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[1] A contribution from Dingell-Johnson Project F-35-R, Michigan.

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Abstract.--An index of biotic integrity (IBI), which is based on fish community structure, was used to evaluate environmental quality at 22 sites on the severely degraded River Rouge system in southeast Michigan. The IBI scores generally decreased from upstream to downstream sites. The IBI scores appeared to reflect the negative impacts of accentuated flood peaks and low flows, along with increased loadings of pollutants such as oils, on environmental suitability for fish. The IBI appeared to be sensitive to differences in both physical and chemical habitat conditions. With minor modifications the IBI could be used on other Michigan warmwater rivers and would prove useful for tracking long-term trends in the well-being of these rivers.

Warmwater rivers in Michigan have been negatively impacted by a wide variety of human-induced factors including pollutants, increased sediment loads, and accentuated flood flows and low flows. The latter two factors act in a number of ways to reduce fish habitat. This type of damage cannot be measured by traditional water-quality monitoring techniques. Karr (1981) proposed that the ability of a system to sustain a balanced fish community could be used to assess the health or biotic integrity of water resources. Fish occupy the apex of the aquatic trophic system and, therefore, provide an integrated view of environmental suitability. Other advantages of using fish communities to assess biological integrity include their presence in all but severely polluted or ephemeral streams, the relative ease with which fish species can be identified, their sensitivity to both acute and chronic stresses, and the abundant life history information available for most species. Finally, the general public can readily comprehend statements about fish community condition (Karr 1981).

Karr (1981) developed an index of biotic integrity (IBI), which is derived by assigning scores to 12 measures or metrics reflecting different attributes of stream fish assemblages. These metrics fall into the three broad categories of species composition, trophic composition, and fish abundance and health. Scores assigned for each metric are tailored to the stream size and zoogeographical region where the index is applied (Karr 1981; Fausch et al. 1984; Karr et al. 1986; Miller et al. 1988). These scores are based on a comparison of fish community attributes with those expected when impacts by man have been minimal. The IBI scores provide a framework for classifying warmwater stream fish communities into categories ranging from excellent to very poor. The IBI has been found to be sensitive to a variety of forms of degradation of midwestern streams including agricultural practices, channelization, sedimentation, and municipal and industrial pollution (Karr 1981; Fausch et al. 1984; Karr et al. 1986; Karr et al. 1987; Angermeier and Schlosser 1987). Moreover, the breadth of information incorporated into the IBI seems to make it more generally useful for detecting degradation than species diversity indices or species richness or abundance (Karr et al. 1987; Angermeier and Karr 1986; Angermeier and Schlosser 1987). Potential uses of the IBI include documentation of habitat improvement or loss, identification of problem areas, and quantitative classification of warmwater stream reaches.

The River Rouge in southeast Michigan is a severely degraded system which is targeted for a variety of water- and habitat-quality improvements. The objective of this study was to determine IBI ratings for stations on the River Rouge system so that baseline data will be available for future evaluation of the effectiveness of river clean-up efforts and habitat improvement.

Study Area

The River Rouge drainage basin, located in the southeastern Michigan counties of Wayne, Oakland, and Washtenaw, encompasses 467 square miles. This heavily populated watershed is composed primarily of urban and suburban areas, including a portion of the City of Detroit with its population of 1.1 million people.

Most precipitation is drained rapidly from this largely water-impermeable watershed into the River Rouge system because of heavy soils, intensive development, ditching, and an extensive sewer system. Physical alterations of the river channel designed to improve drainage include dredging, channelization, and paving of the channel.

Combined sanitary and storm sewers carry both raw sewage and stormwater directly to the River Rouge at a minimum of 180 locations. Although dry weather waste discharges occur at these sites, the greatest amount of raw sewage and industrial waste is bypassed from the sewer system during rain storms. Water quality is further degraded by a multitude of industrial discharges, urban and suburban nonpoint run-off, and some agricultural run-off.

