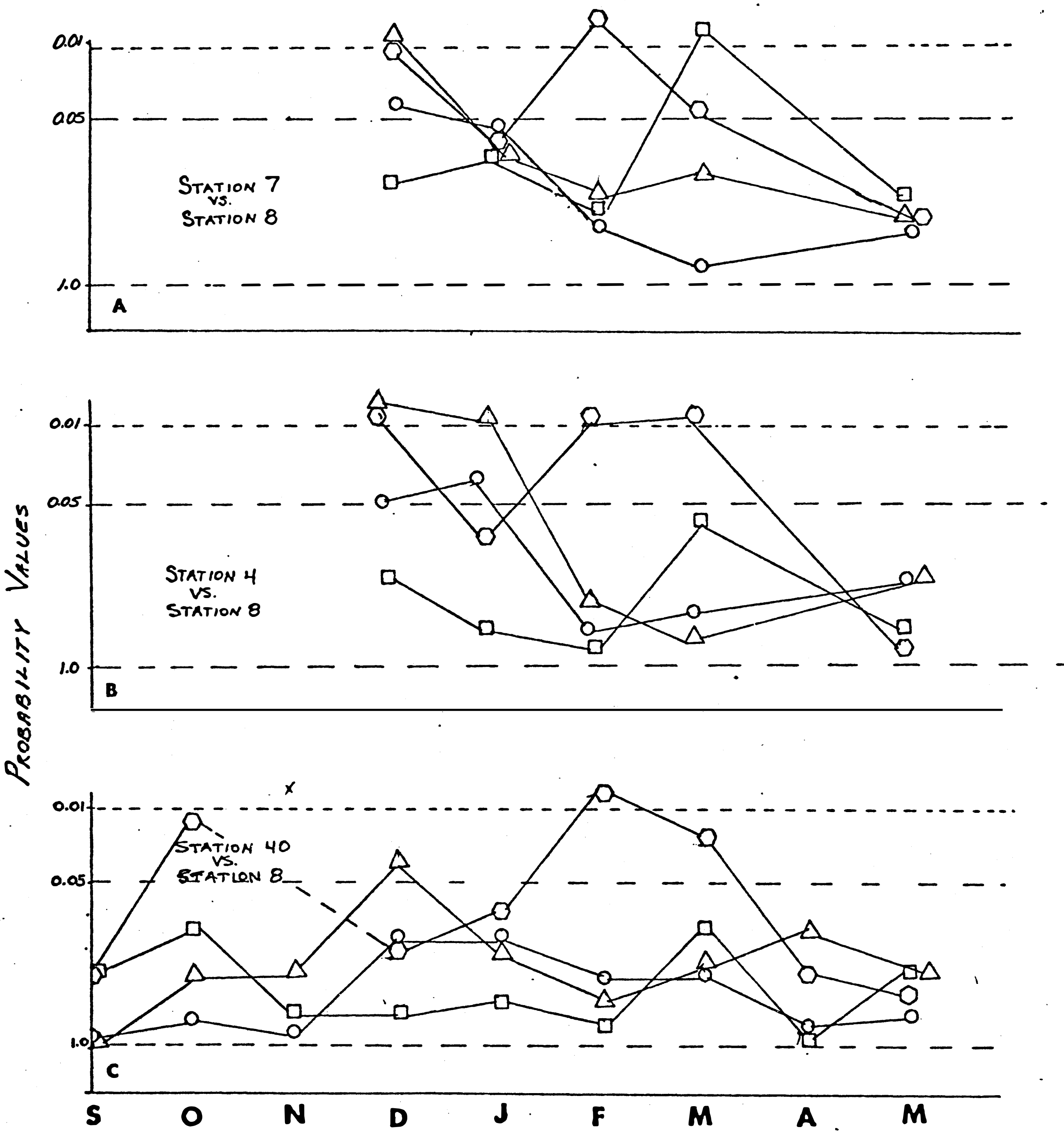


Fig. 4. Probability values from Student's "t" test with selected stations vs. station 8. (△-pH, ⬡-DO, ○-PO_4, □-NO_3)

