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Use of Fishes and Macroinvertebrates in the Assessment of Water Quality in an Illinois Stream Receiving Sewage Effluents

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USE OF FISHES AND MACROINVERTEBRATES IN THE ASSESSMENT OF WATER QUALITY IN AN ILLINOIS STREAM RECEIVING SEWAGE EFFLUENTS

(TITLE)

BY

ROBERT GEORGE MOSHER

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE IN ZOOLOGY

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY

CHARLESTON, ILLINOIS

1979

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING

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BY

ROBERT GEORGE MOSHER

B. S., Eastern Illinois University, 1977

ABSTRACT OF A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Masters of Science in Zoology at the Graduate School
of Eastern Illinois University

CHARLESTON, ILLINOIS
1979

Kickapoo Creek is a medium sized, warm water stream located in the central part of Coles County, Illinois. The creek is the receiving stream for the sewage effluent of the cities of Mattoon and Charleston which recently began treating sewage to the tertiary level. In 1967-70, the fish population of the creek was intensively surveyed at a time when a less advanced method of sewage treatment was employed. This study provided a baseline of information from which a portion of the present study is founded.

Fish were collected from 5 sampling stations utilizing capture techniques comparable with those used in the original study. Forty species of fish from 8 families were collected during an eight month sampling period in 1978. Eight species found were previously unrecorded from the creek while 6 others that were taken in the earlier study were absent. A comparison of the population structures of the two periods revealed that the 1978 population contained a greater percentage of fishes intolerant of pollution than did the 1967-70 population. Groups indicative of good water quality such as darters (Percidae), redhorse (*Moxostoma*), and black bass (*Micropterus*), were more common in the more recent collections.

The Shannon diversity index was applied to the data of both studies and it was determined by the use of a t-test that the 1978 fish population was significantly more diverse than was the 1967-70 population. In general, the diversity of the fish population increased as the stream order increased. A somewhat aberrant diversity was present at the first station containing fish below the Mattoon effluent. No fish were observed immediately below this effluent.

Macroinvertebrate communities were also studied to augment the fish data. Fifty-nine taxa were identified with insects being the most dominant group. Suitable forms of arthropods were used to compute a biotic index.

This index indicated that the macroinvertebrate communities near the Mattoon effluent reflected a very poor water quality. As downstream progression was made, water quality improved to a fair condition as defined by the index. A slight degradation occured immediately downstream from the entrance of a tributary containing the Charleston effluent.

Acknowledgements

Many thanks are due to my advisor, Dr. Leonard Durham whose influence and guidance enabled this study to be completed. Thanks are also due to my committee members, Dr. Michael Goodrich, Dr. Bill Ridgeway, and especially Dr. Richard Funk, whose advice and criticism were greatly appreciated. Dr. Kandy Baumgardner and Mr. H.C. Nilsen provided valuable advice for which I am grateful. Special thanks are due to Mr. Gary Warren of the Illinois Natural History Survey for his help in the identification of many of the aquatic insects. Without assistance in the field, much of my data could not have been collected and I owe much to Kim J. Carney, Dennis Newman, Bob Davis, and many others for their dedicated efforts. Mrs. Vonice Wohlstein, a true friend, typed the final manuscript. I would also like to thank my parents for their support and encouragement.

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Introduction

Aquatic ecosystems, especially streams, are often utilized as avenues of waste disposal. Although unavoidable, this practice usually results in the degradation of water quality. A polluted stream is lost to most municipal, agricultural and recreational uses and may often present a health hazard. In the course of proper resource management it is essential that streams be maintained at the highest practical level of water quality. To achieve this, water pollution must be detected and monitored whenever and wherever it occurs.

It is desirable, but often difficult, to determine the extent of pollution in an aquatic ecosystem. Several general criteria have been used in this process. Physical and chemical methods of ascertaining water quality yield results that are often precise and easily analyzed, yet certain drawbacks are encountered with their use. Periodic use of these methods reflect only the water conditions at the time of sampling and cannot provide information on past fluctuations (Patrick 1950, Wilhm and Dorris 1968). In addition, substances in low concentrations are often overlooked and coverage of all the varieties of pollutional materials affecting water quality is impossible.

In many cases, a biological approach is theoretically superior to physical and chemical analysis in water quality appraisal. Aquatic organisms generally cannot escape adverse environmental conditions and will become reduced in numbers or die when conditions become intolerable. The organisms found in an ecosystem may therefore indicate present as well as past conditions (Hilsenhoff 1977). The limiting factors brought about by pollution result in characteristic aggregations of organisms. These groups of organisms comprise the community structure of an ecosystem (Wilhm and Dorris 1968). Studies of the community structures of various groups such as fishes (Thompson and Hunt 1930), arthropods (Hilsenhoff 1977), and saprotrophs (Bick 1972), have led to a greater understanding of the effects of disturbances on aquatic ecosystems as a whole. Three methods have been widely used to analyze community structure in biological water quality assessment. These are diversity indices, biotic indices, and the indicator organisms concept.

Kickapoo Creek, Coles County, Illinois receives tertiary treated sewage effluent from the cities of Mattoon and Charleston which have a combined population of approximately 40,000. It is of manageable size, has been studied in the past, and therefore presented an excellent opportunity to apply some of the aforementioned biological methods of water quality assessment to a disturbed aquatic ecosystem. A comprehensive survey of the fishes and macroinvertebrates of Kickapoo Creek was carried out. The present fish population was compared to an earlier study (Durham and Whitley 1971) which was done at a time when the cities were treating sewage only to the secondary level. An analysis of the composition and distribution of the fishes and macroinvertebrates lead to conclusions as to the effects of the tertiary treated sewage effluent on the water quality of the creek.

Description of Study Area

Kickapoo Creek is a medium sized, warm water stream located in the central part of Coles County, Illinois. The creek arises on the south edge of the city of Mattoon at an elevation of 216.7 m above sea level. From there it flows east and southeast for 26 km and enters the Embarras River about 4.5 km south of the city of Charleston at 173.7 m above sea level. The resulting gradient of 1.65 m per km is considered to be higher than average for the area.

An area of approximately 248 km^2 are drained by Kickapoo Creek and its tributaries. This area is bounded on the north by the Cerro Gordo moraine and on the south by the Shelbyville terminal moraine. The creek itself is located in a narrow area between the Shelbyville moraine and the smaller Paris moraine (Figure 1). The most recent glaciation left the basin of Kickapoo Creek with a varied topography that ranges through flat to gently rolling to steeply inclined. Level areas such as the prairie sections in the north and the floodplain of the creek in the southeast are heavily farmed in row crops. The steeper moraines are largely left to pasture and woodland but, in the north and east parts of the basin, the moraines are less apparent and fields are often plowed to within a few feet of the creek banks.

Kickapoo Creek has undergone several physical changes over the past few decades. The upper two-thirds of the creek was formerly intermittent, but with the continuous inflow of effluent from the Mattoon and Charleston sewage treatment plants, the creek has become a permanent body of water from the Mattoon plant on. Unlike other area creeks of comparable size, an easily detectable flow could be observed even during drought. During periods of average flow, the creek may vary

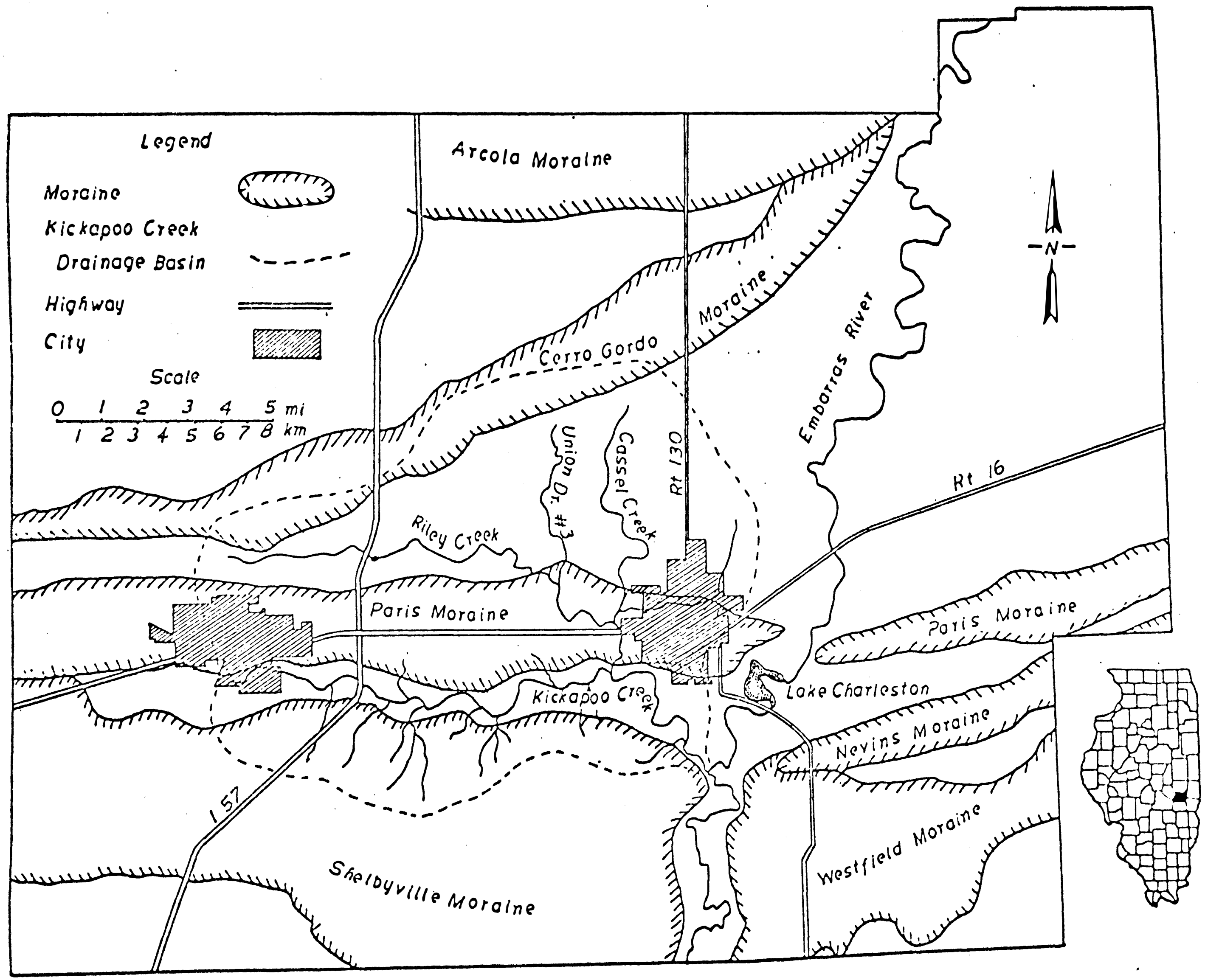

Figure 1. Morainal map of Coles County, Illinois, illustrating the major creeks in the Kickapoo Creek drainage basin. Drawn after Willman and Frye (1970).

between 2 and 5 m wide and have pools up to 75 cm deep in the section from the Mattoon effluent to the mouth of Riley Creek. Downstream from Riley Creek, the creek is between 4 and 7 m wide with pools over 1.5 m in depth.

