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BIOLOGICAL, CHEMICAL AND GEOLOGICAL CHARACTERISTICS DURING AUGUST-SEPTEMBER OF LAKE ERIE TRIBUTARIES OF ERIE COUNTY, PA.

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ABSTRACT

An analysis of Lake Erie tributaries was made, by means of seine samples of fish and kick-samples of benthic invertebrates which were taken at the mouths, mid-sections and heads of twelve Pennsylvania streams during the months of August-September, 1975. Of 7,254 insects in the Orders Coleoptera, Diptera, Ephemeroptera, and Trichoptera, the latter two accounted for 46%. At the same time chemical parameters of Ca^{+2}, K^{+}, pH, O_2 and the temperatures were measured. Geological characteristics of these tributaries, in reference to stream orders, drainage densities, drainage basins, basin reliefs and shapes, stream lengths, gradients and rates of discharge were analyzed statistically. Correlations were made between these various parameters.

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INTRODUCTION

The purpose of this study was to investigate possible relationships and correlations between the biological, chemical, and geological characteristics of Lake Erie tributaries of Pennsylvania. The relative abundance of fish and macroinvertebrates was used in fauna analysis. Chemical sampling included O_2, Ca^{+2}, K^{+}, and pH. Physical parameters measured included temperature, current flow, and stream morphometry. This study represents the first phase of a planned comprehensive study of the streams of Northwestern Pennsylvania. These studies could be utilitzed in future environmental impact studies.

Twelve streams were sampled at 58 sites during August-September, 1975 at the mouth, mid-region, and head-waters. These streams flow across the lake plain (Central Lowlands Province) and the Appalachian Plateau Provinces in Northwestern Pennsylvania. The streams are geologically young due to glaciation. Sampling was confined to the Lake Erie tributaries for this phase of the study; tributaries of the Allegheny River will be sampled and analyzed at a later date (Figure 1).

O'Kelly (1) sampled one stream, Walnut Creek, extensively during the months of June-August in 1972. The highest numbers of individuals were found in August, with Hydropsychidae (Trichoptera) and Chironomidae (Diptera) most abundant. Simulidae (Diptera) was also very abundant, especially around the first of August.

O'Kelly utilized the electro-shock capture method to collect fish samples. The creek chub (*Semotilus atromaculatus*) and longnose dace (*Rhinichthys cataractae*) were predominant. One species *Percina caprodes*, the logperch, was extremely abundant at the mouth of Walnut Creek in mid-June. This study also included over twenty physical parameters, a bacteriological study, and a comprehensive diatom survey with species diversity and correlations.

A survey of fish was completed in August of 1968 by E. L. Cooper of the Pennsylvania State University as data for an unpublished monograph on Pennsylvania fish.

The Erie County Health Department routinely samples streams of the area for water quality control but no data have been published. Two studies have been published on Lake Erie streams of this vicinity by the Erie County Health Department of New York (2, 3). Harrel and Dorris (4) have done stream descriptive work in Oklahoma utilizing geology, physico-chemical conditions and benthic macro-invertebrates. Their study took place on a drainage basin with six stream orders. The highest stream order in the Lake Erie tributaries is fourth order.

DESCRIPTION OF STUDY AREA

Erie County, located in Northwestern Pennsylvania, consists of parts of two physiographic provinces, the Central Lowlands (Lake Plain), and the Appalachian Plateau provinces (Figure 1). the county and surrounding areas were glaciated by Kansan, Illinoisan, and Wisconsin ice sheets. The streams commenced development concomitantly with the melting of the Wisconsin ice sheet; the glacial ice melted away from the area about 12,000 years ago.

The width of the lake plain varies from a distance of 3.22 kilometers in the eastern part of the county to 8.05 kilometers in the western part. Elevation of the lake plain rises slightly above the lake level of 174.34 m to approximately 243.83 m above sea level near its southern boundary (Figures 2, 3, and 4). Maximum relief on the lake plain is found along the valleys of post glacial streams; other relief on the lake plain is due to shoreline features of pre-Lake Erie lakes, and in its southern portion, to late Wisconsin end moraines.

The lake plain has sandy soil near the lake, gravelly and sandy in areas where former shoreline features exist. Locally soils developed on lake clays and silts or on till are finer textured. The finer textured soils have the poorest drainage. Soils along the southern border of the lake plain drain rapidly and are easily leached (5).

An escarpment slope rising from an elevation of 243.83 m at its base to 304.79 m separates the lake plain from the glaciated portion of the Appalachian Plateau. Tributaries of Lake Erie have eroded deep valleys through the escarpment slope (Figures 2, 3, and 4).

The Appalachian Plateau rises from an elevation of 304.79 m along the escarpment to 579.09 m in the southeast part of the county. Maximum relief on the surface of the plateau occurs along the streams which flow in channels 30.48 m to 91.44 m below the surface (Figures 2, 3, and 4).

Poorly drained areas, sites of former swamps, comprise much of the plateau surfaces. The soils have been developed in most areas on glacial till; they are acidic and generally high in nutrients, and moderately to poorly drained (5).

All of the streams have a poorly developed dendritic pattern; the drainage net is incomplete (Figures 2, 3, and 4). The streams have cut down through the glacial deposits and flow on upper Devonian shales and siltstones, and, locally, on cobblestone of bedrock and glacial outwash. Only during periods of intense rainfall and/or the melting of snow and ice do the streams approach coverage of the entire width of their channels. Generally, all the stream channels are characterized by miniature waterfalls, pools, and riffles. Most of the streams flow through beech-sugar maple forests or suburban developments. Beech (*Fagus grandifolia Ehrhart*) often dominates the compact, shaly soils of steep valleys and ravine slopes (6). Willow, aspen and open areas dominate the suburban areas.

