Sustainability Through Biological Monitoring on the Root River, Racine County, Wisconsin

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Abstract

Pollution associated with urban development and agriculture is a serious hazard to the conservation of plant and animal life associated with the Root River, Racine County, Wisconsin. Biological monitoring, the evaluation of an ecosystem based on its existing community structure, provided the basis for this study of the Root River aquatic environment. Macroinvertebrates (insect larvae, snails and leaches) and fish were used as indicator communities. Collection results from five progressively more urban locations were assessed using indices developed for southeastern Wisconsin (Hilsenhoff 1988 and Lyons 1992). Our results show that the water quality of Root River in Racine County varies from good (some organic pollution probable) to poor (very significant organic pollution). Macroinvertebrate results showed a degradation of water quality as the river flows from agricultural into more urban areas. Fish collections indicated lower water quality in agricultural areas of the river. Both fish and macroinvertebrate results indicated that habitat improvements completed at Johnson Park have improved conditions for the aquatic community.

Introduction

A river flowing through a city provides a great deal of insight into the environmental condition of the local community. As rain waters run across lawns, parking lots, and streets and wash down storm drains many of the pollutants released in the community are carried into the stream. The community of animals living in the stream is made up of only those creatures that can withstand the effects of these pollution events. Therefore, an evaluation and annual monitoring of a stream community provides a summary of the benefits derived from environmental improvements that are implemented in the local community. This type of initial evaluation and monitoring of fish and insect life in a river, called biological monitoring, can be an important part of any sustainability program.

A watershed, also referred to as a drainage or catchment basin, is an area that drains water, sediments, and dissolved minerals to a common outlet. This outlet may be any point that connects to a larger body of water, such as river, lake, aquifer, estuary, or the ocean (EPA 1991). The rate at which precipitation reaches a body of water is influenced by the vegetation and soil present in a watershed (Lotspeich 1980). The existence of wetlands within a watershed help prevent flooding by storing water, enhance water quality through nutrient uptake, and provide suitable habitats for wildlife (WDNR 2002b). Natural wetland habits correlate with healthy streams whereas the impacts of urbanization are associated with degraded stream ecosystems. Urbanization decreases permeable surfaces in a watershed resulting in rapid changes in stream morphology and reduced water quality (Wang et al. 1997).

Pollution occurring within a watershed is the result of point and nonpoint sources. Point source pollution usually enters the river through a pipe from a factory or sewage treatment plant. These sources can be identified and directly monitored, thus this form of environmental contamination is no longer the most predominant pollution problem (Carpenter et al. 1998). Instead, nonpoint source pollution is the nation’s leading source of water quality degradation (EPA 2003a). Nonpoint pollution is often the result of plowing, fertilizing, irrigation, runoff from urban streets, new construction, and septic leaching. Pollutants enter a wetland or body of water in a variety of ways, including overland flow, underground seepage, fine inorganic sediment, and through the atmosphere. Because nonpoint sources arise from assorted activities taking place in large regions, it may be difficult to locate and control the sources contributing to environmental pollution (Carpenter et al. 1998, Paul and Meyer 2001).

Nonpoint source pollution from agricultural and urban land use has caused long-term, cumulative harm to stream ecosystems (Wang et al. 1997). The practice of watershed development began when land was converted from forest or prairie to agriculture during European settlement. Degradation of Wisconsin streams and lakes increased after implementation of modern farming practices, such as use of heavy fertilization, high densities of livestock, stream channelization, and wetland drainage. The occurrence of floods increased as these modern farming practices developed and increased paved areas associated with urban development increases the rate and volume of runoff water. Excessive flooding resulted in bank erosion, loss of in-stream cover, and stream bed deposition to Wisconsin streams. High runoff rates and flooding restructures the macroinvertebrate and fish communities and reduces biodiversity (Wang et. al 2001).

An effective way to evaluate the environmental impacts caused by nonpoint source pollution is through biological monitoring. Also know as bioassessment, this technique estimates the condition of a body of water using biological surveys and other means of evaluating the living organisms residing in an area. Along with assorted physical and chemical assessments, bioassessments are very beneficial in determining the health of a river (EPA 2002).

By sampling fish and macroinvertebrates in different sections of a river number "grades" can be calculated that describe the general health of the watershed (Hilsenhoff 1988, Lyons 1992, MDNR 1991). These "grades" are called indices and are based on the pollution tolerance of the organism in the sampled location. This style of biological monitoring is one of the most rapid and cost-efficient of all procedures (Lenat and Barbour 1994). Common indices used are the Hisenhoff Biotic Index (HBI) and Family Biotic Index (FBI) (Hilsenhoff 1988), as well as the multimetric in-stream comparison (MDNR 1991) and Wisconsin Fish Index of Biotic Integrity (Lyons 1992).

The use of macroinvertebrates as biological indicators is an idea that has been employed across Wisconsin and throughout the world. River quality throughout Wisconsin has improved due to the pioneering work of William L. Hilsenhoff. The monitoring efforts established by Hilsenhoff have continued to expand through the years; now the Wisconsin statewide effort involves several agencies collecting approximately 450 BI samples per year (Shepard 1999). By using Hilsenhoff's index of biotic integrity (Hilsenhoff 1988), pollution levels at sampled sectors may be determined. The Root-Pike Partnership Team is using the HBI to improve water quality by monitoring the impact of regulations on both point and nonpoint sources of pollution (WDNR 2002a).

Indices of biotic integrity are implemented to assess environmental degradation and stream quality through the study of macroinvertebrate or fish communities residing at a specific locale (Schleiger 2000). This protocol is dependent upon metrics of taxa richness because structural alterations in aquatic environments, such as shifts among taxa, commonly arise at lower levels of stress (Karr and Chu 1999). The identification and quantification of taxonomic groups allows for the composition of an index of biotic integrity (Plafkin et al. 1989). Macroinvertebrates and fish are the most widely used taxonomic groups in biological monitoring programs for several reasons. Benthic macroinvertebrates are long-lived, ubiquitous, sedimentary organisms that possess limited migration patterns, allowing for the exposure and integration of environmental alterations (Cairns and Pratt 1993, Plafkin et al. 1989, Reice and Wholenberg 1993, Rosenburg and Resh 1993). However, benthic macroinvertebrates do not respond to all impacts and certain groups are taxonomically difficult (Rosenburg and Resh 1993). Sampling of macroinvertebrates occurs at the habitat most sensitive to physical and chemical disturbances – the riffles, regions of relatively shallow depth, fast water velocities, and rocky substrates (Roy et al. 2003). In order to substantially improve the diagnosis of degradation, more than one type of indicator should be sampled (Karr and Chu 1999). Because they are relatively long-lived, mobile, and represent a variety of trophic levels, fish serve as excellent indicators of long-term pollution and habitat degradation (Plafkin et al. 1989). Unlike macroinvertebrates, fish are less affected by modifications occurring within a small localized area (Ehrlick and Roughgarden 1987). This allows for the comparison of alterations taking place over a broader area, when sampling fish at several sectors of a river. Fish also display visible signs of stress and environmental degradation in the form of deformities, eroded fins, lesions, and tumors (DELT). Specific diseases are also associated with environments impaired by large amounts of toxic substances (Karr and Chu 1999, Schleiger 2000). By accurately assessing communities of organisms residing in a stream, the environmental degradation can be evaluated.

Biological monitoring diagnoses the amount of stress organisms experience in a specific environment by providing early warning signs or detecting cycles or trends of habitat deterioration (Cairns and Smith 1994). Stress on an ecosystem may be physical, chemical, or biological. Physical stress is defined as a change in water temperature, water flow, light availability, or habitat type. The existence of toxins, a change in the rates of oxygen consuming materials, or the availability of nutrients located in the water and riverbed is considered chemical stress. Biological stress includes the introduction of an alien or invasive species to the river or surrounding area (Loeb 1994). Any physical, chemical, or biological alteration may lead to endangerment or extinction of an organism inhabiting an aquatic ecosystem. Bioassessment helps monitor and protect the natural aquatic environments and their inhabitants for the welfare of future generations.

From the Andes Mountains in Argentina (Miserendio 2001) to the rivers in Australia (Markwort and Norris 1998), across the United States to Europe (Buffagni et al. 2001), watersheds and the bodies of water that run through them have improved in quality because the citizens of the land are aware of the degree of pollution present in their neighboring natural environments. When plans to restore a habitat are put into action, people aid the watershed in its return to a healthier state. For example, Environment Australia and the Land and Water Resources Research and Development Corporation have set up the National River Health Program, whose primary purpose is to monitor, assess, and improve the health of rivers throughout Australia (Markwort and Norris 1998). In Europe, the Development and Testing of an Integrated Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macroinvertebrates (AQEM), a project that describes the condition of river through indices of biotic integrity involving eight European countries, was designed to put the European Water Framework Directive into practice (Buffagni et al. 2001). Macroinvertebrate samples were collected and water quality parameters were identified from six river basins in order to determine the major variables structuring benthic assemblages in Andean Patagonian rivers and streams (Miserendino 2001).

In North America, the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) is assessing the effects of urbanization on 15 metropolitan area streams (Couch and Hamilton 2002). The Center for Watershed Protection (CWP) developed a watershed restoration plan for a ten square mile watershed in suburban Maryland. The final plan includes construction of 15 stormwater retrofit ponds, nearly two miles of stream restoration and riparian reforestation, along with a watershed education campaign (CWP 2001). American Rivers, Natural Resources Defense Council (NRDC), and Smart Growth America investigated what happens to water supplies when natural areas are replaced with roads, parking lots, and buildings, in order to compare levels of imperviousness in 20 metropolitan areas (Otto et al. 2002).

The Root River of Southeastern Wisconsin is part of the Root River Watershed, which includes 197 square miles of land over Waukesha, Milwaukee, and Racine Counties. Primarily composed of the Root River, the Root River Watershed drains into

Lake Michigan and contains no major lakes or tributaries (Young 2000). The watershed embodies sixteen different municipalities and a total of 117 miles of streams and rivers, ranging in environmental conditions from good to severely degrade. According to the 2002 State of the River-Basin Report published by the DNR, 28.4 miles of streams and lakes do not meet the quality water standards of the DNR (WDNR 2002a).

Nine sub-watersheds contribute flow to the Root River Watershed: the Upper Root, Whitnall Park Creek, East Branch, Lower Root, Middle Root, Root River Canal, West Branch Root River Canal, East Branch Root River Canal, and Hoods Creek. Different purposes are served by each sub-watershed. While the Upper Root is heavily urbanized, the Root River Canal system, the Middle Branch, and Hoods Creek chiefly drains agricultural lands. As Milwaukee County is continually developed, Whitnall Park Creek and the East Branch Watersheds are changing from the residential and agricultural mix to strictly residential (WDNR 2002a).

The headwaters of the Root River are located in west central Milwaukee County. From there, the river flows southeast through the eight sub-watersheds and through the city of Racine, where it empties into Lake Michigan. Included in the Milwaukee County Park System are the majority of the twelve named lakes within the watershed. The Root River Steelhead Facility, located at Lincoln Park in Racine, Wisconsin, aids the Wisconsin Department of Natural Resources in affectively managing Lake Michigan's trout and salmon fisheries (WDNR 2002a).