The effluents that give the creek a large part of its volume have in the past created septic zones. During the study period of Durham and Whitley (1971), septic zones existed for 6.4 km downstream from the Mattoon sewage treatment plant and for 1.3 km below the entrance of Riley Creek due to Charleston's sewage effluent (Horner 1971). No evidence of septic conditions was discovered during the present study.

Other pollutants that find their way into the creek are silt from improperly managed farmlands, agricultural chemicals that accompany the silt and industrial wastes from factories in the cities. Several major fish kills have been reported in recent years. One in 1963 resulted from a cyanide spill in a drainage ditch in Mattoon and led to a complete kill (Durham and Whitley 1971). In May of 1979 a fertilizer plant spilled a quantity of 28% nitrogen solution into Riley Creek that killed nearly all fish in Kickapoo Creek from the mouth of Riley Creek to the Embarras River.

Sampling stations on Kickapoo Creek include 6 of the 9 originally designated by Durham and Whitley (1971) (Figure 2). They are defined as follows:

Station 1A. Located in the NW ¼ of Sec 19, T12N-R8E. Extends from the Odd Fellows Road Bridge upstream to a riffle composed of brick and concrete rubble. Passes through farmland with some woods. Average width, 3 m, average depth, 25 cm. Bottom composed of silt, mud, and sand. Except for the rubble riffle area, this station lacks clear-cut

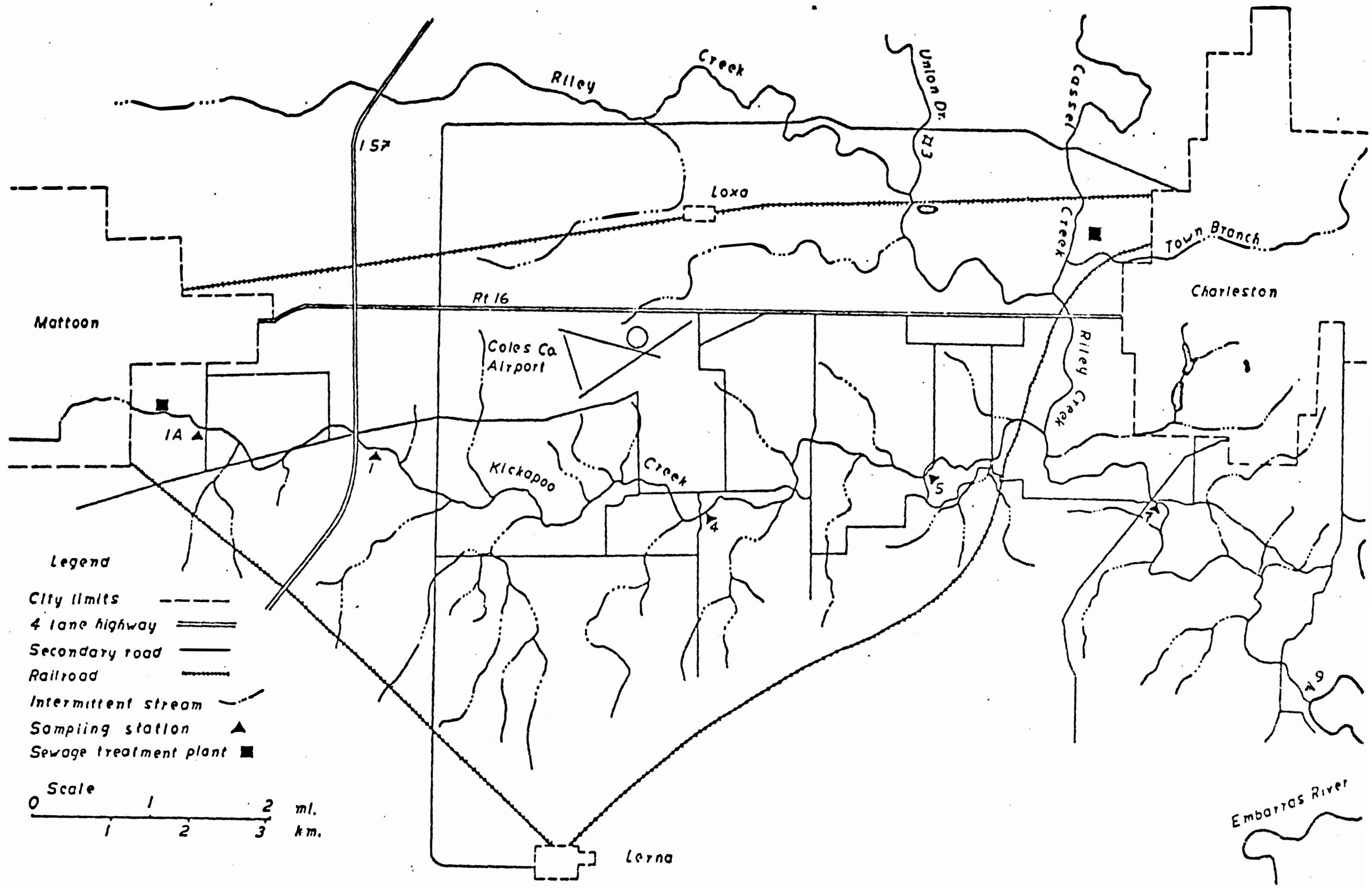

Figure 2. Locations of sampling stations and sewage treatment plants on Kickapoo Creek, Coles County, Illinois.

pools and riffles and most resembles a silted ditch. Formerly a septic area, this station is only .5 km from the Mattoon sewage effluent outlet.

Station 1. Located in the SW ¼, Sec 21, T12N-R8E. Extends from a point 36 m upstream to a point 36 m downstream from a concrete dam located 100 m downstream from Interstate Route 57. Passes through pastureland. Average width, 3.5 m, average depth, 50 cm. Bottom composed of silt, sand and gravel with concrete rubble near the dam. Above the dam the creek is deeper and the current is almost nonexistent. Grassy overhung banks are present and the area is almost pond-like. Immediately below the dam there is a fast, rocky pool and farther downstream the creek is mostly shoal with some small pools.

Station 4. Located in the NW ¼, Sec 25, T12N-R8E. Extends from a large log jam, upstream to several meters above the bridge. Passes through a wooded area with some farmland. Average width, 4 m, average depth, 25 cm. Bottom composed of sand and gravel. Fair sized pools are found at the log jam and underneath the bridge. A large, shallow riffle exists just downstream from the bridge. The remainder of the station consists of sandy, shallow shoal areas with a few slightly undercut banks.

Station 5. Located in the SW ¼, Sec 20, T12N-R9E. Extends from the bridge downstream to just past the first large pool. Also, the area upstream from the bridge to just above the large, rocky riffle was sampled by seine. Passes through a wooded area with some adjoining farmland. Average width, 3.5 m, average depth, 25 cm. Bottom composed of sand, gravel and small rocks. Pools are found at the downstream end of the station and at the bridge. Sandy shoals and shallow riffles are found in-between. Several undercut banks are present.

Station 7. Located in the NW¼, Sec 27, T12N-R9E. From 40 m downstream from the 4th Street bridge, just upstream from a deep, swift pool, downstream to a large, shallow riffle. Passes through woodland. Average width, 6 m, average depth, 75 cm. Bottom composed of sand, gravel, rocks and boulders. The large upstream pool is up to 1.5 m deep. A natural log dam creates a large, slow pool and there are many deeply undercut banks. Current is generally swift and pools are hard-bottomed.

Station 9. Located in the SW¼, Sec 35, T12N-R9E. Extends from a log jam near the point where the creek joins the Embarras River, upstream to an undercut bank pool. Passes through woodland with adjoining farmland. Average width, 6.5 m, average depth, 40 cm. Bottom composed mostly of sand with some gravel. This station consists mainly of sandy shoals which are constantly shifting and often create braided stream conditions. The log jam contains very deep areas but during low periods these fill up with sand. At several times during the study period, water from the Embarras River extended up into this section of the creek.. This condition occurred when the creek was low and the river high.

Methods and Materials

Collecting trips were originally intended to be made monthly, from April to November 1978. This would have resulted in 8 collections per station. However, due to water conditions and the availability of assistants, some stations were not sampled in certain months. In other instances, several collections were made at a station in the same month. Number and intent of sampling trips for each station are given in Table 1.

Fish were collected by a variety of methods to insure that an accurate estimate of the population structure could be made. An electric seine modified from Funk (1949) was employed to collect fish by temporarily stunning them. The seine measured 7 m between the electrodes and spanned the stream in all but the widest places. Three copper chain drag lines were spaced 1 m apart in the center of the seine. A Homelite 115 volt, 13.1 amp portable generator was used as a power source. A 36 m transmission cord was used between the generator and the seine. This cord also served to determine the length of the stations. Sampling commenced a cord's length downstream from the generator and ended a cord's length upstream from the generator. This resulted in collecting sta-
72 m in length. The seine was operated in the manner described by Larimore (1961).

Nylon hand seines having a 6.4 mm mesh and measuring 7.6, 4.6, and 1.2 m long were used to sample the stations defined by the electrofishing procedure. The larger seines were pulled through slower moving water in the usual manner. The 1.2 m seine was placed below a riffle while a disturbance was created upstream by the collectors' feet. This displaced the fish and allowed them to be washed into the seine by the

Table 1. Collecting trips made to Kickapoo Creek, Coles County, Illinois, April through December, 1978.

Station	Number of collections	
	Fish	invertebrate[a]
1A	0[b]	2[b]
1	7	4[c]
4	9	6
5	9	6
7	11	6
9	8	5
Totals	44	29

a Due to high water, invertebrate collections began in May.
b Station 1A was added late in the study and was sampled in December of 1978 and April of 1979. Fish were not observed at this station so no attempt was made to sample for them.
c Invertebrate sampling at Station began in July.

current.

Hoop nets with a stretched mesh size of 4 cm, a hoop diameter of 75 cm, and a total length of 3.2 m were set at all stations except Station 1. Whenever possible, they were placed within the defined collecting stations. When a sufficiently deep pool was absent from a station, the hoop net was placed in a suitable pool nearby. The contents of the hoop nets were removed every 24 hours.