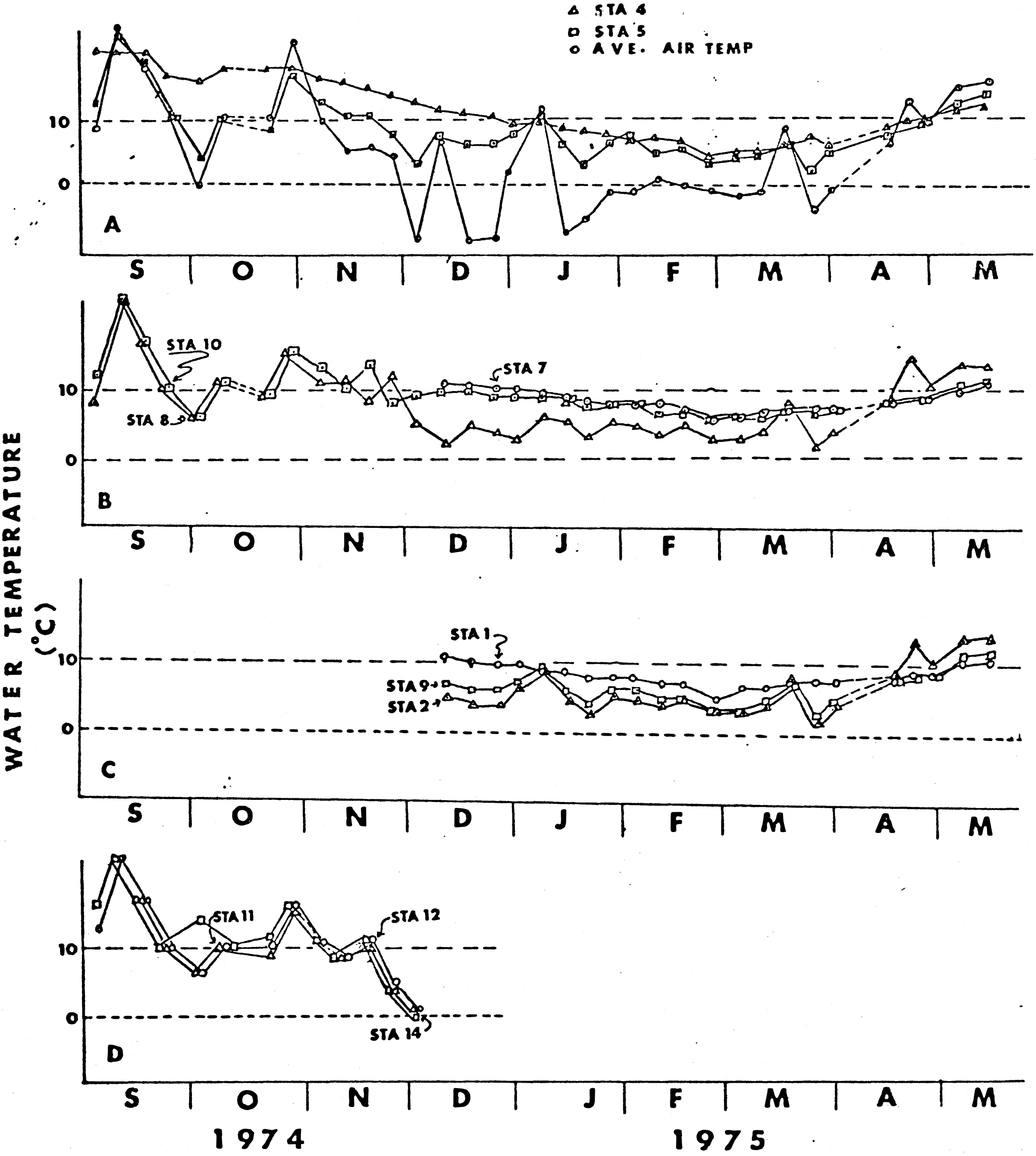


Fig. 5. Average weekly air temperature and weekly water temperatures of selected stations.