Making up over half of the Root-Pike River Basin, the Root River Watershed drains approximately two-thirds of the entire River Basin. Along with the Root River Watershed, the Root-Pike River Basin is composed of Pike River, Pike Creek, Oak Creek, and Wind Point Watersheds. The Basin encompasses 327 square miles consisting of 196 miles of perennial streams, 300 miles of intermitted streams, many named lakes, several small lakes and ponds, and numerous tributaries. Over four percent, 8,500 acres, of the river basin is made up of wetlands (WDNR 2002a).

The Root-Pike River Basin is home to more than 300,000 people, over 38 city and county parks, and an abundance of wildlife. Wildlife habitats include Chiwaukee Prairie, Petrifying Springs, River Bend Nature Center, and Whitnall Park (RPWIN 2003, WDNR 2002a).

The first step in protecting and sustaining the ecosystem of the Root River and the surrounding watershed is biological monitoring. Biological monitoring of the Root River involves a sampling of fish and macroinvertebrates at various locales in order to determine the degree of pollution filtering through the Root River Watershed. By collecting and analyzing organisms from several different locales along the river, the degree of organic pollution present may be determined. From these results, a new management plan may be derived, allowing the local residents to work together to improve the quality of the Root River and the surrounding watershed.

Through the use of monitoring, management, and restoration, the resources of the Root-Pike River Basin can be protected from harmful pollutants that have stressed the watershed for decades. Conducting annual biological monitoring surveys on streams using standardized protocols for fish and macroinvertebrate community sampling will allow identification and prevention of degradation.

Methods

Five representative sites were sampled for fish and macroinvertebrate communities on the Root River in Racine County, Wisconsin, (Figures 1, 2, and 3) during late May and early June 2003. Sample sites were determined in consultation with WDNR biologists and visual surveys. Width measurements were taken at 10 locations at each site spread approximately 50 meters apart downriver in order to find the mean width of the river at a specific locale. The length of river electroshocked was determined by multiplying the mean stream width by a factor of 35 (Lyons 1992).

Site 1 is north of Seven Mile Road in Racine County, Wisconsin, and east of Highway 38 (Figure 1). Further down stream site 2 is located 50 m southeast of the intersection of Nicholson Road and County Line Road (Figure 1). The third site is located in Johnson Park, a residential dog park, south of Four Mile Road off of Highway 38 (Figure 2). Site 4 is 150 m southwest of the intersection of Highway 31 and Four Mile Road (Figure 2). Our fifth and final sample location is west of Highway 38 on West High Street in Colonial Park, located in the city of Racine, south of Quarry Lake Park (Figure 3, Table 1).

Table 1: Site location, length, and mean stream width for sample locales on the Root River, Racine County, Wisconsin, for June 2003.

	Coordinates			
Site	Beginning	End	Site length (m)	Mean stream width (m)
1	N42º 50.516, W87º 54.723	N42º 50.557, W87º 54.472	588.7 m	16.82
2	N42º 50.488, W87º 53.482	N42º 50.417, W87º 53.443	519.4	14.84
3	N42º 46.893, W87º 51.799	N42˚ 46.731, W87º 51.750	570.5	16.3
4	N42º 47.026, W87º 50.207	N42º 46.779, W87º 50.506	679.2	19.24
5	N42º 44.157, W87º 49.176	N42º 44.467, W87º 49.047	641.8	18.25

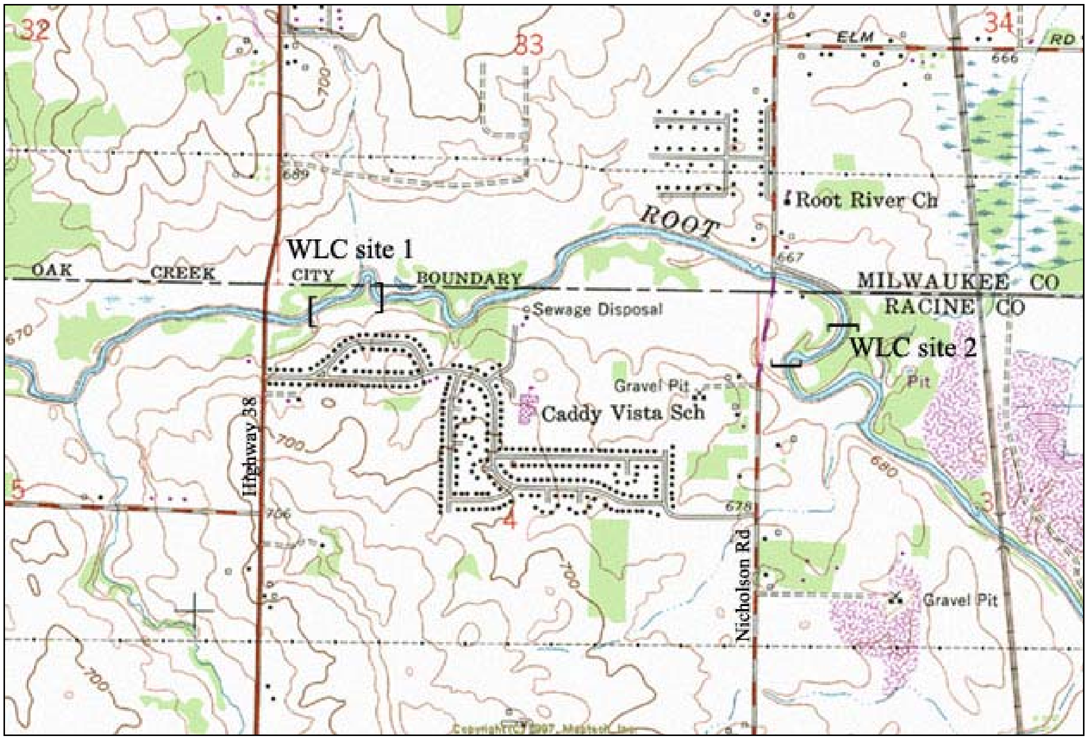


Figure 1: Root River macroinvertebrate and fish sampling sites 1 and 2, Racine County, Wisconsin, for June 2003.

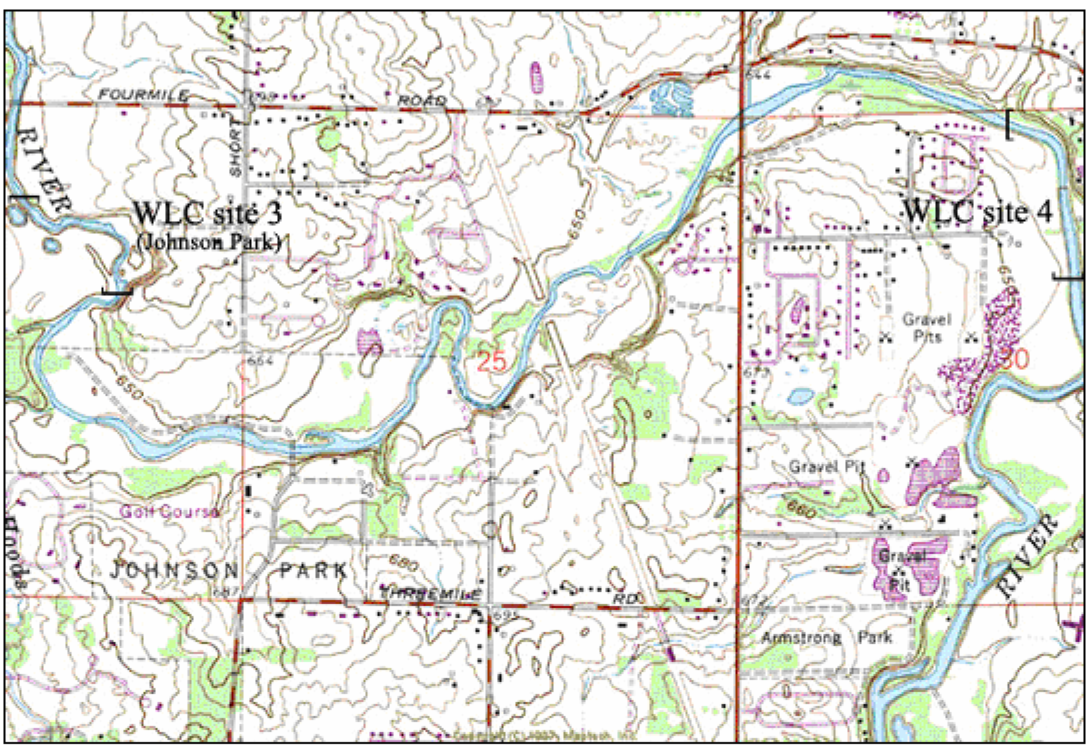


Figure 2: Root River macroinvertebrate and fish sampling sites 3 (Johnson Park) and 4, in Racine County, Wisconsin, for June 2003.

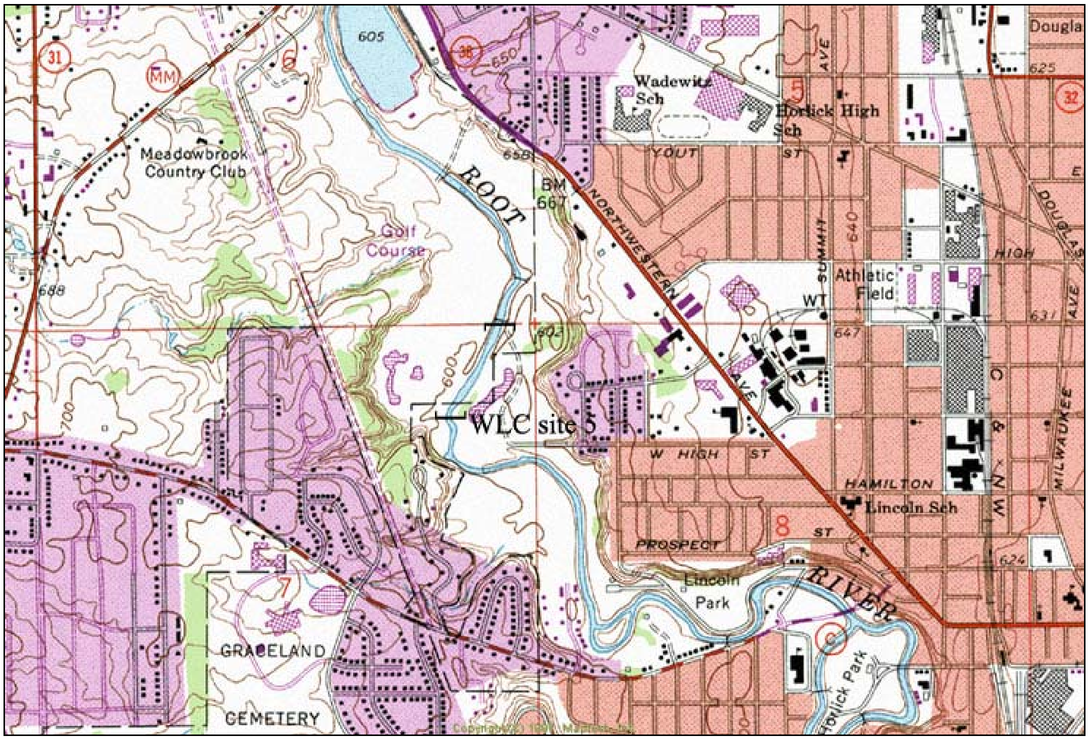


Figure 3: Root River macroinvertebrate and fish sampling sites 5 in Colonial Park, Racine County, Wisconsin, for June 2003.

