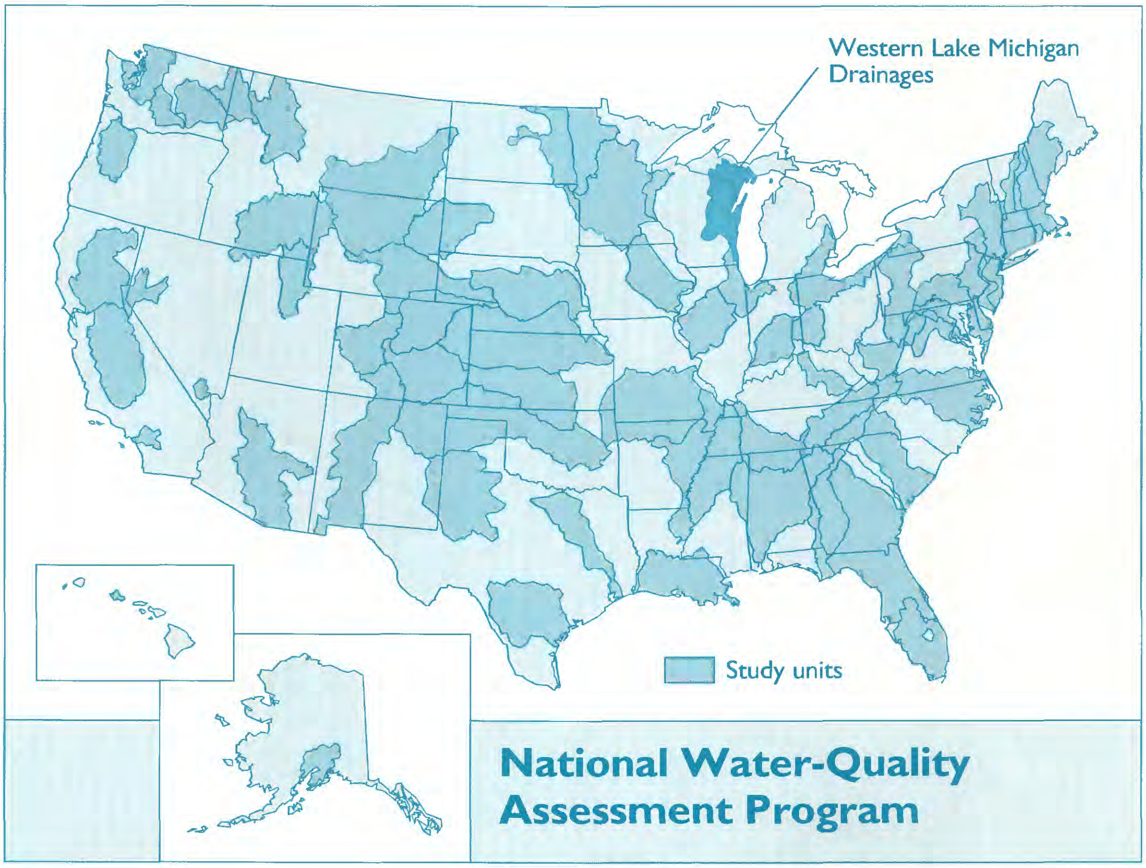
U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 96-4038-D

Fish Communities of Benchmark Streams in Agricultural Areas of Eastern Wisconsin



FISH COMMUNITIES OF BENCHMARK STREAMS IN AGRICULTURAL AREAS OF EASTERN WISCONSIN

By Daniel J. Sullivan and Elise M. Peterson

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NATIONAL WATER-QUALITY ASSESSMENT PROGRAM
WESTERN LAKE MICHIGAN DRAINAGES

Madison, Wisconsin
1997

U.S. DEPARTMENT OF THE INTERIOR
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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS

Multiply	By	To Obtain
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
hectare	2.471	acre
square kilometer (km^2)	0.3861	square mile
cubic meter per second (m^3/s)	35.31	cubic foot per second

MISCELLANEOUS ABBREVIATIONS

DCA	Detrended Correspondence Analysis
GLEAS	Great Lakes Environmental Assessment Section
IBI	Index of Biotic Integrity
NAWQA	National Water-Quality Assessment Program
RHU	Relatively homogeneous unit
USGS	United States Geological Survey
WDNR	Wisconsin Department of Natural Resources

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FISH COMMUNITIES OF BENCHMARK STREAMS IN AGRICULTURAL AREAS OF EASTERN WISCONSIN

By Daniel J. Sullivan *and* Elise M. Peterson

Abstract

Fish communities were surveyed at 20 stream sites in agricultural areas in eastern Wisconsin in 1993 and 1995 as part of the National Water-Quality Assessment (NAWQA) Program. These streams, designated "benchmark streams," were selected for study because of their potential use as regional references for healthy streams in agricultural areas, based on aquatic communities, habitat, and water chemistry. The agricultural benchmark streams were selected from four physical settings, or relatively homogeneous units (RHU's), that differ in bedrock type, texture of surficial deposits, and land use. Additional data were collected along with the fish-community data, including measures of habitat, water chemistry, and population surveys of algae and benthic invertebrates.

Of the 20 sites, 19 are classified as trout (salmonid) streams. Fish species that require cold or cool water were the most commonly collected. At least one species of trout was collected at 18 sites, and trout were the most abundant species at 13 sites. The species with the greatest collective abundance, and collected at 18 of the 20 sites, were mottled sculpin *(Cottus bairdi)*, a coldwater species. The next most abundant species were brown trout *(Salmo trutta)*, followed by brook trout *(Salvelinus fontinalis)*, creek chub *(Semotilus atromaculatus)*, and longnose dace *(Rhinichthys cataractae)*. In all, 31 species of fish were collected. The number of species per stream ranged from 2 to 14, and the number of individuals collected ranged from 19 to 264.

According to Index of Biotic Integrity (IBI) scores, 5 sites were rated excellent, 10 sites rated good, 4 rated fair, and 1 rated poor. The ratings of the five sites in the fair to poor range were low for various reasons. Two sites appeared to have more warmwater species than was ideal for a high-quality coldwater stream. One was sampled during high flow and the results may not be valid for periods of normal flow; the other may have been populated by migrating warmwater species. Two sites had insufficient deep-water habitat to support large numbers of fish, especially top carnivores. Finally, one stream may be too cool to support enough warmwater species and too warm to support trout.

In general, two methods of evaluating site habitat indicate that habitat is not a limiting factor for fish communities. However, two sites were rated as fair according to both habitat evaluation methods due to low base flow. Two sites rated below good according to one habitat evaluation method but rated good or excellent according to the other.