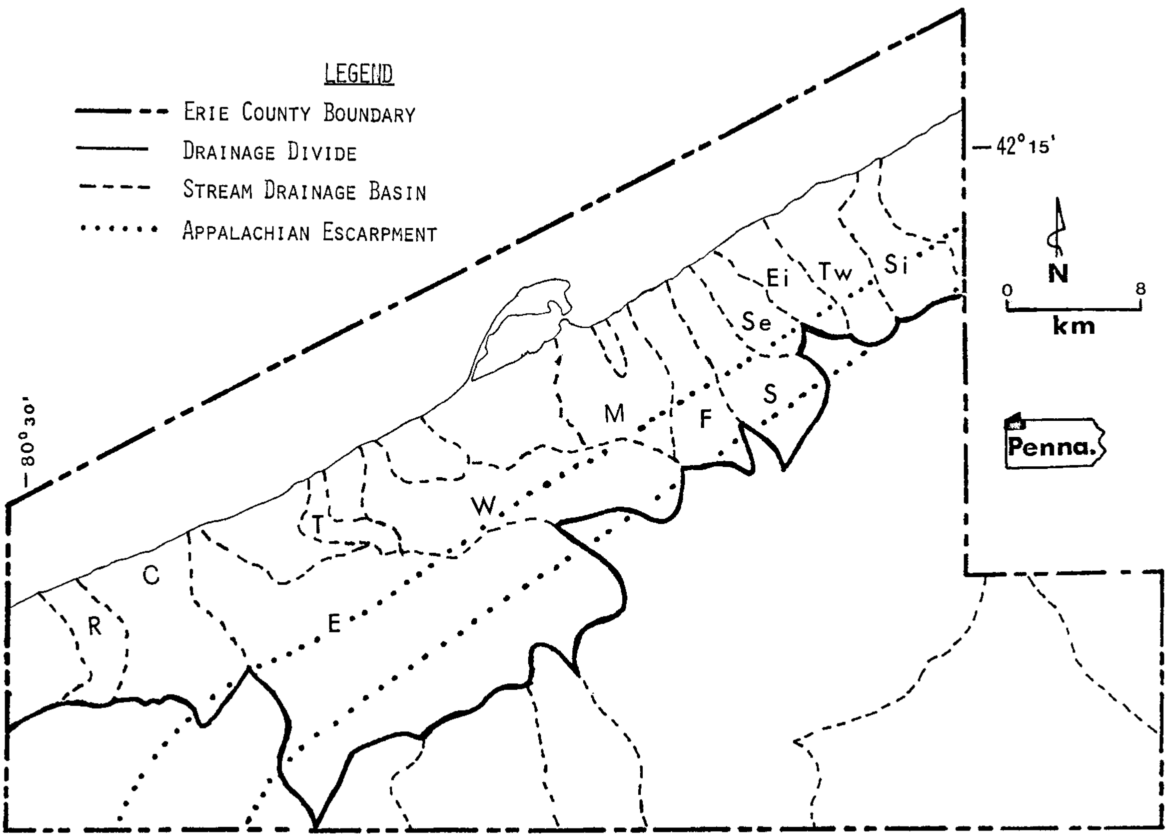

FIGURE 1. Drainage Basins are indicated for Erie County, Pennsylvania. The letters in the basins indicate the stream designation for those sampled and are the same for all succeeding graphs. R, Raccoon Creek; C, Crooked Creek; E, Elk Creek; T, Trout Run; W, Walnut Creek; M, Mill Creek; F, Four Mile Creek; S, Six Mile Creek; Se, Seven Mile Creek; Ei, Eight Mile Creek; Tw, Twelve Mile Creek; Si, Sixteen Mile Creek. This map is modified after Engineering-Science, Inc. The Lake Plain is the area north of the Appalachian Escarpment and the Plateau is to the south.

Erie County has a cool humid continental type of climate. Precipitation averages 101.6 cm per year, and its distribution is quite uniform throughout the year. Average temperature varies from 20°C in the summer to -2.22°C in the winter; annual average temperature is 9.44°C (5).

METHODS

Stream velocity measurements were taken with a Pygmy type water current meter mounted on a support rod graduated in 10 cm intervals. Channel and stream widths determinations were made with a tape. The roughness of the channel, type of sediment and/or bedrock was also determined.

Physio-chemical measurements for dissolved oxygen and temperature were determined with a YSI-oxygen-temperature probe Model 54. Ca^{+2},K^{+}, and pH were determined by specific ion probes and an Orion Model 407 meter.

Riffles were sampled exclusively with the Surber Sampler (net mesh size 1mm) for benthic invertebrates for two minutes with no effort to quantitatively sample for any designated area. This could be interpreted as a kick sample for a timed period. Samples were preserved in 70% ethyl alcohol, brought to the laboratory for sorting to order, and counted. All specimens were retained for utilization in developing a species list (7,8).

All fish were collected by the use of 1.83 m or 3.05m wide seines of 0.64 cm mesh. In swiftly moving water the seine was set and held by one worker while another vigorously stirred up the substrate as he walked toward the net. The walking usually started no further than 7.62 m upstream of the seine. In slow moving water and pools the seine was used to probe into the substrate, under logs, rocks and undercut banks. In each habitat, at least four seine hauls were made, the amount of effort reflecting the size of the stream and the scarcity of specimens therein. Interest in relative numbers of species only precluded the use of a standardized collecting effort.

In most cases, all of the specimens were kept, but when game species such as trout were collected, only representatives less than 15.2 cm in length were kept. In other instances when a preponderance of one species was caught and continued effort was expanded to acquire more diversity, any additional members of the abundant species species were released.

All fish were preserved in the field in 10% buffered (pH 7.0) formalin. After about two days they were transferred to 50% ethanol after the method of Hildebrand (9).

Specimens were identified to species and enumerated for each collecting site. At this writing no attempt has been made to determine age and sec ratios of the specimens.

The Minitab Statistical Package from the statistics department of the Pennsylvania State University and the IBM 360 computer were used for the statistical analyses. Correlations were calculated by the Pearson product-moment coefficient of correlation. Significance levels at the 95% level were computed from the following test statistic:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

where r is the correlation coefficient, n is the sample size and t is the student's t random variable. The square of t equals F from the analysis of variance for regression.