Large, easily identifiable fish were given a distinct fin clip and were measured in total length before being released at the point of capture. Recaptures were noted and were not included as part of the sample. Several individuals of each species were preserved in 10% formalin to be held as reference specimens and to allow accurate weights to be taken. To estimate the weights of released fish, empirical curves were plotted as recommended by Lagler (1952). All smaller fish and those of unknown identity were immediately preserved in 10% formalin. These fish were measured in total length and weighed on a Mettler balance. Identifications were made using Pflieger (1975) and Smith (1979). Several specimens were identified by Dr. Philip Smith of the Illinois Natural History Survey. Scientific names used follow those given by Bailey et al. (1970). Representative specimens of most species have been deposited in the Scruggs Museum, Eastern Illinois University.

Fish population structures for each station and for the creek as a whole were analyzed with the use of the Shannon diversity index. Given by Zar (1974), it reads

$$H = \frac{n \log n - \sum_{i=1}^{k} f_i \log f_i}{n}$$

where H is the diversity value, k is the number of categories, n is the sample size, and f_i is the number of observations in category i.

Maximum possible diversity can be calculated by

$$H_{max} = \log k.$$

A value J, is the proportion of the observed diversity to the maximum possible diversity and is derived by

$$J = \frac{H}{H_{max}}.$$

To test for significant difference between H values, a t-test (Hutcheson 1970) was used. It reads

$$t = \frac{H_1 - H_2}{S_{H_1} - S_{H_2}}$$

where

$$S_{H_1} - S_{H_2} = \sqrt{S^2_{H_1} + S^2_{H_2}}.$$

Degrees of freedom are calculated by

$$DF = \frac{\left(S^2_{H_1} + S^2_{H_2}\right)^2}{\frac{\left(S^2_{H_1}\right)^2}{n_1} + \frac{\left(S^2_{H_2}\right)^2}{n_2}}$$

One tailed tests were performed and a confidence interval of $p = 0.05$ was used.

Macroinvertebrates were largely collected by the method suggested by Hilsenhoff (1977). Sampling was done at the same stations defined by the electrofishing procedure but at times different from fish collecting. Collections were taken back to the laboratory and, if time permitted, the organisms were picked from debris while still alive.

They were then placed in 80% ethanol. If the samples were not to be picked immediately, they were preserved in 80% ethanol in the field.

Macroinvertebrates were identified with the aid of the keys listed in Appendix A. Mr. Gary Warren and others at the Illinois Natural History identified several specimens and verified the identities of many others. Nomenclature used for the insects follows Merrit and Cummins (1978), while Pennak (1953) was used for all other invertebrate groups.

The biotic index proposed by Hilsenhoff (1977) was used to evaluate the arthropod segment of the macroinvertebrate community. Index values were applied to arthropods wherever possible and the biotic index was then calculated using

$$B.I. = \frac{\Sigma\, n_i\, a_i}{N}$$

where n_i is the number of individuals in each taxon, a_i is the suggested index value for that taxon and N is the total number of individuals of all taxa found in the sample.

Results

I. Fishes

Fishes collected from Kickapoo Creek from April to December 1978 totaled 2,918 individuals of 40 species and 8 families. These data resulted in a community diversity index value of 1.0707. Table 2 compares the present study with that of Durham and Whitley (1971), who collected 7,643 individuals of 38 species and 9 families. To allow direct comparison with results obtained by Durham and Whitley, 71 individuals and 4 species collected by hoop net were removed from the present study. This lowered the diversity index value to 1.0395. The relative abundance of fishes by family from both studies is shown in Figure 3.

Community structure varied greatly among the 5 sampling stations containing fish. Community diversity values at each station ranged from a high of 1.1000 at Station 7 to a low of 0.7395 at Station 4 (Table 3). Station 7 also had the greatest number of individuals, 1,106, and species, 31. Station 1 had the lowest number of individuals, 59, and species, 11. Cyprinids dominated the numerical distribution at all stations (Figure 4).

The biomass diversity index value for the entire creek was 1.2450. Biomass diversity at the individual stations generally resembled community diversity. It ranged from 1.0773 at Station 7 to 0.7673 at Station 4 (Table 4). Fish at Station 1 had the highest average weight, 27.8 g, followed by Stations 7, 9, and 4. Station 5 had the lowest average weight per fish, only 7.1 g. Although found at only one station and numbering only 5 individuals, *Cyprinus carpio* comprised more of the total biomass than any other species, 17.97%. *Semotilis atromaculatus*, 11.9%, *Catostomus commersoni*, 8.91%, *Ictalurus natalis*, 8.67%, and

Table 2. Population structure and community diversity of the fishes of Kickapoo Creek, Coles County Illinois. Data from the 1967-70 study (Durham and Whitley 1971) and the present study are given.

Taxon	1967-70 Study		1978 Study	
	Number	Percent of total	Number	Percent of total
Petromyzontidae	-	0.01	-	-
Ichthyomyzon castaneus	1	0.01	-	-
Clupeidae	-	0.64	-	0.55
Dorosoma cepedianum	49	0.64	16	0.55
Esocidae	-	-	-	0.07
Esox americanus	-	-	2	0.07
Cyprinidae	-	89.87	-	87.18
Campostoma anomalum	487	6.37	273	9.36
Cyprinus carpio	115	1.50	5	0.17
Ericymba buccata	1913	25.03	512	17.55
Notemigonus crysoleucas	1	0.01	8	0.27
Notropis chrysocephalus	36	0.47	25	0.86
N. spilopterus	223	2.92	183	6.27
N. stramineus	278	3.64	216	7.40
N. umbratilis	140	1.83	37	1.27
N. whipplei	350	4.58	160	5.48
Phenacobius mirabilis	44	0.58	38	1.30
Pimephales notatus	1078	14.10	327	11.21
P. promelas	217	2.84	12	0.41
P. vigilax	29	0.38	-	-
Semotilus atromaculatus	1959	25.63	748	25.63
Catostomidae	-	6.71	-	5.69
Carpiodes cyprinus	10	0.13	5	0.17
Catostomus commersoni	162	2.12	71	2.43
Erimyzon oblongus	284	3.72	4	0.14
Hypentelium nigricans	7	0.09	20	0.69
Minytrema melanops	15	0.20	1	0.03
Moxostoma anisurum	-	-	14	0.48
M. erythrurum	28	0.37	26	0.89
M. macrolepidotum	7	0.09	25	0.86
Ictaluridae	-	0.61	-	1.64
Ictalurus melas	6	0.08	9	0.31
I. natalis	22	0.29	25	0.86
I. punctatus	16	0.21	10	0.34
Noturus miurus	3	0.04	3	0.10
Pylodictis olivaris	-	-	1	0.03

Table 2. Continued.

Taxon	1967-70 Study		1978 Study	
	Number	Percent of total	Number	Percent of total
Atherinidae	-	0.07	-	-
Labidesthes sicculus	5	0.07	-	-
Cyprinodontidae	-	0.08	-	0.14
Fundulus notatus	6	0.08	4	0.14
Centrarchidae	-	1.79	-	2.67
Lepomis cyanellus	19	0.25	23	0.79
L. humilis	-	-	1	0.03
L. macrochirus	38	0.50	11	0.38
L. megalotis	20	0.26	10	0.34
L. microlophus	-	-	1	0.03
Micropterus punctulatus	59	0.77	23	0.79
M. salmoides	-	-	7	0.24
Pomoxis annularis	1	0.01	1	0.03
P. nigromaculatus	-	-	1	0.03
Percidae	-	0.19	-	2.05
Etheostoma caeruleum	1	0.01	-	-
E. flabellare	1	0.01	-	-
E. nigrum	4	0.05	-	-
E. spectabile	-	-	52	1.78
Percina sciera	9	0.12	8	0.27
Total number	7643		2918	
Total species	38		40	

$H_{1967-70} = 0.9891$ $H_{1978} = 1.0707$

t = 7.04 Difference significant

P = .0005

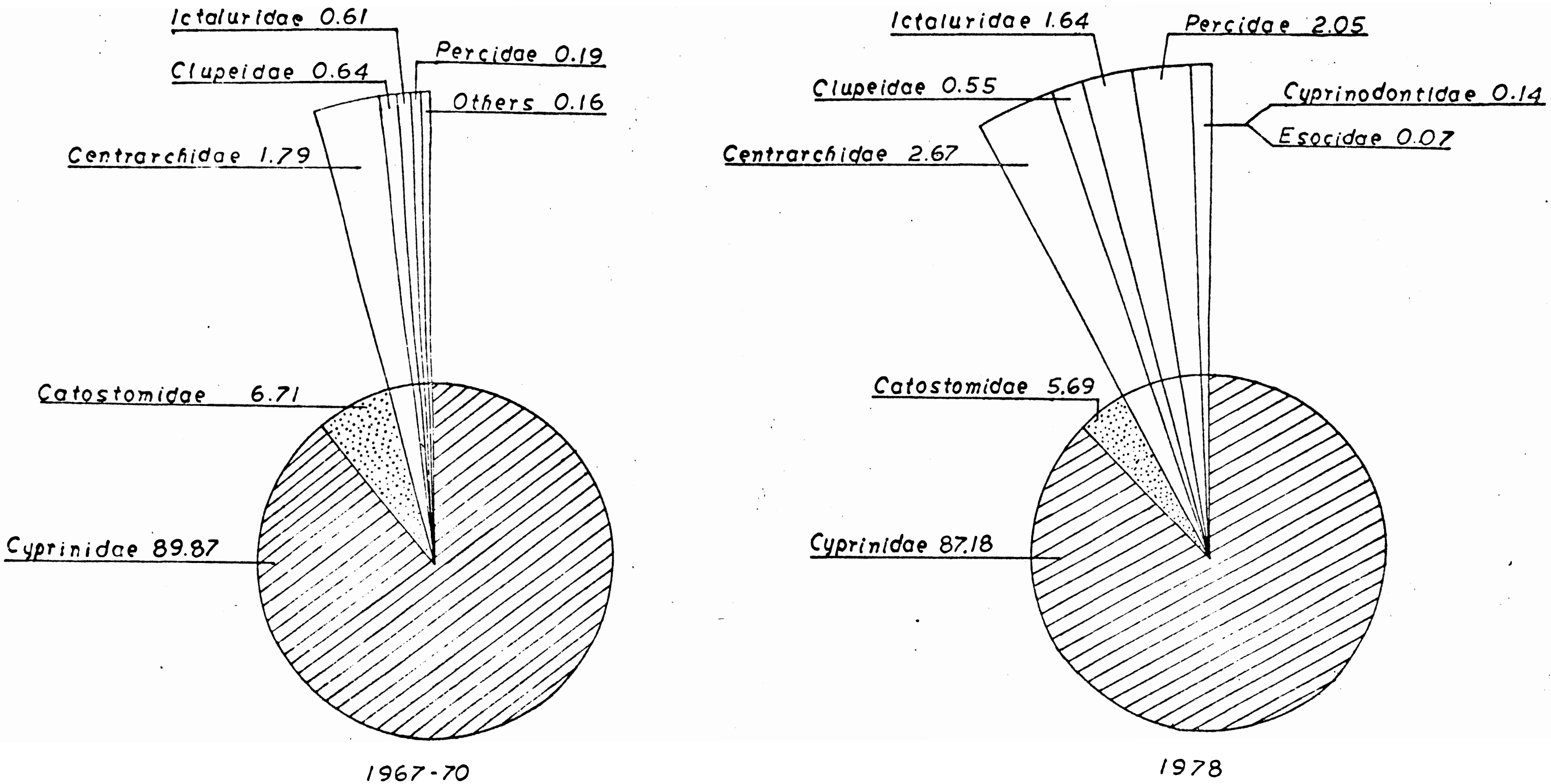

Figure 3. Distribution by family of the fishes of Kickapoo Creek, Coles County, Illinois, the Durham and Whitley (1971) study and the present study given.