Water discharge volume fluctuates widely and quickly after rainfall (Michigan Water Resources Commission 1974). Continuous monitoring of stream discharge at seven stations on the River Rouge indicates that maximum stream discharge exceeds minimum discharge by 52 to 954 times depending upon location (Miller et al. 1985). This flow instability has reduced fish habitat suitability by eliminating undercut banks and sweeping most organic and inorganic debris (fish cover) from much of the river. Flow instability also increases erosion and sediment loads. Dry weather flows approach zero at many locations. Dissolved oxygen levels are depressed during low flow periods particularly in downstream portions of the River Rouge where river gradient is low and organic loading is high (Michigan Water Resources Commission 1974).

Methods

Field Sampling

During July and August 1986 fish communities were sampled at 22 stations on the River Rouge (Figure 1). The river basin was divided into four sub-basins designated as the Main River Rouge, and the Upper, Middle, and Lower River Rouge .

Fish were collected during one thorough sweep of a stream section using pulsed DC electrofishing gear. We attempted to capture all fish. A blocking seine was placed at the upstream end of most stations to prevent escapement from the sampling area. The stream reaches that were sampled encompassed pool-riffle sequences where such features could be identified. Most stations were approximately 150 m long, although sections up to 300 m were sampled where the river was large.

Fish 10 cm in total length or longer were identified in the field, measured, examined for external parasites, lesions, fin erosion, tumors or anomalies, and released back to the stream. Most specimens smaller than 10 cm in total length were preserved in a formalin solution for later identification and examination.

Although it was not required for the

IBI analysis, additional qualitative ratings or measures were made at each site for several variables. These included bank erosion severity, substrate types and percentages, discharge stability, turbidity, presence, and/or amount of oils on surface waters, water odors (normal, sewage, petroleum, chemical, other), amount of oils in sediment, and abundance of slimes, periphyton, filamentous algae, and macroinvertebrates. Stepwise, forward, and backward, multiple regression techniques were used to estimate the effect of these variables on IBI scores.

Scoring of IBI Metrics

Since there were no "unperturbed" sites on the River Rouge, I developed metric scoring criteria primarily from expansion of maximum species richness lines presented in Fausch et al. (1984) for the River Raisin, which lies to the south in the same ecoregion as the River Rouge system (Omernik 1987). Ecoregions are areas that have similar geographical characteristics, such as climate, land forms, soils, vegetation, hydrology, and biota.

The 12 metrics used to derive IBI scores are listed in Table 1. Rating criteria for all metrics were based on principles outlined in Karr (1981); Fausch et al. (1984); Karr et al. (1986); Angermeier and Karr (1986); Angermeier and Schlosser (1987); and Karr et al. (1987). Metrics were assigned a rating of 5, if the community feature was similar to characteristics found in pristine systems. Metrics which deviated moderately from pristine conditions were given a rating of 3, and when there was strong deviation from pristine conditions the metrics received a rating of 1. The ratings for each of the 12 metrics were then summed to obtain a final IBI score. Rating criteria for those metrics listed in Table 1 which vary with stream size are shown in Table 2, and Figure 2. The pollution tolerance and trophic guild categories for fish species collected from the River Rouge are listed in Table 3. Tolerance and trophic relationships were determined primarily by consulting regional experts and references (Trautman 1957; Scott and Crossman 1973; P. R. Yant, The University of Michigan, Ann Arbor, personal communi-ication, 1988).

Quality categories for ranges of IBI scores are shown below.

Class	Index Score
Excellent	57 - 60
Excellent-Good	53 - 56
Good	48 - 52
Good-Fair	45 - 47
Fair	39 - 44
Fair-Poor	36 - 38
Poor	28 - 35
Poor-Very Poor	24 - 27
Very Poor	≤23

Results

The IBI values for stations from all four branches of the River Rouge generally decreased from upstream to downstream stations (Table 4). None of the sites surveyed had fish communities of excellent quality as measured by the IBI. The uppermost station sampled on the Upper Branch of the River Rouge received a "good" rating. The majority of the 22 stations evaluated were rated "poor" or "very poor" (Table 4).