Detrended correspondence analysis (DCA) of data for 17 sites showed three station groupings. These groupings fell along RHU divisions and each group was associated with one of three trout species. A species-richness gradient was evident on the station-ordination diagram. Intolerant species were associated with each grouping, a reflection of the generally high water quality at the sites. However, no significant differences were found between IBI scores or habitat indices among the site groupings. The DCA axis 1 and 2 scores correlated with average velocity and percent pool as well as RHU factors percent sandy surficial deposits, percent wetland, percent agriculture, and bedrock. Average velocity was highest at three sites which also had among the highest measured flow and largest drainage areas. Percent pool was generally lower at sites with smaller percentages of sandy surficial deposits, with one exception.

The usefulness of ordination methods in conjunction with more traditional methods of defining biotic integrity (IBI) has been noted in previous studies. In this study, however, perhaps because of the relative homogeneity of the benchmark streams, the IBI did not correlate with the same kinds of factors as the DCA axis scores did.

INTRODUCTION

In 1991, the first 20 study units of the National Water-Quality Assessment (NAWQA) Program began investigations. This first round of study units were in primarily agricultural regions of the U.S. and thus investigations focussed on effects of agricultural land use on water quality.

Purpose and Scope

This report presents the results of fish-community sampling at 20 stream sites sampled during an ecological survey of benchmark streams in agricultural areas of the Western Lake Michigan Drainages NAWQA study unit. Fish communities are described and compared to reference standards for fish and habitat. In addition, attempts are made to determine which environmental and habitat variables are the most important predictors of fish communities at the 20 sites. The scope of this report is limited to analysis of fish and habitat data collected at 20 stream sites in eastern Wisconsin during 1993 and 1995.

Description of the Western Lake Michigan Drainages

The Western Lake Michigan Drainages study unit encompasses an area of about 51,540 square kilometers in eastern Wisconsin and central Upper Michigan (fig. 1). The study unit, which includes 10 major river systems draining to Lake Michigan, is bounded on the south by the Illinois State line and extends north to about 50 kilometers north of Escanaba, Mich. The following rivers drain directly to Green Bay: the Escanaba and Ford Rivers in the Upper Peninsula of Michigan; the Menominee River, which forms much of the border between Michigan and Wisconsin; the Oconto and Peshtigo Rivers; and the Fox/Wolf River, the largest system in the study unit. The Manitowoc, Sheboygan, and Milwaukee Rivers all drain directly to the western side of Lake Michigan.

Overall population of the study unit is 2,435,000 (U.S. Bureau of the Census, 1991), with urban land use accounting for less than 4 percent of the study unit. The Milwaukee River Basin in the southeastern part of the study unit has the largest human population. Major cities in the study unit and their populations are Milwaukee, 628,000; Green Bay, 96,000; Racine, 84,000; Kenosha, 80,000; and Appleton, 66,000. Agriculture, mainly cropland and pastureland used for the dairy industry, accounts for 37 percent of the land use. Cropland predominates in the southern part of the study unit. Most major urban areas also are in the southern half of the study unit. Forests cover about 40 percent of the study unit, mostly in the northwest part. Wetlands account for about 15 percent of the land cover. Lake Winnebago, a 55,440-hectare lake in the Fox River Basin, is a major surface-water feature in the study unit.

Agriculture is the major land use in the southern half of the study unit and many studies have focused on the effect of agriculture on water quality in disturbed streams in this area. In contrast, few studies have been done to determine the composition of aquatic communities and habitat of largely undisturbed streams in these areas. Thus, a benchmark does not currently exist for researchers to determine the community potential for streams in similar geographic settings and to measure the effects of improvements or the extent of degradation in community composition that may result from changes in agricultural practices.

STUDY DESIGN AND METHODS

Benchmark Streams Study Design

The Western Lake Michigan Drainages NAWQA study-unit team has attempted to address the lack of benchmarks for agricultural streams by identifying and sampling 20 stream sites (fig. 2; table 1) where physical and chemical conditions were judged to be minimally affected by agriculture. Data were collected from June 1993 through August 1995 to describe the physical and chemical conditions and fish, invertebrate, and algal communities of these streams. The environmental settings of these streams are described in Rheaume and others (1996), and the habitat is described in Fitzpatrick and others (1996).