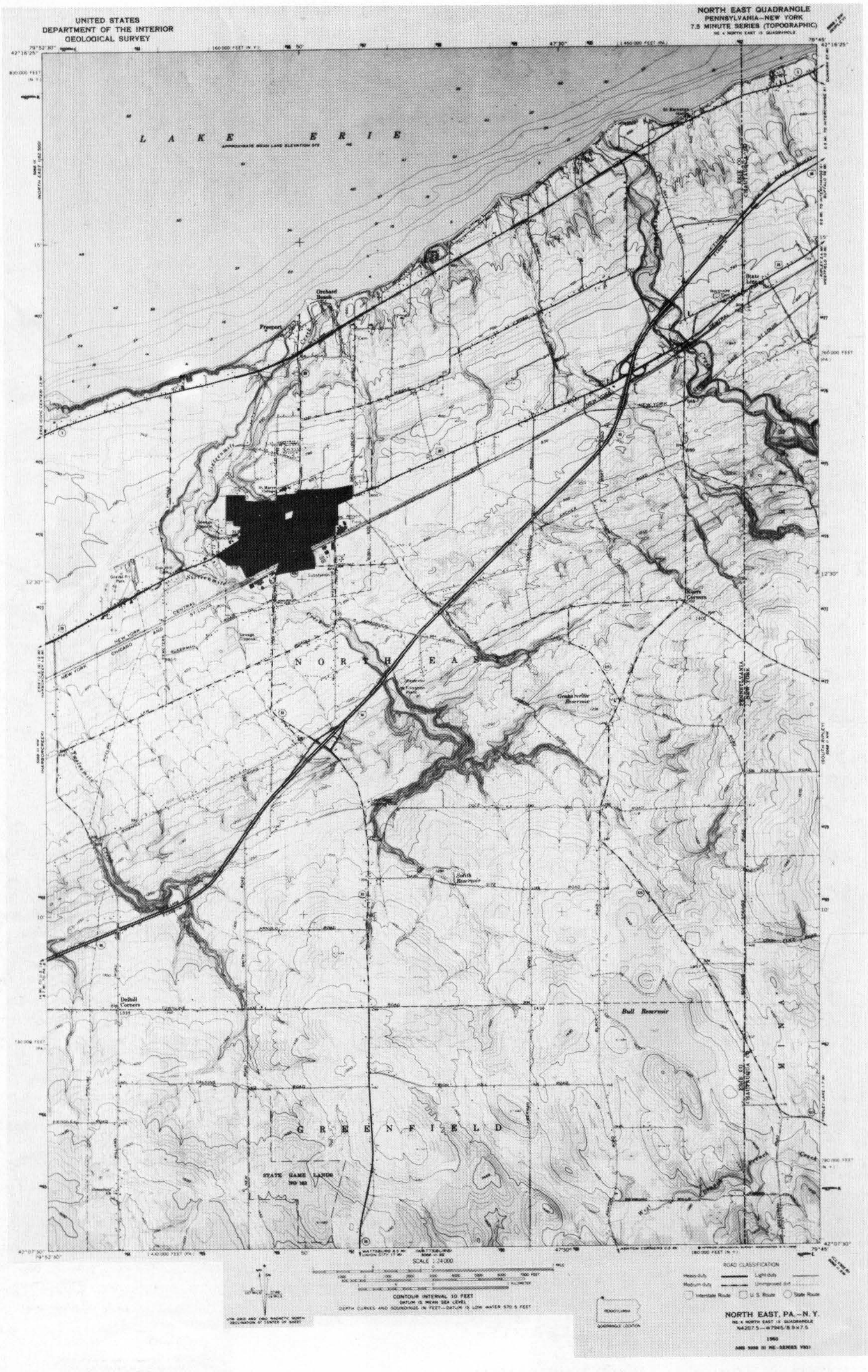

FIGURE 2. Northeast Quadrangle — Pennsylvania-New York: 7.5 minutes topographic series. Map depicts the topography in the Northeastern portion of Erie County. Sampled streams — Sixteen Mile and Twelve Mile (southern portion) are shown.

FIGURE 3. Harborcreek Quadrangle — Pennsylvania: 7.5 minutes series. Area lies topographic adjacent (east) to Figure 2. Streams are Twelve Mile (northern portion), Eight Mile, Seven Mile, and Six Mile Creek.

FIGURE 4. Mosaic of Fairview and Albion Quadrangles — Pennsylvania - 7.5 minute topographic series. Most of Elk Creek drainage basn is depicted on this map. Trout Run is shown in Northeastern part of map and the southern part of Crooked Creek is shown in the southwest.

TABLE 1

Geological Data — Lake Erie Tributaries — Erie County, Pennsylvania

Stream and Parameters		Order	Number of Streams	Total Length (Km)	Average Length (Km)	Average Drainage Area (Km^2)
Racoon		1	14	13.272	.948	
Bifurcation ratio	= 3.75	2	4	2.532	.633	
Stream length ratio	= 6.48	3	1	7.788	7.788	22.191
Drainage Density	= 1.06					
Stream frequency	= 0.86					
Crooked Creek		1	20	27.029	1.351	
Bifurcation ratio	= 2.78	2	6	9.310	1.551	
Stream length ratio	= 1.77	3	2	5.748	2.874	
Drainage Density	= 0.75	4	1	6.669	6.669	64.950
Stream frequency	= 0.45					
Elk		1	85	152.835	1.841	
Bifurcation ratio	= 4.5	2	17	48.208	2.835	
Stream length ratio	= 1.99	3	4	25.433	6.358	
Drainage Density	= 0.966	4	1	28.237	28.237	263.59
Stream frequency	= 0.398					
Trout Run		1	6	6.114	1.019	
Bifurcation ratio	= 6.0	2	1	12.630	12.630	13.531
Stream length ratio	= 12.29					
Drainage Density	= 1.39					
Stream frequency	= 0.52					
Walnut		1	36	77.832	2.162	
Bifurcation ratio	= 3.5	2	9	30.69	3.410	
Stream length ratio	=2.22	3	2	24.814	12.407	
Drainage Density	= 1.67	4	1	17.906	17.906	90.389
Stream frequency	= 0.53					
Millcreek		1	9	11.178	1.242	
Bifurcation ratio	= 3.25	2	2	8.546	4.273	
Stream length ratio	= 2.80	3	1	9.246	9.246	38.622
Drainage Density	= 0.75					
Stream frequency	= 0.31					
Four Mile		1	21	28.707	1.367	
Bifurcation ratio	= 5.0	2	3	10.383	3.461	
Stream Length ratio	= 2.29	3	1	7.083	7.083	36.076
Drainage Density	= 0.69					
Stream frequency	= 0.69					
Six Mile Creek		1	45	54.18	1.204	
Bifurcation ratio	= 4.07	2	14	14.434	1.031	
Stream length ratio	= 6.60	3	2	1.61	.805	
Drainage Density	= 1.76	4	1	14.630	14.630	48.21
Stream frequency	= 1.29					
Seven Mile Creek		1	14	24.906	1.779	
Bifurcation ratio	= 3.75	2	4	7.472	1.868	
Stream length ratio	= 3.63	3	1	11.581	11.581	22.209
Drainage Density	= 1.98					
Stream frequency	= 0.855					
Eight Mile Creek		1	8	23.8	2.975	
Bifurcation ratio	= 2.84	2	3	8.022	2.674	
Stream length ratio	= 1.32	3	1	4.625	4.625	61.0
Drainage Density	= 0.60					
Stream frequency	= 0.20					
Twelve Mile		1	19	27.303	1.437	
Bifurcation ratio	= 4.4	2	5	12.545	2.509	
Stream length ratio	= 3.4	3	1	13.349	13.349	39.32
Drainage Density	= 1.35					
Stream frquency	= 0.64					
Sixteen Mile		1	31	46.624	1.504	
Bifurcation ratio	= 3.18	2	8	9.88	1.235	
Stream length ratio	= 4.47	3	3	3.039	1.013	
Drainage Density	= 1.87	4	1	11.931	11.931	38.189
Stream frequency	= 1.13					