The station with the highest IBI score had stream morphology characterized by deep pools and nearly equal numbers of riffles. The rock gabions and broken concrete used to stabilize erosion at this site appeared to provide good fish cover. At lower quality stations channel morphology was typically characterized by steep and highly eroded banks, a bowl shaped cross-section, and a virtual absence of permanent instream organic or inorganic cover. The lowest quality stations were located on more downstream reaches where water quality was degraded by storm and sanitary sewer pollutants and industrial discharges. Downstream stations also tended to have more severe bank erosion due to greater flood peaks. Multiple regression analysis indicated that the most important variables affecting IBI scores were the amount of oils in sediments and the discharge stability, R = 0.68, P <0.05. The regression analysis indicated that greater amounts of oil and greater discharge instability resulted in lower IBI scores.

Discussion

The IBI appeared to provide a good measure of community integrity which was correlated with known differences in both physical and chemical factors. In all branches of the River Rouge, IBI scores indicated that environmental quality generally was higher at upstream stations. The decline in fish community quality between upstream and downstream stations in the River Rouge occurs in conjunction with increased loadings of pollutants and sediments, which enter the river with regularity along its course. In addition, the magnitude of water discharge fluctuations after rainfall events is greater at downstream sites. For example, during 1985 minimum and maximum stream discharges at Birmingham on the Main Branch of the River Rouge were 4.8 and 401 ft^3/s, respectively, whereas downstream near Inkster on the Lower Branch River Rouge maximum discharge was 954 times the minimum stream discharge of 1.1 ft^3/s (Miller et al. 1985).

I believe that the cause of much of the overall river quality degradation is the severe flow fluctuations resulting from stream channel utilization and redesign for drainage and stormwater transport. Negative effects of channelization on fish populations have been well documented (Schneberger and Funk 1971). Filling of wetlands to accommodate development and paving of the watershed has reduced water retention areas, which in turn has resulted in accentuated flood peaks and diminished base flow. The erosive effects of floods were evident at all stations where fish were collected. These flood flows have tended to eliminate undercut banks, and have flushed potential organic and inorganic fish cover downstream or onto the flood plain. The importance of overhead cover, and of cover which allows fish to escape from high water velocities associated with increases in stream discharge, have been frequently emphasized (Enk 1977; White 1975; Hunt 1971). Heggenes (1988) believed that coarse substrates created essential low-water-velocity microniches which prevented displacement of brown trout when stream discharge increased. Reductions in fish abundance due to deficiencies in cover are frequently greater for larger fish (White 1975).

When flood waters recede, much potential fish cover and invertebrate substrate is dewatered. The remaining stream cross-section is frequently bowl shaped and devoid of cover. Lack of large solid substrates and the low water velocities associated with low flows frequently reduces both the number of species and the biomass of macrobenthic invertebrates which are eaten by fish (Edwards et al. 1984). Low flows also inhibit aeration of the water, and when organic materials decompose, dissolved oxygen levels are lowered. This effect of low flow is most evident in downstream reaches of the Rouge where river gradient is low and organic loading is high (Michigan Water Resources Commission 1974). The significant negative relationship (R = 0.68, P <0.05) between IBI scores and amount of sediment oils and discharge stability suggests that the generally lower IBI scores at downstream stations reflect known physical and chemical causes of stream degradation. Moreover, fish communities appeared to be sensitive to increases in water quality, because IBI scores increased in the Middle River Rouge downstream from Johnson's Drain, which contributed cleaner water to the main stem of the river. Johnson's Drain may have also improved fish community structure in the Middle River Rouge by increasing base flow, thereby increasing both the quality and quantity of suitable physical habitat.