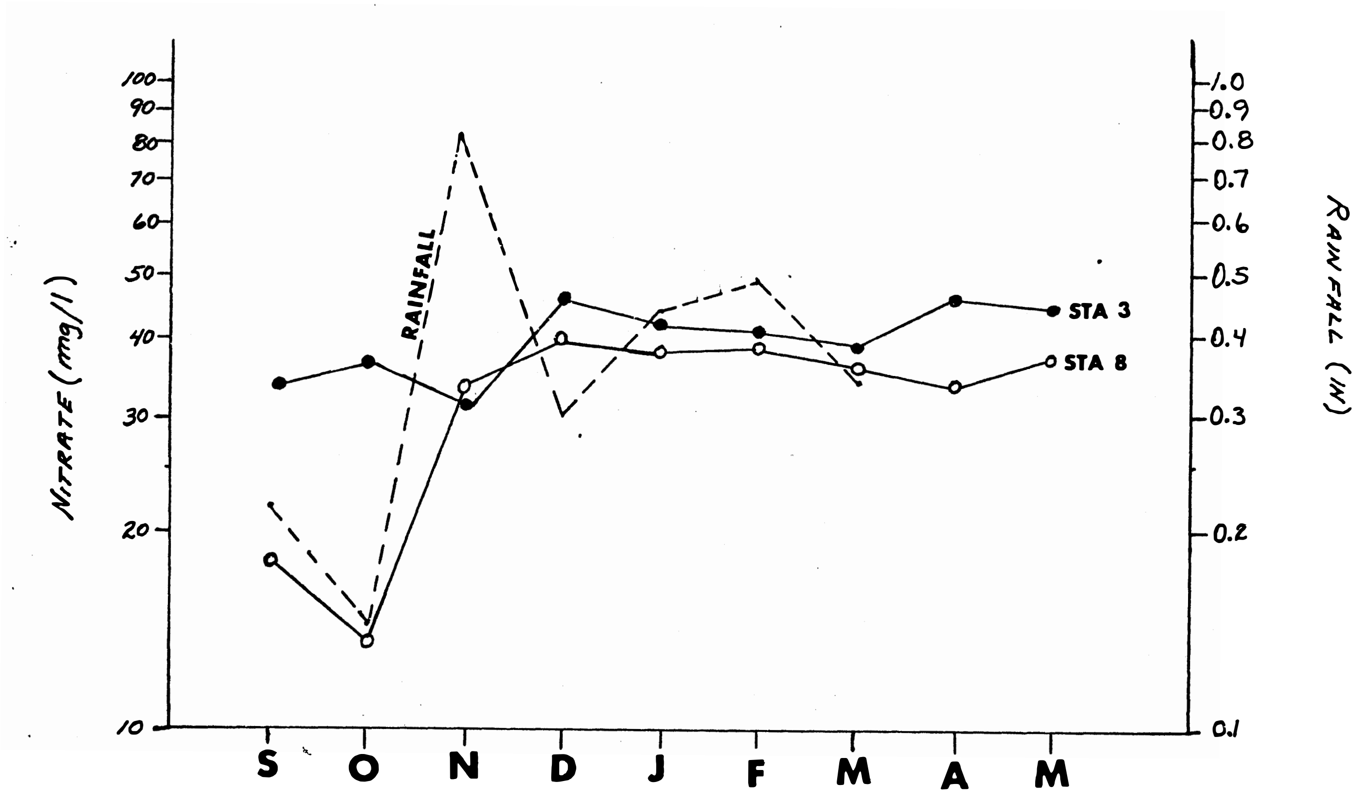


Fig. 6. Monthly mean three-day rainfall and monthly mean nitrate.