In 1984, the Wisconsin Department of Natural Resources determined that the Lyons Index of Biotic Integrity (IBI) possessed excellent potential for biological monitoring techniques for the study of fish communities (Lyons 1992). The IBI has been used as a standard for measuring environmental quality in neighboring states along with Wisconsin; therefore, the Wisconsin IBI was used in our study on the Root River.

The protocol described in Lyons (1992) indicates electroshocking is an efficient method for obtaining a representative sample of the fish population in wadable rivers. This technique is based on previous water quality sampling of warm water rivers. The Root River is defined as a warm water, or non-trout, river. High quality, warm water rivers are characterized by numerous native and intolerant species that are particularly sensitive to pollutants and habitat degradation. Electroshocking upstream through the indicated locales of the river provided a representative sample of the fish community (Lyons 1992).

In middle to late June, a tote barge stream shocker with two hand-held electrodes utilized an electrical current to stun the fish occupying all major habitats within the designated sector. The probes passed four to six amps of electricity from a gas-powered generator that provided 100-150 volts. Black dip nets following the probes were used to capture the stunned fish prior to being placed into the live-well. This compartment temporarily held the captured fish unharmed until they were identified at intermediate points or at the end of the site. All sampling occurred during daylight hours, when the river was at base flow (Lyons 1992).

The overall IBI score assigned to a sector assessed the biotic integrity of the river, while indicating the general water quality. The first step to determining the IBI score was the identification of the fish inhabiting the various sites sampled. Unknown specimens were preserved with formaldehyde for later identification occurring at the Wisconsin Lutheran College biology laboratory. The fish were inspected for lesions and deformities; additionally, the size and abundance of species were noted prior to the fish being returned to the river. After field sampling, the IBI score was calculated. This score was determined by the summing of ten metrics, a process discussed in depth within the results section of this paper. The 10 metric scores compared the number of individual species, percentages of trophic levels, and deformities among the fish collected at a specific site of the river. Using the sum of metrics, the overall IBI score was calculated and the biotic integrity determined for each site (Lyons 1992).

The online version of George C. Becker's *Fishes of Wisconsin* (1983) was used for the identification of fish species. Using Becker (1983), the WDNR has produced a modified book containing the names and pictures of fish that have been commonly encountered in previous studies on the Root River Watershed. The information in the tailored version of Becker's identification key was made available to other researches in the form of a compact disc.

An additional method of estimating the biotic integrity of an intermediate size warmwater river is to sample and identify the macroinvertebrates. Macroinvertebrates serve as useful indicators of water quality because different species are particularly sensitive to varying levels of pollution. Macroinvertebrates include the various families of insects, crustaceans, mollusks, gastropods, oligochaetes, and other invertebrates residing in and around the river. Hilsenhoff explains the kick sample method for collecting macroinvertebrates, in the *Wisconsin DNR Field Procedures Manual* (WDNR 1997).

Sites displaying riffles were sampled for macroinvertebrates in early to middle June 2003. Macroinvertebrates, dislodged from the substrate, were carried into a D-frame net by the current (Hilsenhoff et al. 1972). Organisms were collected on site by direct removal from the net mesh using forceps and by sorting through the material collected in the nets on white enamel pans. All macroinvertebrates were placed into an 80% isopropyl alcohol solution for preservation until laboratory identification. Specimens were identified to the lowest possible taxonomic level using identification keys (Eddy and Hodson 1961; Edmondson 1959; Hilsenhoff 1975, 1982, 1987; Merritt and Cummins 1996; McCafferty 1981; Narf 1989; Pennak 1953; Thorp and Covich 1991; WDNR 2003a, 2003b; Wiederholm 1983). Quantitative data, including species diversity and abundance, gathered from the samples was used to determine the biotic integrity of the locale.

Various indices based upon the macroinvertebrate communities were used as ecological indicators of the biotic integrity of the Root River. These indices included: the multimetric in-stream comparison, *GLEAS Procedure No. 51* (MDNR 1991), the Hilsenhoff Biotic Index (Hilsenhoff 1987), and the Family Biotic Index (Hilsenhoff 1988). The guiding principle for each of these indices was to compare the number of various types of macroinvertebrates collected in a section of a stream. The percent composition of the sample was used to determine a metric score. The total sum of the metric scores correlated with a specific biosurvey category (Table 10), which have been developed based on the sampling of streams in the ecoregion (MDNR 1991). Biosurvey categories relate the macroinvertebrate community to a physical description of the degree of pollution present (Table 11). In the Hilsenhoff approach, species are assigned pollution tolerance values of zero (pollution-sensitive) to ten (pollution-tolerant) (Hilsenhoff 1982, 1987). The sum of the individuals of each species were multiplied by their specific tolerance value then divided by the total number of macroinvertebrates collected in the sample to develop a biotic index value. From this value, the water quality of the sample location was determined.

Water parameters were measured using a Hydrolab DataSonde4 multiprobe unit prior to each macroinvertebrate and fish sampling. The water temperature, pH, dissolved oxygen, and conductivity levels which serve major factors influencing distribution, diversity, and abundance of macroinvertebrates along river courses (Wetzel 2001), were noted at each sampling locale. Measurements were taken at one-third of the water column below the surface.

In addition to the fish sampling, water samples were collected to detect levels of phosphorus. These samples were kept cold until the bottles were placed in the freezer later that day. Samples were then thawed prior to the determination of the concentration of phosphorus in the water. Ten milliliters (ml) of each sample were placed into a capped, acid-washed test tube prior to the addition of 1.5 ml of 5% persulfate solution. Each sample was inverted to homogenize the solution before autoclaving for thirty minutes. After cooling, 2 ml of 14.2 mmol L^{-1} ammonium molybdate tetrahydrate prepared in 3.15 mol L^{-1} sulfuric acid was added to the solution. The reagent reacted with the solution for fifteen minutes before adding 2 ml of 3.5 g L^{-1} polyvinyl alcohol (PVA), prepared by bringing deionized water to eighty degrees Celsius and adding PVA. The solution was cooled to room temperature and 0.35 g L^{-1} of malachite green was added (Ohno et al. 1991). After thirty minutes, the final solution was analyzed using UV-Vis Diode Array Spectrometer, which detects the ultraviolet rays that were not absorbed by the solution, in a 5 cm cuvette. Five standards were analyzed prior to testing the water samples collected at the Root River to calibrate and verify the accuracy of the spectrometer.

Discharge records for the Root River downstream from Horlick Dam obtained from the United States Geological Survey (USGS) were used to evaluate the amount of phosphorus flowing down the river during June 2003 (USGS 2003). In order to determine the phosphorus discharge at each sample location, the phosphorus levels were multiplied by the flow rate.

Results

A total of 954 fish were collected by electrofishing five sites on the Root River during June 2003. These collections included 31 species of fish ranging from exotic species, such as carp (*Cyprinus carpio*) and alewife (*Alosa pseudoharengus*), to native species ranging from black bullhead (*Ictalurus melas*) to northern pike (*Esox lucius*). Fish species occurring at all five sites included brown bullhead (*Ictalurus nebulosus*), green sunfish (*Lepomis cyanellus*), Johnny darter (*Etheostoma nigrum*), yellow bullhead (*Ictalurus natalis*), and the white sucker (*Catostomus commersoni*), which was the most commonly encountered species. Nine additional species not occurring at the four previous sites were collected at Colonial Park (Table 2).

Table 2: Numbers of fish collected by electrofishing at five sites (35 x MSW) on the Root River, Racine County, Wisconsin, during June 2003, as well as calculated IBI score and biotic integrity ratings.

		Highway 38 and County Line Road	Nicholson Road and County Line Road	Johnson Park	Highway 31 and Four Mile Road	Colonial Park	Total
		(Site 1)	(Site 2)	(Site 3)	(Site 4)	(Site 5)	
Alewife	*Alosa pseudoharengus*					15	15
Black bullhead	*Ictalurus melas*					1	1
Black crappie	*Promoxis nigromaculatas*					1	1
Blackchin shiner	*Notropis heterodon*			47	4	28	79
Blacknose shiner	*Notropis heterolepis*	3	1	1		33	38
Blackside darter	*Percina maculata*	1		9		1	11
Bluegill	*Lepomis macrochirus*	1			1	12	14
Bluntnose minnow	*Pimephales notatus*		12	24	21	26	83
Brown bullhead	*Ictalurus nebulosus*	1	1	3	6	2	13
Brown trout	*Salmo trutta*					44	44
Carp	*Cyprinus carpio*	12	8	5	3		28
Channel catfish	*Ictalurus punctatus*			2	15		17
Creek chub	*Semotilus atromaculatus*	1	1	16		20	38
Emerald shiner	*Notropis atherinoides*					4	4
Fathead minnow	*Pimephales promelas*			10	6		16
Golden redhorse	*Moxostoma erythrurum*					1	1
Golden shiner	*Notemigonus crysoleucas*					2	2
Goldfish	*Carassius auratus*			1			1
Green sunfish	*Lepomis cyanellus*	4	3	3	19	15	44
Iowa darter	*Etheostoma exile*	1			10		11
Johnny darter	*Etheostoma nigrum*	5	1	29	6	4	45
Largemouth bass	*Micropterus salmoides*					1	1
Northern pike	*Esox lucius*	3	1		1		5
Rainbow trout	*Salmo gairdneri*					62	62
River redhorse	*Moxostoma carinatum*					10	10
Rock bass	*Ambloplites rupestris*			1	11	2	14
Sand shiner	*Notropis stramineus*		6	43	25	17	91
Tadpole madtom	*Noturus gyrinus*					3	3
Trout-perch	*Percopsis omniscomaycus*					4	4
White sucker	*Catostomus commersoni*	19	24	118	18	35	214
Yellow bullhead	*Ictalurus natalis*	1	2	8	18	15	44
Total		**52**	**60**	**320**	**164**	**358**	954
Number of species		**12**	**11**	**16**	**15**	**25**	
Calculated IBI		**5**	**0**	**32**	**29**	**60**	
Biotic integrity rating		**Very poor**	**Very poor**	**Poor**	**Poor**	**Good**	

Calculated IBI scores demonstrated variation in water quality at each site (Table 3). The biotic integrity of sites 1 and 2 were rated as having very poor water quality. Poor water quality was detected at site 4, while site 3 received a rating of fair. Site 5, located below the dam, received the best rating of good water quality (Figure 4, Tables 4 and 5).

Table 3: IBI scores based on maximum species richness plots and on percent occurrence in trophic and reproductive categories (Lyons 1992) for fish species sampled in the Root River during June 2003.