Because there were no undisturbed sites on the River Rouge, the assumption was made that data from the River Raisin (which lies in the same region) could be used to develop IBI scoring criteria. It is conceivable that fish communities in an undisturbed River Rouge could differ in abundance or species composition from River Raisin communities. It would also have been preferable to make fish collections during spring or early summer, when temporal variability among samples from the same site is lower and when young-of-the-year fishes are less likely to complicate data analysis and interpretation (Angermeier and Schlosser 1987; Angermeier and Karr 1986).

Scoring criteria for IBI metrics are inherently somewhat subjective so other investigators might have scored metrics differently. Some investigators have modified the index extensively particularly to accommodate regional differences in fish communities (Miller et al. 1988). I could not confidently identify cyprinid hybrids, so it is likely that this metric was occasionally given an inappropriately high rating. The metric for the combined incidence of disease and anomalies did not increase at degraded sites as predicted by IBI theory.

Although anomalies such as deformed fins tended to increase at more degraded sites the incidence of disease generally decreased. The primary disease organisms detected in the field were larval trematodes (black spot disease). Because the black spot parasite must successively infect the ram's horn snail, fish, and the belted kingfisher to complete its life cycle, I hypothesize that conditions suitable for all host organisms were more likely to exist at higher quality sites. Support for this hypothesis is provided by Berra and Au (1978), who reported that 89% of fish from some unpolluted waters exhibited black spot disease.

Despite these shortcomings, IBI values computed for River Rouge communities appeared to be sensitive to differences in both physical and chemical habitat conditions. With minor modifications the IBI could be used on other Michigan warmwater rivers and would prove useful for tracking long-term trends in the well-being of these rivers.

Acknowledgments

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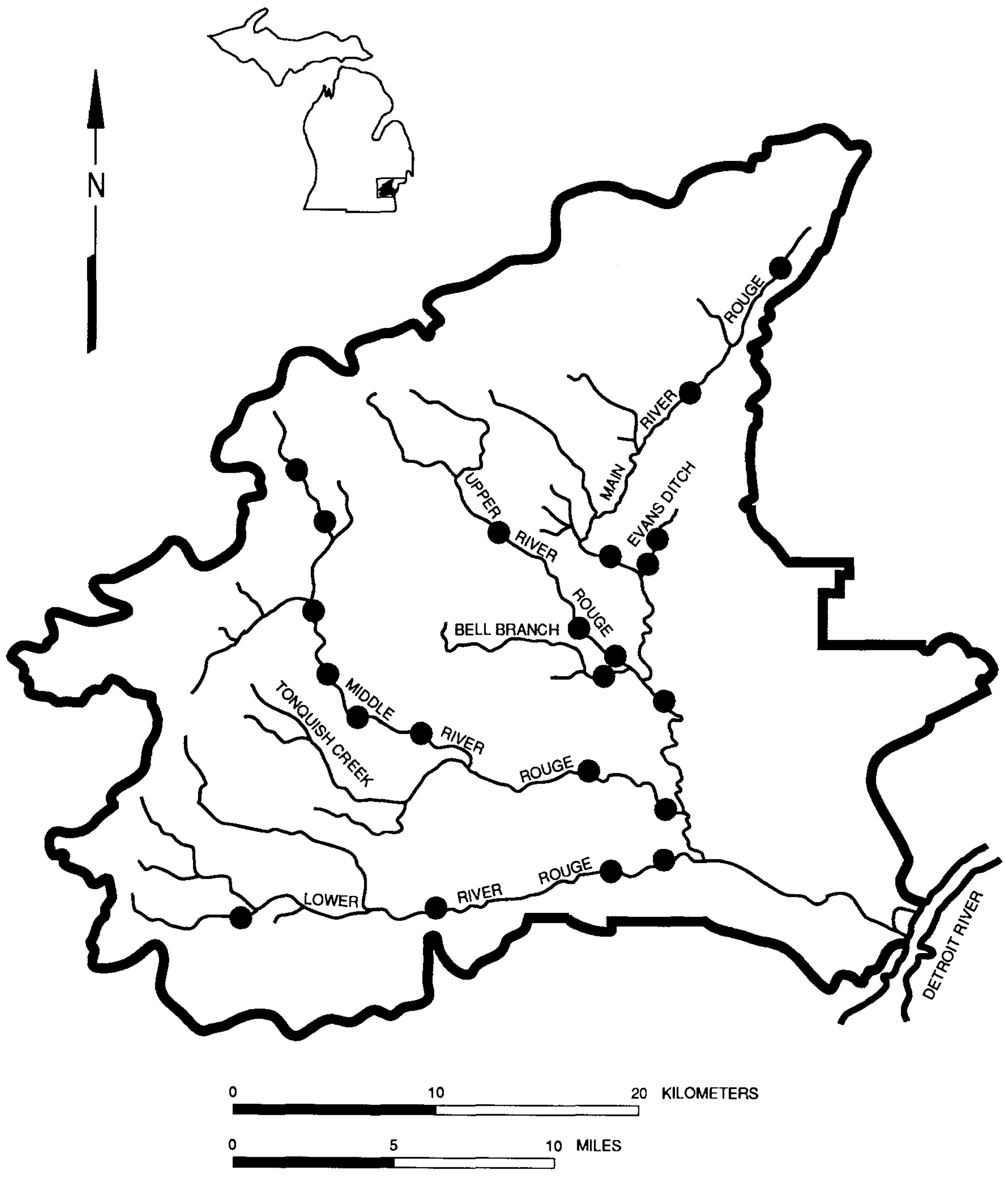