Table 3. Population structure and community diversity values of the fishes of Kickapoo Creek, Coles County Illinois, by sampling station.

Taxon	Station 1		Station 4		Station 5	
	Number	Percent of total	Number	Percent of total	Number	Percent of total
Clupeidae	-	-	-	-	-	-
Dorosoma cepedianum	-	-	-	-	-	-
Esocidae	-	-	-	-	-	-
Esox americanus	-	-	-	-	-	-
Cyprinidae	-	62.71	-	91.33	-	92.01
Campostoma anomalum	8	13.56	133	33.92	111	10.31
Cyprinus carpio	-	-	-	-	-	-
Ericymba buccata	-	-	41	10.46	284	26.37
Notemigonus crysoleucas	1	1.69	-	-	-	-
Notropis chrysocephalus	1	1.69	1	0.26	6	0.56
N. spilopterus	-	-	1	0.26	2	0.18
N. stramineus	-	-	16	4.08	64	5.94
N. umbratilis	-	-	1	0.26	-	-
N. whipplei	-	-	-	-	2	0.18
Phenacobius mirabilis	-	-	14	3.57	13	1.21
Pimephales notatus	-	-	9	2.30	66	6.13
P. promelas	6	10.17	1	0.26	4	0.37
Semotilus atromaculatus	21	35.59	141	35.97	439	40.76
Catostomidae	-	13.56	-	2.81	-	3.90
Carpiodes cyprinus	-	-	3	0.77	2	0.19
Catostomus commersoni	5	8.47	7	1.79	36	3.34
Erimyzon oblongus	3	5.08	-	-	1	0.09
Hypentelium nigricans	-	-	-	-	1	0.09
Minytrema melanops	-	-	1	0.26	-	-
Moxostoma anisurum	-	-	-	-	-	-
M. erythrurum	-	-	-	-	-	-
M. macrolepidotum	-	-	-	-	2	0.18

Table 3. Continued.

Taxon	Station 1 Number	Station 1 Percent of total	Station 4 Number	Station 4 Percent of total	Station 5 Number	Station 5 Percent of total
Ictaluridae	-	5.08	-	-	-	0.56
Ictalurus melas	3	5.08	-	-	4	0.37
I. natalis	-	-	-	-	2	0.19
I. punctatus	-	-	-	-	-	-
Noturus miurus	-	-	-	-	-	-
Pylodictis olivaris	-	-	-	-	-	-
Cyprinodontidae	-	-	-	-	-	-
Fundulus notatus	-	-	-	-	-	-
Centrarchidae	-	18.64	-	1.28	-	1.02
Lepomis cyanellus	9	15.25	1	0.26	5	0.46
L. humilis	-	-	-	-	-	-
L. macrochirus	-	-	2	0.51	1	0.09
L. megalotis	-	-	-	-	1	0.09
L. microlophus	1	1.69	-	-	-	-
Micropterus punctulatus	-	-	-	-	1	0.09
M. salmoides	1	1.69	2	0.51	3	0.28
Pomoxis annularis	-	-	-	-	-	-
P. nigromaculatus	-	-	-	-	-	-
Percidae	-	-	-	4.59	-	2.51
Etheostoma spectabile	-	-	18	4.59	27	2.51
Percina sciera	-	-	-	-	-	-
Total number	59		392		1077	
Total species	11		17		23	
H =	0.8453		0.7395		0.7599	
H_{max} =	1.0414		1.2304		1.3617	
J =	0.8117		0.6010		0.5580	

Table 3. Continued.

Taxon	Station 7		Station 9	
	Number	Percent of total	Number	Percent of total
Clupeidae	-	0.81	-	2.46
Dorosoma cepedianum	9	0.81	7	2.46
Esocidae	-	0.09	-	0.35
Esox americanus	1	0.09	1	0.35
Cyprinidae	-	83.82	-	81.34
Campostoma anomalum	18	1.63	3	1.06
Cyprinus carpio	5	0.45	-	-
Ericymba buccata	180	16.27	7	2.46
Notemigonus crysoleucas	-	-	7	2.46
Notropis chrysocephalus	16	1.45	1	0.35
N. spilopterus	94	8.50	86	30.28
N. stramineus	129	11.66	7	2.46
N. umbratilis	15	1.36	21	7.39
N. whipplei	108	9.76	50	17.61
Phenacobius mirabilis	11	0.99	-	-
Pimephales notatus	209	18.90	43	15.14
P. promelas	1	0.09	-	-
Semotilus atromaculatus	141	12.75	6	2.11
Catostomidae	-	9.04	-	1.76
Carpiodes cyprinus	-	-	-	-
Catostomus commersoni	23	2.08	-	-
Erimyzon oblongus	-	-	-	-
Hypentelium nigricans	19	1.72	-	-
Minytrema melanops	-	-	-	-
Moxostoma anisurum	13	1.18	1	0.35
M. erythrurum	25	2.26	1	0.35
M. macrolepidotum	20	1.81	3	1.06

Table 3. Continued.

Taxon	Station 7		Station 9	
	Number	Percent of total	Number	Percent of total
Ictaluridae	-	2.62	-	3.52
Ictalurus melas	2	0.18	-	-
I. natalis	22	1.99	1	0.35
I. punctatus	5	0.45	5	1.76
Noturus miurus	-	-	3	1.06
Pylodictis olivaris	-	-	1	0.35
Cyprinodontidae				
Fundulus notatus	-	0.18	-	0.70
Centrarchidae	-	2.80	-	7.04
Lepomis cyanellus	6	0.54	2	0.70
L. humilis	1	0.09	-	-
L. macrochirus	5	0.45	3	1.06
L. megalotis	6	0.54	3	1.06
L. microlophus	-	-	-	-
Micropterus punctulatus	11	0.99	11	3.87
M. salmoides	1	0.09	-	-
Pomoxis annularis	1	0.09	-	-
P. nigromaculatus	-	-	1	0.35
Percidae	-	0.63	-	2.82
Etheostoma spectabile	7	0.63	-	-
Percina sciera	-	-	8	2.82
Total number	1106		284	
Total species	31		26	
H =	1.1000		1.0160	
H_{max} =	1.4914		1.4150	
J =	0.7376		0.7180	

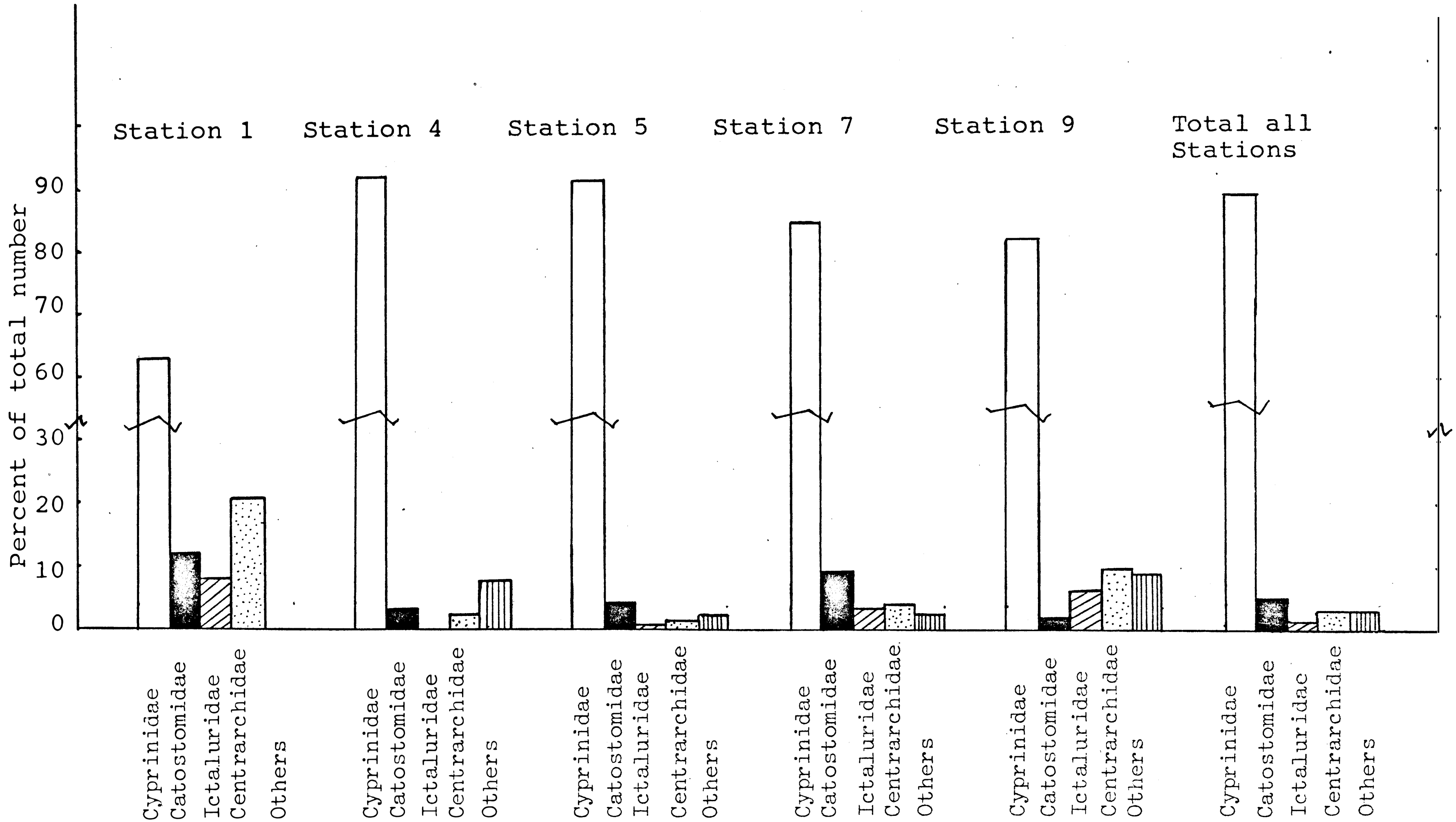

Figure 4. Percent of the total number of fishes from five groups, Kickapoo Creek, Coles County, Illinois. "Others" includes Percidae, Cyprinodontidae, Clupeidae and Esocidae.