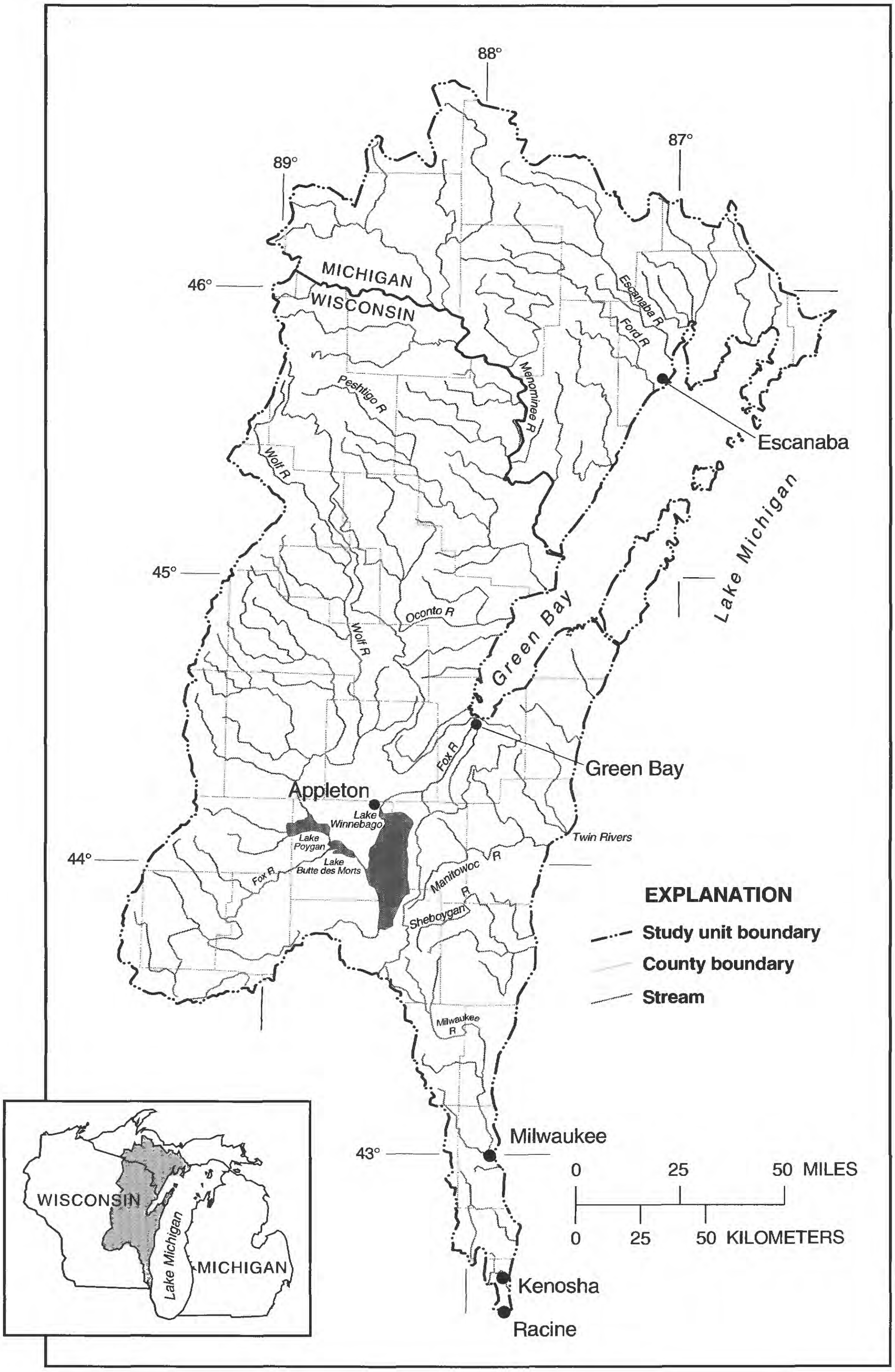

Figure 1. Western Lake Michigan Drainages study unit of the National Water-Quality Assessment Program.

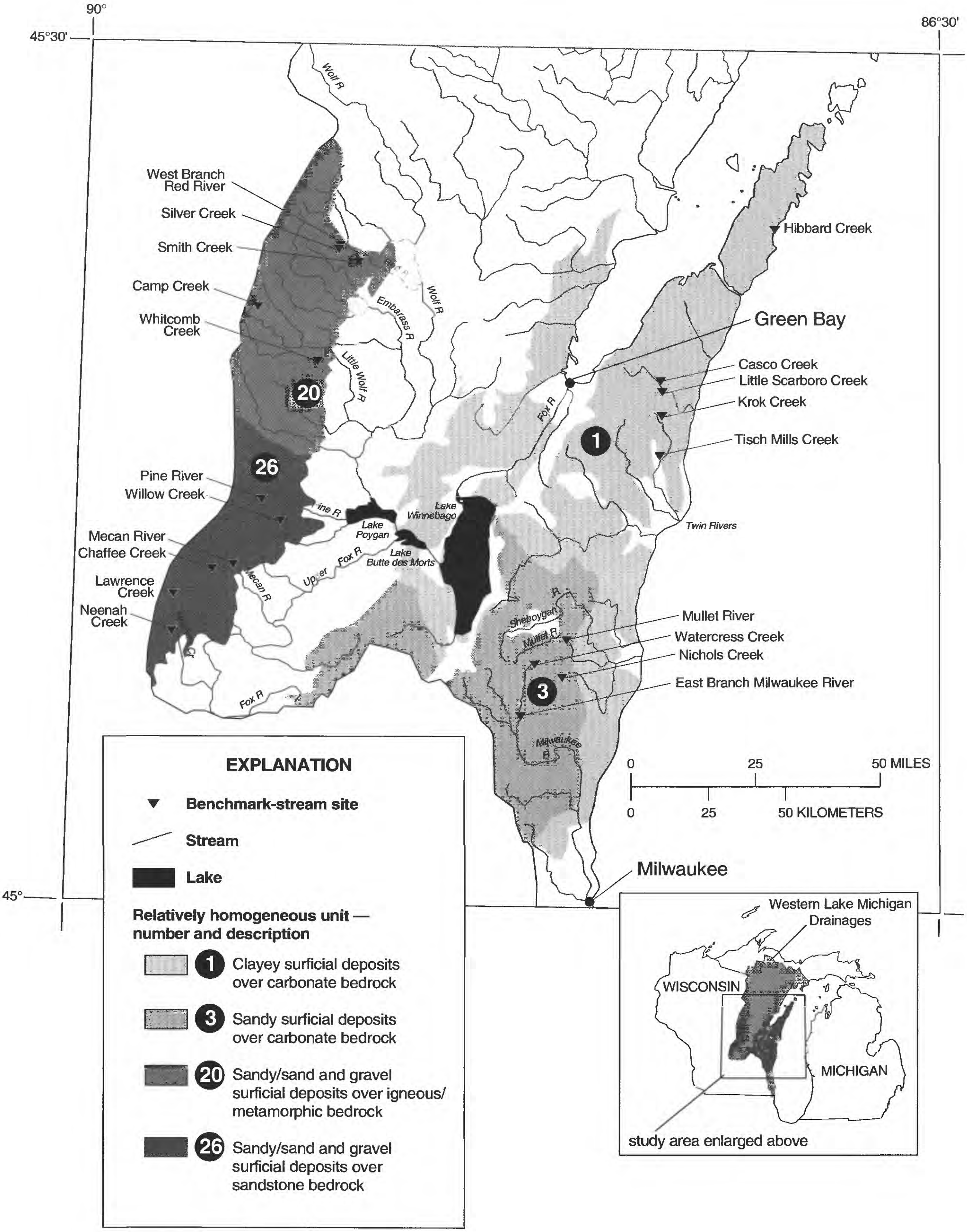

Figure 2. Location of agricultural benchmark-stream sites and four relatively homogeneous units in the Western Lake Michigan Drainages study unit.