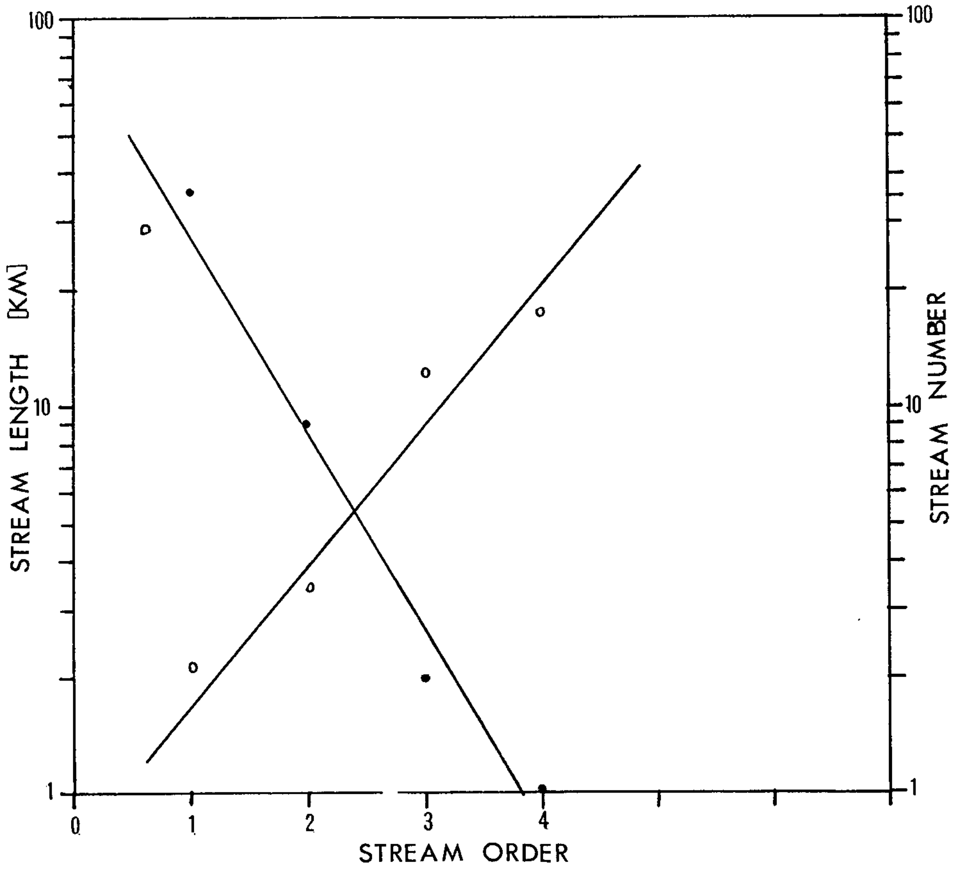

FIGURE 5. Numbers and average lengths of streams of each order in relation to stream order for Walnut Creek basin. (—) = Numbers, (o) average lengths.

RESULTS AND DISCUSSION

Drainage basins of streams depicted on U.S. Geological Survey topographic maps were classified according to Horton (10) and Strahler (11). The smallest, unbranched tributaries of a drainage basin are designated 1st order streams by this system. A 2nd order stream is formed where two 1st order streams join; where two 2nd order streams join, a 3rd order stream is formed; etc. The highest stream-order of the Lake Erie tributaries is 4th (Table 1). In addition to stream order, the structure of the stream systems was analyzed with the following parameters: (a) bifurcation ratio, (b) stream length ratio, (c) drainage density, and (d) stream frequency (Table 1).

A number of stream parameters display geometric relationships with stream order. An inverse geometric progression should be exhibited by the number of streams of each order in a drainage basin (Figure 5). The bifurcation ratio is the ratio of the number of streams of any order to the number of the next lower order. The number of streams, theoretically, should double with each decrease in stream order. According to Horton and Strahler, bifurcation ratios of about two indicate flat or rolling basins and three or four mountainous or highly dissected basins. The bifurcation ratios for the tributaries of Lake Erie vary from 2.78 to 6.0; these high bifurcation ratios are due to the effects of glaciation.

There is a tendency toward a direct geometric relationship between the average lengths of streams of each order in a drainage basin (Figure 5). The stream-length ratio is the ratio of the average length of streams of a given order to that of the next lower order. Well-drained basins are characterized by low stream-length ratio (1-2), and poorly drained basins by high ratios (3-4). Both the low and high stream-length ratios are due to the effects of glaciation in this area.

Drainage density (average stream length/unit area) and stream frequency (average number of streams/unit area) were also determined. Low drainage density and low stream frequency are additional evidence for the fact that the drainage pattern is young and incomplete.

Additional physical stream parameters such as channel width, stream width and depth, and stream velocity were determined in the field. These data are not included in this report because of the extreme variability of the geometry of the stream channels. The chemical parameters determined in the field and in the laboratory are summarized in Table 2.

The six variables — air temperature, water temperature, dissolved O_2, calcium ion, potassium ion, and pH — were correlated among the 12 streams. Of 66 correlation coefficients computed for chemical comparisons between streams only 9 were not highly significant at the 2½% level. Of the twelve streams the correlation coefficient of Crooked Creek with four other streams and Twelve Mile Creek with four other streams was not significant. Crooked Creek and Twelve Mile Creek were highly correlated with each other. This can also be seen in Figure 6.