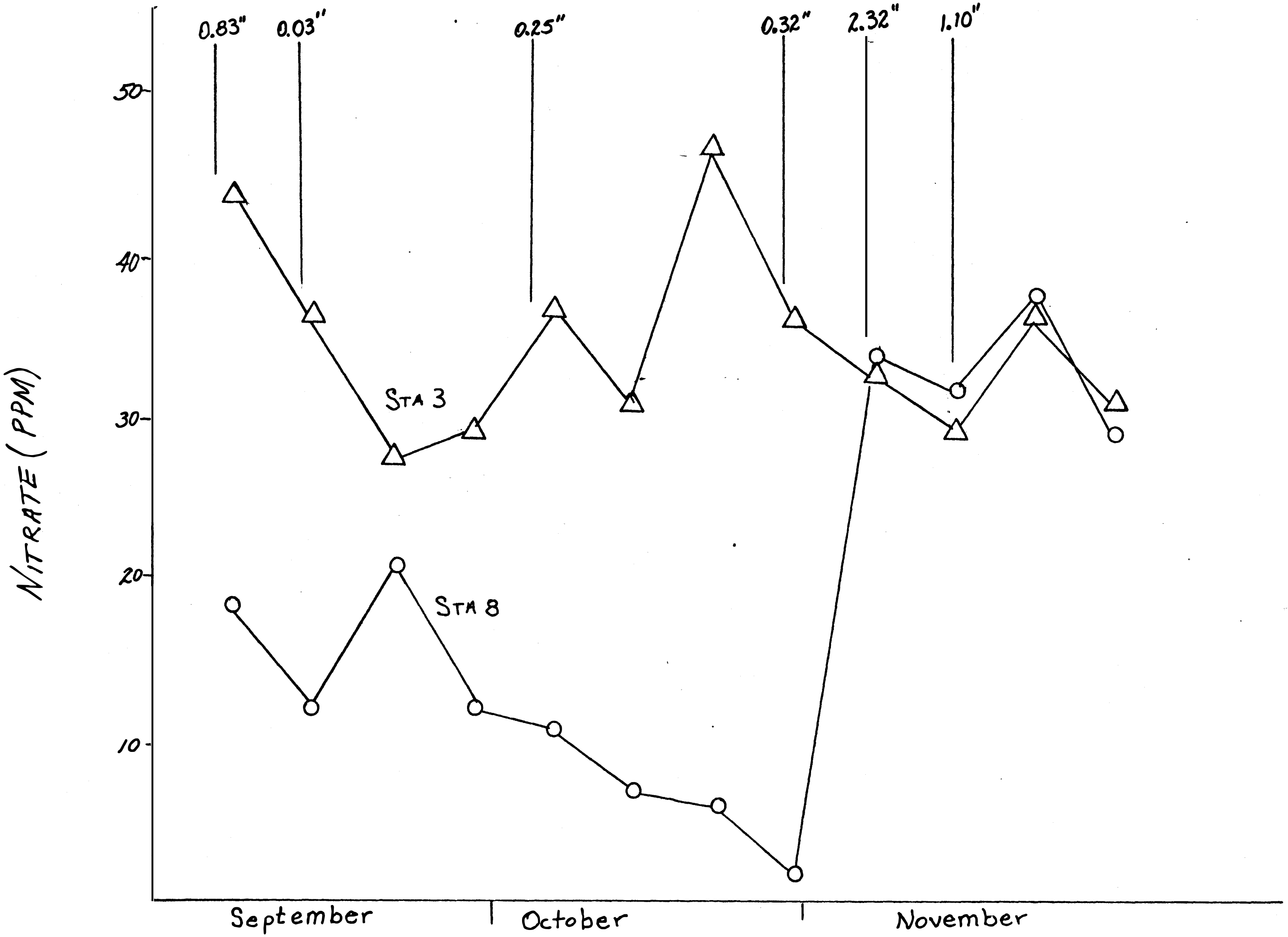


Fig. 7. Fluctuations in nitrate in response to total rain of previous three days at stations 3 and 8.