Table 1. Selected information for agricultural benchmark streams in the Western Lake Michigan Drainages
[km^2, square kilometers; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; RHU, relatively homogeneous unit; --. no data]

Site name	Fish collection date	Drainage area (km^2)	Percent agricultural land use	Discharge on sampling date (m^3/s, [ft^3/s])	
RHU 1					
Tisch Mills Creek at Tisch Mills, Wis.	07/13/93	42.2	80.9	0.35	[12.5]
Krok Creek near Ellisville, Wis.	06/27/95	14.2	60.6	.01	[.51]
Little Scarboro Creek near Luxemburg, Wis.	06/27/95	2.3	93.5	.04	[1.6]
Casco Creek near Casco, Wis.	07/14/93	38.9	89.4	.42	[15.0]
Hibbard Creek at Jacksonport, Wis.	06/27/95	42.5	73.3	.09	[3.3]
RHU 3					
East Branch Milwaukee River near New Fane, Wis.	06/26/95	138.0	55.6	.10	[3.4]
Nichols Creek near Cascade, Wis.	06/26/95	11.9	80.9	5.7	[5.7]
Mullet River near Plymouth, Wis.	07/14/93	117.6	72.3	2.2	[78.0]
Watercress Creek near Dundee, Wis.	06/26/95	31.1	65.7	.02	[.66]
RHU 20					
Whitcomb Creek near Big Falls, Wis.	06/29/95	22.0	30.4	.23	[8.0]
West Branch Red River near Bowler, Wis.	08/03/93	95.8	37.9	1.2	[42.5]
Silver Creek near Bowler, Wis.	08/03/93	40.9	35.4	.46	[16.1]
Smith Creek near Bowler, Wis.	06/28/95	5.7	5.2	.08	[2.7]
Camp Creek near Galloway, Wis.	06/28/95	12.4	18.0	.12	[4.3]
RHU 26					
Lawrence Creek near Lawrence, Wis.	06/30/95	21.5	49.7	.30	[10.7]
Neenah Creek near Oxford, Wis.	07/06/95	63.7	58.2	--	--
Chaffee Creek near Neshkoro, Wis.	07/06/95	23.8	43.6	--	--
Mecan River near Richford, Wis.	07/06/95	73.8	58.7	--	--
Willow Creek near Mount Morris, Wis.	06/29/95	41.7	41.0	.42	[14.8]
Pine River at Wild Rose, Wis.	06/29/95	55.2	57.6	.23	[8.1]

The study unit was divided into areas referred to as "relatively homogeneous units" (RHU's), which are based on unique combinations of land use/land cover, bedrock geology, and surficial deposits (Robertson and Saad, 1995). Four of the largest RHU's in the study unit (1, 3, 20, and 26) are in areas of significant agricultural land use and were selected as the focus of this study (Rheaume and others, 1996). RHU 1 (clayey surficial deposits over carbonate bedrock) and RHU 3 (sandy-till surficial deposits over carbonate bedrock) are in adjacent areas dominated by agricultural land use. RHU 20 (sandy/sand and gravel surficial deposits over igneous/metamorphic bedrock) and RHU 26 (sandy/sand and gravel surficial deposits over sandstone bedrock) are in adjacent areas of mixed agricultural land use and forest.

The 20 streams selected for this study showed minimal adverse effects from human activity on the basis of field reconnaissance and the following criteria: (1) available invertebrate or fisheries data that indicate good to excellent water quality, (2) instream habitat restoration for fisheries enhancement, and (3) land management to protect riparian vegetation (Rheaume and others, 1996). Four to six benchmark streams per RHU were selected for sampling.

The goals for collecting fish in this study were numerous. The main objective was to characterize fish communities at the benchmark-stream sites, and, secondly, to determine whether the communities are representative of fish communities in streams that are minimally affected by agriculture. Another objective was to attempt to determine whether differences exist in fish communities among the four sampled RHU's and, if so, to see whether the factors influencing the differences could be defined. The fish data also complement data on algae, benthic-invertebrate, and water-chemistry and can be used in conjunction with these data to describe the overall environmental and ecological conditions at these sites. If the benchmark streams suitably represent streams in agricultural areas of eastern Wisconsin that are minimally affected by agriculture, then they can be used to define baseline conditions. These baseline conditions can be compared to conditions at affected streams or as goals to reach by implementation of best management practices. Finally, the fish data will be part of a larger NAWQA data base on ecological characteristics of streams across the Nation.

Data Collection Methods

All 20 benchmark streams were first-, second-, third-, or fourth-order (Strahler, 1957). Fish were collected during July and August in 1993 and 1995. Habitat characteristics were measured during May and June 1993.

Fish Community

The fish-collection protocol for the NAWQA program is detailed in Meador, Cuffney, and Gurtz (1993). Fish-community samples were collected by use of direct-current electrofishing gear. Backpack-mounted electrofishers were used on small streams, whereas a towed barge unit was used on larger and deeper streams.

Fish were identified in the field by Daniel Sullivan, USGS, Madison, Wis. The first 30 individuals of each species were weighed and measured. Specimens of selected species were retained for verification of field identifications and reference. Taxonomic verifications were done by Dr. William LaGrande, University of Wisconsin-Stevens Point.

A variation from the NAWQA sampling protocol was that only one sampling pass was made at many sites to avoid excessive disturbance or injury to trout (salmonids). Two passes were made at the five sites sampled in 1993 (table 1) and at the East Branch Milwaukee River in 1995. No new species were collected on second passes, except at Tisch Mills Creek where two new species were captured (these species were included with first-pass data for this site). For consistency, species-abundance data collected during the first pass at each site were used in analyses in this report.

Sampling reach length was determined on the basis of the following criteria used for habitat measurement: (1) at least two types of geomorphic units (pools, riffles, or runs) occurred repetitively in the selected reach, (2) minimum reach length was 20 times the average stream width, and (3) maximum reach length was 300 m. An attempt was made to select reaches that were upstream from bridges to limit effects from roads and channel modifications; however, in certain places where upstream reaches did not adequately characterize the stream segment, downstream reaches were selected. The NAWQA protocol (Meador, Hupp, and others, 1993) recommends a minimum reach length of 150 m; however, owing to the small size of many of the benchmark streams, criterion 2 was substituted, resulting in some cases of reaches less than 150 m long. Because of low species diversity in coldwater streams in Wisconsin, it was felt that sampling reaches of less than 150 m were adequate to characterize the fish communities and determine biotic integrity in these streams.

Habitat

Habitat data were collected in accordance with the NAWQA habitat protocol described by Meador, Hupp, and others (1993). Data were collected at three spatial levels: basin, stream segment between tributaries, and stream reach. All habitat characteristics listed in the NAWQA habitat protocol were measured; additional basin-level characteristics not listed in the protocol but thought to be important in the analysis of invertebrate, fish, and algae communities were measured and are listed in Fitzpatrick and others (1996).