Potassium rather than sodium ion was measured since potassium is more toxic to fish (12). Potassium ion concentrations in the range 50-200 ppm could be toxic. In the 12 streams tested, the minimum potassium ion concentration was 1.75 and the maximum 6.13, so that the Erie County streams' potassium level should be safe for fish.

Calcium reduces the toxicity of other chemicals (e.g., lead, zinc, and aluminum), and does not become toxic until high concentrations are reached (300-1000 ppm) (12). Calcium ranges from this study were 20.31 ppm in Twelve Mile Creek to 46.45 ppm in Walnut Creek. It is

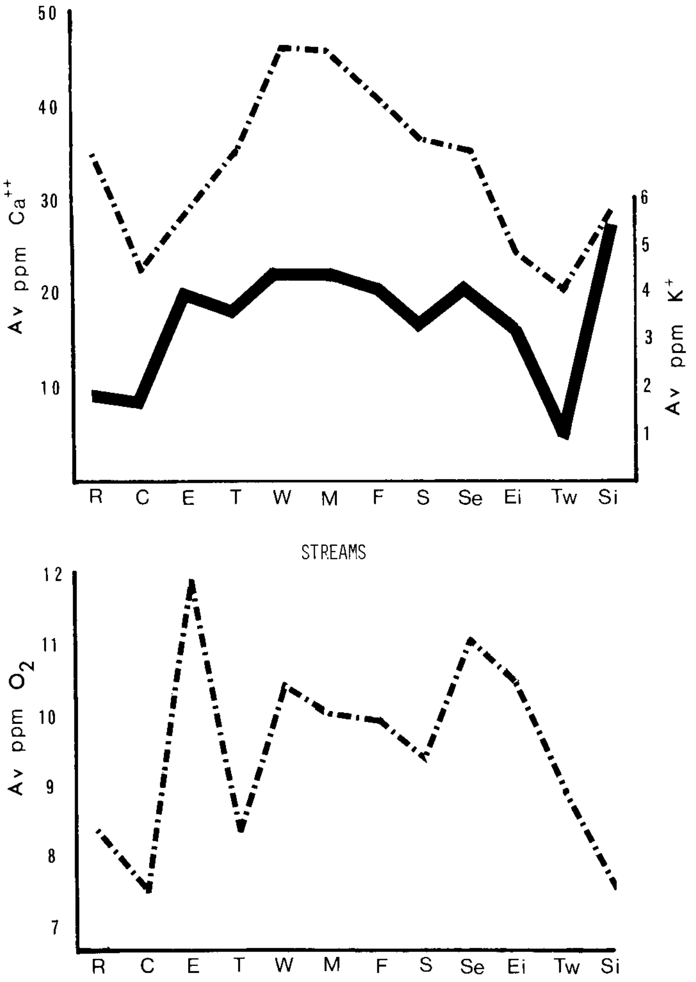

FIGURE 6. Calcium, potassium and dissolved oxygen in Lake Erie tributaries in autumn.

interesting to note that Crooked Creek and Twelve Mile Creek which show a low correlation with other Lake Erie tributaries also have very low calcium and potassium concentration.

Collections at 58 sites on the twelve Lake Erie tributaries over a 30 day period after August 24, 1975, produced more than 7000 insects (13, 14, 15, 16). As the effort in sampling was oriented towards a qualitative description, it is believed that the numbers of insects can be compared on a relative basis, for collections were carried out in exactly the same manner on each stream and no effort was made to determine productivity per unit area. Ninety-seven percent of the insects were in four orders: Ephemeroptera (mayflies), Trichoptera (caddis flies), Diptera, and Coleoptera (beetles) (Figure 7). Of all intervertebrates collected, insects accounted for 99% of the total.

In a comparison of all insects stream by stream a high correlation exists between Elk Creek and Walnut Creek — between Walnut Creek and Twelve Mile Creek, and between Mill Creek and Eight Mile Creek. A positive correlation exists between *R. atratulus* (black nose dace) and Ephemeroptera and *S. atromaculatus* (northern creek chub) and Diptera.

The Ephemeroptera accounted for 28% of all the insects, and 56% of the Ephemeroptera were in three streams: Elk, Seven Mile, and Sixteen Mile Creek. The family Baetidae was the most abundant with *Stenonema* spp. third most frequently collected (Figure 8).

Trichoptera (caddis flies) accounted for 26% of the insect population. Thirty-six percent of the Trichoptera collected were from Walnut Creek and 83% of these were *Cheumatopsyche* spp. *Hydropsyche* spp. was second most abundant throughout the streams (figure 9).

Three genera of Trichoptera were correlated with various physical parameters. *Cheumatopsyche* spp. was positively correlated with dissolved oxygen and Ca^{+2}. *Dolophilodes* (=*Sortosa*) spp. revealed a negative correlation with pH. *Polycentropus* spp. showed a negative correlation with Ca^{+2}.

Roback (17) has reported *Cheumatopsyche* spp. in dissolved oxygen ranges of 6-14 ppm. Our study indicates a preference for high oxygen ranges as well as Ca^{+2}. Roback finds a range of 2-398 ppm acceptable. For two species of *Polycentropus* ranges of 22-70 ppm and 3-49 ppm are reported. Our results showed a negative correlation with Ca^{+2} which tends to agree with the data for these two genera of Trichoptera. Macan (18) has indicated that calcium may be more variable than any other ion in fresh waters.

Coleoptera made up 22% of insects collected, and 33% of these were from Elk Creek and 18% from Trout Run. The elmid *Optioservas* spp. was the most abundant and then *Stenelmis* spp. The water penny *Psephenus herrickii* Dekay in the order Coleoptera was correlated positively with temperature (air and water).

Diptera composed 21% of the insects collected. Fifty-four percent of these were in the family Chironomidae. Simulidae were next most abundant making up 28% of the Dipteran population. Forty-seven percent of the Diptera were in Seven Mile and Sixteen Mile Creek. In Seven Mile Chironomidae were most abundant and imulidae in Sixteen Mile Creek (Figure 11). Within the order Diptera the family Tipulidae showed a positive correlation with dissolved oxygen and a negative correlation with pH and temperature (air and water). The family Rhagionidae was represented by only one species *Atherix variegata* (Walker) and positively correlated with K^+ and temperature (air and water).

Plecoptera, Neuroptera, and Odonata rounded out the insects collected (Figure 12, 13).

