Benthic Invertebrates of Fixed Sites in the Western Lake Michigan Drainages, Wisconsin and Michigan,1993–95

By Bernard N. Lenz and S.J. Rheaume

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND MISCELLANEOUS ABBREVIATIONS

Multiply	By	To Obtain
inch (in.)	2.54	centimeter (cm)
feet (ft)	0.3048	meter (m)
square mile (mi^2)	2.59	square kilometer (km^2)
acre	0.4047	hectare
cubic feet per second (cfs)	0.02832	cubic meter per second (m^3/s)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units: Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical values expressed as mg/L and µg/L are the same as for concentrations in parts per million and parts per billion, respectively.

MISCELLANEOUS ABBREVIATIONS

DATCP	Wisconsin Department of Agriculture, Trade, and Consumer Protection
DL	Detection limit
DNR	(Wisconsin) Department of Natural Resources
GLEAS	Great Lakes Environmental Assessment Section
GRN	Groundwater Retrieval Network
GIS	Geographic Information Systems
HBI	Hilsenhoff Biotic Index
IBI	Index of Biological Integrity
MCL	Maximum Contaminant Level
as N	quantified as measured nitrogen
NAWQA	National Water-Quality Assessment Program
NURE	National Uranium Resources Evaluation
PAH	Polyaromatic hydrocarbons
RASA	Regional Aquifer-System Analysis
SMCL	Secondary Maximum Contaminant Level
STAID	USGS station identification number
STORET	Storage and Retrieval System
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WATSTORE	Water Storage and Retrieval
WMIC	Western Lake Michigan Drainages (NAWQA study area)

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Abstract

This report describes the variability in family-level benthic-invertebrate population data and the reliability of the data as a water-quality indicator for 11 fixed surface-water sites in the Western Lake Michigan Drainages study area of the National Water-Quality Assessment Program. Benthic-invertebrate-community measures were computed for the following: number of individuals, Hilsenhoff's Family-Level Biotic Index, number and percent EPT (Ephemeroptera, Plecoptera, and Tricoptera), Margalef's Diversity Index, and mean tolerance value. Relations between these measures and environmental setting, habitat, and of chemical water quality are examined.

Benthic-invertebrate communities varied greatly among fixed sites and within individual streams among multiple-reach and multiple-year sampling. The variations between multiple reaches and years were sometimes larger than those found between different fixed sites. Factors affecting benthic invertebrates included both habitat and chemical quality. Generally, fixed-site streams with the highest diversity, greatest number of benthic invertebrates, and those at which community measures indicated the best water quality also had the best habitat and chemical quality.

Variations among reaches are most likely related to differences in habitat. Variations among years are most likely related to climatic changes, which create variations in flow and/or chemical quality. The variability in the data analyzed in this study shows how benthic invertebrates are affected by differences in both habitat and water quality, making them useful indicators of stream health; however, a single benthic-invertebrate sample alone cannot be relied upon to accurately describe water quality of the streams in this study. Benthic-invertebrate data contributed valuable information on the biological health of the 11 fixed sites when used as one of several data sources for assessing water quality.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began full-scale implementation of the National Water-Quality Assessment (NAWQA) Program. The objectives of the NAWQA Program are to (1) describe current water-quality conditions for a large part of the Nation's fresh-water streams, rivers, and aquifers, (2) describe trends in water quality over time, and (3) improve understanding of the primary natural and human factors that affect water-quality conditions (Gilliom and others, 1995; Hirsch and others, 1988). This information is useful for planning future management actions and examining their likely consequences. More than 50 study areas have begun activities on a staggered time scale. The Western Lake Michigan Drainages (WMIC) was selected as one of the 20 study areas in which data collection and analysis began in 1991.

One of the major goals of the NAWQA program is to develop a better understanding of the interaction among physical, chemical, and biological characteristics of streams in selected environmental settings (Gurtz, 1994). Ecological studies are included in the NAWQA program to provide data on biological communities that contribute to the understanding of this interaction. Aspects of the NAWQA ecological studies include (1) understanding how biological communities and stream habitat differ among selected environmental settings, (2) identifying physical and chemical characteristics that influence biological communities, (3) understanding how spatial scales affect relations between physical, chemical, and biological characteristics, and (4) understanding how biological communities affect physical and chemical characteristics (Gurtz, 1994). Stream-habitat characteristics, collected at a variety of spatial scales, are useful in expanding the understanding of how physical, chemical, and biological characteristics interact.

Western Lake Michigan Drainages Study Area

The Western Lake Michigan Drainages study area (fig. 1) encompasses 51,541 km^2 of eastern Wisconsin and the Upper Peninsula of Michigan. Ten major rivers drain the study area: the Escanaba and Ford Rivers in Michigan; the Menominee River, which partially defines the state boundary between Wisconsin and Michigan; the Peshtigo and Oconto Rivers in northeastern Wisconsin; the Fox/Wolf River complex in east-central Wisconsin, which drains into Green Bay; and the Manitowoc, Sheboygan, and Milwaukee Rivers, which drain the southeastern part of the study area.

The overall population in the study area is 2,435,000 (U.S. Bureau of Census, 1991). The major cities and their populations are Milwaukee, 628,000; Green Bay, 96,000; Racine, 84,000; Kenosha, 80,000; and Appleton, 66,000. Urban land use accounts for less than 4 percent of the study area. Agriculture makes up 37 percent of the land use in the basin and is devoted almost exclusively to cropland and pasture for dairy production. About 40 percent of the study area is forested; most forested areas are in the northwest part of the study area. Wetlands account for 15 percent of the land use in the study area. Lake Winnebago, a 55,442-hectare lake in the Fox River Basin, is a major surface-water feature of the study area.

Study Design

The WMIC study area was subdivided into 28 environmental settings, called relatively homogeneous units (RHU's), on the basis of bedrock geology, texture of surficial deposits, and land use/land cover which are believed to influence water quality. Eleven fixed stream sites (fig. 2) were established to represent status of and trends in water quality in the WMIC. Eight of the 11 sites were chosen to represent the water quality of one specific RHU. These fixed sites are referred to as "indicator sites" because the water quality at these sites is assumed to be indicative of the average condition for the RHU in which the entire drainage basin for each site is located. The other three sites were chosen to represent a large proportion of the water leaving the WMIC study area (Robertson and Saad, 1995). These fixed sites are referred to as "integrator sites" because the drainage basin for each contains more than one RHU, thereby integrating the effects of several land uses, surficial deposits, or geology types. Three sites, two indicator and one integrator, were selected for frequent and extensive surface-water sampling and are referred to as "intensive" fixed sites. General descriptions and selected information on the environmental setting of the fixed sites is available in Sullivan and others (1995).

Benthic-invertebrate samples were collected at multiple reaches and in multiple years at the 11 fixed sites as one part of multi-metric water-quality assessment at these sites. Benthic-invertebrate samples and additional data including streamflow, water chemistry, organic compounds and trace elements in streambed sediment and biological tissues, fish and algal communities, and stream habitat were collected at the 11 fixed sites from March 1993 through June 1995. Some selected information on the environmental setting of fixed sites can be found in table 1.

This investigation discusses the variability of benthic-invertebrate populations in different streams, reaches, years, and environmental settings, and a general assessment of water quality based on benthic-invertebrate-community measures at each site. Additional biological investigations in this series of fixed-site studies focused on the interaction of water quality, stream habitat, fish populations, and algal communities (Fitzpatrick and Giddings, 1995; Sullivan and Peterson, 1995).

Purpose and Scope

This report provides information on the spatial and temporal variability of benthic-invertebrate communities at 11 fixed stream sites in the WMIC study area. The distribution, relative abundance, and community structure of the benthic invertebrates of these streams are discussed on the basis of samples collected at specific stream reaches described by Sullivan and others (1995). Information provided for macroinvertebrate communities includes richness measures, enumeration, and biotic indices of these invertebrate populations. Effects of environmental setting, habitat, and water quality on benthic-invertebrate communities and the usefulness of the invertebrate communities as water-quality indicators is discussed.