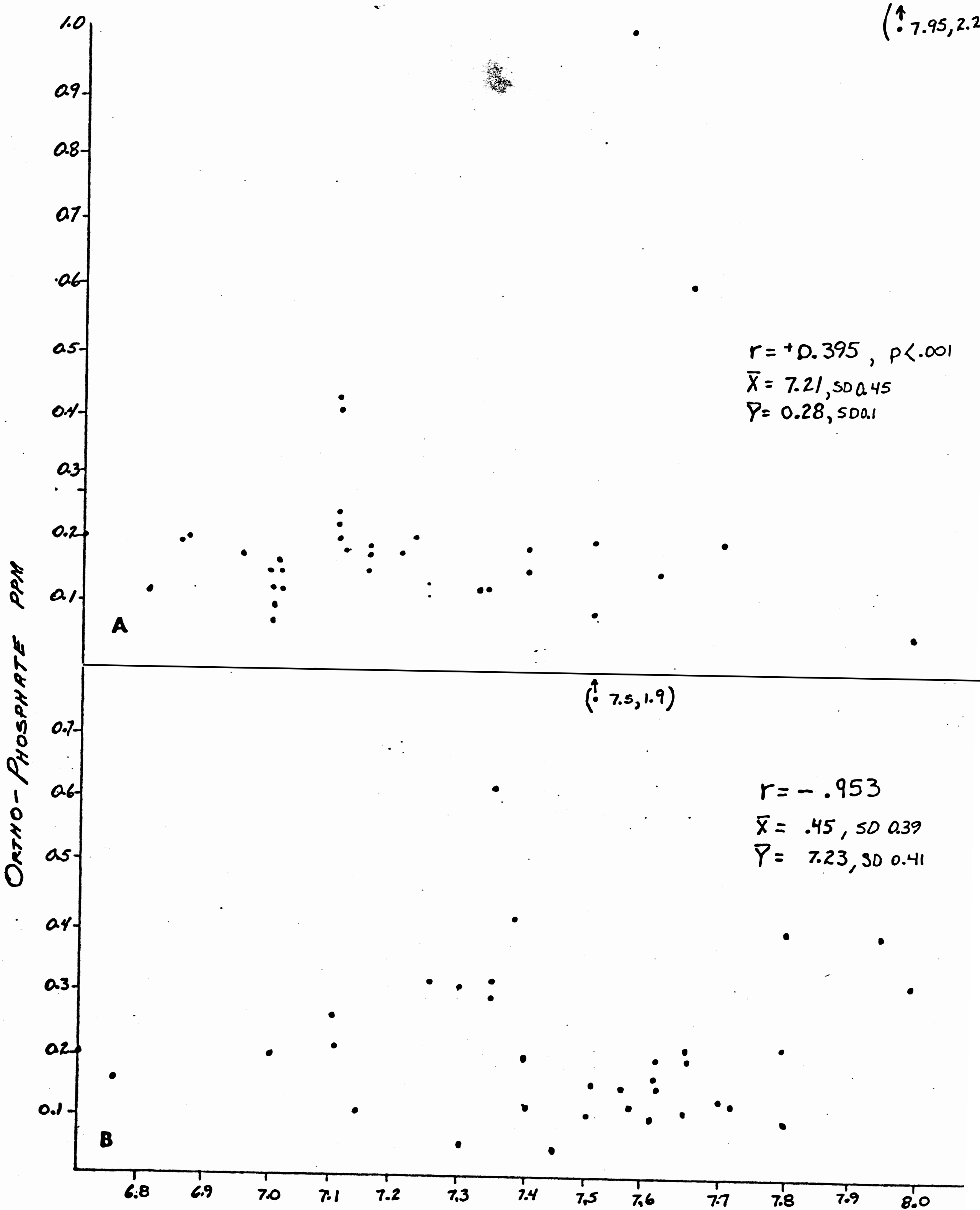


Fig. 8. Two scattergrams of PO_4-ph with related Pearson correlation coefficients of station 3' (A) a field tile and station 8 (B) approximately 6 mi. downstream.

DISCUSSION

Temperature

During the study period, water temperatures in field tile effluents ranged from 4°C to 19°C, while those of open streams varied from 1°C to 23°C. Air temperatures on sampling days for the study period, varied from -8°C to 23°C. Large rapid variations in air temperatures have small effects on tile effluent temperatures, as can be seen in Figs. 5A, 5B, and 5C. In these figures, stations 1, 4, and 7 are field tiles, which have about the same slope of temperature line from December to May. Of particular interest is the way that the effluents modify downstream temperatures. Station 10 is located over 500 yards downstream from station 7, yet it has almost identical water temperatures. These relatively stable temperature conditions could restrict the number of species of fishes present (Odum 1959) and could affect the breeding season of the organisms responding to temperature stimuli (Welch 1952). Effluent water is cooler longer in the spring and summer and is warmer in the fall and winter than downstream water. I observed large numbers and varieties of fishes in the pools at stations 4 and 7. These aggregations of fishes formed in mid-December and continued until the end of February. These fishes were probably drawn into the pools by the warmer temperatures and available food. Larimore and Smith (1963) observed similar aggregations in the Upper Kaskaskia during a period of thermal pollution. Competition for food could be particularly keen in the small pool at station 4. This pool is approximately eight feet wide by ten feet long, with a four feet deep hole in the center. This hole is formed by an artesian outwash from the 27 inch tile. The bottom of the field tile is 3-4 feet below the surface of the water. I observed three orangethroat darters (Etheostoma spectabile Agassiz) at the bottom of this hole, oriented facing into the tile, presumably for feeding purposes. Other darters were arranged around depressions formed by current coming from cracks in the tile. The most numerous food source in the tile are two species of Ascellus, Ascellus kendeighi (Steeves and Seidenberg 1971) and Ascellus communis (Say 1818). Both of the organisms crawl along the undersides of rocks and on the inside of the field tile. The secretive habits of the darters would especially favor them in getting food. These darters appear in large numbers at stations 7 and 10; 29 adult breeding males and three females were seined from one 30 yard rapids area at station 10 on 3 June 1975. Upstream,near the field tile, numerous young were seined, but very few adults. The fishes collected at the field tile stations were depauperate in diversity, possibly because food and temperature no longer held them there in June.