	Highway 38 and County Line Rd		Nicholson Rd and County Line Rd		Johnson Park		Highway 31 and Four Mile Rd		Colonial Park	
	(Site 1)		(Site 2)		(Site 3)		(Site 4)		(Site 5)	
	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Total no. of species	12		11		16		15		25	
Total no. of native species	11	5	10	2	14	5	14	5	22	10
No. of darter species	3	5	1	0	2	2	2	2	2	5
No. of sucker species	1	0	1	0	1	0	1	0	3	5
No. of sunfish species	2	5	1	0	2	5	3	5	4	10
No. of intolerant species	2	0	1	0	6	10	5	5	3	5
% tolerant species	71.2	0	83.3	0	57.5	0	51.8	0	31	5
% omnivores	59.6	0	73.3	0	49.1	0	29.3	5	17.6	10
% insectivores	32.7	5	23.3	0	39.7	5	48.3	5	41.6	5
% top carnivores	5.8	0	2	0	0.94	0	16	10	30.7	5
% lithophilous	38.5	5	40	5	35.3	5	11	0	14.2	0
No. of individuals per 300 m^2* (excluding tolerant species)	7.7		5.78		82.7		35.2		115.6	
Percent DELT*	15.4		8		3.1		3		0	
Correction factor*		-20		-20				-10		0
Overall IBI score		**5**		**0**		**32**		**27**		**60**
Biotic integrity rating		**Very poor**		**Very poor**		**Fair**		**Poor**		**Good**

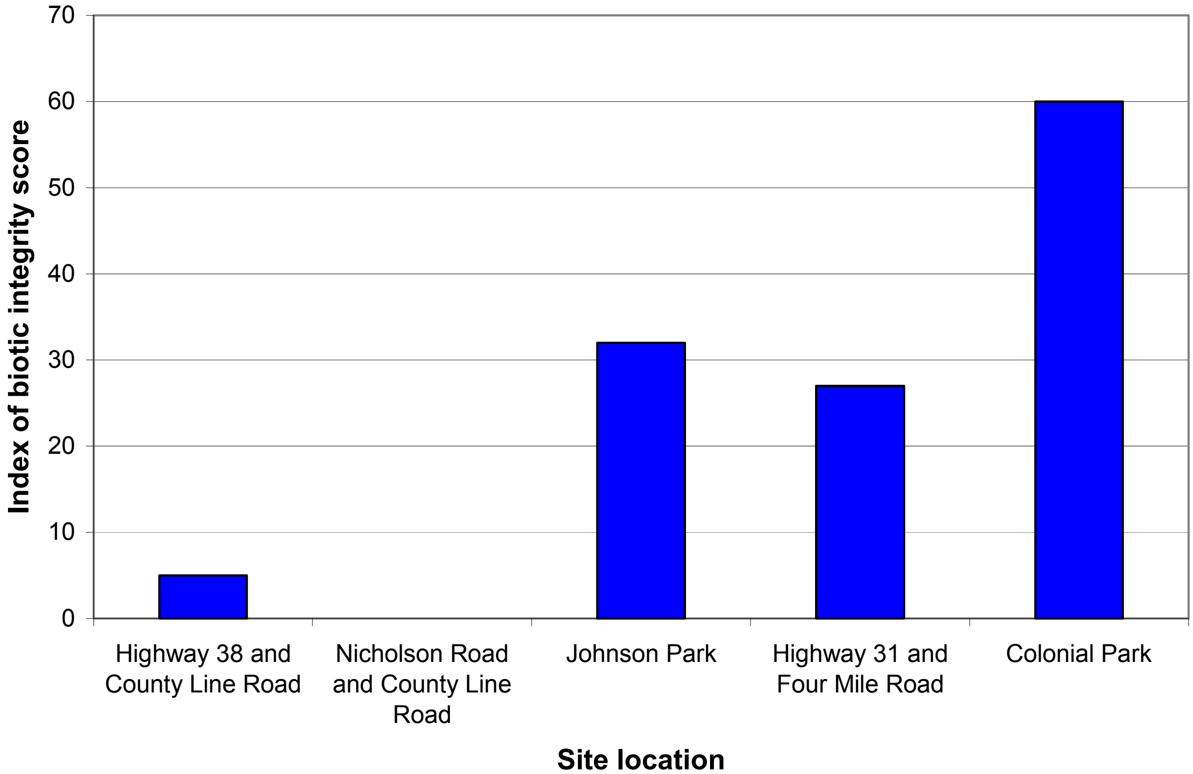
*If less than 50 fish per 300 m^2 or if great than 4% DELT (deformities, eroded fins, lesions, or tumors) subtract 10 from overall IBI score

Table 4: Comparison of the fish communities, overall IBI score, and biotic integrity rating for the five sites sampled on the Root River, Racine County, Wisconsin, during June 2003.

	Highway 38 and County Line Road	Nicholson Road and County Line Road	Johnson Park	Highway 31 and Four Mile Road	Colonial Park
	(Site 1)	(Site 2)	(Site 3)	(Site 4)	(Site 5)
Total	52	60	320	164	358
Number of species	12	11	16	15	25
Overall IBI score	**5**	**0**	**32**	**29**	**60**
Biotic integrity rating	**Very poor**	**Very poor**	**Fair**	**Poor**	**Good**

Table 5: Guidelines for interpreting overall IBI scores. (Lyons 1992)

Overall IBI score	Biotic Integrity rating	Fish community attributes
100 - 65	Excellent	Comparable to the best situations with minimal human disturbances; all regionally expected species for habitat and stream six, including the most intolerant forms, are present with a fully array of age and size classes; balanced trophic structure.
64 - 50	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species, especially top carnivores, are present with less than optimal abundances or size/age distributions; trophic structure shows some signs of imbalance.
49 - 30	Fair	Signs of additional deterioration include decreased species richness, loss of intolerant forms, reduction in simple lithophils, increased abundance of tolerant species, and/or highly skewed trophic structure (*e.g.*, increasing frequency of omnivores and decreased frequency of omnivores and decreased frequency of more specialized feeders); older age classes of top carnivores rare or absent.
29 - 20	Poor	Relatively few species; dominated by omnivores, tolerant forms, and habitat generalists; few or no top carnivores or simple lithophilous spawners; growth rates and condition factors sometimes depressed; hybrids sometimes common.
19 - 0	Very poor	Very few species present, mostly exotics or tolerant forms or hybrids; few large or old fish; DELT fish (fish with deformities, eroded fins, lesions, or tumors) sometimes common.
No score	Very poor	Thorough sampling finds few or no fish; impossible to calculate IBI.



Upstream Downstream

Figure 4: IBI scores of the fish community sampled by electrofishing five sites on the Root River, Racine County, Wisconsin, during June 2003. A water quality rating of 65 – 100 is excellent, 50 – 64 is good, 30 – 49 is fair, 20 – 29 is poor, and 0 – 19 is very poor.

Sixteen-hundred fifty-nine macroinvertebrates were collected while sampling the Root River in early June 2003. A total of 51 taxa were identified from all five sampling locations (Table 6). Non-biting midge larvae (Chironomidae) dominated the samples (44%) followed by stone fly larvae (20%), riffle beetles (8%) and sludge worms (7%).

Hilsenhoff's Family Biotic Index (FBI) indicated a range of integrity varying from poor to very good. Site 3 received the best rating (3.77), with only a slight possibility of organic pollution present. Site 5, which was the furthest downstream, showed very substantial pollution likely with a rating of poor (6.81). (Figure 5, Tables 6 and 7)

Table 6: Biotic indices and water quality assessment based on the abundance of specific taxa of macroinvertebrates collected in the Root River in Racine County, Wisconsin, during June 2003.

Common name	Scientific name	Highway 38 and County Line Road	Nicholson Road and County Line Road	Johnson Park	Highway 31 and Four Mile Road	Colonial Park	Total
		(Site 1)	(Site 2)	(Site 3)	(Site 4)	(Site 5)	
Aquatic sow bug	**Isopoda**						
	Asellus intermedius	1	5	4	9	14	33
Aquatic worm	Oligocheata	10	16	13	47	22	108
Beetles	**Coleoptera**						
Riffle beetle	**Elmidae**						
	Dubiraphia quadrinotata (adult)		1				1
	Macronychus glabratus (adult)		1	1	1		3
	Microcylloepus pusillus (adult)	1					1
	Microcylloepus pusillus (larva)	1	1				2
	Optioservus spp. (larva)	2					2
	Stenelmis spp. (adult)	28	9	25	11	3	76
	Stenelmis spp. (larva)	14	4		15	9	42
Caddisfly larva	**Trichoptera**						
	Cheumatopsyche spp.	33	16	5	18	4	76
	Cyrnellus fraternus					1	1
	Hydropsyche betteni	12	4	1		2	19
	Neotrichia spp.			1			1
	Stactobiella spp.			1			1
	Rhyacophila spp.			1			1
Clams and snails	**Mollusca**						
Fingernail clam	*Sphaerium* spp.	19	1	8	5	5	38
Sinistral snail	*Physa*		1				1
Damselfly	**Zygoptera**						
	Argia apicalis		1	1		1	3
	Argia moesta			1		3	4
	Argia tibialis		3	1			4

Flies	**Diptera**						
Aquatic dance fly	**Empididae**						
	Larva	4		1		1	6
	Pupa	2					2
Blackfly larva	**Simuliidae**						
	Eusimulium aurium			1			1
	Eusimulium latipes			1			1
	Simulium jenningsi			5	1		6
	Simulium pictipes			2			2
	Simulium vittatum	1		4			5
No-see-um	**Certopogonidae**						
	Dasyhelia spp.				1		1
Midge	**Chironomidae**						
	Brillia spp.	4		1			5
	Cardiocladius spp.	9	11	18	5	11	54
	Conchapelopia spp.	17	1	5	2	18	43
	Cryptochironomus spp.	4	4		1	3	12
	Cryptocladopelma spp.			1	1		2
	Dicrotendipes spp.	1			1		2
	Einfeldia spp.				2		2
	Endochironomus spp.		4	1	5		10
	Glyptotendipes spp.		1	1	1		3
	Kiefferulus spp.		1	1			2
	Orthocladius spp.		2	37	8	62	109
	Paratendipes spp.				3		3
	Polypedilum spp.	48	30	41	144	155	418
	Pseudochironomus spp.		1				1
	Stictochironomus spp.	5	17	11	22	7	62
	Thienmanniella spp.		1				1
	Unidentified			2	1		3
	Pupa	10	1	1	1	8	21
Mayfly nymph	**Ephemeroptera**						
	Baetis intercalaris	3		13		22	38
	Caenis spp.	1	3	2			6
	Stenacron spp.	31	4	4		5	44
	Stenonema pulchellum					1	1
	Stenonema terminatum					1	1

Planaria	**Tricladida**						
	Planariidae	1		1			2
Rusty crayfish	**Decapoda**						
	Orconectus rusticus	5	2	12	2	1	22
Scud	**Amphipoda**						
	Gammarus pseudolimnaeus	18	3		1	1	23
Stonefly	**Plecoptera**						
	Neoperla stewarti			3			3
	Perlesta placida	63	50	166	44	2	325
Total		**348**	**199**	**398**	**352**	**362**	1659
Number of families		**16**	**15**	**13**	**11**	**14**	
Family Biotic Index (water quality)		**4.41 (Good)**	**4.90 (Good)**	**3.77 (Very good)**	**6.27 (Fairly poor)**	**6.81 (Poor)**	
Hilsenhoff Biotic Index (water quality)		**5.55 (Fair)**	**5.99 (Fair)**	**5.45 (Good)**	**6.09 (Fair)**	**6.09 (Fair)**	
Multimetric in-stream comparison (water quality)		**44 (Good)**	**36 (Good)**	**Ref. Site**	**26 (Fair)**	**40 (Good)**	

Table 7: Evaluation of water quality using the Hilsenhoff family-level biotic index (Hilsenhoff 1988).

Family Biotic Index	**Water Quality**	**Degree of Organic Pollution**
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

Together with the FBI, Hilsenhoff's Biotic Index (HBI) was also used to assess the macroinvertebrate community. Excluding site 3, the pattern seen from the macroinvertebrate analysis showed a continuum of degradation as the Root River proceeded downstream. Unlike the fish IBI, the macroinvertebrate community at site 5 was not significantly affected by the dam (Figure 5, Tables 6 and 8).