The benthic-invertebrate information included in this report represents only part of the biotic information

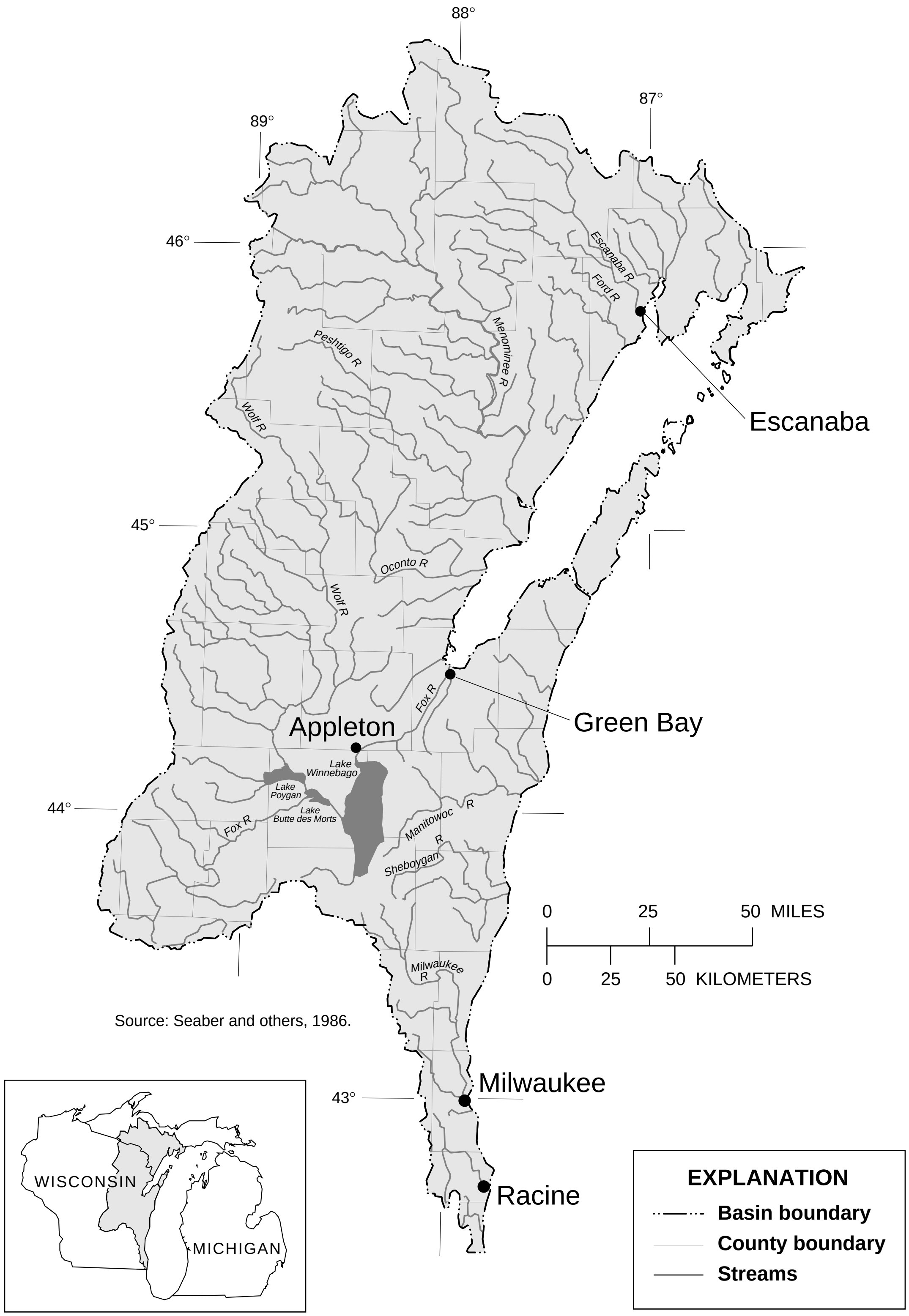
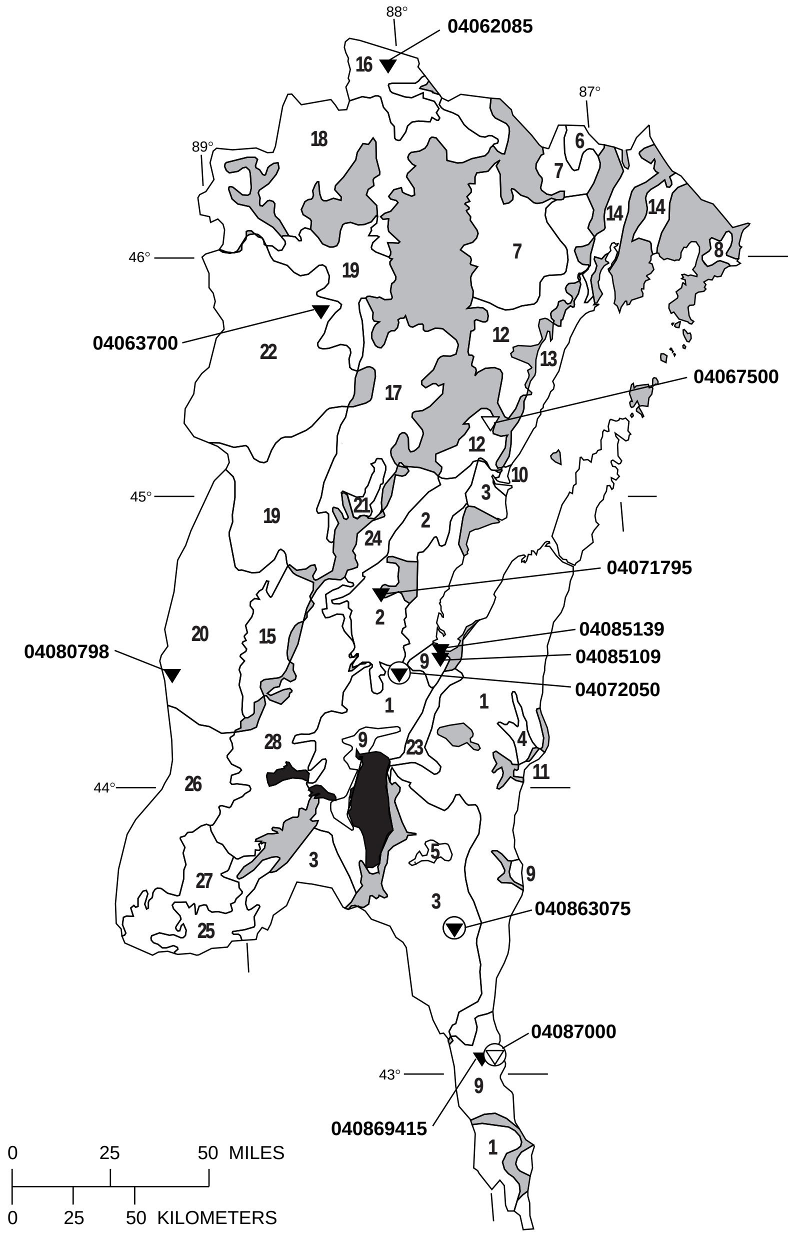


Figure 1. Western Lake Michigan Drainages study unit of the National Water-Quality Assessment Program.



EXPLANATION

Relatively Homogeneous Unit (RHU) and number

Characteristics listed for each RHU are bedrock, land use, and surficial deposit, separated by commas. Abbreviations are as follows: Carb, carbonate; IgMet, igneous and/or metamorphic; Shle, shale; Snds, sandstone; Ag, agriculture

1 Carb, Ag, clayey
2 Carb, Ag, loamy
3 Carb, Ag, sandy
4 Carb, Ag, sand and gravel
5 Carb, Ag/wet forest, sandy/sand and gravel
6 Carb, dry forest, loamy
7 Carb, wet forest, loamy
8 Carb, wet forest, sandy
9 Carb, urban, clayey
10 Carb, urban, sandy
11 Carb, urban, sand and gravel
12 Carb, Ag/wet forest, loamy
13 Carb, wet forest, sandy
14 Carb, wet forest, sandy/sand and gravel
15 IgMet, Ag, loamy/sand and gravel
16 IgMet, dry forest, loamy
17 IgMet, dry forest, loamy/sand and gravel
18 IgMet, dry forest, sandy
19 IgMet, dry forest, sandy/sand and gravel
20 IgMet, dry forest/Ag, sandy/sand and gravel
21 IgMet, wet forest, clayey
22 IgMet, wet forest, sandy/sand and gravel
23 Shle, Ag, clayey
24 Snds, Ag, loamy
25 Snds, Ag, sandy
26 Snds, dry forest/Ag, sandy/sand and gravel
27 Snds, wet Ag, clayey/sandy
28 Snds, wet Ag, clayey

Type of site

▼ Indicator site
▽ Integrator site
Intensive fixed site
Integrator site and intensive fixed site

Mixed areas
Open water

Figure 2. Boundaries of relatively homogeneous units (RHU's) in the Western Lake Michigan Drainages study unit and location of fixed sites.