Data Analysis Methods

The analytical approach used consisted of (1) summarization and description of species collected, (2) comparison of fish-community data to established reference standards, (3) identification and description of relations among sites on the basis of patterns in fish-community structure, and (4) comparison of fish-community structure to environmental variables and habitat information. Fish-community data were compared to standards by calculating an Index of Biotic Integrity (IBI) score. Two indices were calculated to determine the suitability of the aquatic habitat of each site. Multivariate statistics (detrended correspondence analysis, or DCA) were used to determine whether differences, or gradients, exist among fish communities at the benchmark sites. Finally, station axis scores from DCA were checked for correlation with environmental variables to identify important factors that affect the fish communities at the benchmark sites.

Fish-Community Measures

Fish and benthic macroinvertebrates have been found to be particularly effective indicators of the environmental quality of surface waters (Berkman and Rabeni, 1987; Plafkin and others, 1989). The IBI assesses biotic integrity and environmental quality of streams from attributes of the fish community (Karr, 1981; Karr and others, 1986). Several features, or metrics, of the fish assemblage are rated as good, fair, or poor and are then combined to assign an overall score. An IBI has been developed for coldwater streams (Lyons and others, 1996) and warmwater streams (Lyons, 1992) in Wisconsin. Significant differences exist between fish assemblages in streams with different water temperature regimes, so use of the appropriate index is important. In this report, the coldwater index was used for all streams classified as trout streams (Wisconsin Department of Natural Resources, 1980; 1996).

The Wisconsin coldwater index has five metrics: (1) number of intolerant species, (2) percentage of all individuals that are tolerant species, (3) percentage of all individuals that are top carnivore species, (4) percentage of all individuals that are stenothermal coolwater and coldwater species, and (5) percentage of trout individuals that are brook trout *(Salvelinus fontinalis)*. Tolerant and intolerant species as well as stenothermal cool and coldwater species are listed in Lyons and others (1996).

The Wisconsin warmwater index (Lyons, 1992) is more complex than that for coldwater streams, reflecting the more complex fish communities found in warmwater streams in Wisconsin. It has 10 metrics and two correction factors: (1) total number of native species; (2) number of darter (includes a number of species in the percid family) species; (3) number of sucker (catostomid) species; (4) number of sunfish (centrarchid) species; (5) number of intolerant species; (6) percent tolerant species; (7) percent omnivores; (8) percent insectivores; (9) percent top carnivores; and (10) percent simple lithophils. The correction factors are (1) number of individuals per 300 m of stream reach, and (2) percent of fish with deformities, eroded fins, lesions, or tumors.

Habitat Classifications

Two habitat classifications were used to evaluate fish habitat in the benchmark streams: the Michigan Department of Natural Resources, Great Lakes Environmental Assessment Section (GLEAS) procedure 51 (Michigan Department of Natural Resources, 1991) and "Guidelines for Evaluating Fish Habitat in Wisconsin Streams" (Simonson and others, 1994). Habitat data were not collected specifically to satisfy the requirements of these classifications; however, the data collected by NAWQA were sufficient to rate each category of the classification. The goal of the GLEAS procedure is to rate overall stream habitat, not specifically fish habitat. The Wisconsin fish habitat index was developed to standardize fish habitat evaluations that document the quality and quantity of habitat available for fish (Simonson and others, 1994).

Statistical Analyses

Multivariate analysis is useful in studies of community ecology. It helps ecologists discover structure in data and provides objective summarization of data to facilitate interpretation and aid in communicating results (Gauch, 1982). For this report, detrended correspondence analysis (DCA) was used to examine the structure of fish communities among sites. The results of DCA were checked for correlation with selected habitat variables. A brief discussion of these techniques follows.

The CANOCO statistical package (Ter Braak, 1988) was used for DCA. DCA is an eigenvector ordination technique that identifies and describes patterns in community structure by summarizing the pattern of a species-by-samples data matrix (Gauch, 1982). Data were log-transformed to minimize the effect that very abundant species have on samples; this type of transformation has been shown to be appropriate for DCA (Gauch, 1982). Rare species, those present in only one sample and with fewer than five total occurrences, were downweighted. These techniques prevent extremely abundant or extremely rare taxa from having undue influence on the ordination.

The resulting sample-ordination diagram arranges the species and samples in a low-dimensional space in which similar entities are close to each other. Two ordination diagrams can be made, one for sites and one for species. The importance of species in determining the location of a site on a diagram can be seen by comparing like areas on the two diagrams.

Groupings identified by DCA were tested for significant differences of their IBI and GLEAS habitat scores using a Wilcoxon rank-sum test (a two-sample t-test on ranked data). The SAS statistical software package (SAS Institute, Inc., 1990) was used for rank correlations and the Wilcoxon rank-sum test.

Spearman's rho, a nonparametric correlation coefficient, was used to identify environmental and habitat variables most closely related to fish-community structure. Correlation coefficients between DCA station axis scores, IBI scores, and selected environmental and habitat , variables were examined. Correlation coefficients with $p < 0.05$ were considered significant.

FISH COMMUNITIES OF BENCHMARK STREAMS

Nineteen of the benchmark streams are classified as trout, or coldwater, fisheries (Wisconsin Department of Natural Resources, 1980; 1996). In general, high-quality coldwater streams in Wisconsin support few fish species and are dominated by trouts and sculpins (cottids) (Lyons and others, 1996). By contrast, high-quality warmwater streams in Wisconsin generally are characterized by greater species richness than coldwater streams. High-quality warmwater fish communities are characterized by the presence of many native species, including darters, suckers, and sunfishes (Lyons, 1992). Environmental degradation in coldwater streams often results in an increase in the number of species; in warmwater streams the number of species often declines.

Fish species from 10 families were collected at the benchmark sites (appendix). The total number of species per site ranged from 2 at Lawrence Creek to 14 at Casco Creek; the average was 6.6 (table 2). The number of individuals collected in one sampling pass ranged from 19 at Smith Creek to 264 at Casco Creek, with an average of 104. The largest number of species (12) were in the carps and minnows (cyprinids) family. Other families represented by more than one species were the perches with five, sunfishes with four, trouts with three, and suckers with two.

Fish species that require cold or cool water were the most commonly collected at the benchmark sites. Mottled sculpin *(Cottus bairdi)* were collected at the most sites (18) and were the most abundant species overall with a combined total of 423 captured at the 18 sites (table 1). At least one species of trout also was collected at each of the same 18 sites. The second most abundant species overall was brown trout *(Salmo trutta)*, followed by brook trout, creek chub *(Semotilus atromaculatus)*, and longnose dace *(Rhinichthys cataractae)* (table 2). At ten sites, more than one species of trout was collected; all three species were collected at two sites (appendix). The sites at which no coldwater species were collected were the Mullet River, perhaps because of high-flow conditions at the time of sampling, and the warmwater East Branch Milwaukee River.