Table 4. Weight distribution and biomass diversity values of the fishes of Kickapoo Creek, Coles County Illinois, by sampling station and by all stations combined.

Taxon	Station 1		Station 4		Station 5	
	Grams	Percent of total	Grams	Percent of total	Grams	Percent of total
Clupeidae	–	–	–	–	–	–
Dorosoma cepedianum	–	–	–	–	–	–
Esocidae	–	–	–	–	–	–
Esox americanus	–	–	–	–	–	–
Cyprinidae	–	47.58	–	50.72	–	56.11
Campostoma anomalum	74.2	4.53	591.7	12.58	412.0	5.36
Cyprinus carpio	–	–	–	–	–	–
Ericymba buccata	–	–	72.0	1.53	583.4	7.58
Notemigonus crysoleucas	34.9	2.13	–	–	–	–
Notropis chrysocephalus	1.4	0.08	1.4	0.03	12.0	0.16
N. spilopterus	–	–	4.0	0.09	10.0	0.13
N. stramineus	–	–	33.5	0.71	120.4	1.57
N. umbratilis	–	–	0.9	0.02	–	–
N. whipplei	–	–	–	–	10.4	0.13
Phenacobius mirabilis	–	–	46.2	0.98	53.8	0.70
Pimephales notatus	–	–	16.0	0.34	186.4	2.42
P. promelas	17.7	1.08	1.2	0.03	7.2	0.09
Semotilus atromaculatus	651.9	39.76	1618.5	34.41	2920.7	37.97
Catostomidae	–	24.43	–	37.36	–	35.00
Carpiodes cyprinus	–	–	1418.0	30.16	638.0	8.29
Catostomus commersoni	266.3	16.24	272.0	5.78	1839.0	23.90
Erimyzon oblongus	134.2	8.19	–	–	1.8	0.02
Hypentelium nigricans	–	–	–	–	104.0	1.35
Minytrema melanops	–	–	67.0	1.42	–	–
Moxostoma anisurum	–	–	–	–	–	–
M. erythrurum	–	–	–	–	–	–
M. macrolepidotum	–	–	–	–	109.8	1.43

Table 4. Continued.

Taxon	Station 7		Station 9		All Stations	
	Grams	Percent of total	Grams	Percent of total	Grams	Percent of total
Clupeidae	-	3.26	-	19.38	-	4.21
Dorosoma cepedianum	960.0	3.26	1116.0	19.38	2076.0	4.21
Esocidae	-	0.22	-	0.34	-	0.17
Esox americanus	65.0	0.22	19.3	0.34	84.3	0.17
Cyprinidae	-	41.35	-	10.05	-	41.10
Campostoma anomalum	66.6	0.23	22.2	0.39	1166.8	2.37
Cyprinus carpio	8854.0	30.04	-	-	8854.0	17.97
Ericymba buccata	350.1	1.19	17.4	0.30	1022.9	2.08
Notemigonus crysoleucas	-	-	6.2	0.11	41.0	0.08
Notropis chrysocephalus	389.3	1.32	1.9	0.03	405.9	0.82
N. spilopterus	314.5	1.07	226.8	3.94	555.2	1.13
N. stramineus	233.6	0.79	13.5	0.23	401.0	0.81
N. umbratilis	19.0	0.06	13.5	0.23	33.4	0.07
N. whipplei	801.9	2.72	237.9	4.13	1050.1	2.13
Phenacobius mirabilis	37.6	0.13	-	-	137.6	0.28
Pimephales notatus	448.9	1.52	32.0	0.57	638.3	1.39
P. promelas	2.4	0.01	-	-	28.6	0.06
Semotilus atromaculatus	668.5	2.27	7.7	0.13	5867.3	11.91
Catostomidae	-	32.82	-	6.87	-	30.30
Carpiodes cyprinus	-	-	-	-	2056.0	4.17
Catostomus commersoni	2021.5	6.86	-	-	4398.8	8.93
Erimyzon oblongus	-	-	-	-	136.0	0.28
Hypentelium nigricans	1455.4	4.94	-	-	1559.4	3.17
Minytrema melanops	-	-	-	-	67.0	0.14
Moxostoma anisurum	1143.5	3.88	175.1	3.04	1318.6	2.68
M. erythrurum	2608.0	8.85	2.7	0.05	2610.7	5.30
M. macrolepidotum	2444.1	8.29	217.9	3.78	2771.8	5.63

Table 4. Continued.

Taxon	Station 1		Station 4		Station 5	
	Grams	Percent of total	Grams	Percent of total	Grams	Percent of total
Ictaluridae	-	9.04	-	-	-	3.93
Ictalurus melas	148.2	9.04	-	-	231.2	3.00
I. natalis	-	-	-	-	70.9	0.92
I. punctatus	-	-	-	-	-	-
Noturus miurus	-	-	-	-	-	-
Pylodictis olivaris	-	-	-	-	-	-
Cyprinodontidae	-	-	-	-	-	-
Fundulus notatus	-	-	-	-	-	-
Centrarchidae	-	18.95	-	11.63	-	4.67
Lepomis cyanellus	207.3	12.65	51.0	1.08	62.8	0.82
L. humilis	-	-	-	-	-	-
L. macrochirus	-	-	233.8	4.97	76.6	1.00
L. megalotis	-	-	-	-	2.4	0.03
L. microlophus	13.8	0.84	-	-	-	-
Micropterus punctulatus	-	-	-	-	87.0	1.13
M. salmoides	89.6	5.47	262.2	5.57	130.6	1.70
Pomoxis annularis	-	-	-	-	-	-
P. nigromaculatus	-	-	-	-	-	-
Percidae	-	-	-	0.28	-	0.29
Etheostoma spectabile	-	-	13.3	0.28	22.5	0.29
Percina sciera	-	-	-	-	-	-
Total weight	1639.5		4702.7		7692.9	
	$H =$ 0.7910		$H =$ 0.7673		$H =$ 0.8628	
	$H_{max} =$ 3.2147		$H_{max} =$ 3.6723		$H_{max} =$ 3.8861	
	$J =$ 0.2461		$J =$ 0.2089		$J =$ 0.2220	

Table 4. Continued.

Taxon	Station 7		Station 9		All Stations	
	Grams	Percent of total	Grams	Percent of total	Grams	Percent of total
Ictaluridae	–	15.14	–	23.67	–	12.74
Ictalurus melas	207.3	0.70	–	–	586.7	1.19
I. natalis	3832.0	13.00	370.0	6.42	4272.9	8.67
I. punctatus	424.5	1.44	362.8	6.30	787.2	1.60
Noturus miurus	–	–	10.5	0.18	10.5	0.02
Pylodictis olivaris	–	–	620.0	10.77	620.0	1.26
Cyprinodontidae	–	0.01	–	0.03	–	0.01
Fundulus notatus	3.4	0.01	1.5	0.03	4.9	0.01
Centrarchidae	–	7.18	–	39.44	–	11.38
Lepomis cyanellus	24.6	0.08	3.0	0.05	348.7	0.71
L. humilis	6.6	0.02	–	–	6.6	0.01
L. macrochirus	270.4	0.92	67.4	1.17	648.2	1.32
L. megalotis	249.5	0.85	74.5	1.29	326.4	0.66
L. microlophus	–	–	–	–	13.8	0.03
Micropterus punctulatus	1277.9	4.34	2032.6	35.29	3397.5	6.90
M. salmoides	208.0	0.71	–	–	690.4	1.40
Pomoxis annularis	80.0	0.27	–	–	80.0	0.16
P. nigromaculatus	–	–	94.0	1.63	94.0	0.19
Percidae	–	0.02	–	0.22	–	0.10
Etheostoma spectabile	5.2	0.02	–	–	41.0	0.08
Percina sciera	–	–	12.7	0.22	12.7	0.02
Total weight	29472.9		5759.0		49267.0	
	H = 1.0773		H = 0.9161		H = 1.2450	
	H_{max} = 4.4694		H_{max} = 3.7603		H_{max} = 4.6926	
	J = 0.2416		J = 0.2436		J = 0.2653	

Micropterus punctulatus, 6.90%, also contributed significant amounts to the biomass. The weight distribution of families for all collecting stations is shown in Figure 5.

A grid comparing the results of t-tests preformed on the community and biomass diversity index values of each station vs. every other station is given in Table 5. Biomass diversity values for the stations proved to be significantly different from each other in all cases. Community diversity values demonstrated a more complex pattern of significant difference. Stations 7 and 9 were not significantly different from each other in community diversity but were significantly more diverse than all other stations.

Stations 1 and 5, and 4 and 5, had similar diversities but Station 1 was significantly more diverse than was Station 4. Figure 6 illustrates the relationships of the fish diversity values of each station to the sewage effluents entering the creek from Charleston and Mattoon.

II. Macroinvertebrates

Fifty-nine taxa of macroinvertebrates were identified from collections made on Kickapoo Creek for the May through December 1978 sampling period (Table 6). Insects dominated this community in numbers of both species and individuals. Present in the creek were 13 taxa of Coleoptera, 10 Ephemeroptera, 7 Hemiptera, 9 Odonata, 5 Diptera, 4 Trichoptera, and 1 taxon each of Collembola and Plecoptera. Due to the limitations of identification keys and the author's experience, other taxa (especially dipterans) almost certainly present in the samples could not be identified.

