Benthic Macroinvertebrates as Indexes of Water Quality in the Upper Cuyahoga River[1]

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ABSTRACT. The upper Cuyahoga River in northeastern Ohio is the major source of domestic water for the City of Akron, an important recreational area, and a designated Ohio Scenic River. Indexes of water quality based on benthic invertebrate community composition indicate a wide range in water quality along the river, but overall water quality is relatively high compared to areas of the Cuyahoga River below Akron and to most nearby river systems. Highest quality areas are located in the most headwater region and in the lowermost region near Lake Rockwell. These areas are characterized by a large number of taxa (>50), moderate density of organisms ($\cong 2{,}000/m^2$), high ratios of scraper-grazers to detritivores (>0.5), high ratios of amphipods to isopods, and less than 1% organic pollution-tolerant organisms. Moderate degradation of water quality due to organic sedimentation in these areas is indicated by large proportions of organic pollution-facultative organisms (27-66%), especially a great variety of chironomids. Lowest quality areas occur 1-2 km below wastewater outfalls from small villages and below groups of rural streamside dwellings. These areas are characterized by up to 62% fewer species, very low ratios of amphipods to isopods (usually <2), and large proportions of organic pollution-facultative and tolerant organisms (43-95%), especially chironomids and oligochaetes.

OHIO J. SCI. 88 (3): 91-98, 1988

INTRODUCTION

The upper Cuyahoga River in northeastern Ohio is the major source of domestic water for the City of Akron, an important recreational area, and a designated Ohio Scenic River (Ohio Department of Natural Resources 1968). Water quality is monitored periodically by the City of Akron for selected chemical-physical and bacteriological characteristics. Complete reliance in the future upon this system of water quality monitoring may be inadequate because of the growing importance of the river for recreational activities and because of the increasing potential for inadequately controlled waste discharges from industrial and domestic developments within the watershed.

The use of natural benthic macroinvertebrate assemblages is one of the best understood, most convenient, and most economical water quality monitoring systems, and can be used to complement chemical-physical moni-

[1]Manuscript received 12 March 1987 and in revised form 13 July 1987 (#87-12).

toring of water quality (Hynes 1960, Hawkes 1979, Lenat et al. 1980, Tesmer and Wefring 1981). A major advantage of this system is that benthic macroinvertebrates continuously "monitor" water quality and reflect long-term water quality conditions. Assessments of water quality based on benthic macroinvertebrates were conducted at Hiram Rapids near the mid-reach of the upper Cuyahoga River in 1973-74 (Olive 1976) and 1980 (Trauben and Olive 1983). An assessment also was conducted in the downstream reach near Lake Rockwell in 1984 (Ohio Environmental Protection Agency 1984). We report here the results of a benthic macroinvertebrate assessment of water quality in 1986 from nine areas along the upper Cuyahoga River, including the two areas that were addressed in the previous studies.

THE STUDY AREA

The Cuyahoga River is located in northeastern Ohio and is a small tributary of Lake Erie (Fig. 1). The upper Cuyahoga River extends from its origin in Geauga County south to Lake Rockwell in Portage County near Kent, Ohio, a distance of approximately 57 km. According to the Horton-Strahler geomorphological system (Strahler 1964) for classifying drainage basins, most of the upper river can be assigned second-order status, if the East and West Branches are regarded as first-order streams. The river within the study area varies in width from a few meters in headwater reaches to approximately 30 m in downstream areas. Maximum water depths vary from less than 1 m in headwater areas to 2-3 meters at various locations downstream. The long-term annual average discharge at Hiram Rapids is 5.8 m^3 per sec.