Temperature may be affected in these streams at this autumnal season as they are relatively shallow, commonly 5-20 cm, narrow with respect to channel width, and have extensive areas of unshaded banks, smooth bedrock and alluvium. Stream temperatures, therefore, fluctuate very closely with air temperature in relation in depth and width of the stream. O'kelly (1) found a large diurnal fluctuation of water temperature in Walnut Creek in August.

As temperature increased the water penny, *P. herricki* and the dipteran *A. variegata* increased in occurrence but Tipulidae decreased. From other collections from these streams it has been found that certain species occur only in the winter or spring periods when water temperatures are cooler and probably much less diurnal fluctuation occurs.

The six most frequently occurring species of fish in this study are the stoneroller, *Campostoma anomalum;* common shiner, *Notropis cornutus;* black-nosed dace, *Rhinichthys atratulus;* creek chub, *Semotilus atromaculatus:* the common or white sucker, *Catastomus commersonii;* and the rainbow darter, *Etheostoma caeruleum* (Figure 14).

An interesting distribution can be seen if one compares the streams to the east and the west of Mill Creek (Table 2). There is clearly a greater diversity of species in the western streams with *Campostoma* spp., *Rhinichthys* spp. and *Notropis* spp. dominating in terms of numbers (Species diversity index from 2.49-3.55). To the east *Rhinichthys* spp. is by far the most abundant species in a rather sparse fauna (Species diversity index from 0.94-2.35). *Notropis* spp. was rather strictly confined to the western side of the county while *Etheostoma* spp. occurred sporadically throughout the western two thirds of the county. *Semotilus* spp. achieved its greatest number on the western and eastern extremes of the county, while *Catastomus* spp. often occurred in large schools of virtually single species. This was also the case with *Notropis* spp. where it occurred. The others were usually found mingling with other species.

Comparisons of 14 species of fish with the physical and chemical parameters showed a positive correlation between dissolved oxygen and two species, *Campostoma anomalum* and *Catastomus commersonii,* while *Rhinichthys atratulus* strangely showed an inverse relationship.

TABLE 2

Distribution of total collected fish fauna from sampled streams.

	Raccoon Ck (4)	Crooked Ck (4)	Elk Ck	Trout Run	Walnut Ck	Mill Ck	4-Mile Ck	6-Mile Ck	7-Mile Ck	8-Mile Ck	12-Mile Ck	16-Mile Ck	TOTAL
Petromyzontidae (1)													
Lampetra lamottei					1								1
Salmonidae (2)													
Salmo gairdneri				18*	1							1	20
Salmo trutta			5		2								7
Cyprinidae (18)													
Campostoma anomalum	16	44	137	2	244	38	1	50	27	24		9	592
Clinostomus elongatus			28	3	57			8		66			162
Cyprinus carpio												4	4
Ericymba buccata	14	47	2										63
Hybopsis amblops		1	11		7								19
Nocomis biguttatus					2								2
Nocomis micropogon		3	2		58								63
Notropis atherinoides							1						1
Notropis boops	25	4	2		1								32
Notropis cornutus	15	65	113	24	108	28	1	10		2			366
Notropis hudsonius					1								1
Notropis stramineus		4	8		7								19
Notropis volucellus		1					2						3
Pimephales notatus	4	13	49	3	4								73
Pimephales promelas	3			1	5		2			1		4	16
Rhinichthys atratulus	5	11	165	8	72	42	151	154	73	20	204	319	1224
Rhinichthys cataractae		6	17	3	22		38	11		1	4	74	176
Semotilus atromaculatus	43	19	100	9	78	30	4	5	6	58	37	115	504
Catastomidae (2)													
Catastomus commersonii	4	15	65	20	49	31		9	3	15		3	214
Hypentelium nigricans	3	6	3	1									13
Ictaluridae (3)													
Ictalurus melas			1										1
Ictalurus nebulosus											1		1
Noturus flavus		1	1										2
Gasterosteidae (1)													
Culaea inconstans			6										6
Centrarchidae (7)													
Ambloplites rupestris	12	2	2										16
Lepomis cyanellus		1	3										4
Lepomis gibbosus	13				10			1	3		8		35
Lepomis macrochirus	2	2	40		4			1					49
Micropterus dolomieu	1	5	13		5							11	35
Micropterus salmoides					1								1
Pomoxis nigromaculatus												19	19
Percidae (4)													
Etheostoma caeruleum	43	6	33	3	63	4		4	29				185
Etheostoma flabellare	1	1		1	5					1			9
Etheostoma nigrun	4	6	32	3	8			1		1			55
Percina caprodes			1										1
Cottidae (1)													
Cottus bairdii	7	10	6			3		1		2		1	30
TOTALS													
No. Species	18	23	26	14	24	7	8	12	6	11	5	11	
No. Individuals	215	273	845	99	814	176	200	255	141	191	254	560	4024

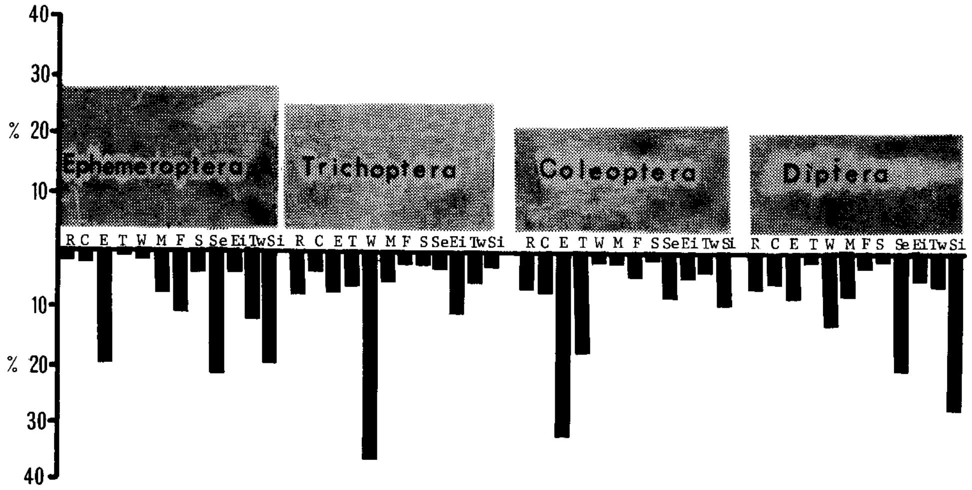

FIGURE 7. Most abundant aquatic insects by percent in autumn in Lake Erie tributaries for all streams and the percentage of each insect order in each stream sampled.*

* R — Raccoon ck.	F — Four Mile ck.
C — Crooked ck.	S — Six mile ck.
E — Elk ck.	Se — Seven Mile ck.
T — Trout Run	Ei — Eight Mile ck.
W — Walnut ck.	Tw — Twelve Mile ck.
M — Mill ck.	Si — Sixteen Mile ck.