Table 1. Selected information for the fixed sites in the Western Lake Michigan Drainages study unit

[Mean discharge calculated through September 1994; USGS, U.S. Geological Survey; mi^2, square miles; km^2, square kilometers; ft^3/s, cubic feet per second; m^3/s, cubic meters per second; --, no measurement made; ft, feet; m, meters]

Site name	USGS number	Latitude-longitude	Drainage area (mi^2 [km^2])	Mean discharge (ft^3/s [m^3/s])	Stream type	Mean width (ft [m])	Reach length (ft [m])	Percent of each in reach		
								Riffle	Run	Pool
Peshekee River near Martins Landing, Mich.	04062085	88°01’20" 46°36’35"	49.0 [127]	[1]73 [2.1]	Meandering	39 [12]	745 [227]	44	0	56
Popple River near Fence, Wis.	04063700	88°27’50" 45°45’50"	139 [360]	119 [3.4]	Meandering	69 [21]	1,090 [332]	10	45	45
Menominee River at McAllister, Wis.	04067500	87°39’40" 45°19’20"	3,930 [10, 200]	3,470 [98.3]	Meandering	--	110 [360]	0	100	0
Pensaukee River near Krakow, Wis.	04071795	88°16’35" 44°45’09"	35.8 [92.7]	12 [.34]	Meandering	23 [7]	508 [155]	29	51	20
Duck Creek near Oneida, Wis.	04072050	88°13’08" 44°27’57"	95.5 [247]	[2]53 [1.5]	Meandering	30 [9]	492 [150]	37	50	13
Tomorrow River near Nelsonville, Wis.	04080798	89°20’16" 44°31’28"	44.0 [114]	31 [.88]	Meandering	30 [9]	469 [143]	7	30	63
East River near DePere, Wis.	04085109	88°04’47" 44°23’12"	47.0 [122]	[3]60 [1.7]	Meandering	16 [5]	564 [172]	15	69	16
Fox River at Green Bay, Wis.	04085139	88°00’16" 44°32’22"	6,332 [16,400]	5,330 [151]	Channelized	--	--	0	0	100
North Branch Milwaukee River near Random Lake, Wis.	040863075	88°03’10" 43°33’25"	51.4 [133]	35 [.99]	Meandering	36 [11]	705 [215]	14	21	65
Lincoln Creek at 47th Street at Milwaukee, Wis.	040869415	87°58’20" 43°05’49"	9.6 [24.8]	8.5 [.24]	Channelized	37 [11]	922 [281]	19	40	41
Milwaukee River at Milwaukee, Wis.	04087000	87°54’32" 43°06’00"	696 [1,800]	431 [12.2]	Channelized	--	--	--	--	--

[1]Mean discharge for station 04062085 was calculated from drainage-area ratio and discharge record from station 04062100 (66.5 mi^2 drainage area).

[2]Mean discharge for station 04072050 was calculated from drainage-area ratio and discharge record from station 04072150 (108 mi^2 drainage area).

[3]Mean discharge calculated from average of monthly mean discharge owing to missing record.

collected at these streams in the WMIC study area of the NAWQA program. Other information collected to assess the water quality of these fixed stream sites includes environmental settings, habitat, water chemistry, and algal and fish community data and appear in additional reports in this series.

METHODS AND MATERIALS

Collection of Benthic Invertebrates

Benthic invertebrates were collected from eight wadeable and three nonwadeable streams. The eight wadeable streams were sampled in the spring of 1993, 1994, and 1995 for multiple-year comparisons with the same reaches being sampled each year at approximately the same time of year. In 1994, at three of these wadeable streams, samples were collected at three reaches to compare within-stream variation. The three nonwadeable streams were sampled at one reach in the spring of 1995. Sample procedures and protocol remained the same throughout the study to allow for among-stream, -year, and -reach comparisons.

Sampling Gear and Techniques

Benthic-invertebrate samples were collected from habitat most likely to have the greatest variety and quantity of organisms, usually the largest two riffles in each stream reach. A riffle was considered to be the part of the stream where the water flows swiftly over completely or partially submerged coarse substrate that produce surface agitation. Samples were collected from locations within the riffle where the greatest number and diversity of invertebrates in the reach were most likely to be found, as inferred by substrate, water depth, flow, and canopy cover. Sample locations generally had an open canopy, gravel or cobble substrate, the highest flow velocities in the riffle, and water depth sufficient to remain submerged during low flows.

Samples were collected according to the NAWQA protocol as defined by Cuffney and others (1993a,b). Data from 10 of the 11 streams in this report came from kick samples collected by use of a modified Slack sampler (425-µm mesh). One stream-reach sample consisted of a composite of six kick samples—three each collected at an upstream and downstream riffle in the same reach—which were processed and identified as one sample. Distances between kick samples in the same riffle were rarely greater than 5 m. The sample area for each kick sample was 0.5 m by 0.5 m (depth 0.1 m). According to protocol, the 1995 Fox River sample was collected by means of artificial substrate (rock baskets) owing to the lack of natural coarse-grain substrate and snags at this nonwadeable site.

Sample Preservation and Identification

Samples were processed in the field in accordance with the NAWQA protocol. Composite samples were reduced in the field by swirling and sieving (425-µm mesh sieve) until sample volumes were less than 750 mL. Samples were preserved in the field in 10 percent buffered formalin, and within 3 days they were drained and refilled with 70 percent ethanol and stored until they could be shipped to the USGS laboratory for identification. Benthic-invertebrate enumeration and taxonomic identifications were done by the USGS National Water Quality Laboratory, Biological Unit, at Arvada, Colo., using methods described by Cuffney and others (1993b). All benthic invertebrates collected were processed.

Determination of Benthic-Invertebrate-Community Measures

Benthic-invertebrate measures were calculated by use of a program created at the University of Wisconsin–Stevens Point (http://www.uwsp.edu/acad/cnr/biomonitoring/index3.htm). A detailed accounting of the calculation of these measures can be found in Rheaume and others (1996). Only measures that use taxonomic identifications of family level or higher are discussed in this report because much of the taxonomic data for this report is identified only to the family level. Data on community structure of aquatic arthropods collected from the 11 streams are summarized in tables 2–5.

BENTHIC-INVERTEBRATE COMMUNITIES AT FIXED SITES

The invertebrates collected at each of the 11 fixed-site streams were identified to the lowest taxonomic level possible (table 6, at back of report). Most major aquatic invertebrate taxa common to Wisconsin were represented in the 11 fixed-site stream samples;

Table 2. Breakdown of the number of families identified in benthic-invertebrate samples at fixed sites in the Western Lake Michigan Drainages study unit, 1993–95

Stream	Year-Reach	Found in individual Sample	Reach A: Multiple-year samples		1994: Multiple-reach samples		Multiple-year and reach samples
			Found in each of 3 years	Found in any year	Found in each of 3 reaches	Found in any reach	Found in any year in any reach
Peshekee River	93-A	24	15	33			
	94-A	25					
	95-A	24					
Popple River	93-A	24	13	32			
	94-A	26					
	95-A	19					
Menominee River	95-A	13					
Pensaukee River	93-A	14	8	18			
	94-A	14					
	95-A	12					
Duck Creek	93-A	15	8	18	8	17	22
	94-A	10					
	94-B	15					
	94-C	12					
	95-A	11					
Tomorrow River	93-A	26	15	27	16	24	30
	94-A	17					
	94-B	23					
	94-C	19					
	95-A	18					
East River	93-A	9	2	11			
	94-A	5					
	95-A	4					
Fox River	95-A	12					
North Branch Milwaukee River	93-A	18	12	23	16	23	24
	94-A	21					
	94-B	18					
	94-C	20					
	95-A	13					
Lincoln Creek	93-A	2	1	5			
	94-A	3					
	95-A	2					
Milwaukee River	95-A	5					

54 families within 14 orders were identified. Trichoptera was the best-represented order (13 families), followed by Chironomidae (10 families), and Ephemeroptera (9 families). Chironomidae was the most abundant family in terms of numbers of individuals in the sample (46 percent of the total).

Taxonomic population data were used to calculate common quantitative community measures. Variability observed among fixed sites, difference among multiple-reach data at specific fixed sites, and difference in the data from three years of sampling were analyzed by comparing presence/absence data for benthic-invertebrate families and by statistical comparison of selected invertebrate measures using Kruskal-Wallis and Tukey tests (Iman and Conover, 1983).

Invertebrate measures calculated for this study include count (per area) (Weber, 1973; Resh and Grodhaus, 1983), Hilsenhoff's Family-Level Biotic Index (FBI) (Hilsenhoff, 1988), number and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) (Lenat, 1988), Margalef's Diversity Index (MDI) (Margalef, 1969; Rosenberg and Resh, 1993), and average tolerance value (Lillie and Schlesser, 1994).

Variability Among Fixed Sites

The total number of families identified in any one sample ranged from 2 at Lincoln Creek in 1995 to 26 at Tomorrow River in 1993 and at Popple River in 1994. The total number of families identified at individual streams throughout the study (1993–95) ranged from 5 at Lincoln Creek to 33 at Peshtigo River (table 2). No individual sample collected from the streams in this study contained every family found at that stream. Any one individual sample contained as few as 45 percent to as many as 88 percent of all families found at that stream during this study.