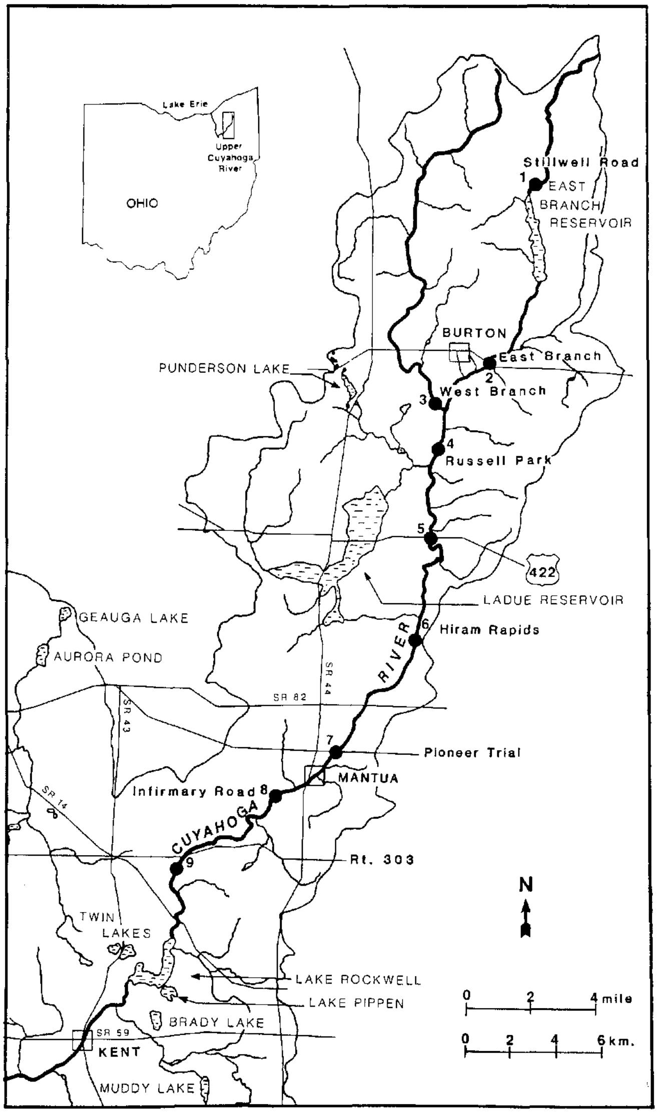

FIGURE 1. Map of the upper Cuyahoga River, Ohio showing locations of sampling stations for benthic macroinvertebrates and for chemical-physical data on water quality.

The gradient of the upper river is gentle, and the stream has extensive swampy and lentic-littoral habitats. The major biotopes are runs with eroding substrates of clay, sand, and gravel in midstream and depositional substrates of decomposing organic matter along the stream margins. Poorly developed riffles occur only in short segments of the headwaters, in the mid-reach, and in the lowermost part of the study area. The stream banks are well-forested in most areas, but eroding soils from cleared lands beyond the forest may be a pollutant. Untreated and inadequately treated organic wastes from several villages, small businesses, and rural housing along the river may be sources of pollution.

Average annual precipitation varies in the study area from 117 cm at East Branch Reservoir to 91 cm near Lake Rockwell. Annual variation in snowfall is considerable. Average seasonal snowfall is 287 cm at East Branch Reservoir and decreases to about 152 cm at Lake Rockwell. Total precipitation is well distributed throughout the year, with about half the precipitation falling during the months of April through August. In a typical year there will be at least 2.5 cm of snow on the ground for 43 d (Williams and McCleary 1982, Ritchie et al. 1978).

Akron owns three reservoirs and manages approximately 6,700 ha of the 53,600-ha watershed of the upper Cuyahoga River for its domestic water supply. The reservoirs supply an average of 178,000 m^3 of water per d. Groundwater is an abundant resource in the study area. The principal aquifers are the Sharon Sandstone and outwash gravels (Stout et al. 1943, Winslow and White 1966, Rau 1968).

The Sharon Sandstone dips to the south about 0.5 m per km; the Cuyahoga River flows on the sandstone much like a consequent stream. The Sharon is well described by Fuller (1947, 1955), Heimlich et al. (1970), and Coogan et al. (1974). Glacial derangement of earlier drainage systems produced the present direction of flow in the study area. Where the river flows over buried valleys, the floodplain is wider, and the stream gradient is less than where the river flows on bedrock. Local variations in stream characteristics affect water quality. Water of excellent quality for domestic and industrial use is available in large amounts from surface runoff, glacial outwash, and the Sharon Sandstone in the area. Other rock units in the study area are tapped for ground water, but production per well and quality of the water are lower in these units than in the Sharon Sandstone and outwash (White 1982).

METHODS

Nine sampling stations were established along the upper Cuyahoga River extending from Stillwell Road (No. 1) above East Branch Reservoir downstream to Route 303 (No. 9) near Lake Rockwell (Fig. 1). Sampling stations were approximately equally spaced to ensure representative coverage of the stream. Convenient access to the river also was a factor in the selection of sampling areas. The designated name, number, nearest access road, and geographic location for each station are given in Table 1.

CHEMICAL-PHYSICAL ANALYSES. Water samples for selected chemical-physical analyses were collected at approximately biweekly intervals during 1986. Hydrogen ion activity (pH), conductivity, and total hardness were determined to provide an index of potential biological productivity. Hydrogen ion activity was determined within 2 h of sample collection with a pH/ion meter. Conductivity was measured with a conductivity meter (Yellow Springs Instruments, Model 31). Total hardness was determined by the EDTA titrimetric method (American Public Health Association 1985). Ammonia was selected as an index of decomposing organic matter. Total ammonia was determined within 2 h of collection by direct Nesslerization (American Public Health Association 1985).

Chlorides were selected as an indicator of potential road salt and brine pollution. The mercuric nitrate method was used for determining chloride levels (American Public Health Association 1985). Dissolved oxygen concentrations were measured *in situ* with an oxygen meter (Yellow Springs Instruments, Model 57). Water temperatures were measured *in situ* with a mercury thermometer.

BENTHIC MACROINVERTEBRATE ANALYSES. Benthic macroinvertebrates were collected twice in 1986 from each station, once in late spring (April-June) and once in late summer (August-September). Results from the spring collection are reported here because late summer collections provided little additional information concerning water quality. Collections were made on the following dates in 1986: 4 April, Route 303; 7 April, Infirmary Road; 5 May, Hiram Rapids; 23 May, Stillwell Road; 2 June, Pioneer Trail, Russell Park, East Branch; 4 June, Route 422, West Branch. Although seasonal differences occur in benthic macroinvertebrate communities, longitudinal and water quality differences are more dramatic (Olive and Smith 1975, Hawkins and Sedell 1981).