Trout were the most abundant species collected at thirteen sites: brook trout and brown trout at six each and rainbow trout *(Oncorhynchus mykiss)* at one. Mottled sculpin was the most abundant species collected at three sites, various minnows at three, and yellow perch *(Perca flavescens)* at one (appendix).

Five sites had one or more species unique to that site. The Mullet River had common carp *(Cyprinus carpio)*, green sunfish *(Lepomis cyanellus)*, blacknose shiner *(Notropis heterolepis)*, and fathead minnow *(Pimephales promelas)*; the East Branch Milwaukee River had fantail darter *(Etheostoma flabellare)*, tadpole madtom *(Noturus gyrinus)*, and logperch *(Percina caprodes)*; the Mecan River had northern hogsucker *(Hypentelium nigricans)*; Watercress Creek had yellow perch; and Neenah Creek had largemouth bass *(Micropterus salmoides)*. The unique species collected at Watercress and Neenah Creeks (yellow perch and largemouth bass, respectively) are primarily lake-dwelling species (Becker, 1983) that may have been temporary residents from downstream lakes. The unique species collected at the East Branch Milwaukee River are often found in rocky runs and riffles (Becker, 1983), a habitat abundant in this warmwater stream.

Intolerant and intermediate-tolerance species outnumbered tolerant species in all RHU's (fig. 3), an expected finding given the purpose of this study. When all sites are considered, the number of intolerant and intermediate tolerance species are similar. The proportion of intolerant species was highest in RHU 20, owing to the greater abundance of brook trout over

Table 2. Selected fish-community information for agricultural benchmark streams in the Western Lake Michigan Drainages
[RHU, relatively homogeneous unit; Y, yes; N, no; NA, not applicable.]

Site name	Number of species collected	Number of individuals collected	Two most abundant species		Currently stocked?[1]
Tisch Mills Creek at Tisch Mills, Wis.	8	95	Mottled sculpin	Longnose dace	Y - 2
Krok Creek near Ellisville, Wis.	8	51	Blacknose dace	Mottled sculpin	Y - 2
Little Scarboro Creek near Luxemburg, Wis.	5	43	Rainbow trout	Mottled sculpin	Y - 2,3
Casco Creek near Casco, Wis.	14	264	Mottled sculpin	Longnose dace	N
Hibbard Creek at Jacksonport, Wis.	6	39	Brook trout	Rainbow trout	Y - 1,2,3
East Branch Milwaukee River near New Fane, Wis.	11	152	Stoneroller	Common shiner	NA
Nichols Creek near Cascade, Wis.	3	52	Brown trout	Mottled sculpin	N
Mullet River near Plymouth, Wis.	12	146	Creek chub	Blacknose dace	Y - 2
Watercress Creek near Dundee, Wis.	8	68	Yellow perch	Mottled sculpin	Y - 1
Whitcomb Creek near Big Falls, Wis.	7	83	Brook trout	Creek chub	N
West Branch Red River near Bowler, Wis.	9	135	Brook trout	Creek chub	N
Silver Creek near Bowler, Wis.	5	107	Brook trout	Mottled sculpin	N
Smith Creek near Bowler, Wis.	4	19	Mottled sculpin	Brook trout	N
Camp Creek near Galloway, Wis.	5	99	Brook trout	Mottled sculpin	N
Lawrence Creek near Lawrence, Wis.	2	91	Brook trout	Mottled sculpin	N
Neenah Creek near Oxford, Wis.	7	246	Brown trout	Mottled sculpin	N
Chaffee Creek near Neshkoro, Wis.	3	72	Brown trout	Mottled sculpin	N
Mecan River near Richford, Wis.	7	154	Brown trout	Mottled sculpin	N
Willow Creek near Mount Morris, Wis.	4	53	Mottled sculpin	Brown trout	Y - 2
Pine River at Wild Rose, Wis.	3	115	Brown trout	Brook trout	N

[1]Based on communications with Wisconsin Department of Natural Resources fishery personnel: 1, brook trout; 2, brown trout; 3, rainbow trout.

other intermediate-tolerance trouts. The proportion of tolerant species by RHU ranged from about 6.5 percent in RHU 26 to almost 20 percent in RHU 3.

Comparison to Reference Standards

Reference standards provide a means of comparing the benchmark streams to established standards. In this section the benchmark streams are evaluated on the basis of an IBI and two habitat ratings.

Index of Biotic Integrity

Of the 19 coldwater stream sites, 5 were rated as having excellent biotic integrity based on IBI scores, 10 as good; 3 as fair; and 1 as poor (table 3). The East Branch Milwaukee River was rated fair by use of the warmwater IBI. For the coldwater streams rated as good, the metric that downgraded them from excellent was most often "percentage of trout individuals that are brook trout." In order to score excellent in this category, more than 96 percent of trout must be brook trout. The five sites in RHU 20 and one site in RHU 26 (Lawrence Creek) were the only sites where brook trout made up at least 96 percent of the total fish population. Brook trout were the only trout collected at those six sites.

Trout streams in Wisconsin are rated by the Wisconsin Department of Natural Resources (WDNR) as either Class I or Class II (Wisconsin Department of Natural Resources, 1980) (table 3). Class I streams are characterized by the highest quality trout habitat and water-quality conditions suitable for self-sustaining trout populations. All of the benchmark streams with IBI ratings of excellent are listed as Class I trout streams by the WDNR. Three other sites classified as Class I trout streams had good IBI ratings: Little Scarboro Creek, Neenah Creek, and Whitcomb Creek. This