Invertebrate measures consistently indicated Peshekee River, Popple River, Tomorrow River, and North Branch of Milwaukee River had the best water quality of the fixed-sites samples. FBI values, which are based on the benthic-invertebrate populations' tolerance to organic pollution and the associated drop in dissolved oxygen, classify the water quality of these streams in a range from excellent (0.00–3.75) to very good (3.76–4.50) (Hilsenhoff, 1988). Ephemeroptera, Plecoptera, and Trichoptera (EPT), which are known to be intolerant to pollution, were present in high numbers at these sites. The high numbers of individuals and families collected, as well as higher MDI values, show strong overall abundance and diversity in the benthic-invertebrate populations of these streams. These streams drain both agricultural and forest land with loam, sand, or sand and gravel surficial deposits.

Invertebrate measures for Lincoln Creek, East River, and Milwaukee River indicate the poorest water quality of sites in the study. FBI values classify the water quality in these streams as very poor (10.00–8.51) to fair (5.51–6.50). Few or no pollution-intolerant EPT taxa were found in these streams, total numbers of individuals were low, and diversity was low; all these measures indicate that the benthic invertebrates in these streams have been negatively impacted. These streams drain agricultural and urban land with clay surficial deposits (table 3).

Multiple-Reach Variability

Three streams were sampled at three different reaches in 1994. The variability in multiple-reach samples differed among rivers. Eight of the 17 (47 percent) families identified in samples from Duck Creek, 16 of the 24 (67 percent) families in samples from Tomorrow River, and 16 of the 23 (70 percent) families in samples from North Branch of the Milwaukee River were identified in every reach sampled. Invertebrate samples from a single reach contained as few as 59 percent to as many as 96 percent of the families identified in all samples from multiple reaches of the respective rivers (table 2, fig. 3).

Between reach variability in calculated community measures was greatest for the Tomorrow River. The greatest variation was in number of individuals, which ranged from 180 in reach A to 7,861 in reach B. Each reach sampled in the Tomorrow River was dominated by a different family (table 4).

Enumeration measures such as number of individuals, number of families, and number of EPT varied as much between samples from multiple reaches in the same stream as they did between samples from different streams. FBI and mean tolerance value were the only measures that varied less between reaches than between streams based on Kruskal-Wallis tests ($p<0.05$). Mean tolerance was the only measure with statistically significant differences between streams in Tukey tests making it the only benthic-invertebrate-community measure that indicated differences in water quality at the three fixed sites using multiple-reach sampling.

Table 3. Summary statistics of benthic-invertebrate measures at 11 fixed sites in the Western Lake Michigan Drainages study unit, 1995

[%, percent; MDI, Margalef's Diversity Index; EPT, Ephemeroptera, Plecoptera, and Trichoptera; FBI, Hilsenhoff's Family-Level Biotic Index]

Stream name	Station Number	RHU	Number of individuals	Number of families	MDI	Dominant family/ Percent dominant family	Number of EPT	Percent EPT	FBI	Mean tolerance value
Peshekee River	04062085	16	3,631	24	2.67	Simuliidae/47%	1,289	35	4.46	1.84
Popple River	04063700	22	4,839	19	1.11	Chironomidae/84%	697	14	3.52	3.46
Menominee River	04067500	--	4,939	13	1.94	Chironomidae/45%	164	3	5.56	3.57
Pensaukee River	04071795	2	24,955	12	.94	Chironomidae/62%	530	2	5.73	5.29
Duck Creek	04072050	1	4,307	11	1.41	Chironomidae/68%	968	22	4.01	5.00
Tomorrow River	04080798	20	5,757	18	1.86	Chironomidae/65%	1,099	19	3.02	3.29
East River	04085109	23	2,260	4	.30	Chironomidae/96%	33	1	10.00	10.00
Fox River	04085139	--	19,970	12	.51	Chironomidae/93%	552	3	5.24	7.00
North Branch of Milwaukee River	040863075	3	4,282	13	1.95	Chironomidae/53%	1,519	35	1.89	4.31
Lincoln Creek	040869415	9	2,336	2	.76	Chironomidae/78%	0	0	6.00	6.00
Milwaukee River	04087000	--	1,498	5	1.15	Chironomidae/69%	32	2	4.22	5.60

Table 4. Multiple-reach summary statistics of benthic-invertebrate measures at three fixed sites in the Western Lake Michigan Drainages study unit, 1994

[%, percent; MDI, Margalef's Diversity Index; EPT, Ephemeroptera, Plecoptera, and Trichoptera; FBI, Hilsenhoff's Family-Level Biotic Index]

Stream name	Station Number	Reach	Number of individuals	Number of families	MDI	Dominant family/ Percent dominant family	Number of EPT	Percent EPT	FBI	Mean tolerance value
		A	180	17	3.52	Hydropsychidae/29%	128	71	2.82	2.64
Tomorrow River	04080798	B	7,861	23	3.30	Elmidae/25%	2,146	27	3.33	3.42
		C	6,535	19	2.62	Chironomidae/42%	1,589	24	3.10	3.06
		A	3,475	10	2.04	Chironomidae/43%	1,068	31	5.36	4.67
Duck Creek	04072050	B	2,311	15	2.76	Chironomidae/39%	594	26	4.84	5.50
		C	1,703	12	1.81	Chironomidae/56%	388	23	4.12	5.33
		A	4,885	21	2.79	Chironomidae/41%	2,026	41	3.48	4.50
North Branch of Milwaukee River	040863075	B	3,393	18	1.93	Chironomidae/62%	781	23	4.07	3.92
		C	5,926	20	1.66	Chironomidae/72%	1,066	18	3.71	4.07

Multiple-Year Variability

Benthic-invertebrate collections were made at eight wadeable fixed sites during three consecutive years at approximately the same date each year. The number and types of families collected from a site tended to vary from year to year. At a given site, a single yearly sample contained as few as 36 percent and as many as 96 percent of all the families identified in all samples at that site. The consistency at which families were identified in samples also varied. Two of the eleven (18 percent) families in samples from East River were identified all three years while 15 of the 27 (55 percent) families in samples from Tomorrow River were identified all three years. Other families were identified in only one or two of the years (table 2, fig. 4).

No one fixed site had significantly greater multiple-year variations in community measures than another. The benthic-invertebrate measures for number of individuals, number of families, and FBI value show statistically significant differences between sites based on Kruskal-Wallis tests ($p<0.05$). Additional analysis with Tukey tests show these differences to be statistically significant only between some of the fixed sites. The sites with significant differences also had the greatest difference in chemical water quality and habitat. Kruskal-Wallis tests show variation in the values of EPT enumeration, EPT percent, and MDI are as great between years as between sites ($p>0.05$). Tomorrow River was the only stream dominated by a different family each year (table 5).

RELIABILITY OF BENTHIC-INVERTEBRATE DATA AS A WATER-QUALITY INDICATOR AT FIXED SITES

The variability of the invertebrate measures, along with taxa presence, distribution, and abundance are discussed in the following paragraphs with reference to how they were affected by environmental setting, habitat, and chemical water quality. Chemical water-quality and habitat data for fixed sites were taken from Sullivan and others (1995) (table 7, at back of report) and from Fitzpatrick and Giddings (1995) (table 8, at back of report). Mean benthic-invertebrate measures were compared to median habitat, environmental setting factors, and chemical water-quality data collected at fixed sites between 1993 and 1995 (fig. 5). Quartiles were calculated for non-categorical data. Streams where invertebrate measures indicate the best water quality also tended to have the best chemical water quality and habitat.

Factors Affecting Variability in Invertebrate Communities Among Fixed Sites

Variability in benthic-invertebrate populations at fixed sites can be influenced by differences in chemical water quality, available habitat, and flow variability. Variations in sample collection method or analysis precision can also cause variations in the data.

The fixed-site streams where benthic-invertebrate measures indicated the best water quality were Popple, Peshekee, and Tomorrow Rivers. These streams have been rated excellent by overall Great Lakes Environmental Assessment Section (GLEAS) habitat scores, (Michigan Department of Natural Resources, 1991) had low erodability and embeddedness scores, and all maintain consistent year-round base flows. These three streams drain mainly forested land; however, Tomorrow River also drains a considerable amount of agricultural land, mostly in parts of the basin away from the river. These three streams have the lowest average phosphorus, nitrite plus nitrate, and ammonia concentrations of the fixed sites (tables 7 and 8).

The fixed-site streams where benthic-invertebrate measures indicated the poorest water quality were Lincoln Creek and East River. These streams have been rated fair by GLEAS habitat scores and are more erodible and embedded than other fixed-site streams. Both basins have clay surficial deposits and highly variable flow regimes that include periods of extremely low flow. These streams also had the highest average specific conductance and ammonia concentration of the fixed sites (tables 7 and 8).