To determine the number of benthic samples required for estimating the number of taxa at each station, the results of a previous study on the upper Cuyahoga River (Pliodzinkas 1973) were used. At a 20% level of precision, seven sample units were required from this relatively species-rich area (Elliott 1977). Although most areas along the river would not have required this many samples, at least six sample units of 0.05 m^2 each were taken from each station. Because of the low gradient of the river, the primary biotopes at each station were runs with eroding substrates in mid-river and depositional substrates along the river margins. At Stillwell Road and Route 303, the runs approached the characteristics of a riffle, resulting perhaps in slightly biased results. Because substrate-type is an important determinant of benthic community structure (Minshall 1984), similar substrates were sampled at each station. The upper Cuyahoga River is relatively shallow so all samples were taken with a modified shovel sampler (Prater et al. 1977). This device is very efficient for collecting surface-dwelling and hyporheic organisms.

Benthic macroinvertebrates were separated from substrates by agitating the samples in water to suspend the organisms. The suspended organisms were strained from the water with a U.S. Standard No. 30 soil sieve.

Organisms and residual debris retained in the screen were placed on ice. Within 24 h after collection, the organisms were hand-picked, sorted into major taxonomic groups and preserved in 75% ethanol. The organisms were identified from standard taxonomic keys (e.g. Pennak 1978, Merritt and Cummins 1984). A complete list of the taxa taken at each station is available from the senior author.

RESULTS AND DISCUSSION

CHEMICAL-PHYSICAL WATER CHARACTERISTICS. Selected chemical-physical water quality data for the upper Cuyahoga River are shown in Table 2. These data show that the entire upper river is neutral to slightly alkaline (mean pH range = 7.2-7.5), with moderate concentrations of dissolved solids as indicated by mean conductivity values of 219-302 μmhos/cm and mean total hardness levels of 88-107 mg/L as $CaCO_3$. Assuming that no toxic compounds contribute to hardness or conductivity, the river should be capable of moderately high biological productivity and suitable for most native aquatic life and most human cultural uses (U.S. Environmental Protection Agency 1986).

The levels of ammonia, a potential toxin and an indicator of excessive decomposing organic matter, were moderately high (range of maximum ammonia = 0.86-2.1 mg/L) in most areas during the summer. These levels may have been an important limiting factor for many aquatic species especially during summer when water temperatures and pH were maximum and dissolved oxygen levels were minimum. Under these conditions, un-ionized ammonia, the most toxic form, is most highly concentrated (U.S. Environmental Protection Agency 1986). The effects on aquatic life of excessive levels of ammonia may be most severe at Infirmary Road (No. 8) below the village of Mantua, Russell Park (No. 4), Hiram Rapids (No. 6), Pioneer Trail (No. 7), and East Branch (No. 2). Each of these areas is located near a suspected source of organic enrichment.

Chlorides were measured in the upper Cuyahoga River because expanding drilling operations for oil and gas increase the potential for pollution of the river with chloride-containing brines. As shown in Table 2, chloride levels currently are relatively low (mean chloride range = 19-29 mg/L), and do not exceed background levels for soil water in the region.

Dissolved oxygen levels in the upper Cuyahoga River ranged from 2.8 to 14 mg/L (Table 2). It is generally recognized that dissolved oxygen levels should not fall below 5 mg/L at any time because dissolved oxygen is a major factor in protecting the aesthetic qualities of water

TABLE 1

Location data for benthic macroinvertebrate sampling stations along the upper Cuyahoga River, Ohio.

Station No.	Station Designation	Distance from Lake Rockwell (km)	Access road	Longitude deg	Longitude ′	Longitude ″	Latitude deg	Latitude ′	Latitude ″	USGS 7.5′ topographic map
1	Stillwell Rd.	51	Stillwell Rd.	81	06	10	41	30	35	East Claridon
2	East Branch	41	Rt. 87	81	07	40	41	27	50	Burton
3	West Branch	39	Rapids Rd.	81	09	30	41	27	00	Burton
4	Russell Park	36	Rapids Rd.	81	09	15	41	25	40	Burton
5	Route 422	31	Rt. 422	81	09	27	41	23	10	Burton
6	Hiram Rapids	25	Winchell Rd.	81	10	00	41	20	26	Mantua
7	Pioneer Trail	19	Pioneer Trail	81	12	06	41	18	00	Mantua
8	Infirmary Rd.	13	Infirmary Rd.	81	14	45	41	16	07	Mantua
9	Route 303	9	Rt. 303	81	17	18	41	14	36	Kent

TABLE 2

Chemical-physical water data for the upper Cuyahoga River, Ohio, January-December 1986. N, number of analyses; $\bar{x}$, mean; Min, minimum value; Max, maximum value; SE, standard error.