Figure 1. Fish sampling locations on the River Rouge (Wayne and Oakland counties, Michigan), July and August 1986.

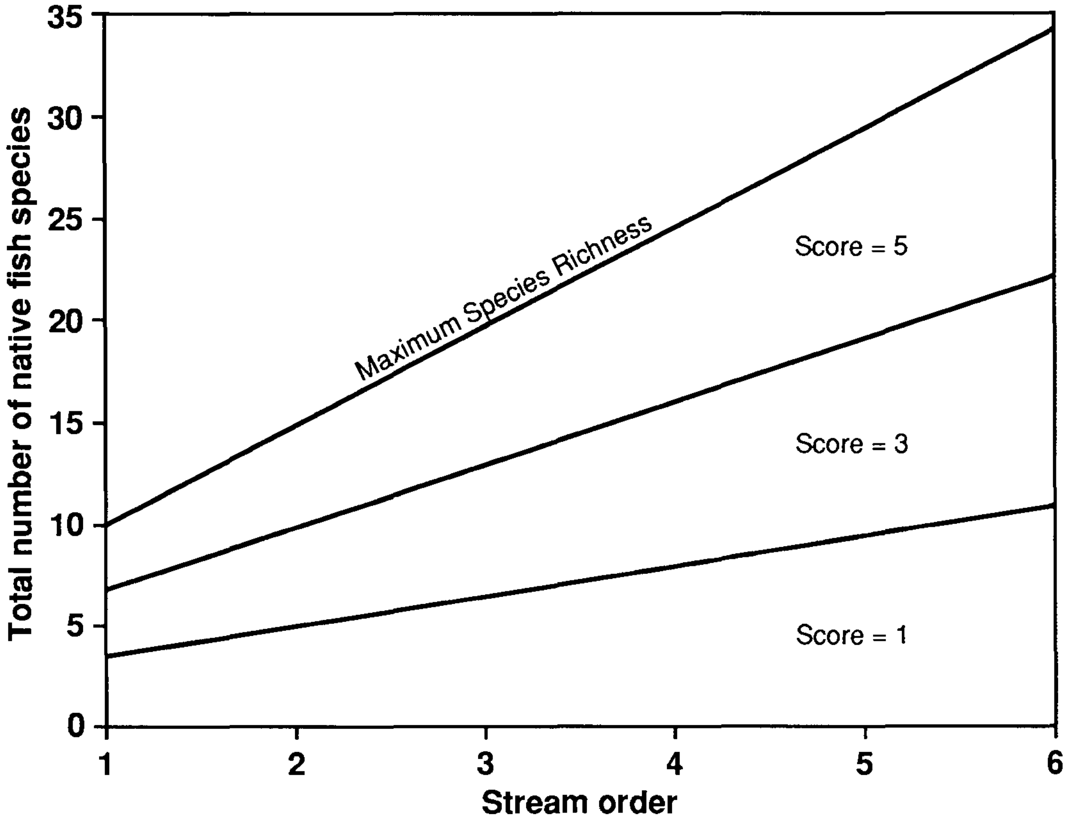

Figure 2. Metric scoring criteria for number of native fish species by stream order (Strahler 1957). The maximum species richness line is derived from River Raisin data reported in Fausch et al. (1984). If the number of species fell on a line, the lower score was assigned.

Table 1. Fish community metrics and scoring criteria used to calculate the River Rouge index of biotic integrity.

		Scoring criteria		
Category or class	Metric	5(best)	3(fair)	1(worst)
Species composition	Total number of native fish species.	Varies with stream size. (See Figure 2.)		
	Number of darter species and kind.	Varies with stream size. (See Table 2)		
	Number of sunfish species and kind.	Varies with stream size. (See Table 2)		
	Number of sucker species and kind.	Varies with stream size. (See Table 2)		
	Presence of intolerant species.	1 or more		None
	Proportion of individuals as green sunfish.	<5%	5-20%	>20%
Trophic composition	Proportion of individuals as omnivores[1].	<20%	20-45%	>45%
	Proportion of individuals as insectivorous cyprinids.	>45%	20-45%	<20%
	Proportion of individuals as top carnivores 1:[2]	>2	0-2	0
	2:	>20	11-20	0-10
	3:	>25	16-25	0-15
	4:	>25	16-25	0-15
Fish abundance and health	Number of individuals in sample.	Varies with stream size and sampling technique.		
	Proportion of individuals as hybrids.	0	0-1%	>1%
	Proportion of fish with disease or anomalies.	0	0-1%	>1%

[1]Omnivores are species with diets composed of more than 25% plant material, the rest being animal material (Fausch et al. 1984).

[2]Stream order.