Factors Affecting Multiple-Reach Variability in Invertebrate Communities

Although many of the same common benthic-invertebrate taxa were found in all three reaches of a particular river, taxa number and (or) type of taxa collected differed among reaches at all three streams. Measures associated with invertebrate sensitivity to water quality, such as FBI, appear to be less variable than enumeration measures for multiple-reach sampling. Most taxa in the stream, regardless of family, had similar

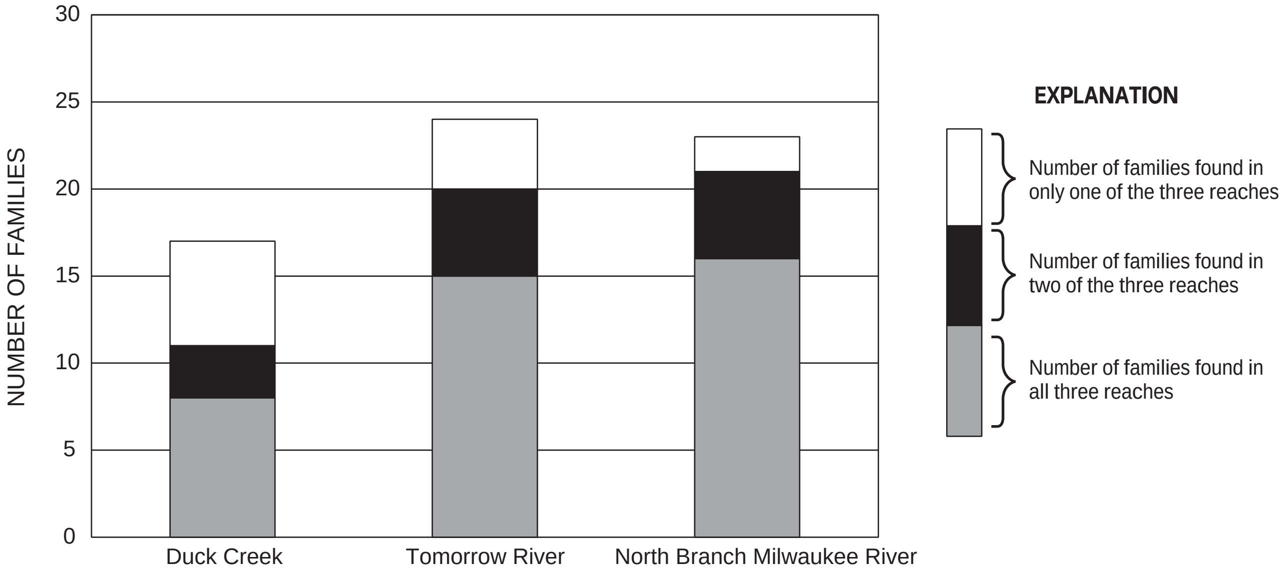


Figure 3. Number of benthic-invertebrate families repeatedly identified during multiple-reach sampling at selected fixed stream sites in the Western Lake Michigan Drainages study unit.

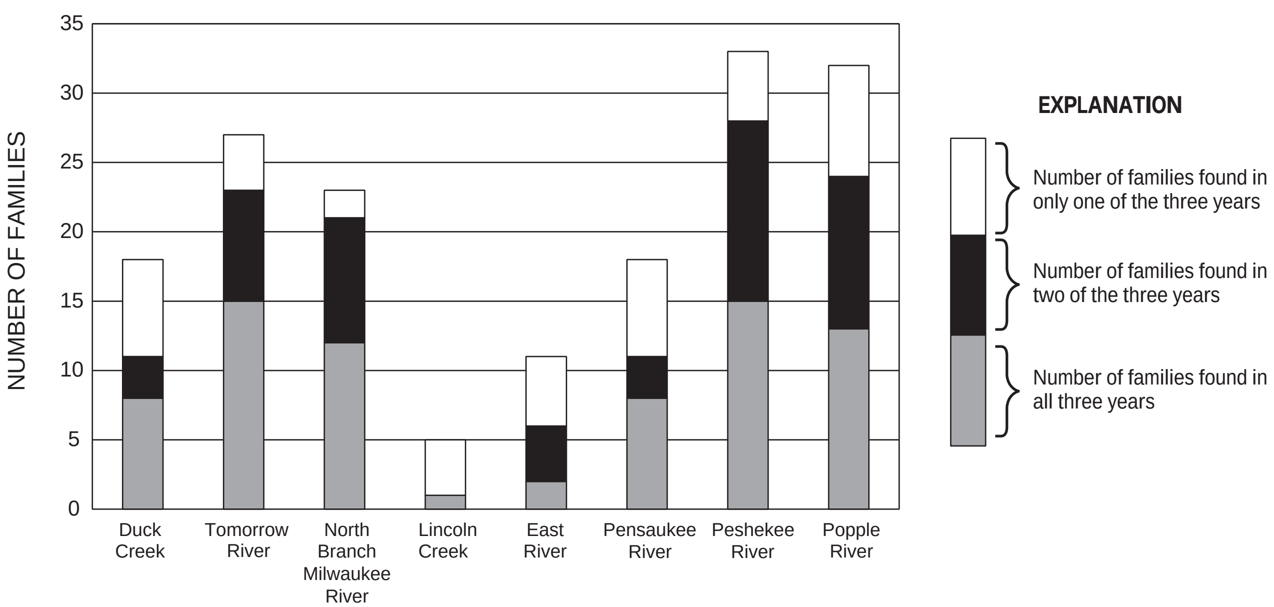


Figure 4. Number of benthic-invertebrate families repeatedly identified during multiple-year sampling at selected fixed stream sites in the Western Lake Michigan Drainages study unit.

Table 5. Multiple-year summary statistics of benthic-invertebrate measures at eight fixed sites in the Western Lake Michigan Drainages study unit, 1993–95

[%, percent; MDI, Margalef's Diversity Index; EPT, Ephemeroptera, Plecoptera, and Trichoptera; FBI, Hilsenhoff's Family-Level Biotic Index]

Stream name	Station Number	Year	Number of individuals	Number of families	MDI	Dominant family/ Percent dominant family	Number of EPT	Per-cent EPT	FBI	Mean toler-ance value
Peshekee River	04062085	1993	5,941	24	2.81	Chironomidae/37%	2,222	37	3.90	2.50
		1994	3,987	25	2.81	Simuliidae/40%	1,323	33	4.62	2.41
		1995	3,631	24	2.67	Simuliidae/47%	1,289	35	4.46	1.84
Popple River	04063700	1993	3,906	24	2.97	Chironomidae/41%	1,488	38	3.19	3.05
		1994	7,177	26	2.02	Chironomidae/57%	2,924	41	3.53	2.65
		1995	4,839	19	1.11	Chironomidae/84%	697	14	3.52	3.46
Pensaukee River	04062085	1993	6,473	14	1.55	Chironomidae/61%	738	11	6.62	6.00
		1994	13,362	14	2.06	Chironomidae/30%	3,939	29	3.92	5.57
		1995	24,955	12	.94	Chironomidae/62%	530	2	5.73	5.29
Duck Creek	04072050	1993	8,450	15	1.20	Chironomidae/79%	760	9	4.53	4.80
		1994	3,475	10	2.04	Chironomidae/43%	1,068	31	5.36	4.67
		1995	4,307	11	1.41	Chironomidae/68%	968	22	4.01	5.00
Tomorrow River	04080798	1993	3,752	26	2.66	Brachycentridae/28%	2,007	53	2.05	3.94
		1994	180	17	3.52	Hydropsychidae/29%	128	71	2.82	2.64
		1995	5,757	18	1.86	Chironomidae/65%	1,099	19	3.02	3.29
North Branch of Milwaukee River	040863075	1993	1,659	18	1.73	Chironomidae/70%	196	12	3.70	4.00
		1994	4,885	21	2.79	Chironomidae/41%	2,026	41	3.48	4.50
		1995	4,282	13	1.95	Chironomidae/53%	1519	35	1.89	4.31
East River	04085109	1993	450	9	1.14	Chironomidae/82%	17	4	5.00	6.00
		1994	4,885	21	2.79	Chironomidae/41%	2,026	41	3.48	4.50
		1995	2,260	4	.30	Chironomidae/96%	33	1	10.00	10.00
Lincoln Creek	040869415	1993	96	2	.25	Chironomidae/96%	4	4	4.00	5.00
		1994	776	3	1.78	Chironomidae/51%	256	33	3.67	6.00
		1995	2,336	2	.76	Chironomidae/78%	0	0	6.00	6.00