	1 Stillwell Rd.*	2 E. Branch	3 W. Branch	4 Russell Pk.	5 Rt. 422*	6 Hiram Rapids	7 Pioneer Tr.	8 Infirmary Rd.	9 Rt. 303
pH (units)									
N	5	21	23	23	9	26	26	25	26
$\bar{x}$	7.6	7.3	7.5	7.3	7.5	7.2	7.4	7.5	7.4
Min	7.1	5.6	5.5	5.7	6.9	5.2	5.3	5.3	5.5
Max	8.0	8.1	8.5	8.1	8.3	8.1	8.2	9.1	8.5
SE	.16	.16	.15	.14	.39	.16	.15	.18	.17
Conductivity (μmhos/cm)									
N	3	18	18	21	8	21	21	20	20
$\bar{x}$	254	240	240	229	302	219	219	231	246
Min	202	145	125	135	228	140	140	140	150
Max	313	440	365	370	548	315	320	330	350
SE	32	19	18	16	37	11	11	12	14
Total Hardness (mg/L as $CaCO_3$)									
N		21	23	25		26	26	25	26
$\bar{x}$		101	103	88		96	92	101	107
Min	No data	62	48	46	No data	64	70	70	76
Max		142	156	118		142	118	160	148
SE		5	6	4		4	3	4	5
Ammonia (mg/L)									
N		20	23	25		26	26	24	26
$\bar{x}$		1.05	.45	.63		.6	.49	.51	.48
Min	No data	.5	.15	.16	No data	.21	.17	.16	.05
Max		2.0	.86	1.5		2.1	1.22	1.8	1.7
SE		.1	.04	.07		.08	.05	.07	.07
Chloride (mg/L)									
N	5	21	22	22	9	23	23	22	23
$\bar{x}$	19	24	27	27	29	24	24	24	27
Min	8	10	8	10	23	13	12	14	13
Max	28	72	51	61	43	46	45	36	46
SE	3.7	2.7	1.9	2.6	2.1	1.5	1.4	1.2	1.5
Dissolved oxygen (mg/L)									
N	4	22	25	25	6	27	27	25	27
$\bar{x}$	9.3	6.3	8.8	6.9	8.5	7.3	8.1	8.4	9.2
Min	6.8	2.8	5.7	3.3	6.2	3.6	3.7	5.0	5.6
Max	12.1	12.0	14	13.4	11.3	13.6	13.3	13	13.5
SE	1.1	.6	.5	.5	.8	.5	.5	.5	.5
Water Temperature (°C)									
N	4	27	27	27	6	27	27	27	27
Min	7.2	0	0	0	11.1	0	0	0	0
Max	21	27	25	28	22.5	26	25.5	26	27

*Data provided by the City of Akron Water Department.

and in maintaining aerobic aquatic communities. Dissolved oxygen levels fell below 5 mg/L at least once at East Branch, Russell Park, Hiram Rapids, and Pioneer Trail. This may be an important limiting factor for many species of aquatic life in these areas. Each of these areas is near a suspected source of oxygen-demanding organic wastes. As noted above, excessive levels of ammonia also occur in these areas, increasing the risk of damage to aquatic organisms from synergistic effects of low levels of dissolved oxygen and high levels of ammonia (Downing and Merkens 1955, Merkins and Downing 1957).

BENTHIC MACROINVERTEBRATE PARAMETERS. Approximately 146 taxa of macroinvertebrates were collected from the upper Cuyahoga River during the spring of 1986. Benthic insects accounted for about 86% of the taxa, mollusks 9%, and amphipods and isopods 2%. Oligochaetes, hirudineans, and turbellarians accounted for the remainder. In terms of numbers of individuals per taxon, a few chironomids, the isopod *Asellus,* and the amphipod *Hyalella azteca* were the most numerous in most areas of the river. Among insects, in addition to the chironomids, coleopterans and trichopterans accounted for the most taxa and the largest numbers of individuals per taxon. Typical riverine insects such as ephemeropterans, megalopterans, and plecopterans were few in number of taxa and number of individuals per taxon.

Four functional feeding groups including shredders, collectors, scrapers, and predators (Cummins and Merritt 1984) were present at each station. Approximately 80 to 90% of the organisms in most areas could be assigned to a particular functional group with a high degree of confidence. The remaining organisms of "uncertain status" were not included in data reduction calculations. Collectors, including gatherers and filterers, accounted for more than 50% of the organisms at each station except for Stillwell Road, the most upstream of all the sampling stations. The largest proportions of collectors occurred at Hiram Rapids (88%), Russell Park (74%), and Infirmary Road (71%). Shredders usually were the least abundant organisms, accounting for less than 7% of the organisms at each station. Scraper-grazers varied from less than 1% of the benthic community at Russell Park and Infirmary Road to greater than 20% at Stillwell Road, East Branch, and Route 303. Predators were relatively abundant at all stations, ranging from 6-22% of the benthic communities.

Table 3 shows for each station the number of taxa collected, the density of organisms, the ratio of scraper-grazers to detritivores (S-G/D), the ratio of amphipods to isopods (A/I), and the proportion of organisms that are intolerant, facultative, and tolerant of organic pollution. These measures of benthic community structure were selected because each can provide a useful index of water quality. Each is sensitive to changes in water quality that may be caused by human activity in the river system. Domestic sewage pollution, for example, is known to reduce the number of taxa and to increase the density of tolerant organisms (Hynes 1960, Hawkes 1979). Sewage pollution also eliminates predators, herbivorous shredders, and scraper-grazers while encouraging detritivores. Changes in proportion of various feeding groups will change S-G/D ratios. Silt from eroding soils, a common water pollutant in Ohio, usually reduces the density of organisms and the number of taxa, especially scraper-grazers, shredders, and predators. The A/I ratio is a useful indicator of organic pollution because amphipods and isopods are somewhat sympatric, but isopods feed more extensively on fine particulate organic matter and are more tolerant of habitats containing decomposing organic matter (Hynes 1960, Hawkes 1957, Watton and Hawkes 1984). Amphipod/isopod ratios therefore are maximum in unpolluted habitats. The A/I ratio is especially useful in the upper Cuyahoga River as an index of water quality because amphipods and isopods are most abundant in lotic-depositional and lentic-littoral habitats. These habitats are very common along the upper Cuyahoga River because of its natural low gradient.