Differences in community structure amoung collecting stations were obvious in many cases. The number of taxa increased as a downstream

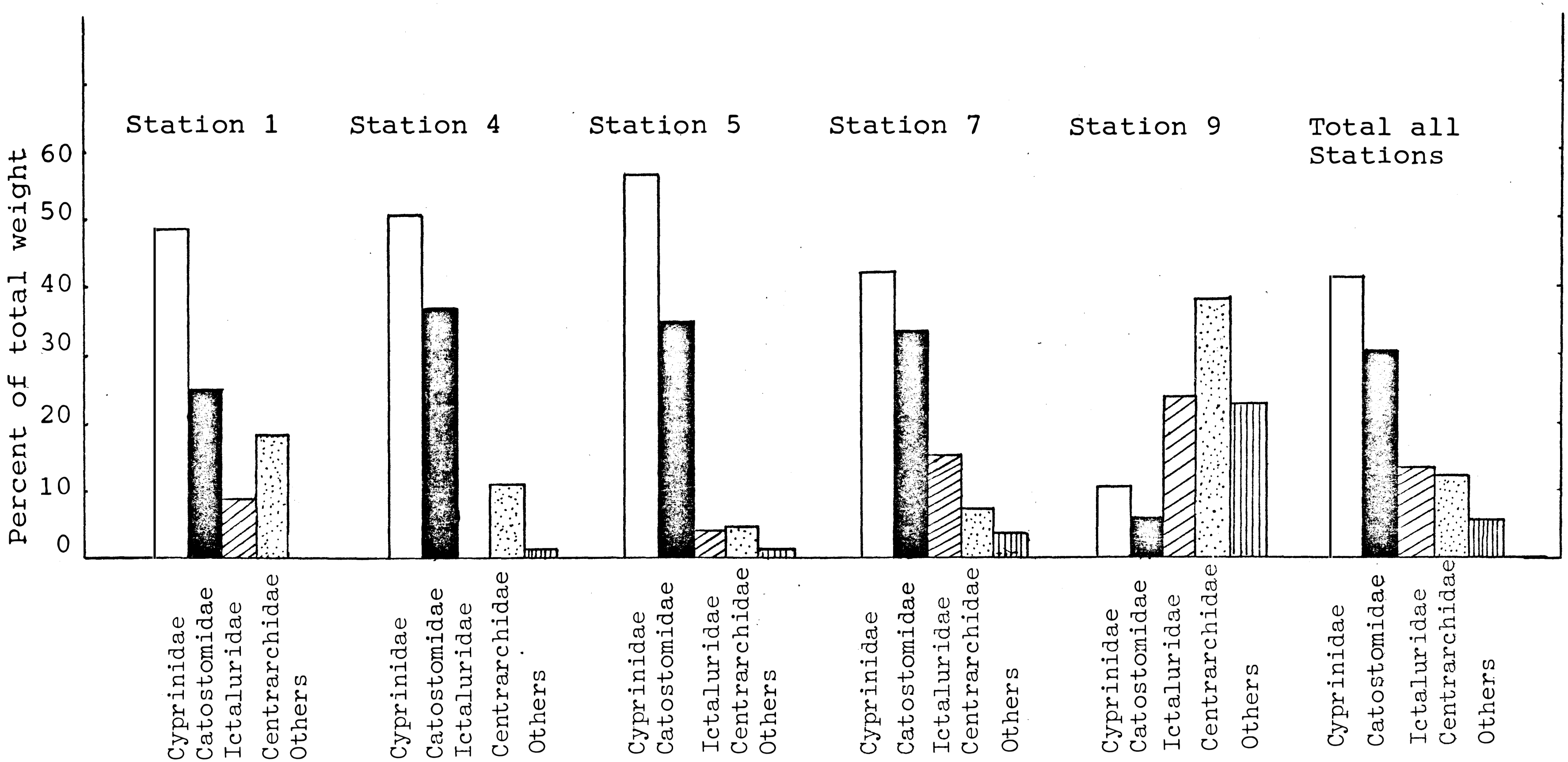

Figure 5. Percent of the total weight of fishes from five groups, Kickapoo Creek, Coles County, Illinois. "Others" includes Percidae, Cyprinodontidae, Clupeidae and Esocidae.

Table 5. T-test (Hutcheson 1970) results from a station to station comparison of community and biomass diversity values of the fishes of Kickapoo Creek, Coles County, Illinois. Community diversity t-test values are given in the lower right half of the table and biomass diversity t-test values are given in the upper right half.

Station	Station 1	Station 4	Station 5	Station 7	Station 9
1	– –	t= 2.0217 S.D.	t= 6.2501 S.D.	t= 28.1612 S.D.	t=10.6302 S.D.
4	t= 1.9278 S.D.	– –	t=10.7218 S.D.	t=43.5277 S.D.	t=16.0587 S.D.
5	t= 1.6645 N.S.D.	t= 0.6975 N.S.D.	– –	t=31.8806 S.D.	t= 5.9440 S.D.
7	t= 5.0066 S.D.	t=12.6600 S.D.	t=16.3733 S.D.	– –	t=22.3993 N.S.D.
9	t= 2.4119 S.D.	t= 4.8635 S.D.	t= 4.7952 S.D.	t= 1.5851 N.S.D.	– –

S.D. = Significant Difference
N.S.D. = No Significant Difference
(P = 0.05 one tailed tests)

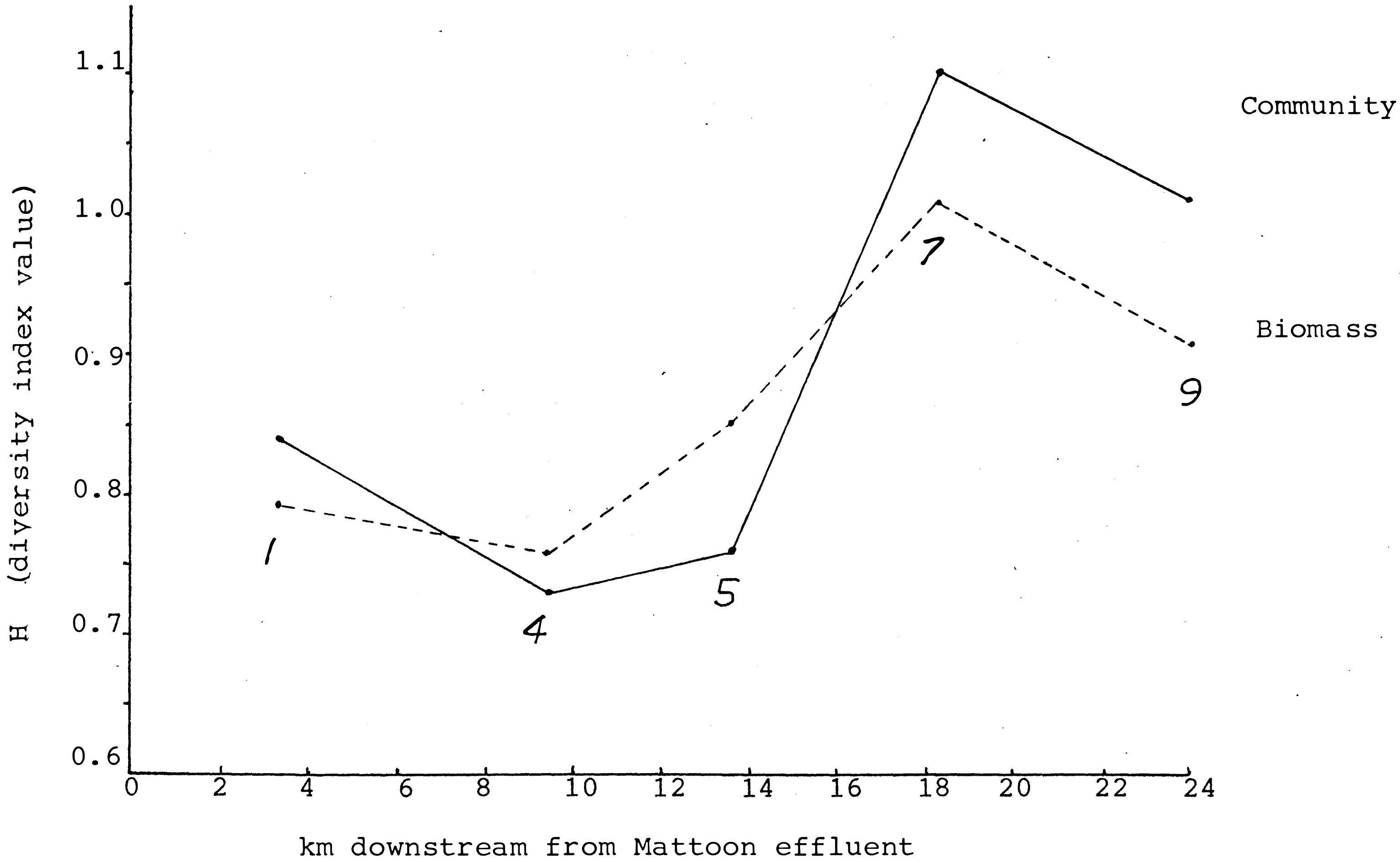

Figure 6. Community and biomass diversity index values for the fishes of all collecting stations, Kickapoo Creek, Coles County, Illinois, shown in relation to the Mattoon effluent.

Table 6. Distribution of macroinvertebrates collected from Kickapoo Creek, Coles County, Illinois.

Taxon	Number per station						Total all stations
	1A	1	4	5	7	9	
Nematomorpha							
Gordioidea	-	-	-	3	-	-	3
Annelida							
Oligochaeta	P*	P	P	P	P	P	-
Hirudinea							
Glossiphoniidae							
Placobdella	-	-	-	-	1	-	1
Erpodellidae	-	-	-	2	2	-	4
Arthropoda							
Insecta							
Collembola							
Sminthuridae							
Sminthurides	-	-	1	-	-	-	1
Ephemeroptera							
Siphlonuridae							
Isonychia	-	-	-	9	19	4	32
Baetidae							
Baetis	-	-	16	5	7	5	33
Callibaetis	-	5	-	-	1	-	6
Pseudocloeon	-	-	7	8	3	3	21
Heptageniidae							
Heptagenia	-	-	-	-	-	1	1
Heptagenia diabasia	-	-	-	-	3	-	3
Stenacron	-	-	8	3	3	2	16
Stenacron interpunctatum	-	-	52	8	13	10	83
Stenonema (pulchelum group)	-	-	-	4	6	1	11
Stenonema terminatum	-	-	-	-	4	-	4
Tricorythidae							
Tricorythodes	-	-	-	-	-	1	1
Caenidae							
Caenis	-	-	3	16	5	1	25
Ephemeridae							
Hexagenia	-	-	-	5	1	1	7
Odonata							
Libellulidae	-	-	-	-	-	1	1
Plathemis lydia	8	8	-	1	-	1	18
Calopterygidae							
Calopteryx maculata	-	-	14	37	38	4	93
Coenagrionidae	4	70	1	10	-	-	85
Anomalagrion hastatum	2	6	1	-	-	-	9
Argia	-	1	16	27	53	15	112
Enallagma	2	12	2	-	-	-	16
Ischnura	16	36	2	-	36	7	97
Plecoptera							
Perlidae							
Perlesta placida	-	-	-	-	4	-	4

Table 6. Continued.