Site type	Stream name	Dominant Land Use	Flow	Benthic invertebrate measures: Hilsenhoff (family-level) Biotic Index [1]	Benthic invertebrate measures: Percent EPT	Benthic invertebrate measures: Margalef's Diversity Index	Habitat: GLEAS [2]	Habitat: Erodibility	Habitat: Embeddedness	Water quality: Conductance	Water quality: Total Phosphorus	Water quality: Nitrite + Nitrate	Water quality: Ammonia
INDICATOR SITES	***Peshekee River***	F	Missing data	Good	0–25th	0–25th	Good	0–25th	0–25th	0–25th	0–25th	0–25th	26th–50th
INDICATOR SITES	***Popple River***	F		Excellent	0–25th	51st–75th	Good	0–25th	26th–50th	0–25th	0–25th	0–25th	0–25th
INDICATOR SITES	***Pensaukee River***	Ag	L	Poor	51st–75th	51st–75th	Good	26th–50th	26th–50th	26th–50th	76th–100th	51st–75th	26th–50th
INDICATOR SITES	***Duck Creek***	Ag	L, H	Fair	26th–50th	51st–75th	Fair	51st–75th	0–25th	51st–75th	76th–100th	51st–75th	76th–100th
INDICATOR SITES	***Tomorrow River***	Ag/F	H	Excellent	0–25th	26th–50th	Good	0–25th	51st–75th	26th–50th	0–25th	76th–100th	0–25th
INDICATOR SITES	***East River***	Ag	L, H	Poor	76th–100th	76th–100th	Fair	76th–100th	76th–100th	76th–100th	76th–100th	76th–100th	76th–100th
INDICATOR SITES	***N. Br. Milwaukee River***	Ag	H	Excellent	26th–50th	0–25th	Fair	76th–100th	51st–75th	51st–75th	26th–50th	76th–100th	51st–75th
INDICATOR SITES	***Lincoln Creek***	Ur	H	Poor	51st–75th	76th–100th	Fair	76th–100th	76th–100th	76th–100th	26th–50th	26th–50th	51st–75th
INTEGRATOR SITES	***Menominee River***	Ag		Fair	76th–100th	0–25th	Missing data	26th–50th	Missing data	0–25th	0–25th	0–25th	0–25th
INTEGRATOR SITES	***Fox River***	Ag		Fair	76th–100th	76th–100th	Missing data	26th–50th	Missing data	26th–50th	51st–75th	26th–50th	76th–100th
INTEGRATOR SITES	***Milwaukee River***	Ag		Good	76th–100th	51st–75th	Missing data	26th–50th	Missing data	51st–75th	26th–50th	26th–50th	26th–50th

[1] Hilsenhoff (family-level) Biotic Index categories in Hilsenhoff, 1988

[2] GLEAS categories in Michigan Department of Natural Resources, 1991

EXPLANATION

Abbreviations

EPT	Number of Ephemeroptera, Plecoptera, and Trichoptera genera
GLEAS	Michigan Great Lakes Environmental Assessment Section Procedure
Ag	Agricultural
F	Forest
Ur	Urban
L	Two-year, seven-day low flow of zero
H	Two-year flood greater than ten times annual mean flow

Categories

- Excellent
- Good
- Fair
- Poor
- Very poor
- Missing data

Quartiles (Best to Worst)

- 0–25th percentile
- 26th–50th percentile
- 51st–75th percentile
- 76th–100th percentile
- Missing data

Figure 5. Comparison of benthic-invertebrate measures, habitat, and chemical water quality at selected fixed stream sites in the Western Lake Michigan Drainages study unit.

tolerances to increased concentrations of organic pollutants and the associated decrease in dissolved oxygen.

Variations in benthic-invertebrate-community measures between reaches could be attributed to the preference of benthic invertebrates for certain habitat and flow characteristics. Numerous microhabitats are present in all streams. Some streams, such as the Tomorrow River, have highly varied types of substrate, vegetation, canopy cover, and flow within a single reach. Picking a representative sampling location that includes all microhabitats in a reach is difficult if not impossible. An effort was made to minimize variation by selecting a representative reach and by compositing six riffle samples from different locations in the reach.

Although the type and number of benthic invertebrates collected from multiple reaches varied, the associated tolerance to organic pollution of those invertebrates that were collected tended to be fairly similar. This relation was observed in past studies as well (Lenz and Miller, 1995; Rheaume and others, 1996), an indication of the strength of these tolerance-based measures in predicting water quality at the fixed sites.

The choice of sample location and the homogeneity of the stream can affect how representative a single benthic-invertebrate sample is of the overall population in the stream and result in variations between multiple samples.

Factors Affecting Multiple-Year Variability in Invertebrate Communities

Invertebrates were collected near the same date each spring to minimize variance associated with emergence and differences in instars (life stages between molts). Because different species of invertebrates emerge from the river as adults to mate and reproduce at different times, young instars are not present or are not identifiable at certain times. Hence, the population of the benthic-invertebrate community that can be collected and identified changes throughout the year.

Yearly variations in temperature and streamflow can affect when invertebrates emerge and the success of individual species' reproduction that year. Emergence dates may be a function of degree days and/or flow rather than calendar days (Hilsenhoff, 1988). An unusually warm, cold, wet, or dry spring may shift the emergence cycle of a river and cause variations in the invertebrate community sampled, even when collection occurred near the same calendar day each year. Weather patterns throughout the year can affect the survival rates of the adults and the instars. Dry conditions and resulting low flows can expose critical riffles, whereas a large rain event and resulting high flow can scour the channel and wash invertebrates out of riffles. The amount of surface-water runoff and the organic contaminants associated with it vary yearly and can have a significant effect on benthic-invertebrate populations in streams.

Streams in this study had unusually high flows in 1993 because of the unusually wet Midwestern summer. In contrast, parts of the Pensaukee River (mostly riffles) were dry in 1995 because dry weather conditions were compounded by newly constructed beaver dams upstream from the sampling reach. These and other variations in runoff, flow, and associated change in water quality likely caused much of the variability seen in multiple-year samples at the sites.

SUMMARY

Benthic invertebrates were one of several water-quality indicators for which data were collected as part of the USGS NAWQA program in the WMIC study area; other data collected include those on chemical water quality, stream habitat, and fish and algal communities. Benthic-invertebrate populations vary between streams, reaches on a given stream, years, and environmental settings, but can be a good indicator of a stream's general health.

Benthic-invertebrate samples were collected at eight wadeable fixed sites once a year for three years; at three of these sites, multiple-reach samples were collected. Three nonwadeable streams were sampled once in 1995. Most dominant aquatic invertebrates common to Wisconsin were represented in the 11 fixed-site stream samples; 54 families within 14 orders were identified. The results of the sampling were analyzed for variability among streams, reaches, and years.

In all cases, sampling in multiple reaches or in multiple years resulted in more invertebrate families being identified at a given stream than would have been identified in a single sample, a single year, or a single reach. Any one benthic-invertebrate sample identified as many as 88 percent (North Branch Milwaukee River, Reach A, 1994) and as few as 45 percent (Duck Creek, Reach A, 1994) of all the families found in that river during this study. The percentage of families identified every year during multiple-year sampling ranged from 55 percent at Tomorrow River to 18 percent at East River. The percentage of families identified in every reach during

multiple-reach sampling ranged from 70 percent at the North Branch of the Milwaukee River to 47 percent at Duck Creek.

Benthic-invertebrate communities and measures of these communities varied among fixed sites. Factors affecting benthic-invertebrate samples included habitat, chemical water quality, and flow variability. Generally, fixed-site streams containing the highest number of invertebrate families intolerant to organic pollution, and the highest invertebrate diversity were those fixed sites with the best habitat and chemical water quality.

Benthic-invertebrate communities and community measures at individual streams also varied among reaches and years. Variations among multiple reaches and years were larger than those found between different fixed sites in some cases. Mean tolerance value was the only benthic-invertebrate-community measure that indicated statistically significant differences in water quality at the three fixed sites using multiple-reach sampling. Number of individuals, number of families and FBI value all indicate statistically significant differences in water quality only between some of the multiple-year sampling sites—those which also had the greatest difference in water quality and habitat. The values of EPT enumeration, EPT percent, and MDI varied as much between years as between sites during multiple-year sampling.

The variations in benthic-invertebrate communities found in this study show how benthic invertebrates are affected by changes in both habitat and chemical water quality. Variation among years can most likely be attributed to climatic changes causing variations in flow and (or) chemical water quality, whereas variation between reaches is likely due to habitat variations. Major differences between fixed sites with significantly different chemical water quality, habitat, or environmental setting can be distinguished by use of benthic-invertebrate data; however, a single benthic-invertebrate sample cannot, alone, be relied upon to accurately describe water quality at the streams in this study. Benthic-invertebrate data contributed valuable information on the biological health of the 11 fixed sites when used in conjunction with other data sets to assess overall water quality.