The tolerances of benthic macroinvertebrates to decomposing organic wastes have been estimated and classified by various authors (e.g., Weber 1973, Hawkes 1979, Hilsenhoff 1977, Rabeni et al. 1985). Although there is general agreement for assigning organisms to a particular category, a small degree of overlap occurs for some groups, especially the chironomids. In the present study, all coleopterans, ephemeropterans, hemipterans, lepidopterans, megalopterans, plecopterans, and trichopterans were regarded as intolerant of organic pollution. Oligochaetes, hirudineans, chironomids of the genus *Chironomus,* and the snail *Physella* were assigned organic pollution-tolerant status. All other organisms were regarded as intermediate or facultative in their tolerance to organic pollution. This classification follows closely tolerance categories assigned to various macroinvertebrates by Hilsenhoff (1977) and Rabeni et al. (1985). These investigators used six and four categories, respectively; we used only three categories.

Numerous indexes of water quality have been derived from measures of benthic macroinvertebrate community structure (Hellawell 1978). There is no general agreement, however, as to which measures provide the best indexes for assessing water quality. Each has advantages and disadvantages. Criteria for relating index values to water quality levels also are not well established. Expected index values for undisturbed rivers are not well known because of differences associated with geographic location and natural variations in water quality between localities. Until recently, relatively few quantitative studies of benthic macroinvertebrates were attempted because of the effort and cost required for obtaining and processing quantitative samples, and because of uncertainties associated with available sampling techniques. Although quantitative studies are increasing, most rivers in agricultural-industrial regions have been severely affected by various pollutants. Therefore, it seldom is possible to determine what should be the "natural" number of taxa, density of organisms, or proportion of organic pollution-intolerant organisms. Values often are available for extreme headwaters of rivers in populated areas and for entire rivers in unpopulated areas of the world, but these values are not necessarily valid for all rivers.

TABLE 3

Measures of benthic macroinvertebrate community structure for nine locations along the upper Cuyahoga River, Ohio, April-June 1986.

Station						Tolerance to Organic Pollution***		
No.	Designation	No. taxa	Density (no./m^2)	S-G/D*	A/I**	Intolerant	Facultative	Tolerant
1	Stillwell Rd.	61	2400	1.2	No isopods	72	27	1
2	East Branch	36	970	.31	0.5	57	42	1
3	West Branch	38	700	.02	3.5	67	29	4
4	Russell Park	39	5500	.01	1.8	7	92	1
5	Route 422	52	4700	.03	1.6	22	75	3
6	Hiram Rapids	63	3600	.02	3.1	50	49	1
7	Pioneer Trail	47	1300	.3	5.3	43	44	13
8	Infirmary Rd.	24	900	.01	5.5	5	48	47
9	Route 303	58	2000	.5	No isopods	34	66	0

*Scraper-grazer to detritivore ratio
**Amphipod to isopod ratio
***Percent of total individuals

Sampling techniques, sample processing, and identification of organisms must be standardized before index values can be compared among river systems. This is especially important in Ohio, where the entire length of almost all streams is affected by human activities. The best that can be done is to obtain index values from headwater areas that are relatively undisturbed and then to compare these to index values from downstream sections of the stream. Although this method is the best available, proper account is not taken of the fact that biological characteristics differ between headwater and downstream areas even in undisturbed streams (Vannote et al. 1980, Hawkins and Sedell 1981).

To obtain a quantitative estimate of water quality in the upper Cuyahoga River, each measure of community structure was evaluated according to the criteria listed in Table 4. These criteria are based on published and unpublished benthic invertebrate assessments of water quality in the Cuyahoga River (Olive 1976, Trauben and Olive 1983, Ohio Environmental Protection Agency 1984) and nearby rivers in Ohio (Olive and Smith 1975, Ohio Environmental Protection Agency 1983). Based on the criteria shown in Table 4, relative values for each index of water quality are shown in Table 5. A composite score shown in the last column is the sum of all individual values. Stations were ranked according to the composite scores. It was assumed that composite scores are directly proportional to water quality. As described below, however, these scores may have been somewhat biased against stations with mostly depositional and lentic-littoral habitats.

An overview of the indexes of water quality from Table 5 indicated a wide range in water quality in the study area. Despite the wide range within the river system, overall water quality was relatively good compared to most downstream areas of the Cuyahoga River (Olive 1976, Trauben and Olive 1983). Composite scores indicated that the highest levels of water quality occur at Stillwell Road, Pioneer Trail, and Route 303. In most cases, these areas had a large variety of species, moderate densities of organisms, high A/I ratios, and, except for Pioneer Trail, high S-G/D ratios. Several genera of pollution-intolerant stoneflies and mayflies were present at each station. These indicators of water quality reflected minimal impact on water quality from pollution that could reduce the variety of species, greatly change the density of organisms, or favor detritivores over scraper-grazers.