Other water dependent organisms are affected by the field tile effluent pools. One bullfrog (Rana catesbeiana Shaw) was observed at station 4, sitting at the edge of the water. When approached, it jumped into the water and escaped as would any typical Rana, except that the air temperature was -8°C and the date was 18 December. Air temperature for the preceding four weeks averaged only 2°C. Thus, growing seasons and life cycles can be affected by prolonging the time necessary for hibernation by some organisms.

The correlation coefficients described on page 12 compared station 8 with upstream stations for temperature and showed better correlations with those stations nearer to it. There was also better correlation with all stations in the fall than in the spring, indicating that the water and soil lost heat more uniformly than they gained heat.

Nitrate

Nitrate values were quite variable among the stations. The field tiles had the highest values more often. For example, station 6 exceeded 45 mg/l 77% of the sampling time. Station 7 exceeded 45 ppm 54% of the 22 weeks that it was sampled. The streams exceeded 45 mg/l for 10% of the study period. The mean value for stations 6 and 7 were 52.5 and 47.1 mg/l NO_3 for the five winter-spring months. Nitrate values peaked in December and April. Nitrate showed continous fluctuation from week to week. In relation to other parameters, a correlation coefficient of -.483, $p<.01$ was found with phosphate at station 8. This may indicate that the factors or conditions that cause nitrates to increase cause decreased phosphate.

It has long been assumed that nitrates dilute as they move downstream (Harmeson 1973). To better understand this relationship, the precipitation for the three days prior to sampling was summed. The monthly means of these sums were plotted against monthly means of nitrates at stations 3 and 8 in Fig. 6. In general, this figure shows a timelag between rainfall and increases in nitrates. Furthermore, stream nitrates seem to respond faster to rainfall than field tiles do. In small well-drained watersheds, rapid runoff carrying nitrate fertilizers from fields and animal wastes from pastures could elevate the nitrate levels in streams above those in normally high field tiles. Such a situation is shown in Fig. 7. Three-day total rainfall is shown with resulting effects most evident in November. Heavy, sustained rainfall seems to have a more lasting and elevating effect on nitrate levels in streams.

P values derived from Student's "t" are plotted in Fig. 4. This figure shows an association among factors in field tiles in Fig. 4A. Due to the uniformity of the water quality from the field tile, clusters might indicate that the parameters are varying together rather than independently, as in open stream systems.

Phosphate - pH

In Fig. 4 the plot of p values for the mean differences between field tile effluents (stations 7 and 4) and downstream water (station 8) show the apparent similarity in relationship of PO_4 and pH with station 8. Although the p values cannot show relationship between variables upstream, they do help to understand which variables are acting in a similar way. Having suspected a possible relationship between PO_4 and pH, I plotted PO_4 and pH in a scattergram and calculated the Pearson correlation coefficient for PO_4 - pH. These values are shown for stations 3 and 8 in Figs. 8A and 8B respectively. These data indicate that there is a low positive correlation at station 3 and an extremely probable inverse relationship downstream at station 8. Correlations were .395 and -.953 respectively.

Mac Crimmon and Kelso (1970) found that phosphate peaked in the fall and had its lowest concentrations in late winter. I found similar results with most stations having lowest values in January. Station 6, however, was low throughout the winter and station 4 was relatively high throughout the winter, with peak values in January. Phosphate readings were high at station 5 throughout the study. This may be due to a hog lot operation located 500 yards upstream. Römkens and Nelson (1974) feel that feedlot operations may produce significant P in runoff. At this same station, fecal coli was also significantly higher than the other stations. Improvement of farming practices could make a significant decrease in total P at this station (Weidner et al. 1969).