	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	Four Mile Ck	Six Mile Ck	Seven Mile Ck	Eight Mile Ck	Twelve Mile Ck	Sixteen Mile Ck	TOTAL
Baetidae													
Unidentified genera	31	1	102	8	1	91	118	32	301	23	109	319	1136
Pseudocloeon spp.	—	—	1	—	2	3	28	9	36	9	—	—	88
Caenidae													
Caenis spp	—	1	34	—	11	14	—	—	2	—	6	—	68
Heptageniidae													
Stenonema spp	1	7	216	1	8	19	17	37	28	39	132	12	517
Stenacron spp	—	—	4	—	—	—	8	—	1	—	2	—	15
Heptagenia spp	3	5	2	—	—	—	8	4	24	—	—	—	46
Leptophlebiidae													
Paraleptophlebia spp	—	—	1	—	—	3	53	1	46	—	—	4	108
Choroterpes sp	—	—	1	—	—	—	—	—	—	—	—	—	1
Habrophlebiodes spp	1	—		—	—	—	—	—	—	—	—	1	
Ephemeridae													
Ephemera spp	—	21	—	—	—	9	—	—	—	—	8	—	38
Ephemerellidae													
Ephemerella spp	—	2	—	—	1	—	2	2	1	10	2	—	20
Tricorythidae													
Tricorythodes spp	—	—	8	—	—	—	—	—	—	—	—	—	8
Siphlonuridae													
Isonychia spp	—	3	27	—	3	1	1	—	—	—	—	2	37
TOTAL	36	40	396	9	26	139	235	86	439	81	259	337	2083

FIGURE 8. Relative numbers of autumn two-minute kick samples of Ephemeroptera.

	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	Four Mile Ck	Six Mile Ck	Seven Mile Ck	Eight Mile Ck	Twelve Mile Ck	Sixteen Mile Ck	TOTAL
Hydropsychidae													
Hydropsyche spp	18	23	72	61	102	51	21	8	29	5	7	5	402
Cheumatopsyche spp	96	38	61	72	580	69	32	47	35	197	85	23	1335
Philopotamidae													
Chimarra spp	44	8	8	—	13	2	—	2	—	—	—	10	87
Dolophilodes = (Sortosa)	—	2	5	—	1	1	1	2	1	11	7	11	42
Psychomyiidae													
Polycentropus spp	—	4	2	1	—	2	1	2	2	2	8	4	28
Rhyacophilidae													
Rhyacophila spp	—	—	—	—	—	—	1	—	1	—	1	—	3
Glossosoma spp	—	2	3	1	—	—	—	—	—	—	—	—	6
Limnephilidae													
Neophylax sp	—	—	1	—	—	—	—	—	—	—	—	—	1
Leptoceridae													
Oecetis spp	—	—	—	—	—	—	—	—	—	—	2	—	2
Hydroptilidae													
Hydroptila spp	1	—	—	—	—	—	1	—	—	—	1	—	3
Helicopsychidae													
Helicopsyche sp	2	—	1	—	—	—	—	—	—	—	—	—	3
Phyganeidae	—	—	1	—	—	—	—	—	—	—	—	—	1
TOTAL	161	77	154	135	696	125	57	61	69	215	111	53	1913

FIGURE 9. Relative numbers of autumn two-minute kick samples of Trichoptera.

	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	Four Mile Ck	Six Mile Ck	Seven Mile Ck	Eight Mile Ck	Twelve Mile Ck	Sixteen Mile Ck	TOTAL
Elmidae													
Dubiraphia spp	—	—	4	1	—	—	—	—	4	—	—	—	9
Macronychus sp	—	1	—	—	—	—	—	—	—	—	—	—	1
Optioservus spp	43	54	344	145	17	—	1	6	89	8	1	145	853
Oulimniuis sp	—	1	—	—	—	—	—	—	—	—	1	—	2
Stenelmis spp	40	53	154	119	4	22	1	7	3	—	—	—	403
Psephenidae													
Psephenus sp	27	6	31	31	7	20	68	13	30	62	47	10	352
Hydrophilidae													
Berosus spp	—	—	1	—	5	—	—	—	—	—	—	—	6
Hydrobius spp	—	—	1	—	—	—	—	—	—	—	—	—	1
Haliplidae													
Peltodytes spp	—	—	—	—	—	1	—	—	—	—	—	—	1
Dryopidae													
Helichus sp	2	—	—	—	—	—	—	—	—	—	—	—	2
TOTAL	112	115	535	296	33	43	70	26	126	70	49	155	1630

FIGURE 10. Relative numbers of autumn two-minute kick samples of Coleoptera.

The only chemical measurement to show correlation with fish was potassium which was positively related to the abundance of *Rhinichthys cataractae* and *Semotilus atomaculatus* and negatively related to the mottled sculpin, *Cottus bairdii.*

Similar statistical comparisons between the fish species and benthic insect species showed positive correlations between mayflies and *Rhinichthys atratulus* and between aquatic beetles and *Semotilus atromaculatus.* In his review of the literature on *Rhinichthys atratulus,* Schontz (19) indicated that while the species doesn't seem to be very selective in its food habits, it nevertheless shows some preference for Ephemeropterans.

Food studies and age and growth studies are currently under way on the six most common species found in the stream study. No data are yet available, however.

The geological data reported here should provide a good basis for further analysis. We believe that more seasonal chemical and biological data are necessary before definitive correlations can be made. This study suggested future studies in relation to correlations stated earlier in this paper. We are in the process of collecting more data on current flow and monitoring over a period of time.