Despite these indications of high quality water, the high proportion of facultative organisms occurring in these areas indicated substantial organic sedimentation. At Stillwell Road and Route 303, most facultative organisms were collector-gatherer chironomids such as *Orthocladius* and *Cricotopus,* which are normally associated with depositional habitats. This is especially important because most chironomids were collected from erosional habitats rather than depositional habitats, a further indication of excessive sedimentation. An assessment of water quality based on benthic macroinvertebrates at Route 303 was conducted in 1984 by the Ohio Environmental Protection Agency (1984). The results of this

TABLE 4

Criteria based on benthic macroinvertebrate community structure for establishing levels of water quality in the upper Cuyahoga River, Ohio.

Community structure characteristic	Relative index value 1	2	3	4	5
No. of species (or taxa)	0-10	11-20	21-30	31-40	>40
Density (no./m^2)	<500 or >4000		500-1000 or 2000-4000		1000-2000
A/I*	<1-1		1-2		>2
S-G/D**	<0.2	.2-.4	.4-.6	.6-.8	>.8
Organic pollution intolerant***	<20	21-40	41-60	61-80	>80

*Amphipod isopod ratio
**Scraper-grazer to detritivore ratio
***Percent of total organisms

TABLE 5

Indexes of water quality for nine locations along the upper Cuyahoga River, Ohio, April-June 1986. Qualitative values from 1 to 5 were derived from criteria shown in Table 4. Stations are ranked according to composite scores.

Station	No. taxa	Density (no./m^2)	S-G/D*	A/I**	Organic-pollution intolerant	Composite score
Stillwell Rd. (No. 1)	5	3	5	5	4	22
Rt. 303 (No. 9)	5	5	3	5	2	20
Pioneer Trail (No. 7)	5	5	2	5	3	20
West Branch (No. 3)	4	3	1	5	4	17
Hiram Rapids (No. 6)	5	3	1	5	3	17
East Branch (No. 2)	4	3	2	1	3	13
Infirmary Rd. (No. 8)	3	3	1	5	1	13
Rt. 422 (No. 5)	5	1	1	3	2	12
Russell Park (No. 4)	4	1	1	3	1	10

*Scraper-grazer to detritivore ratio
**Amphipod to isopod ratio

assessment were similar to the results reported here. In general, the same taxa, dominated by facultative chironomids, were noted in each study.

At Pioneer Trail, a sizeable proportion (13%) of the benthic organisms were organic pollution-tolerant oligochaetes and pulmonate snails, indicating excessive organic sedimentation. Pioneer Trail is located within a few kilometers of suspected sources of domestic farm animal wastes and domestic household wastes from streamside cabins.

Lowest water quality areas along the upper Cuyahoga River occurred at East Branch, Infirmary Road, Route 422, and Russell Park. The relatively low water quality ranking of these stations was the result of differing sets of conditions at each station. For East Branch, a moderate number of taxa, moderate density of organisms, and moderate proportion of pollution-intolerant organisms indicated relatively good water quality. However, the low A/I and S-G/D ratios and high proportion of facultative organisms indicated reduced water quality. As noted above, low levels of dissolved oxygen and excessive concentrations of ammonia occurred in this area during summer. The cause of these conditions probably was organic enrichment from Middlefield, a cheese-making business, and decomposing organic matter from an upstream swamp. Overall, water quality may be better than indicated by measures of benthic macroinvertebrate community structure. The absence of prominent erosional habitats in the East Branch area rather than poor water quality may have been an important factor contributing to the low number of taxa. The area has extensive substrates of clay and peat, both of which are poor substrates for benthic invertebrates (Minshall 1984).

Russell Park and Route 422 had large numbers of organisms and high proportions of detritivores and organic pollution-facultative organisms. Infirmary Road had relatively few taxa, a large proportion of detritivores, and a large fraction of organic pollution-facultative and tolerant organisms such as the chironomids, *Chironomus* and *Tanytarsus,* and the amphipod, *Hyallela azteca.* These conditions usually reflect organic enrichment (Hawkes 1979). These three areas have in common similar substrates and the potential for receiving untreated or poorly treated domestic organic wastes. Each also has a mid-stream run with clay, sand, and gravel substrates. These substrates are relatively unstable and generally poor habitat for benthic macroinvertebrates (Minshall 1984). The observed small variety of taxa, therefore, did not necessarily reflect poor water quality. River margins in these "lowest quality" areas are depositional habitats with dense summer growths of aquatic vascular plants. These habitats normally support organisms such as amphipods, isopods, certain chironomids, damselflies, and pulmonate snails that are highly tolerant of organic enrichment. The presence of large numbers of these organisms under lotic conditions usually reflects organic enrichment (Hynes 1960, Hawkes 1979). However, because of the extensive natural lentic-littoral areas in the upper Cuyahoga River, the abundance of organic pollution-tolerant and facultative organisms is not necessarily an indication of degraded water quality.

Despite the difficulties in relating benthic community measures to water quality in these "lowest quality" areas, it is important to note that suspected sources of organic enrichment were located 1-2 km upstream from each area. Russell Park is situated downstream from Burton's wastewater treatment plant, and the Route 422 station is located within 200 m of probable domestic organic wastes from a small business. The Infirmary Road station is located 2 km below the village of Mantua wastewater treatment plant. The results of this study do not indicate the effects, if any, of organic enrichment on the benthic community structure in this area. An assessment of benthic community structure from lentic-littoral habitats immediately upstream from the potential sources of organic enrichment could help differentiate between domestic organic enrichment and natural conditions associated with lentic-littoral habitats.