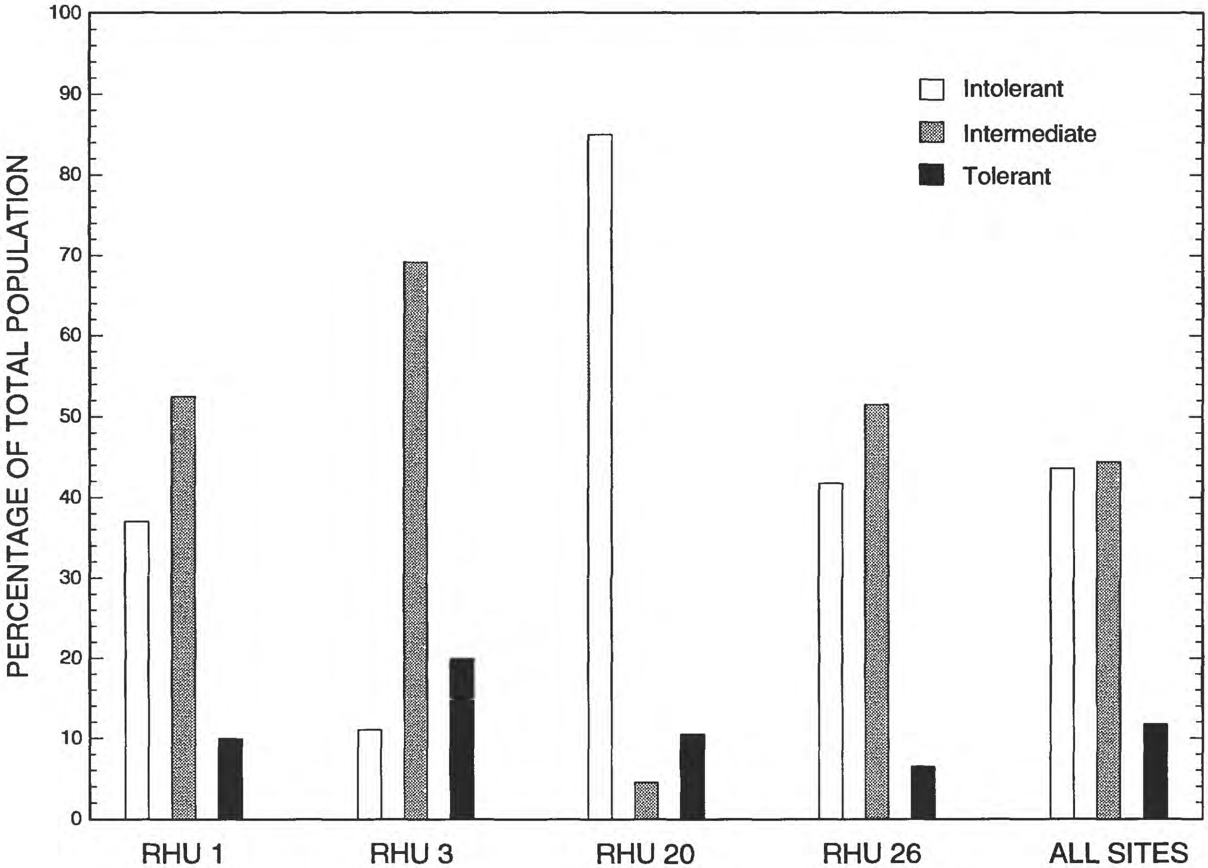

Figure 3. Proportions of fish species (grouped by tolerance level) at agricultural benchmark streams in the Western Lake Michigan Drainages, 1993 and 1995. (RHU, relatively homogeneous unit.)

latter group failed to achieve a higher IBI score because of a higher percentage of tolerant species. Only one stream listed as Class I—Casco Creek—scored below good with the IBI.

At Casco Creek, the number of trout was low relative to the total sample (12 trout out of a total of 264 fish collected). The sampling site fell within the final 2.3 km of Casco Creek, the only stretch of this stream that is classified as trout stream. Thus, the relatively high numbers of species more typical of warmwater streams may be the result of species migration.

Conversely, few fish were collected at Krok and Watercress Creeks, where low streamflow results in a lack of habitat. Isolated pools probably contain the most fish in these two streams during summer low-flow periods. The few top carnivores present in these streams were found in isolated pools.

The Mullet River sample scored poor in every IBI category except "number of intolerant species," in which it scored fair. The fish assemblage of the Mullet River resembled that of a warmwater stream and included five tolerant species—the most of all the benchmark streams—and no top carnivore species. Because this site was sampled during high flow, this score may not be indicative of the overall environmental quality of this stream. Additional low-flow sampling would be needed to more accurately characterize the fish community of this site.

The developers of the coldwater IBI recommend that scores are calculated without counting stocked trout. Stocking status of streams, based on communica-

Table 3. Index of Biotic Integrity and habitat ratings for agricultural benchmark streams in the Western Lake Michigan Drainages, 1993 and 1995

[GLEAS, Great Lakes Environmental Assessment Section; No., number; G, good; F, fair; E, excellent; P, poor]

Site name	Index of Biotic Integrity[1]	GLEAS habitat rating[2]	Wisconsin habitat rating[3]	No. of intolerant species	No. of tolerant species	Trout stream class[4]
Tisch Mills Creek at Tisch Mills, Wis.	G (60)	G (97)	G (70)	2	3	II
Krok Creek near Ellisville, Wis.	F (30)	F-G (71)	F (46)	2	3	II
Little Scarboro Creek near Luxemburg, Wis.	G (80)	G (99)	E (79)	2	1	I
Casco Creek near Casco, Wis.	F (30)	G (93)	G (69)	2	3	I/II
Hibbard Creek at Jacksonport, Wis.	G (80)	G (93)	G (68)	3	1	II
East Branch Milwaukee River near New Fane, Wis.	F (42[5])	G (91)	G (56)	1	2	NA
Nichols Creek near Cascade, Wis.	E (90)	G-E (108)	E (75)	2	0	I
Mullet River near Plymouth, Wis.	P (10)	G-E (103)	G (50)	1	5	II
Watercress Creek near Dundee, Wis.	F (50)	F (46)	F (40)	2	1	II
Whitcomb Creek near Big Falls, Wis.	G (70)	F-G (68)	G (64)	2	1	I
West Branch Red River near Bowler, Wis.	G (80)	G (89)	G (72)	2	3	II
Silver Creek near Bowler, Wis.	E (100)	G-E (106)	E (78)	2	2	I
Smith Creek near Bowler, Wis.	G (70)	G (75)	--	2	1	II
Camp Creek near Galloway, Wis.	E (100)	G (82)	G (70)	2	1	I
Lawrence Creek near Lawrence, Wis.	E (100)	F-G (74)	E (75)	2	0	I
Neenah Creek near Oxford, Wis.	G (60)	G (80)	G (74)	2	0	I
Chaffee Creek near Neshkoro, Wis.	G (70)	G (75)	E (80)	1	0	II
Mecan River near Richford, Wis.	G (70)	G (86)	G (69)	3	2	II
Willow Creek near Mount Morris, Wis.	G (70)	G (96)	E (77)	2	1	II
Pine River at Wild Rose, Wis.	E (90)	G (86)	G (73)	2	0	I

[1]Index of Biotic Integrity for fish in coldwater streams of Wisconsin (Lyons and others, 1996). Highest possible score is 100. Scores are ranked as 90–100, excellent; 60–80, good; 30–50, fair; 10–20, poor; and 0 or no score, very poor.