Table 8: Evaluation of water quality using the Hilsenfhoff biotic index (Hilsenhoff 1987).

Biotic Index	**Water Quality**	**Degree of Organic Pollution**
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution likely

The multimetric in-stream comparison evaluated each macroinvertebrate community with respect to the reference site, Johnson Park, which received the highest water quality rating according to the FBI and HBI (Figure 2, Table 6). Multimetric ratings ranged from moderate to slightly impaired aquatic ecosystems. Only site 4 received a rating of fair and demonstrated less than optimal conditions, which included reduced numbers of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa. No apparent pattern was detected among the results of the multimetric in-stream comparison however the scores seem to reflect habitat conditions at individual sampling locales (Figure 9, Tables 9-11).

Table 9: Metric values and scores for macroinvertebrate collections on the Root River, Racine County, Wisconsin, during June 2003. Scores based on Johnson Park as the reference site (MDNR 1991).

	Ref. Site Johnson Park	Highway 38 and Four Mile Road			Nicholson Road and County Line Road		
	(Site 3)	(Site 1)			(Site 2)		
Metric		Value	%	Score	Value	%	Score
Total taxa*	16	15	93.8	6	13	81.3	6
Total mayfly taxa*	3	3	100	6	2	66.7	4
Total caddisfly taxa*	3	1	33.3	2	1	33.3	0
Total stonefly taxa*	1	1	100	6	1	100	6
Percent mayfly*	4.8	10.1	210	6	3.5	73.7	2
Percent caddisfly*	2.0	12.9	643	6	10.1	50.0	6
Percent dominant taxon	42.5	28.2		0	37.2		2
% Isopods, snails, & leeches	1.0	0.3		6	3.0		4
% Surface dependent	0	0		6	0		6
Total Score				**44**			**36**
Biosurvey Category				**Good**			**Good**

*Compared to reference site values

Table 9: Continued

	Ref. Site Johnson Park	Highway 31 and Four Mile Road			Colonial Park		
	(Site 3)	(Site 4)			(Site 5)		
Metric		Value	%	Score	Value	%	Score
Total taxa*	16	11	68.8	4	14	87.5	6
Total mayfly taxa*	3	0	0	0	2	66.7	4
Total caddisfly taxa*	3	1	33.3	0	2	66.7	4
Total stonefly taxa*	1	1	100	6	1	100	6
Percent mayfly*	4.8	0	0	0	8.0	168	6
Percent caddisfly*	2.0	5.1	254	6	1.9	96.2	6
Percent dominant taxon	42.5	56.0		0	72.9		0
% Isopods, snails, & leeches	1.0	2.6		4	3.9		2
% Surface dependent	0	0		6	0		6
Total Score				**26**			**40**
Biosurvey Category				**Fair**			**Good**

*Compared to reference site values

Table 10: Macroinvertebrate scoring criteria and biosurvey categories based on the multimetric in-stream comparison, *GLEAS Procedure No. 51* (MDNR 1991).

Metric	**6**	**4**	**2**	**0**
1. Total Number of Taxa*	>80	60-80	40-60	<40
2. Total Number of Mayfly Taxa*	>80	60-80	40-60	<40
3. Total Number of Caddisfly Taxa*	>80	60-80	40-60	<40
4. Total Number of Stonefly Taxa*	>90	80-90	70-80	<70
5. Percent Mayfly*	>90	80-90	70-80	<70
6. Percent Caddisfly*	>80	60-80	40-60	<40
7. Percent Contribution of Dominant Taxon	<20	20-30	30-40	>40
8. Percent Isopods, Snails, and Leeches	<1	1-3	3-5	>5
9. Percent Surface Dependent	<5	5-20	20-40	>40

*Compared to reference site values

Table 11: Macroinvertebrate scoring criteria and biosurvey categories based on the multimetric in-stream comparison, *GLEAS Procedure No. 51* (MDNR 1991).

Total Score (Sum of 9 Metric Ratings)	**Biosurvey Category**	**Attributes**
46-54	Excellent (non-impaired)	Expected situation in ecoregion. Balanced community and dominance.
30-45	Good (Slightly impaired)	Less than optimal due to some loss of intolerant forms.
10-29	Fair (Moderately Impaired)	Loss of intolerant forms and reduced E, P, and T.
<10	Poor (Severely impaired)	Few taxa present. If high densities, dominated by one or two taxa.

Phosphorus concentrations at the five Root River sample sites ranged from 0.1703 at site 2 to 0.3322 mg L^{-1} at site 1. Total phosphorus discharge ranged from 583 mg s^{-1} to 299 mg s^{-1} (Table 12 and Figure 5).

Table 12: Absorbance, phosphorus levels, and flow rates of five sample locations in the Root River during June 2003.

Site	Sample Location	Absorbance	Phosphorus levels (ppb)	Phosphorus levels (mg L^{-1})	Flow rate (L s^{-1})	Phosphorus discharge (mg s^{-1})	Daily load (lb day^{-1})
1	Highway 38 and County Line Road	0.2296	332.2	0.3322	1755.84	583.3	22.91
2	Nicholson Road and County Line Road	0.2086	170.3	0.1703	1755.84	299.0	11.74
3	Johnson Park	0.2231	282.2	0.2822	1472.64	415.6	16.32
4	Highway 31 and Four Mile Road	0.2182	244.4	0.2444	1472.64	360.0	14.13
5	Colonial Park	0.2219	273.0	0.2730	764.64	208.7	8.198

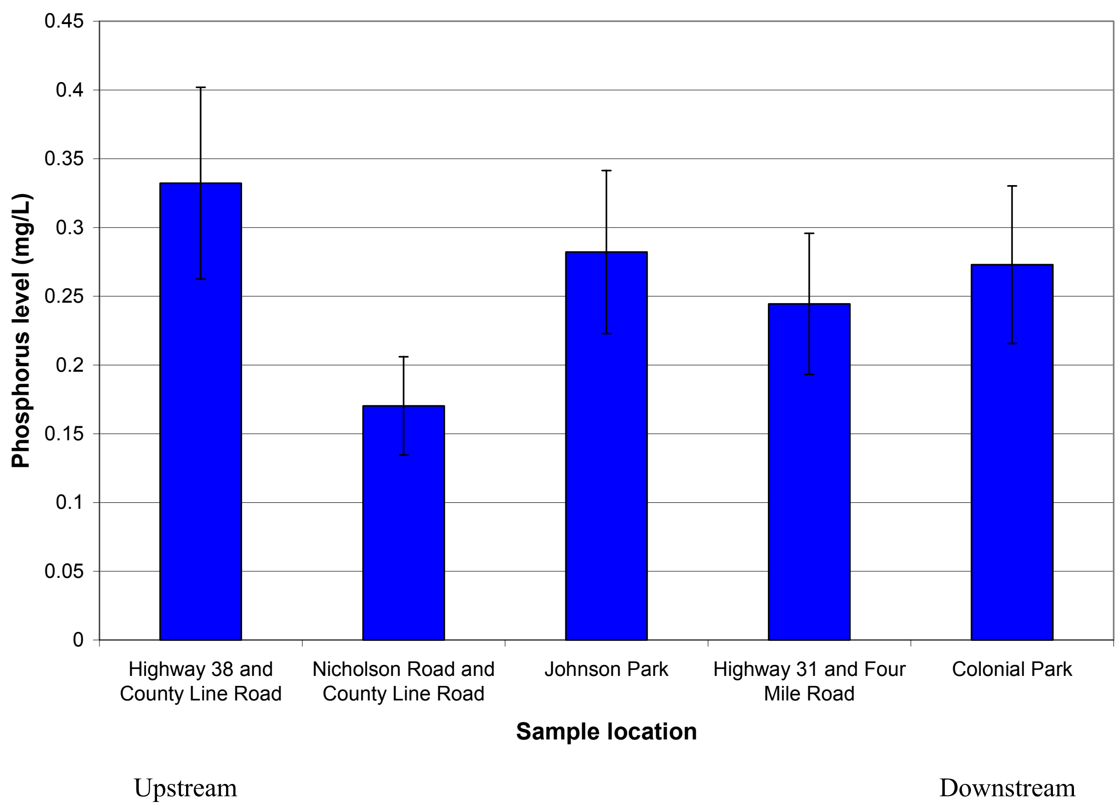


Figure 5: Phosphorus levels, measured by UV-Vis Spectrometer, from samples collected at five sites on the Root River during June 2003.

Discussion

The most severe threats to contemporary plant and animal life include pollution and urbanization. According to the United States Environmental Protection Agency (EPA), nonpoint source pollution is the nation's leading source of water quality degradation. When excessive amounts of compounds containing phosphorus and nitrogen enter a body of water they promote eutrophication, the fertilization of surface waters. Severe consequences result from the process of eutrophication including the proliferation of algae, cyanobacterial blooms, depletion of dissolved oxygen, and the ultimate decline of aquatic biodiversity. As the most widespread pollution problem in the United States today, eutrophication accounts for approximately sixty percent of all river sectors listed as impaired (Carpenter et al. 1998).

Phosphoric and nitrogenous pollutants that enter into an ecosystem by way of nonpoint pollution sources are commonly associated with agricultural and urban activities. Inputs of pollution are the result of seasonal agricultural activities, such as planting, plowing, and irrigation. Surface runoff, the development of wetlands, and septic leaching are primary sources of urban pollution. Because nonpoint sources arise from assorted activities taking place in large regions, it may be difficult to locate and control the sources contributing to environmental pollution (Carpenter et al. 1998, Paul and Meyer 2001).

Like the many forms of pollution, urbanization easily disturbs the delicate balance of a river system. Even something as simple as a concrete sidewalk along a peaceful stream damages the environment by increasing the rate of runoff. Caused by hindrance to the natural process of absorption, runoff is often a source of nonpoint pollution. As rainwater makes its way through a developed watershed and into a body of water, pollutants are picked up while traveling through parking lots, sidewalks, or driveways (Tong and Chen 2002). Urbanizing areas affect the water holding capacity of the soil by reducing the pervious surfaces (Alp et al. 2001). Filling in wetlands into urban areas degrades aquatic ecosystems by reducing the water storage capacity of the area and increasing storm-water runoff. This leads to frequent, more severe flooding and stream bank erosion. Flooding alters stream channel form and stream bed composition which is an important part of the habitat for organisms living in the stream. Relatively minute amounts of urbanization in a watershed can lead to major changes in the ecosystem (Wang 2001).

Based on sampling and analysis of the fish communities, the IBI indicates the Root River currently exhibits very poor to good water quality when compared to typical Wisconsin warm water streams. Water quality is described as the biological, chemical, and physical characteristics of a stream and is influenced by natural and anthropogenic disturbances (Alp et al. 2001). Lake Michigan fish communities have access to site 5, located below Horlick Dam, therefore this location received a better rating than upstream sites. As a result, nine species of fish were found inhabiting site 5 that were not found in the upstream sampling locations. Just upstream from the dam, site 4 had the largest mean stream width of the sites sampled for this study. The reduced flow, buildup of silt, and possible containment of pollutants may have contributed to the poor water quality at this site. A similar phenomenon was seen at sites 1 and 2 where log jams acted as small dams. Sites 3 and 5 showed greater flow rates and numerous regions of riffles. An intolerant species, the blackchin shiner (*Notropis heterodon*), was more commonly encountered at these sites (Table 2).