Taxon	1A	1	4	5	7	9	Total all stations
	Number per station						
Hemiptera							
Veliidae							
Microvelia	-	1	7	-	4	-	12
Gerridae	-	1	-	1	1	-	3
Gerris	5	2	1	2	1	1	12
Metrobates	-	-	-	-	-	1	1
Rheumatobates	-	-	-	-	2	3	5
Trepobates	-	-	1	-	1	1	3
Corixidae							
Hesperocorixa	-	1	-	-	-	-	1
Sigara	-	15	-	1	1	6	23
Trichoptera							
Hydropsychidae	-	-	1	-	1	-	2
Cheumatopsyche	-	-	26	41	48	5	120
Hydropsyche	-	-	-	-	3	-	3
Hydropsyche simulans	-	-	1	5	19	12	37
Symphitopsyche bifida complex	-	-	-	-	1	-	1
Hydroptilidae							
Hydroptila	-	-	1	-	-	-	1
Coleoptera							
Gyrinidae							
Dineutus	-	2	-	1	-	2	5
Gyrinus	-	-	-	-	-	3	3
Haliplidae							
Peltodytes	-	4	-	-	-	-	4
Dytiscidae							
Laccophilus	-	4	1	1	-	-	6
Hydrophilidae							
Enochrus	-	2	-	-	-	1	3
Tropisternus (larvae)	-	-	-	1	-	-	1
Tropisternus lateralis	-	1	1	-	-	2	4
Tropisternus natator	-	1	-	2	-	-	3
Dryopidae							
Helichus	-	-	1	1	8	2	12
Elmidae							
Ancyronyx variegata	-	-	-	-	3	-	3
Dubiraphia (larvae)	-	-	-	-	2	-	2
Dubiraphia vittata	-	-	-	2	3	-	5
Macronychus glabratus	-	-	-	-	10	1	11
Stenelmis	-	-	2	1	12	-	15
Heteroceridae							
Heterocerus	-	-	-	-	-	1	1
Diptera							
Tipulidae	-	-	-	3	-	-	3
Tipula	-	-	2	5	6	1	14
Simuliidae							
Simulium	-	-	28	11	17	-	56
Chironomidae	32	50	73	83	56	22	316

Table 6. Continued.

Taxon	Number per station						Total all stations
	1A	1	4	5	7	9	
Stratiomyidae	-	-	1	-	-	-	1
Empididae	-	-	1	2	-	-	3
Crustacea							
Isopoda							
Asellidae							
<u>Asellus</u>	-	-	-	-	31	-	31
Amphipoda							
Talitridae							
<u>Hyalella azteca</u>	-	-	1	1	1	-	3
Gammaridae							
<u>Crangonyx minor</u>	-	1	2	1	-	3	7
Decapoda							
Astacidae							
<u>Orconectes propinquus</u>	-	-	-	1	4	1	6
<u>Orconectes virilis</u>	-	5	2	3	-	1	11
Mollusca							
Gastropoda							
Ancylidae							
<u>Ferrissia</u>	-	-	-	-	3	-	3
Physidae							
<u>Physa</u>	-	19	1	4	20	2	46
Pelecypoda							
Sphaeriidae	-	-	-	-	-	1	1
Total individuals	69	247	277	310	457	130	1490
Total taxa	7	21	30	32	37	35	59

* P = Present. The exact number of Oligochaeta was impossible to determine due to breakage.

progression was made, with a maximum of 37 at Station 7. Station 9 did not conform to this trend but it had only 2 less taxa than did Station 7. Station 1A had an extremely depauperate fauna consisting of only 7 taxa.

The quality of taxa differed even more radically amoung the stations than did the quantity. Station 1A contained macroinvertebrates from only 4 orders. The most common forms were odonates and chironomids. Station 1 exhibited a greater variety of forms but many of these appeared to be pond species. The remaining stations were more conventional in their population structures. They contained a variety of forms and in general, resembled one another.

When a biotic index was applied to the usable arthropod data for the entire creek, a value of 3.01 was obtained (Table 7). Biotic index values for the individual stations ranged from 2.70 at Station 5, to 3.90 at Station 1A. Figure 7 illustrates the relationship of the Mattoon and Charleston effluents to the biotic index values of each station.

Table 7. Biotic Indices of six collecting stations on Kickapoo Creek, Coles County, Illinois, with a list of taxa used in their computation.

Taxon	Biotic Index Value (Hilsenhoff 1977)	Numbers per station						
		1A	1	4	5	7	9	Total all stations
Isonychia	2	–	–	–	9	19	4	32
Baetis	3	–	–	16	5	7	5	33
Callibaetis	3	–	5	–	–	1	–	6
Pseudocloeon	2	–	–	7	8	3	3	21
Heptagenia diabasia	3	–	–	–	–	3	–	3
Stenacron interpunctatum	3	–	–	52	8	13	10	83
Stenonema terminatum	2	–	–	–	–	4	–	4
Tricorythodes	2	–	–	–	–	–	1	1
Caenis	4	–	–	3	16	5	1	25
Hexagenia	2	–	–	–	5	1	1	7
Calopteryx maculata	1	–	–	14	37	38	4	93
Anomalgrion hastatum	3	2	6	1	–	–	–	9
Enallagma	4	2	12	2	–	–	–	16
Ischnura	4	16	36	2	–	36	7	97
Perlesta placida	2	–	–	–	–	4	–	4
Cheumatopsyche	4	–	–	27	41	48	5	121
Hydropsyche simulans	3	–	–	1	5	22	12	40
Symphitopsyche bifida complex	3	–	–	–	–	1	–	1
Hydroptila	3	–	–	1	–	–	–	1
Helichus	1	–	–	1	1	8	2	12
Ancyronx variegata	1	–	–	–	–	3	–	3
Dubiraphia vittata	3	–	–	–	2	5	–	7
Macronychus glabratus	1	–	–	–	–	10	1	11
Stenelmis (larvae)	3	–	–	–	–	9	–	9
Empididae	4	–	–	1	2	–	–	3
Tipula	2	–	–	2	5	6	1	14
Asellus	5	–	–	–	–	31	–	31
Hyalella azteca	4	–	–	1	1	1	–	3
Total number		20	59	131	145	278	57	690
Biotic Index		3.90	3.81	2.98	2.70	2.99	2.81	3.01

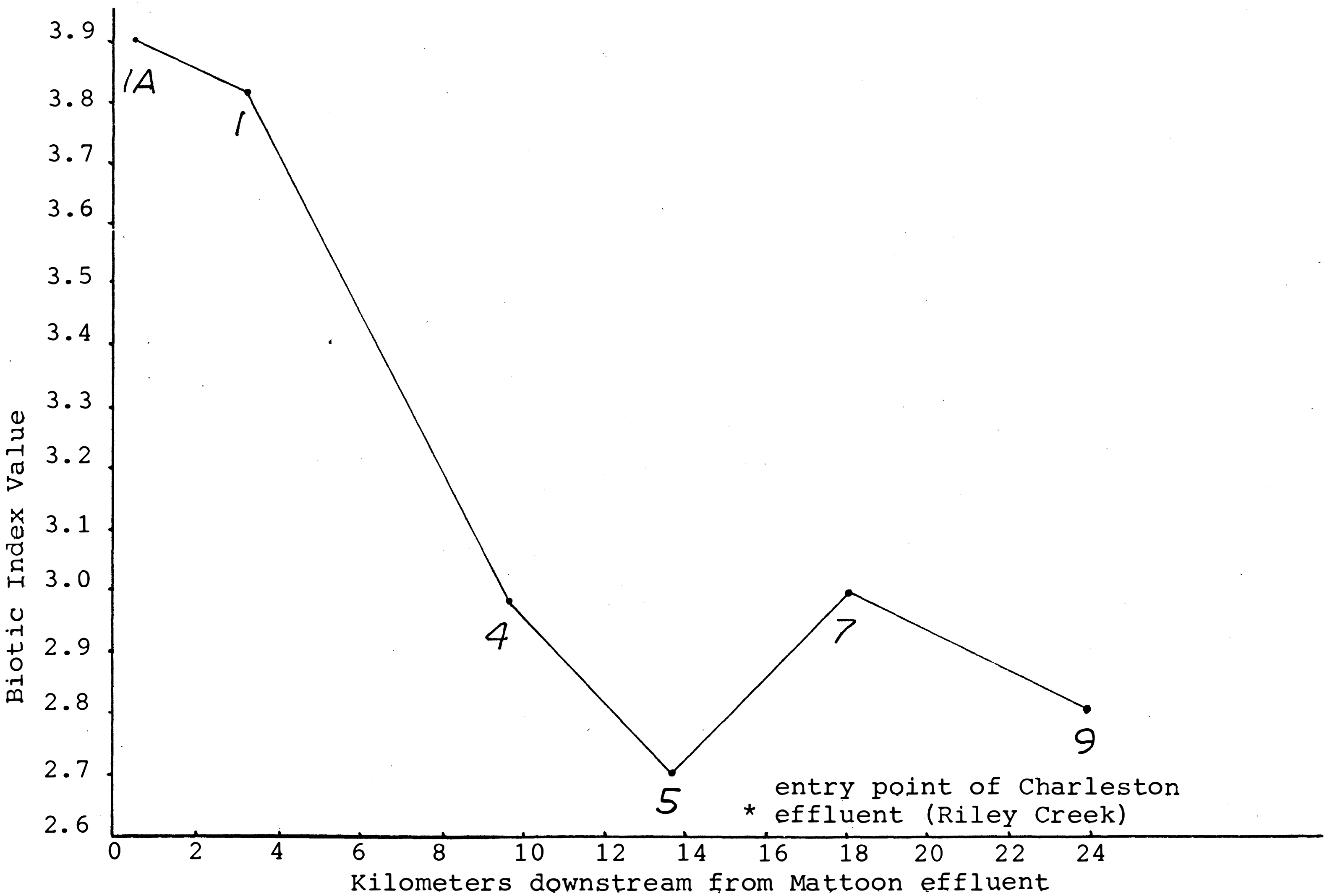

Figure 7. Biotic Index Values for collecting stations on Kickapoo Creek, Coles County, Illinois, shown in relationship to the Mattoon and Charleston effluents.

Discussion

I. Fishes

Application of the Shannon diversity index to the fish data collected in 1967-70 by Durham and Whitley (1971) yielded a value of 0.9891. A t-test comparing the diversity values of the two study periods indicated that the fish community was significantly (p=<005) more diverse in 1978 than in 1967-70. Since hoop netting was added as a method of fish capture in the present study, it was possible that this change in procedure was responsible for the difference in diversity. To discount this possible bias, another t-test was conducted omitting the hoop net data. A t value of 2.2538 with infinite degrees of freedom was obtained. Again, the fish community of 1978 was significantly (p=<0.05) more diverse than it was in 1967-70.

It is widely agreed that the diversity of a given community of stream organisms increases as distance from a pollution source increases (Stein and Denison 1967, Wilhm and Dorris 1968). Basically, low diversities exist near a pollution source because pollutional conditions create a very restricted habitat that is advantageous to the survival of a few species while causing the elimination of many others. A large number of individuals belonging to only a few species is the result of this habitat alteration and a highly predictable, and hence, poorly diversified community is formed.

As successive communities or organisms act upon pollutants, the limiting effects of those pollutants are usually nullified and once again a clean water community exists. Clean water environments contain a greater variety of habitats and may support many species. Typically, a few species with many individuals and many species with a few individuals are present. This results in more uncertainty within a community and yields a greater diversity.