Table 2. Metric score for number of darter, sunfish, and sucker species, by stream order (Strahler 1957)

Number of species	Stream order 1	2	3	4
Darters				
0	1	1	1	1
1	1	1[1]	1	1
2	3	3	3	3
3	5	5	3	3
4+	5	5	5	5
Sunfish[2]				
0	1	1	1	1
1	3	1	1	1
2	5	3	3	1
3	5	5	5	3
4	5	5	5	3
5+	5	5	5	5
Suckers				
0	5	1	1	1
1	5	3	1	1
2	5	5	3	3
3+	5	5	5	5

[1]In second order streams with only one darter species, a score of one was assigned to johnny darters and a score of three was assigned to other darter species.

[2]Fish in the genus *Micropterus* are not included in these species counts.

Table 3. Suggested trophic guilds (top carnivore-TC, insectivorous cyprinid-IC, omnivore-OM), and pollution tolerance status (intolerant-IN), of fish collected from the River Rouge, Michigan.

Scientific name	Common name	Guild or tolerances
Clupeidae		
Dorosoma cepedianum	Gizzard shad	
Umbridae		
Umbra limi	Central mudminnow	
Esocidae		
Esox lucius	Northern pike	TC
Cyprinidae		
Campostoma anomalum	Central stoneroller	
Carassius auratus	Goldfish	OM
Cyprinus carpio	Carp	OM
Nocomis biguttatus	Hornyhead chub	IC
Notropis cornutus	Common shiner	IC
Phoxinus eos	Northern redbelly dace	
Pimephales notatus	Bluntnose minnow	OM
Pimephales promelas	Fathead minnow	OM
Rhinichthys atratulus	Blacknose dace	IC
Clinostomus elongatus	Redside dace (threatened)	IC, IN
Semotilus atromaculatus	Creek chub	IC
Catostomidae		
Carpiodes cyprinus	Quillback	OM
Catostomus commersoni	White sucker	
Hypentelium nigricans	Northern hog sucker	IN
Ictaluridae		
Ictalurus melas	Black bullhead	
Ictalurus natalis	Yellow bullhead	
Ictalurus nebulosus	Brown bullhead	
Ictalurus punctatus	Channel catfish	TC
Noturus flavus	Stonecat	IN
Gasterosteidae		
Culaea inconstans	Brook stickleback	