One approach to evaluating the impact of agricultural and urbanization activity in the Root River Watershed is to compare biological monitoring results of this study to the results of biological monitoring on the East Branch of the Milwaukee River. The East Branch of the Milwaukee River, located in a wooded area, achieved the highest water quality rating among warm water streams sampled in the 1998 Milwaukee River South Priority Watershed study (Wang et al. 1998). Fish communities in the East Branch of the Milwaukee River were compared to the electrofishing results from the best Root River site (Johnson Park). Greater numbers of insectivores, darters, yellow perch, logperch, and total fish species contributed to the higher rating received at the East Branch of the Milwaukee River in comparison to the Root River. The fish IBI score of the East Branch of the Milwaukee River in 1998 was 60 while the 2003 Root River fish IBI score was 32. The higher fish IBI score of the East Branch of the Milwaukee River demonstrates the higher quality river system associated with a less developed watershed.

Previously conducted wadable stream fish community evaluations on the Root River by WDNR stream ecologist Craig Helker and others were used for further assessment of the water quality. The fish IBI for the 2002 Rawson Avenue location in Milwaukee County (Figure 6) received a very poor rating, a score of seven. In 2001, the Johnson Park locale (Figure 7) scored a 50, a good water quality rating (Table 13). The good water quality rating at Johnson Park may be attributed to the abundance of shiners, darters, and top carnivore species. However, lack of individuals, darter species, and an increase in tolerant species contributed to the very poor water quality at Rawson Avenue (Figure 8, Table 14; WDNR 2003b). Comparing these results to the 2003 samples, the Rawson Avenue location and site 1 (Figure 1) demonstrated similar results. However, further downstream at Johnson Park, the rating declined over a two-year period.

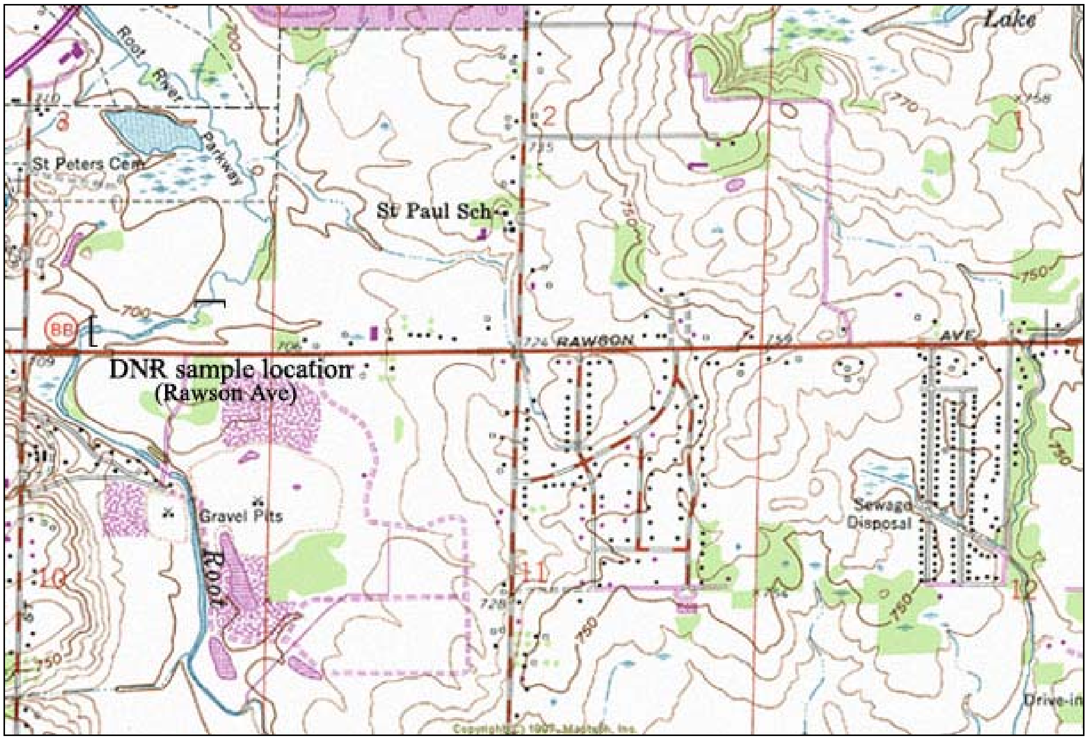


Figure 6: Root River WDNR fish sampling site 125 m upstream from Rawson Avenue Bridge, Milwaukee County, Wisconsin, for September 2002.

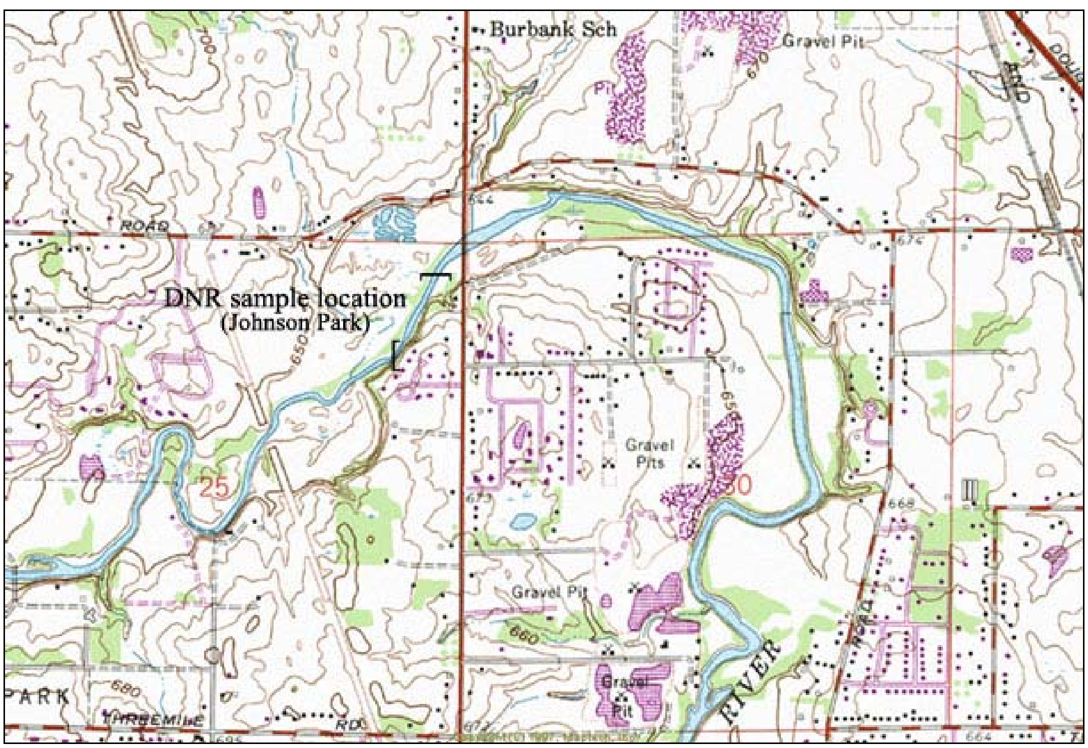


Figure 7: Root River WDNR fish sampling site 200.7 m upstream of Highway 31 at Johnson Park, Racine County, Wisconsin, for August 2001.

Table 13: IBI scores based on maximum species richness plots and percent occurrence in trophic and reproductive categories (Lyons 1992) for fish species sampled in the Root River by the WDNR during August 2001 at Johnson Park and September 2002 at Rawson Avenue (WDNR 2003b).

	Johnson Park		Rawson Avenue	
	August 8, 2001		September 10, 2002	
	Rating	Score	Rating	Score
Total number of species	18		13	
Total number of native species	16	5	12	5
Number of darter species	3	5	2	2
Number of sucker species	1	0	1	0
Number of sunfish species	3	10	1	0
Number of intolerant species	2	0	0	0
Percent tolerant species	27.2	5	76.1	0
Percent omnivores	20.5	5	47	0
Percent insectivores	76.5	10	40.4	5
Percent top carnivores	3.9	0	3.9	0
Percent lithophilous	81.2	10	22.5	5
Number of individulas per 300m* (excluding tolerant species)	507.4		51	
Percent DELT*	0		1.1	
Correction factor*		0		-10
Overall IBI score		**50**		**7**
Biotic integrity rating		**Good**		**Very poor**

*If less than 50 fish per 300m^2 or if great than 4% DELT (deformities, eroded fins, lesions, or tumors) subtract 10 from overall IBI score

Table 14: Comparison of the fish communities, overall IBI score, and biotic integrity rating of two sites sampled on the Root River, Racine County, during June 2003, to the WDNR sample locations at Johnson Park, August 2001, and at Rawson Avenue, September 2002 (WDNR 2003b).

	Rawson Avenue (WNDR) 2002	Highway 38 and County Line Road 2003	Johnson Park (WDNR) 2001	Johnson Park 2003
Total	289	52	1217	320
Number of species	13	12	18	16
Overall IBI score	**7**	**5**	**50**	**32**
Biotic integrity rating	**Very poor**	**Very poor**	**Good**	**Fair**

While the fish community reflected general water quality, the macroinvertebrates more closely exhibited the characteristics of specific habitats. Variability in benthic communities on the Root River can be influenced by changes in chemical composition, available habitat, and flow inconsistency (Lenz and Rheaume 2000). Thus, the stream quality ratings based on the macroinvertebrate samples were higher than the results attained by the fish community analysis. The best FBI and HBI ratings were found at Johnson Park due to the improved river habitat resulting in the colonization of a species of stonefly (*Perlesta placida*) as well as a diverse community of macroinvertebrates. The abundance of midge fly larvae at Colonial Park contributed to the lowest FBI and HBI scores among the sites sampled. Colonial Park, which was the furthest downstream station received pollutants from urbanization and agricultural activities, had the lowest FBI and HBI score and was predominantly colonized by chironomids. Comparing the results of the macroinvertebrate samples collected at the five sites on the Root River demonstrated the water quality decline as the river travels toward Lake Michigan (Table 6). This may be attributed to increasing pollutants entering the stream as it travels into urbanized Racine County. Whereas the first two upstream sites were located in agricultural regions, the sites downstream were located near or in developed neighborhoods which become more urbanized as the river meanders to the lakefront. The only exception was Johnson Park due to its improved stream habitat. Compared to the other sampling stations, the river had abundant riffles and runs without extensive pools. Johnson Park primarily had a rocky substrate, greater flow rate, and decreased amount of sediment buildup.

The FBI (Hilsenhoff 1988) and HBI (Hilsenhoff 1987) were developed as a comparison to Wisconsin streams sampled by Hilsenhoff. The Root River showed lesser water quality than the average Wisconsin stream. This study used the metrics from the multimetric in-stream comparison (MDNR 1991) to evaluate the macroinvertebrate community of the Root River. Because the sample collected at Johnson Park had the greatest number of taxa, it was used as the Root River reference site. The macroinvertebrates collected at the other four sampling locations were compared to the Johnson Park sample (Figure 8). These comparisons demonstrated the differences in water quality within the stream as opposed to comparing each site to the average Wisconsin stream. Thus, the other four sites appeared to receive higher water quality ratings using the multimetric in-stream comparison.