Composite scores (Table 5) for West Branch and Hiram Rapids indicated moderate water quality ratings for these areas. For West Branch, relatively high water quality was indicated by a moderate number of taxa and a moderately high percentage of organic pollution-intolerant organisms. The large fraction of detritivores, however, indicated reduced water quality. The latter may reflect the impact of the extensive sandy substrates in the area rather than impaired water quality. Sandy habitats usually are very poor substrates for benthic macroinvertebrates (Minshall 1984).

At Hiram Rapids the large number of taxa indicated relatively high water quality. However, the large proportion of detritivores, high density of organisms, and large fraction of organic pollution-facultative organisms indicated excessive organic sedimentation. This is especially important because Hiram Rapids has a large erosional habitat and would not be expected to support these kinds or such large numbers of organisms.

The presence of decomposing organic matter at this site also was indicated by low levels of dissolved oxygen and high levels of ammonia during summer (Table 2). The source of organic enrichment probably was effluent from nearby domestic septic systems. Water quality at Hiram Rapids has improved since similar water quality studies based on benthic macroinvertebrate indicators were conducted in 1973-74 (Olive 1976) and in 1980 (Trauben and Olive 1983). According to Trauben and Olive, no major changes in water quality occurred between 1974 and 1980.

In May 1974, only 34 taxa of benthic macroinvertebrates were collected at Hiram Rapids. Of these, 9% were sensitive to decomposing organic matter. The density of organisms was approximately $20{,}000/m^2$, of which 69% were facultative blackfly larvae (Simulidae); the A/I ratio was less than one. In the present study, 63 taxa were collected, of which 50% were sensitive to decomposing organic matter. The density of organisms declined to $3600/m^2$, with the trichopterans, *Cheumatopsyche* and *Hydropsyche,* and the chironomids, *Cricotopus, Orthocladius,* and *Eukiefferiella,* accounting for approximately 66% of the organisms. Blackflies accounted for less than 1% of the organisms, and the A/I ratio increased to 3.1. These changes in the community structure of the benthic macroinvertebrates indicate improved water quality in the Hiram Rapids area.

ACKNOWLEDGMENTS. This study was supported by the Division of Natural Areas and Preserves of the Ohio Department of Natural Resources; the Department of Biology of The University of Akron; and the Center for Environmental Studies of The University of Akron. R. Dremann assisted with chemical-physical water analyses. T. Bauer and G. Wallace typed the manuscript.

LITERATURE CITED

American Public Health Association 1985 Standard methods for the examination of water and wastewater. Am. Public Health Assn., Am Waterworks Assn., and Water Poll. Contr. Fed. Washington, D.C. 1268 p.

Coogan, A. H., R. M. Feldmann, E. J. Szmuc and J. V. Mrakovich 1974 Sedimentary environments of the lower Pennsylvanian Sharon Conglomerate near Akron, Ohio. *In:* R. A. Heimlich and R. M. Feldmann (eds.), Guidebook No. 2, Selected field trips in northeastern Ohio. Ohio Geological Survey. pp. 19-41.

Cummins, K. W. and R. W. Merritt 1984 Ecology and distribution of aquatic insects. *In:* R. W. Merritt and K. W. Cummins, An introduction to the aquatic insects of North America. 2nd ed. Dubuque, IA: Kendall/Hunt Publ. Co., p. 59-65.

Downing, K. M. and J. C. Merkens 1955 The influence of dissolved-oxygen concentration on the toxicity of un-ionized ammonia to rainbow trout (*Salmo gairdnerii* Richardson). Ann. Appl. Biol. 43(2): 243.

Elliott, J. M. 1977 Some methods for the statistical analysis of samples of benthic invertebrates (2nd ed.). Sci. Publ. Freshwat. Biol. Assoc. 25. 160 p.

Fuller, J. O. 1947 Sharon Conglomerate, a source of high-silica raw material. Ohio State Univ. Engineering Expt. Sta. News, 19: 48-55.

——— 1955 Source of the Sharon Conglomerate of northeastern Ohio. Geol. Soc. America Bulletin, 66: 159-176.

Hawkes, H. A. 1957 Biological aspects of river pollution. *In:* L. Klein (ed.), Aspects of river pollution. London: Butterworths, p. 191-251.

——— 1979 Invertebrates as indicators of river water quality. *In:* A. James and L. Evison (eds.), Biological indicators of water quality. New York: John Wiley & Sons, p. 2-1 - 2-45.

Hawkins, C. P. and J. R. Sedell 1981 Longitudinal and seasonal changes in functional organization of macroinvertebrate communities in four Oregon streams. Ecology 62(2): 387-397.

Heimlich, R. A., J. V. Mrakovich and G. W. Frank 1970 The Sharon Conglomerate. *In:* P. O. Banks and R. M. Feldmann (eds.), Guide to the geology of Northeastern Ohio. Northern Ohio Geol. Soc., pp. 125-134.

Hellawell, J. M. 1978 Biological surveillance of rivers. A biological monitoring handbook. Stevenage, England: Water Research Centre.

Hilsenhoff, W. L. 1977 Use of arthropods to evaluate water quality of streams. Tech. Bull. No. 100. Wisconsin Dept. Nat. Resources, Madison, WI. 16 p.