Table 3. Continued:

Scientific name	Common name	Guild or tolerances
Centrarchidae		
Ambloplites rupestris	Rock bass	TC, IN
Lepomis cyanellus	Green sunfish	
Lepomis gibbosus	Pumpkinseed	
Lepomis gulosus	Warmouth	
Lepomis macrochirus	Bluegill	
Lepomis megalotis	Longear sunfish	IN
Micropterus salmoides	Largemouth bass	TC
Pomoxis nigromaculatus	Black crappie	TC
Percidae		
Etheostoma caeruleum	Rainbow darter	
Etheostoma nigrum	Johnny darter	
Cottidae		
Cottus bairdi	Mottled sculpin	IN

Table 4. Index of biotic integrity values for 22 sites in the River Rouge, 1986. Sites are arranged from upstream to downstream.

Station number	Station location	IBI value	Quality rating
	Upper Branch		
U-1	Upper Rouge-Powers Street	48	Good
U-2	Upper Rouge-7 Mile Road	26	Poor-Very poor
U-3	Upper Rouge-5 Mile Road	28	Poor
U-4	Bell Branch-Sarasota Road	30	Poor
	Middle Branch		
MD-1	Middle Rouge-Novi Road	36	Fair-Poor
MD-2	Middle Rouge-9 Mile Road	32	Poor
MD-3	Middle Rouge-Northville Road	46	Good-Fair
MD-4	Middle Rouge-Hines Drive	42	Fair
MD-5	Middle Rouge-Haggerty Road	44	Fair
MD-6	Middle Rouge-Wayne Road	34	Poor
MD-7	Middle Rouge-Inkster Road	22	Very poor
MD-8	Middle Rouge-Outer Drive	20	Very poor
	Lower Branch		
L-1	Lower Rouge-Sheldon Road	36	Fair-Poor
L-2	Lower Rouge-Newburgh Road	28	Poor
L-3	Lower Rouge-Gulley Road	16	Very poor
L-4	Lower Rouge-Ford Field	16	Very poor
	Main Branch		
MN-1	Main Rouge-Beach Road	46	Good-Fair
MN-2	Main Rouge-Lahser Road	36	Fair-Poor
MN-3	Main Rouge-Beech Road	26	Poor-Very poor
MN-4	Main Rouge-Spinoza Road	26	Poor-Very poor
MN-5	Evans Ditch-Lahser Road	24	Poor-Very poor
MN-6	Evans Ditch-Berg Road	20	Very poor

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Appendix I. Fish species and number of individuals captured in 1986 at four stations on the Upper Branch of the River Rouge, Michigan.

Species	Station U-1	U-2	U-3	U-4
Central mudminnow	4	---	2	3
Central stoneroller	4	---	---	2
Goldfish	---	---	2	---
Common shiner	12	10	---	3
Bluntnose minnow	---	---	---	3
Fathead minnow	---	16	4	5
Blacknose dace	58	---	---	---
Redside dace	2	---	---	---
Creek chub	176	34	10	33
White sucker	62	14	50	48
Northern hog sucker	26	---	---	---
Brown bullhead	---	---	2	---
Stonecat	2	---	---	---
Brook stickleback	---	---	---	2
Green sunfish	16	6	---	3
Pumpkinseed	2	---	4	---
Bluegill	2	---	2	---
Largemouth bass	2	---	2	---
Pumpkinseed x bluegill	---	---	6	---
Mottled sculpin	58	---	---	---
Total	426	80	84	102

Appendix II. Fish species and number of individuals captured in 1986 at eight stations on the Middle Branch of the River Rouge, Michigan.