In a stream the size of Kickapoo Creek, however, other factors besides pollution are likely to influence the species diversity of the fish community. The relationship between stream order (Horton 1945) and fish diversity has to be seriously considered. Stream order is a consistent method of characterizing drainage systems. Unbranched headwater tributaries are classified as first order streams. The confluence of 2 first order streams creates a second order stream; 2 second order streams may join and form a third order stream and so on. Although much depends on mean annual precipitation, an idea of the relative size and character of the drainage basin can be gleaned from stream order. It has been observed that the degree of fish diversity is directly proportional to increases in stream order (Harrel et al. 1967). Apparently, the unstable physical conditions of a low order stream are too rigorous for the survival of all but the hardiest species. This allows for the occurrence of large numbers of individuals belonging to only a few headwater species and results in a low diversity.

In Kickapoo Creek's case, it would be unwise to attribute the fish diversity pattern to anything other than stream order if it were not for the fact that fish were entirely absent from Station 1A. Although only classed as a second order stream at this location, the constant water supply provided by the Mattoon sewage effluent counteracts the unstable water conditions that this section of creek would normally have. Certainly, several headwater adapted species would find this area suitable were it not for the pollution in the Mattoon effluent.

Unlike Station 1A, the species diversity of fish at Station 1 was substantially higher than what would normally be expected at such a location, given the limiting effects of stream order and pollution. This brings to focus another physical influence on fish diversity: depth of water. Sheldon (1968) found that depth was even more of a factor than was stream order on the diversity of small stream fishes. He found that an increase in depth produced greater species diversity regardless of position in the stream order. Station 1 exhibits a greater average depth than do Stations 4 and 5. This is due to a low concrete dam located in the center of the station. It is apparent that this dam accounts for the aberrantly high fish diversity present at this station because of the increased depth and the resulting expansion of habitats it creates.

The gradual increase in fish diversity as downstream progression was made leveled off at Station 7. It would be difficult to determine if the significantly greater diversities at Station 7 and 9 were due to an improved water quality or to the increased stream order (these stations are in the fifth stream order). The number and variety of species found in this section of creek compared favorably with the fish composition of similarly sized, unpolluted Illinois streams (Lewis and Elder 1953, Lewis 1957, Stegman 1959, and Buth 1974). Although no studies were found in the literature that were comparable to this one, it appears that the diversity of fish communities of Stations 4 through 9 approached a normal situation.

The species composition of the fishes of Kickapoo Creek, although not directly related to species diversity, had also changed since the Durham and Whitley (1971) study. Six species taken in 1967-70, Icthyomyzon castaneus, Pimephales vigilax, Labidesthes sicculus, Etheostoma caeruleum, E. flabellare, and E. nigrum were not encountered in the present study. None of these species were very common in 1967-70; together they comprised only 0.52% of the total population. With the possible exception of Pimephales vigilax, which composed 0.38% of the population, the failure of members of these species to be recaptured in the present study was most likely due to random sampling error. P. vigilax was listed by Smith (1971) as being decimated in Illinois due to desication of streams during drought periods. Its absence from Kickapoo Creek in 1978 may reflect a continued reduction of this species from the area.

Eight species, Esox americanus, Moxostoma anisurum, Pylodictus olivarus, Lepomis humilis, L. microlophus, Micropterus salmoides, Pomoxis nigromaculatus, and Etheostoma spectabile were collected in this study but not in 1967-70. Moxostoma anisurum, Micropterus salmoides, and Etheostoma spectabile were common enough in 1978 to suggest that random sampling error was not a factor in their absence from the earlier collections. In addition to these new species, Moxostoma macrolepidotum and Hypentelium nigricans were much more abundant in 1978 than in 1967-70. Cyprinus carpio and Erimyzon oblongus, however, were more common in 1967-70 than they were in the present study. Trautman (1957) stated that Moxostoma anisurum, M. macrolepidotum, and Hypentelium nigricans were intolerant of domestic and industrial wastes. He and Smith (1979) agreed that Cyprinus carpio was often associated with sewage effluents and showed a preference for organically enriched waters. Darters (Percidae) and black bass (Micropterus) were believed to be indicators of clean water in Lytle Creek, Ohio by Katz and Gaufin (1953). A substantial increase in abundance of these species was seen in 1978 collections over those of 1967-70.

The preceding observations seem to indicate a trend toward a fish community that is generally less tolerant of pollution than was the 1967-70 community. Possibly, the tertiarily treated sewage effluent now produced by both cities has allowed this to occur. Thompson and Hunt (1930) and White, et al. (1977), cite instances in which they believed that sewage effluent appeared to enrich fish populations in number and size of individuals. Larimore and Smith (1963) agree but warm that there is a fine line between desirable enrichment and harmful pollution. According to the latter authors, enrichment becomes undesirable when the following sequence occurs in the fish community: (1) a reduction in the total number of species, (2) a reduction of the total weight, and (3) a reduction in the number of individuals.

Several of these trends appeared to be evident in the upper reaches of Kickapoo Creek. Etheostoma spectabile was absent from Station 1 but was common at Stations 4, 5, and 7. Poor water quality seemed to be the only factor responsible for the absence of this headwater species from the upper creek. Ericymba buccata, Notropis stramineus, and Phenacobius mirabilis were other species present in the creek that would be expected to be found in an area such as Station 1 but were not. Few individuals as well as few species were taken at Station 1 while at the next station downstream this situation improved. Oddly enough, fish at Station 1 had the highest average weight of any station. Possibly the sewage enriched water produced a more abundant food supply. This appeared to be the only benefit of the sewage effluent to the fishes of that station.

II. Macroinvertebrates

By their nature, macroinvertebrates are superior to fish for use in the evaluation of aquatic ecosystems. The most important advantage over fish comes from the fact that aquatic macroinvertebrates are seldom very mobile and cannot easily avoid pollution by moving up or downstream. They also form more recognizable species associations when confronted with environmental stresses such as sewage effluents. In addition to these associations, individual species have been designated as "indicator" organisms which may be classified as tolerant, facultative, or intolerant of a given type of pollution.

The use of indicator organisms in the assessment of water quality has serious drawbacks. Gaufin and Tarzwell (1956) placed little confidence in the ability of a few organisms found in a given locality to express the true water quality of an ecosystem. Many factors may account for the presence of an individual organism. In streams, species indicative of a clean environment may drift down into a polluted area from a clean upstream habitat and cause misinterpretations. Also, "tolerant" species are often found in water of very good quality which would cause other complications. It is now generally believed that water quality should be ascertained from associations or communities of macroinvertebrates (Wilhm and Dorris 1968).

The diversity index, as applied to fish in this study, takes into account information on the variety as well as the abundance of individuals in a community. Although excellent results can be obtained under certain circumstances, this system also has its drawbacks. Infertile streams will produce very low macroinvertebrate diversities even though they may be unaltered by pollution. Stream order has been found to influence macroinvertebrate diversities (Harrel and Dorris 1968), although less substantially so than on fish populations. When fast evaluations are desired, conducting diversity indices would be an inconvencience because of the involved mathematics which usually requires the use of a computer. Also, identifications in theory, should be made to the species level which is often nearly impossible.

A biotic index, such as the one proposed by Hilsenhoff (1977), incorporates the most useful characteristics of both the diversity index and the indicator organism concept while being fast and easy to conduct. This particular biotic index utilizes arthropods that are strictly dependent on the aquatic environment for survival and have limited powers of locomotion. In this way those aquatic arthropods which can utilize atmospheric oxygen or can easily move from one area to another to escape pollution are excluded from the index. Many Hemiptera, adult Coleoptera and Decapoda fit this description. Suitable organisms are assigned a numerical value indicating their tolerance of pollutional conditions. A value of 5 would imply that the arthropod could withstand extremely severe pollution while a value of 0 would mean that only the cleanest water could be tolerated. In this way an entire community can be evaluated with weight given to more common species so that rare forms, which may represent aberrations, will not be of enough importance to cause misconceptions. A calculation simple enough to be used in the field will yield the biotic index value for the community in question. Values are then interpreted into water quality parameters with the use of a table (Appendix B).

Biotic index values of the six macroinvertebrate sampling stations on Kickapoo Creek were influenced strongly by the Mattoon and, to a lesser extent, by the Charleston sewage effluents. Stations 1A and 1 are placed in the "very poor" category indicating that their macroinvertebrate communities were severely altered by the Mattoon effluent. A gradual improvement is evident as distance from this effluent is increased. The lowest biotic index value on the creek was reached at Station 5. This, however, was only a "fair" rating. This indicates that the creek does not totally recover from the effects of the Mattoon effluent before the Charleston effluent enters at the confluence of Riley Creek.

It should be noted that the Hilsenhoff biotic index was designed for use in Wisconsin. Due to climatic and physical differences between this area of Illinois and Wisconsin, the index may be too stringent for literal use in this area. Hence, Station 5 might possibly be rated higher than "fair."

Charleston's sewage effluent is modified by several kilometers of passage through Cassel and Riley Creeks before entering Kickapoo Creek. Therefore, Station 7 exhibited only a slight degradation of water quality from that of Station 5. Again, recovery continues at Station 9 so that water entering the Embarras River from Kickapoo Creek is of a "fair" quality.

Conclusions

The analysis of the fish population of Kickapoo Creek indicates that water quality conditions have improved since the initiation of tertiary sewage treatment methods by the cities of Mattoon and Charleston. While the creek near the Mattoon sewage treatment plant outfall still does not support fish, the previously septic conditions no longer exist. Although probably attributable to several factors, an increase in the diversity, and thus an increase in quality of the fish population is apparent as downstream progress is made. The Charleston sewage effluent seems to have no measurable effect on the fishes of the creek. From the area of recovery from the Mattoon effluent on the fish population approahces an unaltered condition.

Macroinvertebrates proved to be a more suitable group with which to ascertain the water quality of the creek. This community displayed greater sensitivity to degrees of pollution than did the fishes. The community structure of macroinvertebrates appears to be influenced to some extent by the sewage effluents for the entire length of the creek. Periodic overflows of inadequately treated sewage during heavy rains probably accounts for much of the damage done to the macroinvertebrate community structure. Should this problem be resolved, an improvement from the current "fair" water quality rating of Kickapoo Creek should be noticed.

Appendix A

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Appendix B

The Hilsenhoff (1977) Biotic Index assigns selected stream dwelling arthropods a value from 0 to 5. A value of 0 would indicate that the organism is found only in streams of the highest water quality while a value of 5 would mean that the organism is capable of surviving in severely polluted water. The following table correlates Biotic Indices to water quality and is taken directly from Hilsenhoff (1977).

Table 6. Water quality determination from biotic index values.

Biotic Index	Water Quality	State of the Stream
1.75	Excellent	Clean undisturbed
1.75-2.25	Good	Some enrichment or disturbance
2.25-3.00	Fair	Moderate enrichment or disturbance
3.00-3.75	Poor	Significant enrichment or disturbance
3.75	Very Poor	Gross enrichment or disturbance

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