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TABLES 6–8

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95

ORDER FAMILY *Genus and Species*	Lincoln			Mil-wau-kee	Fox	Duck					East			North Branch Milwaukee				
	1993	1994	1995	1995	1995	1993	1994A	1994B	1994C	1995	1993	1994	1995	1993	1994A	1994B	1994C	1995
PLECOPTERA						2	756	128		192	8		33					
PERLIDAE															28	3	1	
PERLODIDAE																		
Isoperla sp.																	1	
COLLEMBOLA			512															
EPHEMEROPTERA						3		16	1							32	32	
BAETIDAE	4			32	4	567	260	196	65	547	5			2	1053	588	746	
Acerpenna sp.										6								
CAENIDAE					276													
Caenis sp.					128			1	1									
HEPTAGENIIDAE						84	17	55	132	36					37	2		64
Stenacron interpunctatum															3	1		
Stenonema sp.														1	32	2		2
S. femoratum						24	2	57	165	102								
S. mediopunctatum															16	12	11	6
POTAMANTHIDAE																		
Anthopotamus sp.														2				
LEPTOPHLEBIIDAE								17	1									
ODONATA																		
COENAGRIONIDAE					4													
TRICHOPTERA					4									13	34		9	2
GLOSSOSOMATIDAE															22	1		
Protoptila sp.														10	302	1	64	826

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER FAMILY *Genus and Species*	Lincoln			Mil-wau-kee	Fox	Duck					East			North Branch Milwaukee				
	1993	1994	1995	1995	1995	1993	1994A	1994B	1994C	1995	1993	1994	1995	1993	1994A	1994B	1994C	1995
HELICOPSYCHIDAE																		
Helicopsyche sp.																1		
H. borealis						16									1		1	
HYDROPSYCHIDAE						32			2	8	4	4		7	48	1	2	10
Cheumatopsyche sp.						3	2	107	17	60		32		1	68	18	8	8
Hydropsyche sp.										6		32			21	2	3	1
H. betteni						1				3								3
Ceratopsyche bronta																		6
C. morosa bifida															5		71	66
C. morosa morosa														16	69	52		14
HYDROPTILIDAE					128	1	16							27	82			197
Hydroptila sp.		128				1								8	5	1	33	1
H. grandiosa															5			
Ochrotrichia sp.						16									8			
LEPTOCERIDAE														8				
Oecetis sp.					4										1			
LIMNEPHILIDAE																1		
Anabolia sp.								1	1	2		2						
Pycnopsyche sp.						9	15		3	6					2	2	2	1
PHILOPOTAMIDAE																		
Chimarra sp.		128												1	4		1	
Wormaldia sp.						1		16										

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER FAMILY *Genus and Species*	**Lincoln**			**Mil-wau-kee**	**Fox**	**Duck**					**East**			**North Branch Milwaukee**				
	1993	**1994**	**1995**	**1995**	**1995**	**1993**	**1994A**	**1994B**	**1994C**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994A**	**1994B**	**1994C**	**1995**
POLYCENTROPODIDAE					8									1	8			
Polycentropus sp.															1	2	1	
Paranyctiophylax sp.														1				
PSYCHOMYIIDAE														32	8	16		64
Psychomyia flavida														44	113	34	69	202
UENOIDAE																2		
Neophylax sp.														22	50	7	11	46
COLEOPTERA																		
DRYOPIDAE																		
Helichus striatus										1								
ELMIDAE																		
Ancyronyx sp.				32		8	70	157	33	138					350		100	272
Dubiraphia sp.														1				
D. bivittata																		1
Macronychus glabratus																	1	
Optioservus sp.						292								27	10	18	33	1
O. fastiditus										36								
Stenelmis sp.						182		4		76				48	55	45	35	65
DYTISCIDAE					1	49												
HALIPLIDAE																		
Haliplus sp.					4													

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER FAMILY *Genus and Species*	Lincoln			Mil-wau-kee	Fox	Duck					East			North Branch Milwaukee				
	1993	1994	1995	1995	1995	1993	1994A	1994B	1994C	1995	1993	1994	1995	1993	1994A	1994B	1994C	1995
DIPTERA						52				96	4	96			17			
CERATOPOGONIDAE				8		129					4				9	32		
Bezzia sp.						32												
CHIRONOMIDAE	92	392	1824	1034	18561	6645	1488	891	951	2920	369	586	2162	1158	2018	2109	4240	2288
EMPIDIDAE									8						3			2
Clinocera sp.										4								
Hemerodromia sp.					4			17						2	25		1	
Rhamphomyia sp.											1							
PSYCHODIDAE																		
Psychoda sp.													1					
SIMULIIDAE						298	816	465	17	3	4	128		50	125	75	32	2
TABANIDAE								1										
TIPULIDAE														1				1
Antocha sp.														1	40	34	32	3
Tipula sp.														1				
AMPHIPODA					388		33	131	298	64				32	20	48		
GAMMARIDAE																		
Gammarus sp.					455			3		1								
ISOPODA				392	1	1					31	1536	64	141	186	112	353	128
HETEROPTERA						2			8								33	
CORIXIDAE											20				1			
NEUROPTERA																		
SISYRIDAE																		
Climacia areolaris								48										

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER	**Pensaukee**			**Tomorrow**					**Popple**			**Peshekee**			**Menominee**
FAMILY *Genus Species*	**1993**	**1994**	**1995**	**1993**	**1994 A**	**1994 B**	**1994C**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1995**
PLECOPTERA				10					64	32		5	32		
CHLOROPERLIDAE													32		
Haploperla sp.														1	
LEUCTRIDAE												114	16		
Leuctra sp.										64		6	1	130	
NEMOURIDAE											32				
Amphinemura sp.						64									
Nemoura sp.						64									
PERLIDAE	169	739		4	4				128	14		56	10	32	
Acroneuria sp.									40	9	1	117	13	16	
A. lycorias													3		
Paragnetina sp.						2	1								
P. media				2	1		1		6		5	7	1		
Agnetina sp.										1					
A. capitata									1						
PERLODIDAE															
Isoperla sp.					2		1	1		10	6	5	1	9	
I. cotta													2		
PTERONARCYIDAE															
Pteronarcys sp.												2		32	1
EPHEMEROPTERA	48								7	96		40	64		96
BAETIDAE	1	2561	513	59	4	72	128		297	782	325	337			
CAENIDAE	32	64													
Caenis sp.	48										32				

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER FAMILY *Genus Species*	Pensaukee			Tomorrow					Popple			Peshekee			Menominee
	1993	1994	1995	1993	1994 A	1994 B	1994C	1995	1993	1994	1995	1993	1994	1995	1995
EPHEMERELLIDAE				17		1			284		34				
Ephemerella sp.						68	2			21	51		49	95	
Eurylophella sp.										69					
EPHEMERIDAE										64					
Ephemera sp.										19	2			1	
Hexagenia sp.				2											2
HEPTAGENIIDAE	16			16					17	164		228	225	322	
Epeorus sp.										32		16	35		
E. vitreus												56		76	
Rhithrogena sp.													16	42	
Stenacron sp.				1											
S. interpunctatum	8		1					1							
Stenonema femoratum	3	6	2												
S. vicarium					7	69		9		13	1		8	38	
S. modestum									3						
LEPTOPHLEBIIDAE									81	195		273	32	195	
Paraleptophlebia sp.									1	6		3		32	
LEPTOHYPHIDAE	1														
ISONYCHIIDAE															
Isonychia sp.									1						
ODONATA												32			
AESHNIDAE															
Boyeria sp.									1	1		1	1		
B. vinosa													4		
Cordulegaster sp.						1									

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER	**Pensaukee**			**Tomorrow**					**Popple**			**Peshekee**			**Menominee**
FAMILY *Genus Species*	**1993**	**1994**	**1995**	**1993**	**1994 A**	**1994 B**	**1994C**	**1995**	**1993**	**1994**	**1995**	**1993**	**1994**	**1995**	**1995**
GOMPHIDAE									1		1	21	49	7	
Hagenius brevistylus										1					
Ophiogomphus sp.													10	4	1
Stylogomphus albistylus													1		
Stylurus sp.															1
TRICHOPTERA	33			69	3	261	68			4		8	2		
BRACHYCENTRIDAE				1595	9	385	768				32				
Brachycentrus americanus					3	65	64	2							
Micrasema sp.						1			16	98		19			
M. rusticum							8								
GLOSSOSOMATIDAE															
Glossosoma sp.									33	36		46	73	46	
Protoptila sp.				20	15	348	135	270							
HELICOPSYCHIDAE															
Helicopsyche borealis						1			2	2					
HYDROPSYCHIDAE	21	57	3	1	9	16		6	22	6		113		1	
Cheumatopsyche sp.	23	241	4	18	2	66	65	2	2	11	32			3	
Hydropsyche sp.		66							74	5	1				
H. betteni	2	8	2								1				
Ceratopsyche morosa bifida				83		1	66	4	78		10	261		107	1
C. morosa morosa					1					45			101		
C. slossonae					40	188	40	26							