Species	Station MD-1	MD-2	MD-3	MD-4	MD-5	MD-6	MD-7	MD-8
Central mudminnow	---	2	2	---	---	---	---	---
Northern pike	---	8	---	---	---	---	---	---
Central stoneroller	---	2	8	3	---	---	---	---
Goldfish	---	---	---	---	---	30	10	10
Common carp	---	28	7	---	---	15	4	3
Hornyhead chub	---	---	---	---	16	---	---	---
Common shiner	---	---	3	---	---	---	2	---
Bluntnose minnow	---	10	7	24	24	---	---	---
Fathead minnow	2	2	---	---	---	---	22	5
Blacknose dace	---	---	12	---	---	---	---	---
Creek chub	40	48	8	20	16	---	22	3
White sucker	2	68	47	13	52	10	4	---
Northern hog sucker	---	2	---	---	---	---	---	---
Yellow bullhead	---	4	---	5	---	---	---	---
Channel catfish	---	2	---	---	---	---	---	---
Brook stickleback	2	---	---	---	---	---	---	---
Rock bass	---	6	3	47	92	15	---	---
Green sunfish	2	68	12	8	---	---	---	---
Pumpkinseed	---	16	3	51	40	7	---	---
Bluegill	---	---	---	17	164	15	---	---
Longear sunfish	---	---	---	---	2	2	---	---
Largemouth bass	---	6	---	3	20	2	---	---
Black crappie	---	6	---	---	---	---	---	---
Pumpkinseed x bluegill	---	---	---	1	2	---	---	---
Pumpkinseed x green sunfish	---	4	---	---	---	---	---	---
Rainbow darter	---	---	2	---	---	---	---	---
Johnny darter	---	14	---	5	2	---	---	---
Mottled sculpin	---	---	83	3	---	---	---	---
Total	48	296	276	200	430	96	64	21

Appendix III. Fish species and number of individuals captured in 1986 at four stations on the Lower Branch River Rouge, Michigan.

	Station			
Species	L-1	L-2	L-3	L-4
Central mudminnow	75	28	9	22
Carp x goldfish hybrid	---	---	42	6
Central stoneroller	12	---	---	---
Goldfish	3	---	---	2
Common carp	65	8	---	28
Common shiner	140	8	---	---
Northern redbelly dace	3	---	---	---
Fathead minnow	153	2	3	2
Creek chub	178	54	---	---
White sucker	37	146	---	6
Black bullhead	3	---	---	---
Brook stickleback	22	2	---	---
Green sunfish	25	22	---	---
Pumpkinseed	---	---	3	---
Bluegill	3	---	---	---
Gizzard shad	---	2	---	---
Total	719	282	57	66

Appendix IV. Fish species and number of individuals captured in 1986 at six stations on the Main Branch River Rouge, Michigan.

Species	Station					
	MN-1	MN-2	MN-3	MN-4	MN-5	MN-6
Central stoneroller	61	12	---	---	---	---
Goldfish	---	---	---	12	---	---
Common carp	4	---	4	---	---	3
Hornyhead chub	54	---	---	---	---	---
Common shiner	169	52	10	---	---	---
Northern redbelly dace	---	---	---	---	---	---
Bluntnose minnow	19	3	---	---	---	---
Fathead minnow	22	---	---	---	---	5
Blacknose dace	---	10	2	---	---	---
Creek chub	119	131	14	26	---	3
White sucker	36	31	16	---	---	---
Stonecat	6	---	---	---	---	---
Rock bass	45	1	4	---	---	---
Green sunfish	7	3	8	---	---	3
Pumpkinseed	6	1	---	---	4	3
Bluegill	6	---	---	---	---	---
Largemouth bass	9	---	---	---	---	---
Total	563	244	58	38	4	17