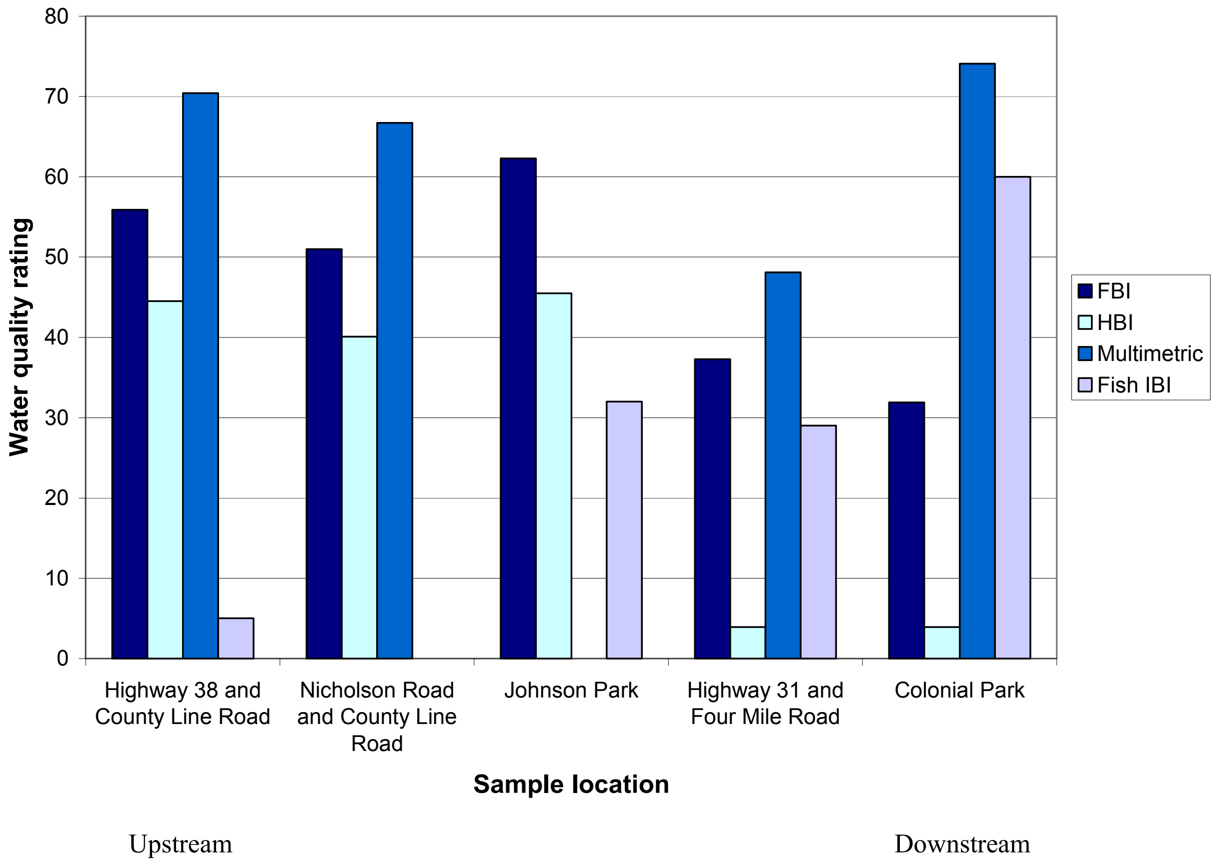


Figure 8: Water quality ratings based on biotic indices for macroinvertebrates and fish collected in the Root River, Racine County, Wisconsin, during June 2003. For HBI and FBI, a water quality rating of 65 – 100 is excellent, 55 – 64 is very good, 45 – 54 is good, 35 – 44 is fair, 25 – 34 is fairly poor, 15 – 24 is poor, and 0 – 14 is very poor. For the multimetric in-stream comparison, 85 – 100 is excellent, 56 – 84 is good, 19 – 55 is fair, and 0 – 18 is poor. (MDNR 1991) Lyon's fish IBI indicates a water quality rating of 65 – 100 is excellent, 50 – 64 is good, 30 – 49 is fair, 20 – 29 is poor, and 0 – 19 is very poor (Lyons 1992).

The WDNR performs routine macroinvertebrate community evaluations at established sites on the Root River and other streams within the Root River Watershed. Macroinvertebrates were collected at Johnson Park on June 6, 1999, and December 1, 2000. A sample was also taken at the Highway 31 bridge on November 29, 2000, and November 13, 2001. The WDNR identified macroinvertebrates and determined water quality using the HBI (Hilsenhoff 1987). Although samples collected at Johnson Park and Highway 31 received good and fair water quality ratings, the HBI score continues to increase, demonstrating that these locales are progressively degrading (Figure 9, Table 15). Similarly, the fish IBI scores showed degradation at Johnson Park and upstream near site 1 over the last two years. This may be attributed to increased urbanization and agricultural activities upstream and near the sample locations.

Table 15: Results of macroinvertebrate collections obtained from the Root River at Johnson Park and Highway 31, Racine County, during June 2003 compared to WDNR results from Johnson Park, sampled in 1999 and 2000, and Highway 31, sampled in 2000 and 2001 (WDNR 2003a).

Sample location	Total number of organisms collected	Number of families	HBI	Water quality rating
Johnson Park (DNR) 1999	195	14	5.021	Good
Johnson Park (DNR) 2000	208	14	5.07	Good
Johnson Park 2003	398	13	5.45	Good
Highway 31 (DNR) 2000	166	12	5.551	Fair
Highway 31 (DNR) 2001	190	5	5.481	Good
Highway 31 and Four Mile Road 2003	352	11	6.09	Fair

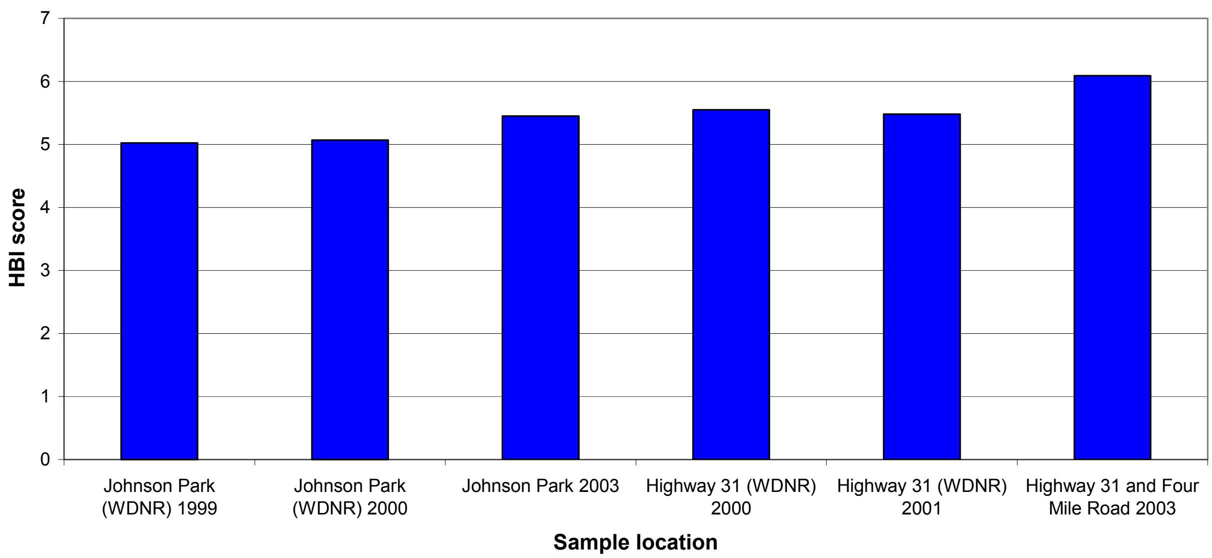


Figure 9: HBI scores of macroinvertebrate samples collected from the Root River at Johnson Park and Highway 31, Racine County, during June 2003 in comparison to results collected by the WDNR at Johnson Park on June 9, 1999, and December 1, 2000, and upstream of Highway 31 on November 29, 2000, and November 13, 2001 (WDNR 2003a). An HBI score of 0.00 – 3.50 receives a water quality rating of excellent, 3.51 – 4.50 is very good, 4.51 – 5.50 is good, 5.51 – 6.50 is fair, 6.51 – 7.50 is fairly poor, 7.51 – 8.50 is poor, and 8.51 – 10.00 is very poor (Hilsenhoff 1987).

The aquatic ecosystem of the Root River Watershed consists of the interactions among all organisms and the water on which they are dependent. Human interference, such as urbanization, easily impairs or alters the natural balance of the ecosystem. Consequences resulting when an aquatic environment is disturbed include the loss of pollution-intolerant species, the accelerated proliferation of pollution-tolerant organisms, increased numbers of organisms possessing deformities, lesions, or tumors (DELT), and changes in the chemical composition of ecosystem (EC 2000). Of the fish sampled at the five sites in the Root River, 2.9% were classified as DELT. Although this was not an extensive percentage, fish classified as DELT were found at each sampling locale except site 5. Pollution present in the Root River is a reflection of the interdependent relationships between the river, the neighboring terrestrial plant and animal life, and the activities of the citizens residing in the watershed.

Urbanization contributes to the degradation of the Root River Watershed by increasing the rates of runoff, due to the presence of numerous impervious surfaces, and through the destruction of in-stream cover and stream corridors. The EPA has determined that up to 70% of the pollution in our surface waters is from stormwater (WMEAC 2003). Currently, gutters and sewers direct water toward retention ponds that aid in the reduction of flooding and turbidity. However, retention ponds ultimately dispose stormwater at a great distance from where the rain fell. On the other hand, rain gardens decrease the rate of runoff allowing stormwater to percolate into the ground, reducing flooding. In addition, plants, bacteria, and soil clean the water as it seeps into the ground. Finally, stormwater is not exposed to excess pollutants in contrast to runoff from impervious surfaces. Altogether, rain gardens make for better surface water quality, groundwater quality, and overall hydrological health (Cozzetto 2001). Modification of a stream corridor has profound impacts on the ecosystem of the Root River Watershed. Trees, shrubs, and grasses provide shade while stabilizing streambanks, filtering runoff, and attracting insects and wildlife. Degradation of the corridor results in loss of shade and soil retention, decreasing the water quality (WDNR 2002a).

Impaired waters of the Root River system, hindered by organic enrichment and low DO levels, include the Root River from the Racine Harbor, upstream to the Horlick Dam, the Root River Canal and its West Branch, as well as 12 miles of the main stem of the Root River (EPA 2003c). Dams may contribute to the degradation of the Root River Watershed. Regardless of size, dams have a profound effect on stream ecosystems by changing flowing streams into bodies of water resembling lakes while displacing species inhabiting runs and riffles. Dam structures prevent or slow migration of fish and other aquatic life within a stream ecosystem thereby having effects throughout the food chain. These structures dampen high flows that move sediment, building up sediment behind dams while disrupting spawning beds and the conditions necessary for survival of fish (Clarkson and Childs 1999). Dams induce upstream waters to increase in temperature, which has a negative effect on species sensitive to temperature fluctuations as well as attracting tolerant species, such as carp and white sucker, to the warm water pools (WDNR 2002a). Removal of dams may restore a river to its free-flowing form. The positive change in flow, temperature, and dissolved oxygen concentration creates habitats suitable for smallmouth bass, northern pike, rock bass, and other river species (WDNR 2003d).