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER	Pensaukee			Tomorrow					Popple			Peshekee			Menominee
FAMILY *Genus Species*	1993	1994	1995	1993	1994 A	1994 B	1994C	1995	1993	1994	1995	1993	1994	1995	1995
HYDROPTILIDAE	300	66		4	1	1		512	97	651	64	2	128		
Hydroptila sp.	32	129		32		212	194		98	226		46	129	32	
Oxyethira rivicola									8						
Stactobiella delira									16						
LEPTOCERIDAE									4	7			1		
Oecetis sp.													4		
Setodes sp.									16	76			1		
S. oligius											4				
LEPIDOSTOMATIDAE															
Lepidostoma sp.				8		67	24				32	16		2	
LIMNEPHILIDAE	1	1		8											
Anabolia sp.		1	5		2										
Hydatophylax sp.													1		
Limnephilus sp.				1											
Onocosmoecus sp.						1									
O. unicolor				1											
Pycnopsyche sp.					2	32	9	1					1	1	
ODONTOCERIDAE															
Psilotreta sp.													1		
P. indecisa														1	
PHILOPOTAMIDAE													2		
Chimarra sp.				1					92	1		444	337	74	64
POLYCENTROPODIDAE										32					
Neureclipsis sp.													2		

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER	Pensaukee			Tomorrow					Popple			Peshekee			Menominee
FAMILY / *Genus Species*	1993	1994	1995	1993	1994 A	1994 B	1994C	1995	1993	1994	1995	1993	1994	1995	1995
PSYCHOMYIIDAE										64					
Lype sp.							1								
Lype diversa								4							
Psychomyia sp.										32					
P. flavida				32	4	133	1	258		33	32				
UENOIDAE				1											
Neophylax sp.				22	19	28	13	3		4		2		1	
MEGALOPTERA															
CORYDALIDAE															
Nigronia sp.				8					1			6	1		
N. serricornis					8	4	5	2		1			4		
SIALIDAE															
Sialis sp.								4							
LEPIDOPTERA															
PYRALIDAE				8											
COLEOPTERA															
DRYOPIDAE															
Helichus striatus			2												
ELMIDAE															
Ancyronyx sp.	68	147	513	317	6	1961	1101	142	482	99	32	262	167	167	448
Dubiraphia sp.	1	16													
Optioservus sp.				4					32						
O. fastiditus			33		4	8	64								
O. trivittatus						4	64						16		
Stenelmis sp.									17	15		16			

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER / FAMILY / *Genus Species*	Pensaukee			Tomorrow					Popple			Peshekee			Menominee
	1993	1994	1995	1993	1994 A	1994 B	1994C	1995	1993	1994	1995	1993	1994	1995	1995
DYTISCIDAE		65	2												
HALIPLIDAE	1														
DIPTERA									128			1	32		32
ATHERICIDAE															
Atherix sp.				1		1			1			42	1		
A. variegata								1						2	
BLEPHARICERIDAE															
Blepharicera sp.													16	6	
CERATOPOGONIDAE			512	4					1						64
CHIRONOMIDAE	3920	4075	15373	892	27	1911	2739	3719	1610	4065	4044	2210	706	292	2239
EMPIDIDAE		17		17		70	1		5			39			
Hemerodromia sp.				24		65			19	32		58	49		64
Chelifera sp.				40		64		128			1		1		
SIMULIIDAE	51	657	6412	8	2	321	257		66	37	64	992	1605	1697	1796
TABANIDAE				4											65
Chrysops sp.				3											
TIPULIDAE				28		4	65		2			1			
Anocata sp.				257	4	782	324	5	52	1		36	1		
Hexatoma sp.				1								1		38	1
Tipula sp.							1	1		1					
TANYTARSINI															
Stempellina sp.														129	

Table 6. Numbers and types of benthic invertebrates collected in samples from 11 fixed site streams in the Western Lake Michigan Drainages study unit, 1993–95—Continued

ORDER	Pensaukee			Tomorrow					Popple			Peshekee			Menominee
FAMILY *Genus Species*	1993	1994	1995	1993	1994 A	1994 B	1994C	1995	1993	1994	1995	1993	1994	1995	1995
AMPHIPODA	87	2560	3	125		517	322	640							
GAMMARIDAE															
Gammarus sp.	2	94	24		1	2	3	16							
ISOPODA	13	1728	1551												
ASELLIDAE	1592	64													
NEUROPTERA															
SISYRIDAE															
Climacia sp.												1			
COLLEMBOLA				4											64

Table 7. Median values of selected water-chemistry characteristics of fixed sites in the Western Lake Michigan Drainages study unit, 1993–95

[µs/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter, N, nitrogen; P, phosphorus; $CaCO_3$, calcium carbonate]

	Indicator sites								Integrator sites		
	Peshekee River near Martins Landing, Mich.	Popple River near Fence, Wis.	Pensaukee River near Krakow, Wis.	Duck Creek near Oneida, Wis.	Tomorrow River near Nelsonville, Wis.	East River near DePere, Wis.	North Branch Milwaukee River near Random Lake, Wis.	Lincoln Creek at 47th Street at Milwaukee, Wis.	Menominee River at McAllister, Wis.	Fox River at Green Bay, Wis.	Milwaukee River at Milwaukee, Wis.
Specific conductance (µS/cm at 25°C)	38	148	628	733	381	770	684	768	248	394	682
pH (standard units)	7.0	7.6	8.0	8.1	8.0	8.0	8.3	8.0	8.0	8.4	8.4
Ammonium, dissolved, mg/L as N	.04	.03	.065	.085	.03	.10	.07	.08	.02	.12	.035
Nitrate plus nitrite, dissolved, mg/L as N	.073	.057	.78	.84	1.8	1.0	1.6	.54	.096	.32	.76
Phosphorus, total, mg/L as P	.008	.02	.16	.15	.02	.24	.14	.045	.02	.12	.11
Phosphorus, dissolved, mg/L as P	.007	.008	.095	.10	.005	.18	.085	.025	.01	.05	.05
Alkalinity, mg/L as $CaCO_3$	16	68	280	260	190	270	310	160	110	160	260

Table 8. Selected habitat characteristics of fixed sites in the Western Lake Michigan Drainages study unit, 1993–95

[--, missing data; km^2, square kilometers; mi^2, square miles; km, kilometers; m, meters; m^3/s, cubic meters per second; ft^3/s, cubic feet per second]

	Indicator sites								Integrator sites		
	Peshekee River near Martins Landing, Mich.	Popple River near Fence, Wis.	Pensaukee River near Krakow, Wis.	Duck Creek near Oneida, Wis.	Tomorrow River near Nelsonville, Wis.	East River near DePere, Wis.	North Branch Milwaukee River near Random Lake, Wis.	Lincoln Creek at 47th Street at Milwaukee, Wis.	Menominee River at McAllister, Wis.	Fox River at Green Bay, Wis.	Milwaukee River at Milwaukee, Wis.
USGS site number	04062085	04063700	04071795	04072050	04080798	04085109	040863095	040869415	04067500	04085139	04087000
Relatively homogeneous unit[1]	16	22	2	1	20	23	3	9	--	-	--
Drainage area (km^2, [mi^2])	127 [49.0]	360 [139]	92.7 [35.8]	247 [95.5]	114 [44.0]	122 [47.0]	133 [51.4]	24.8 [9.56]	10,200 [3,930]	16,400 [6,330]	1,800 [696]
Great Lakes Environmental Assessment Score	102	84	73	66	86	45	67	37	--	-	--
Erodibility factor[2]	.13	.14	.26	.27	.16	.29	.28	.33	.24	.20	.26
Embeddedness	3.4	2.6	2.5	2.8	1.8	0.5	1.5	1.4	2.4	--	2.4
2-year flood (m^3/s, [ft^3/s])	--	19 [680]	13 [450]	31 [1,100]	10 [360]	35 [1,300]	18 [650]	7 [250]	430 [15,000]	420 [15,000]	130 [4,700]
Annual mean flow (m^3/s, [ft^3/s])	2.4 [85]	3.1 [110]	.28 [10]	1.8 [64]	.82 [29]	1.2 [41]	.88 [31]	.24 [8.5]	79 [2,800]	170 [6,000]	14 [500]
2-yr 7-day low flow (m^3/s [ft^3/s])	--	.86 [30]	0 [0]	0 [0]	.49 [17]	0 [0]	.11 [4.0]	.07 [2.3]	41 [1,400]	38 [1,400]	1.5 [55]
Dominant Land Use	Forest	Forest/ Wetland	Agriculture	Agriculture	Agriculture/ Forest	Agriculture	Agriculture	Urban	Forest	Agriculture/ Forest	Agriculture/ Urban

[1]Relatively homogeneous units are described in Robertson and Saad (1995a).

[2]Percentage of erodibility factor was obtained from U.S. Department of Agriculture (1991).