<u>Fecal Coliform</u>

Fecal coliform bacteria have been used as pollution indicators by many governmental agencies (MCRPC 1971). Sources of fecal coli are animal, insect, and human wastes. It is generally considered that within limits temperature directly affects bacteria (Welch 1952). Fecal bacteria peaked sharply in November at the same time as the heavy rains, previously discussed under <u>Nitrate</u>. Fecal coli counts increased generally throughout the study. Counts/100 ml varied from 0 to 16,150. Counts were lower in field tiles than in open flowing streams, but at times counts in field tiles exceeded 2900/100 ml. At several different times during the monitoring of the streams, potential sources of pollution were discovered and identified. At station 5, consistently high fecal counts were correlated with the proximity of a small village through which it flows. Upon following this stream, I found a hog lot operation with a pond formed by damming the stream. Liquid manure from the operation is spread on the surrounding farmland, which according to the owner does not drain into the stream or pond. Considerable fecal matter was observed near the edge of the pond, however. Counts up to 6,000 are not unreasonably high for agricultural pollution, but most of the sampling was done in cooler weather when counts are expected to be lower(interview 18 December 1974 with John P. Lehn, bacteriologist, MCPHD, Decatur, Illinois).

Fishes

The species listing of the fishes collected is in Table 15. Of those listed, Larimore and Smith (1963) place the following species in the small creek habitat: *Campostoma anomalum*, *Etheostoma spectabile*, *Semotilus atromaculatus*, *Fundulus notatus*, *Pimephales notatus*, *Catostomus commersoni*, and *Lepomis cyanellus*.

These fishes occur in headwater streams and in relatively clean water. All of them have either been observed or collected at the field tile stations. Burton and Odum (1945) noted that in spring brooks certain headwater and cold-adapted species occurred throughout the course of the stream. The *E. spectabile* is found in far greater numbers in the stream that has the swiftest current, cleanest water, and coolest temperatures in its riffle areas (station 10). These fish may extend farther downstream; however, the stream soon flattens out, so that within one mile it becomes a sluggish, warm water, silt-bottomed creek. Larimore and Smith (1963) place the *E. spectabile* in a fine gravel habitat. At station 10 where the greatest number of adults were collected, the stream was flowing at 6-8 ft/s over 4"-8" diameter rocks. Other habitats upstream included silt-bottom pools, weed beds, clay bottom riffles, sand bottom riffles, and a deep rocky pool. The swift rapids habitat was undoubtedly the most preferred habitat by the adult darters at that time. Young darters could be seen around the edge of the rapids but none in deeper waters (3 ft.). There was also an abundance of young darters in the clay-sand-bottom riffles.

Isopods and Amphipods

The blind isopod *Ascellus kendeighi* (Steeves and Seidenberg 1971) was collected at stations 3, 6, and 7. These stations are on deep field tiles of reportedly large drainage areas. This isopod had previously been identified only from the type-locality in Champaign County, Illinois. The blind amphipod *Bactrurus mucronatus* was also collected at those stations and is often in association with *A. kendeighi* (personal interview 13 March 1975 with Dr. Lawrence Page, Illinois Natural History Survey, Urbana, Illinois).

Dissolved Oxygen

The dissolved oxygen of downstream station 8 correlates well with other streams, but it does it in the same order that it correlated best with temperatures. The dependence of oxygen solubility on temperature is well known and saturation levels can be determined given the temperature (APHA 1965). In the fall DO of station 8 has less correlation with field tile stations than it does in the spring.

The cooler temperatures of the spring and summer effluents may provide a reason for aggregations of fishes to form there when the shallow streams approach 30°C and DO levels fall below tolerance levels.

Thus effluents may provide a means for many fishes to survive the summer when oxygen levels are too low for them to survive in downstream water.

CONCLUSIONS

Water quality parameters of field tiles are related to downstream water quality parameters. Water temperatures of field tile effluents have the least correlation of the parameters with downstream stations. These thermally stable effluents affect the distributions of fishes by providing warm water in the winter and cool highly oxygenated water in the summer. Nitrate-nitrogen levels are low in the fall, but rise sharply with heavy rains and remain between 40 and 45 ppm through the spring. Phosphates in the Big Creek-Long Creek drainage area are high in the fall, reach low points in mid-winter, and rise again through the spring. Fecal coliform bacteria are usually low in field tile effluents but may get dangerously high during heavy rains. Pearson product-moment correlation coefficients and Student's "t" tests are useful tools in determining the relationship between stream stations and stream parameters. These statistics were used to verify observed facts.

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