	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	4-Mile Ck	6-Mile Ck	7-Mile Ck	8-Mile Ck	12-Mile Ck	16-Mile Ck	TOTAL
Chironomidae	84	46	73	18	155	108	19	10	223	24	72	88	920
Simulidae	2	22	6	9	2	5	3	2	45	3	4	327	430
Tipulidae	10	11	28	2	18	12	15	6	28	36	2	8	176
Rhagionidae	9	12	4	—	6	2	1	3	—	1	3	1	42
Tabanidae	3	1	3	1	—	—	—	—	—	—	—	—	8
Ephyridae	—	2	3	1	14	1	—	—	11	1	3	6	42
Empididae	3	1	1	1	—	—	—	—	2	—	1	—	9
Dolichopodidae	—	—	—	—	—	—	—	—	—	1	—	—	1
Anthomyidae	1	—	1	—	2	—	—	—	—	6	—	—	10
Syrphidae	—	1	—	—	—	—	—	—	—	—	—	—	1
Unidentified Diptera	—	—	—	1	1	—	—	—	1	—	—	—	3
TOTALS	112	96	119	33	198	128	38	21	310	72	85	430	1642

FIGURE 11. Relative numbers of autumn two-minute kick samples of Diptera.

	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	Four Mile Ck	Six Mile Ck	Seven Mile Ck	Eight Mile Ck	Twelve Mile Ck	Sixteen Mile Ck	TOTAL
Group Euholognatha Superfamily Nemouridae													
Family Nemouridae													
Family Taeniopterygidae													
Taeniopteryx spp	—	—	—	—	4	—	—	—	—	—	—		4
Family Capniidae													
Allocapnia spp	—	—	—	—	—	1	4	2	—	—	—	—	7
Capnia spp	—	—	—	—	1	—	—	—	—	3	1	—	5
Group Systellognatha Superfamily Perloidea													
Family Chloroperlidae													
Alloperla spp	—	—	6	—	—	—	18	13	1	—	6	—	44
Hastaperla spp	—	—	—	—	—	5	—	2	1	—	—	—	8
Family Perlidae													
Acroneuria spp	—	—	2	—	—	—	—	—	4	—	—	1	7
Paragnetina spp	—	—	8	—	—	—	—	9	3	—	—	—	20
Phasganophora sp	—	—	2	—	2	10	1	4	8	—	—	4	31
Unidentified	—	—	5	—	—	—	—	—	—	—	—	—	5
TOTALS			23		7	16	23	30	17	3	7	5	131

FIGURE 12. Relative numbers of autumn two-minute kick samples of Plecoptera.

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	Raccoon Ck	Crooked Ck	Elk Ck	Trout Run	Walnut Ck	Mill Ck	4-Mile Ck	6-Mile Ck	7-Mile Ck	8-Mile Ck	12-Mile Ck	16-Mile Ck	TOTAL
Odonata													
Zygoptera													
Calopterygidae	—	—	1	—	1	—	—	—	—	—	—	—	2
Calopteryx sp													
Agrionidae													
Amphiagrion sp	—	—	—	—	—	2	—	—	—	—	—	—	2
Agria sp	—	—	2	—	—	2	—	—	—	—	—	—	4
Anisoptersa													
Aeshnidae													
Aeshna spp	—	—	1	—	—	1	—	—	—	—	—	—	2
TOTAL	—	—	4	—	1	5	—	—	—	—	—	—	10
Neuroptera													
Sialidae													
Sialis sp	—	—	—	—	—	—	—	—	—	—	—	9	9
Corydalidae													
Nigronia sp	1	1	3	—	—	1	—	—	1	1	—	1	9
TOTAL	1	1	3	—	—	1	—	—	1	1	—	10	18

FIGURE 13. Relative numbers of autumn two-minute kick samples of Odonata and Neuroptera.

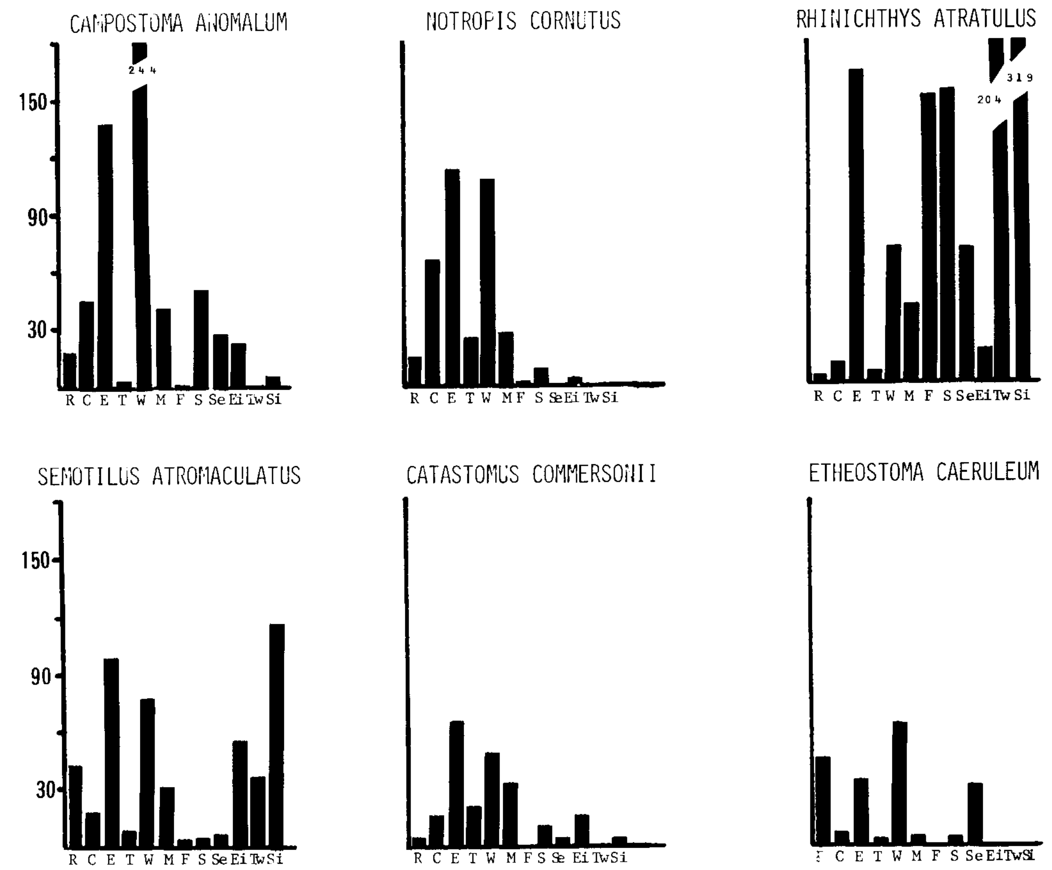

FIGURE 14. Relative numbers of six most abundant species of fish in Lake Erie tributaries.

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