Floodplains are lands which have been or may be covered by flood water during regional floods (WDNR 2002c). The macrophytes that cover floodplains act as natural filters of pollutants and trap sediments. Additionally, these lands support a vast assemblage of terrestrial and aquatic life. Destruction of floodplains by urbanization degrades the integrity of a watershed by disrupting the natural flow of floodwaters. The

WDNR has given the power to municipalities to prohibit any development which will cause an obstruction to flood flows or an increase in regional flood discharge or will adversely affect the existing drainage courses or facilities (WDNR 2002c). Damage to floodplains degrades a watershed and is extremely difficult to revert.

Our assessment of the macroinvertebrate and fish communities of the Root River provides insight into the quality of the watershed ecosystem. Identification and collection of indicator species is a process of biological monitoring that establishes parameters for the integrity of the river. The condition of the Root River is a result of urbanization, pollution, and stream modification throughout the years. Given that the Root River flows through agricultural, metropolitan, rural, and undeveloped lands, the comparison of fish IBI ratings to those determined for East Branch Milwaukee River demonstrates the destructive effects of development. Continual use of biological monitoring as a tool to evaluate the integrity of the Root River will track improvements or further degradation of the aquatic system. This form of consistent monitoring will help the Racine community achieve ecological harmony.

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Appendix A: Comprehensive list of fish community parameters obtained by electrofishing five stations on the Root River, Racine County, Wisconsin, during June 2003.

Table 1: Fish species arranged by size and site location, obtained by electroshocking (35xMSW) on the Root River, Racine County, Wisconsin, during June 2003.

	‹ 60 mm					60 - 175 mm					176 – 400 mm				
	Site #1	Site #2	Site #3	Site #4	Site #5	Site #1	Site #2	Site #3	Site #4	Site #5	Site #1	Site #2	Site #3	Site #4	Site #5
Alewife										15					
Black bullhead										1					
Black crappie															1
Blackchin shiner			31	4	15			16		13					
Blacknose shiner					13	3	1	1		20					
Blackside darter			4		1	1		5							
Bluegill										12	1			1	
Bluntnose minnow		8	12	20	7		4	12	1	19					
Brown bullhead									4		1	1	3	2	2
Brown trout															44
Carp														1	
Channel catfish									8				2	3	
Creek chub			2			1	1	14		18					2
Emerald shiner										4					
Fathead minnow								10	6						
Golden redhorse															
Golden shiner										2					
Goldfish													1		
Green sunfish					3	4	3	3	18	11				1	1
Iowa dartar				2		1	8								
Johnny darter	4	1	29	6	3	1				1					
Largemouth bass															1
Northern pike									1						

	< 60 mm					60 - 175 mm					176 – 400 mm				
	Site #1	Site #2	Site #3	Site #4	Site #5	Site #1	Site #2	Site #3	Site #4	Site #5	Site #1	Site #2	Site #3	Site #4	Site #5
Rainbow trout										60					2
River redhorse										1					2
Rock bass									6	2			1	5	
Sand shiner		2	12	7			4	31	18	17					
Tadpole madtom										3					
Trout-perch										4					
White sucker						10	18	65	1	5	8	6	51	17	23
Yellow bullhead				2	2		2	6	15	13	1	2		1	

Table 1: Continued

	> 400 mm				
	Site #1	Site #2	Site #3	Site #4	Site #5
Alewife					
Black bullhead					
Black crappie					
Blackchin shiner					
Blacknose shiner					
Blackside darter					
Bluegill					
Bluntnose minnow					
Brown bullhead					
Brown trout					
Carp	12	8	5	2	
Channel catfish				4	
Creek chub					
Emerald shiner					
Fathead minnow					
Golden redhorse					1
Golden shiner					
Goldfish					

	› 400 mm				
	Site #1	Site #2	Site #3	Site #4	Site #5
Green sunfish					
Iowa dartar					
Johnny darter					
Largemouth bass					
Northern pike	3	1			
Rainbow trout					
River redhorse					7
Rock bass					
Sand shiner					
Tadpole madtom					
Trout-perch					
White sucker	1		2		7
Yellow bullhead					

Table 2: Number of fish collected by electroshocking, calculated IBI score, and biotic integrity rating for Site #1, Highway 38 and County Line Road, Racine County, Wisconsin, on June 12, 2003, sampled between 1030 and 1325 hours.

Common name	Scientific name	Number
Blacknose shiner	*Notropis heterolepis*	3
Blackside darter	*Percina maculata*	1
Bluegill	*Lepomis macrochirus*	1
Brown bullhead	*Ictalurus nebulosus*	1
Carp	*Cyprinus carpio*	12
Creek chub	*Semotilus atromaculatus*	1
Green sunfish	*Lepomis cyanellus*	4
Iowa darter	*Etheostoma exile*	1
Johnny darter	*Etheostoma nigrum*	5
Northern pike	*Esox lucius*	3
White sucker	*Catostomus commersoni*	19
Yellow bullhead	*Ictalurus natalis*	1
Total		**52**
Number of species		**12**
Calculated IBI		**5**
Biotic integrity rating		**Very poor**

Table 3: Electroshocking results, calculated IBI score, and biotic integrity rating for fish sampled at Site #2, Nicholson Road and County Line Road, Racine County, Wisconsin, on June 12, 2003, between 1545 and 1755 hours.

Common name	Scientific name	Number
Blacknose shiner	*Notropis heterolepis*	1
Bluntnose minnow	*Pimephales notatus*	12
Brown bullhead	*Ictalurus nebulosus*	1
Carp	*Cyprinus carpio*	8
Creek chub	*Semotilus atromaculatus*	1
Green sunfish	*Lepomis cyanellus*	3
Johnny darter	*Etheostoma nigrum*	1
Northern pike	*Esox lucius*	1
Sand shiner	*Notropis stramineus*	6
White sucker	*Catostomus commersoni*	24
Yellow bullhead	*Ictalurus natalis*	2
Total		**60**
Number of species		**11**
Calculated IBI		**0**
Biotic integrity rating		**Very poor**

Table 4: Number of fish collected by electroshocking, calculated IBI score, and biotic integrity rating for Site #3, Johnson Park, Racine County, Wisconsin, on June 13, 2003, sampled between 0930 and 1200 hours.

Common name	Scientific name	Number
Blackchin shiner	*Notropis heterodon*	47
Blacknose shiner	*Notropis heterolepis*	1
Blackside darter	*Percina maculate*	9
Bluntnose minnow	*Pimephales notatus*	24
Brown bullhead	*Ictalurus nebulosus*	3
Carp	*Cyprinus carpio*	5
Channel catfish	*Ictalurus punctatus*	2
Creek chub	*Semotilus atromaculatus*	16
Fathead minnow	*Pimephales promelas*	10
Goldfish	*Carassius auratus*	1
Green sunfish	*Lepomis cyanellus*	3
Johnny darter	*Etheostoma nigrum*	29
Rock bass	*Ambloplites rupestris*	1
Sand shiner	*Notropis stramineus*	43
White sucker	*Catostomus commersoni*	118
Yellow bullhead	*Ictalurus natalis*	8
Total		**320**
Number of species		**16**
Calculated IBI		**32**
Biotic integrity rating		**Fair**

Table 5: Electroshocking results, calculated IBI score, and biotic integrity rating for fish sampled at Site #4, Highway 31 and Four Mile Road, Racine County, Wisconsin, on June 13, 2003, between 1345 and 1545 hours.

Common name	Scientific name	Number
Blackchin shiner	*Notropis heterodon*	4
Bluegill	*Lepomis macrochirus*	1
Bluntnose minnow	*Pimephales notatus*	21
Brown bullhead	*Ictalurus nebulosus*	6
Carp	*Cyprinus carpio*	3
Channel catfish	*Ictalurus punctatus*	15
Fathead minnow	*Pimephales promelas*	6
Green sunfish	*Lepomis cyanellus*	19
Iowa darter	*Etheostoma exile*	10
Johnny darter	*Etheostoma nigrum*	6
Northern Pike	*Esox lucius*	1
Rock bass	*Ambloplites rupestris*	11
Sand shiner	*Notropis stramineus*	25
White sucker	*Catostomus commersoni*	18
Yellow bullhead	*Ictalurus natalis*	18
Total		**164**
Number of species		**15**
Calculated IBI		**27**
Biotic integrity rating		**Poor**

Table 6: Number of fish collected by electroshocking, calculated IBI score, and biotic integrity rating for Site #5, Colonial Park, Racine County, Wisconsin, on June 19, 2003, sampled between 0930 and 1220 hours.

Common name	Scientific name	Number
Alewife	*Alosa pseudoharengus*	15
Black bullhead	*Ictalurus melas*	1
Black crappie	*Promoxis nigromaculatas*	1
Blackchin shiner	*Notropis heterodon*	28
Blacknose shiner	*Notropis heterolepis*	33
Blackside darter	*Percina maculata*	1
Bluegill	*Lepomis macrochirus*	12
Bluntnose minnow	*Pimephales notatus*	26
Brown bullhead	*Ictalurus nebulosus*	2
Brown trout	*Salmo trutta*	44
Creek chub	*Semotilus atromaculates*	20
Emerald shiner	*Notropis atherinoides*	4
Golden redhorse	*Moxostoma erythrurum*	1
Golden shiner	*Notemigonus crysoleucas*	2
Green sunfish	*Lepomis cyanellus*	15
Johnny darter	*Etheostoma nigrum*	4
Largemouth bass	*Micropterus salmoides*	1
Rainbow trout	*Salmo gairdneri*	62
River redhorse	*Moxostoma carinatum*	10
Rock bass	*Ambloplites rupestris*	2
Sand shiner	*Notropis stramineus*	17
Tadpole madtom	*Noturus gyrinus*	3
Trout-perch	*Percopsis omniscomaycus*	4
White sucker	*Catostomus commersoni*	35
Yellow bullhead	*Ictalurus natalis*	15
Total		**358**
Number of species		**25**
Calculated IBI		**60**
Biotic integrity rating		**Good**

Table 8: Guidelines for interpreting overall IBI scores (Lyons 1992).

Overall IBI score	Biotic Integrity rating	Fish community attributes
100 - 65	Excellent	Comparable to the best situations with minimal human disturbances; all regionally expected species for habitat and stream six, including the most intolerant forms, are present with a fully array of age and size classes; balanced trophic structure.
64 - 50	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species, especially top carnivores, are present with less than optimal abundances or size/age distributions; trophic structure shows some signs of imbalance.
49 - 30	Fair	Signs of additional deterioration include decreased species richness, loss of intolerant forms, reduction in simple lithophils, increased abundance of tolerant species, and/or highly skewed trophic structure (*e.g.*, increasing frequency of omnivores and decreased frequency of omnivores and decreased frequency of more specialized feeders); older age classes of top carnivores rare or absent.
29 - 20	Poor	Relatively few species; dominated by omnivores, tolerant forms, and habitat generalists; few or no top carnivores or simple lithophilous spawners; growth rates and condition factors sometimes depressed; hybrids sometimes common.
19 - 0	Very poor	Very few species present, mostly exotics or tolerant forms or hybrids; few large or old fish; DELT fish (fish with deformities, eroded fins, lesions, or tumors) sometimes common.
No score	Very poor	Thorough sampling finds few or no fish; impossible to calculate IBI.