Hynes, H. B. N. 1960 The biology of polluted waters. Liverpool, UK: Liverpool Univ. Press.

Lenat, D. R., L. A. Smock and D. L. Penrose 1980 Use of benthic macroinvertebrates as indicators of environmental quality. *In:* D. L. Worf (ed.), Biological monitoring for environmental effects. Lexington, MA: Lexington Books, p. 97-112.

Merkins, J. C. and K. M. Downing 1957 The effect of tension on dissolved oxygen on the toxicity of un-ionized ammonia to several species of fish. Ann. Appl. Biol. 45: 521.

Merritt, R. W. and K. W. Cummins (eds.) 1984 An introduction to the aquatic insects of North America. 2nd ed. Dubuque, IA: Kendall/Hunt Publ. Co.

Minshall, G. W. 1984 Aquatic insect-substratum relationships. *In:* V. H. Resh and D. M. Rosenberg (eds.), The ecology of aquatic insects. New York: Praeger Publ., pp. 358-400.

Ohio Department of Natural Resources 1968 State of Ohio scenic rivers act. Ohio Dept. Nat. Resources, Columbus, OH.

Ohio Environmental Protection Agency 1983 Unpublished benthic macroinvertebrate data for the Tuscarawas River, Ohio. Biomonitoring Section, Ohio Env. Prot. Agency, Columbus, OH.

Ohio Environmental Protection Agency 1984 Unpublished benthic invertebrate data for the Cuyahoga River. Biomonitoring Section, Ohio Env. Prot. Agency, Columbus, OH.

Olive, J. H. 1976 Chemical-physical and biological assessment of water quality in the Cuyahoga River (1973-1974). Ohio J. Sci. 76(1): 5-15.

——— and K. R. Smith 1975 Benthic macroinvertebrates as indexes of water quality in the Scioto River system (Ohio). Ohio Biol. Survey New Series Bulletin. 5(2) 124 p.

Pennak, R. W. 1978 Freshwater invertebrates of the United States. 2nd ed. New York: John Wiley & Sons.

Pliodzinskas, A. 1973 Benthic macroinvertebrate assemblages and sediment particle-size of the upper Cuyahoga River in Portage County, Ohio. Akron, OH: The Univ. of Akron. Thesis.

Prater, B. L., D. R. Barton and J. H. Olive 1977 New sampler for shallow-water benthic macroinvertebrates. The Progressive Fish Culturist. 39(2): 58.

Rabeni, C. F., S. P. Davies and K. E. Gibbs 1985 Benthic invertebrate response to pollution abatement: structural changes and functional implications. Water Res. Bull. 21(3): 489-497.

Rau, J. L. 1968 The evolution of the Cuyahoga River: its geomorphology and environmental geology. *In:* G. D. Cooke (ed.), Proceedings of Symposium, The Cuyahoga River Watershed 1 Nov 1968. Kent, OH: Kent State Univ., pp. 9-39.

Ritchie, A., J. R. Bauder, R. L. Christman and P. W. Reese 1978 Soil Survey of Portage County, Ohio. U.S. Dept. of Agriculture, Soil Conservation Service, 113 p.

Stout, W., K. Ver Steeg and G. F. Lamb 1943 Geology of water in Ohio. Ohio Geological Survey Bulletin 44, 694 p.

Strahler, A. N. 1964 Quantitative geomorphology of drainage basins and channel networks. *In:* Chow, V. T. (ed.), Handbook of applied hydrology. New York: McGraw-Hill.

Tesmer, M. G. and D. R. Wefring 1981 Annual macroinvertebrate sampling — a low-cost tool for ecological assessment of effluent impact. *In:* J. M. Bates and C. J. Weber (eds.), Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 730. Philadelphia, PA: Am. Soc. Testing and Materials; pp. 264-279.

Trauben, B. K. and J. H. Olive 1983 Benthic macroinvertebrate assessment of water quality in the Cuyahoga River, Ohio — an update. Ohio J. Sci. 83(4): 209-212.

U.S. Environmental Protection Agency 1986 Quality criteria for water. EPA 440/5-86-001 U.S. Env. Prot. Agency, Washington, D.C. 256 p.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell and C. E. Cushing 1980 The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

Watton, A. J. and H. A. Hawkes 1984 The performance of an invertebrate colonization sampler (S. Auf. U.) in bological surveillance of lowland rivers. *In:* D. Pascoe and R. W. Edwards (eds.), Freshwater biological monitoring. Adv. Water Poll. Contr., Int. Assoc. Water Poll. Res. and Control. New York: Pergamon Press; pp. 15-24.

Weber, C. I. (ed.) 1973 Biological field and laboratory methods for measuring the quality of surface waters and effluents. Cincinnati, OH: EPA 670/4-73-001 National Env. Research Center, U.S. Env. Prot. Agency.

White, G. W. 1982 Glacial geology of northeastern Ohio. Ohio Geol. Surv. Bull. 68, 75 p.

Williams, N. L. and F. E. McCleary 1982 Soil survey of Geauga County, Ohio. U.S. Dept. of Agriculture, Soil Conservation Service, 169 p.

Winslow, J. D. and G. W. White 1966 Geology and groundwater resources of Portage County, Ohio. U.S. Geological Survey Prof. Paper 511, 80 p.