[2]Great Lakes Environmental Assessment Section (GLEAS) rating for habitat (Michigan Department of Natural Resources, 1991). Highest possible score is 135. Scores are ranked as 111–135, excellent; 75–102, good; 39–66, fair; and 0–30, poor.

[3]Wisconsin fish habitat rating system (Simonson and others, 1994). Highest possible score is 100. Scores are ranked as >74, excellent; 50–74, good; 25–49, fair; and 0–24, poor.

[4]Classification based on Wisconsin Department of Natural Resources, 1980. Class I - streams in this category are high grade trout waters with conditions favorable for natural reproduction. These streams require little or no stocking of hatchery fish. Class II - streams that have some native trout but not in sufficient numbers to use available food and space are placed in this class. Moderate to heavy stocking is required to maintain good fishing.

[5]Index of Biotic Integrity for fish in warmwater streams of Wisconsin (Lyons, 1992). Highest possible score is 100. Scores are ranked as 65–100, excellent; 50–64, good; 30–49, fair; 20–29, poor; 0–19, very poor.

tions with WDNR fisheries personnel, is noted in table 1. However, some natural reproduction probably occurs in many of the stocked streams. For this report, IBI scores were calculated using all fish collected; no attempt was made to determine if individual fish were stocked.

Habitat Classifications

On the basis of the GLEAS habitat rating system, 16 of the benchmark streams had good or good to excellent aquatic habitat (table 3). Krok, Lawrence, and Whitcomb Creeks scored above fair and just below good. Watercress Creek scored fair and was near the bottom in each of the GLEAS categories (Fitzpatrick and others, 1996). Of the five streams with excellent IBI scores, only Lawrence Creek scored below good on the GLEAS scale. This site scored very low on the percent pool metric, although it had abundant deep runs that probably contained deep, low-velocity refuges. Streams that scored fair to good were Krok Creek, Whitcomb Creek, and Lawrence Creek, whereas Watercress Creek rated fair.

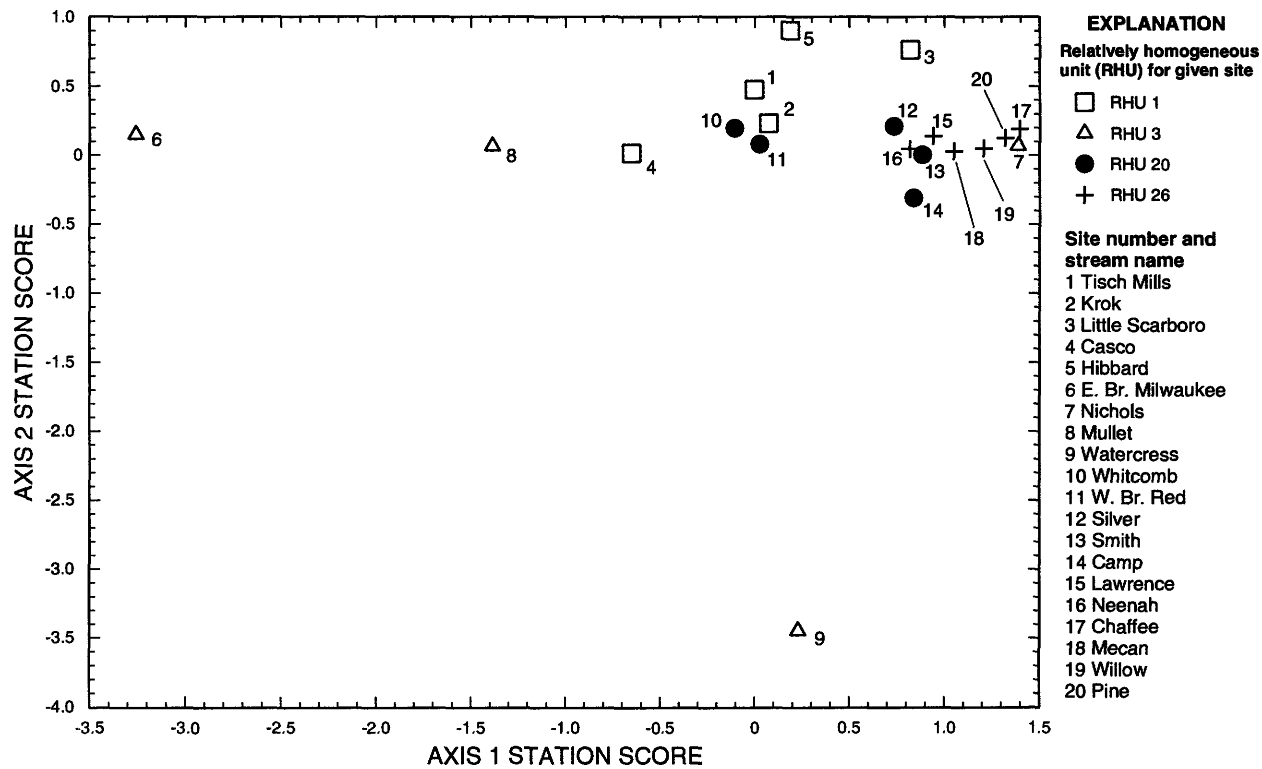

Figure 4. Station-ordination diagram from detrended correspondence analysis of 20 agricultural benchmark streams in the Western Lake Michigan Drainages.

On the basis of the Wisconsin fish-habitat rating system, 17 of 19 benchmark streams had good or excellent habitat for fish (table 3). Data were insufficient to compute a Wisconsin fish-habitat rating for Smith Creek. Krok and Watercress Creeks again scored lower, each rated as fair under this system. Whitcomb and Lawrence Creeks each moved up a category as compared to their GLEAS rating.

Detrended Correspondence Analysis

DCA was performed on log-transformed species-abundance data for all 20 benchmark sites. Three sites—East Branch Milwaukee River, Mullet River, and Watercress Creek—appear to be outliers (fig. 4). The large number of unique species at the East Branch Milwaukee and Mullet Rivers explains their position in the ordination; a large number of yellow perch caught at Watercress Creek influenced its position. The other 17 sites were tightly grouped. To differentiate among the 17 tightly grouped sites, DCA was performed with the three outlier sites downweighted to minimize their influence on the ordination.

The major patterns in fish-community structure among the benchmark sites are expressed by the first and second DCA axes, with eigenvalues of 0.431 and 0.170, respectively. Because eigenvalues for additional axes were small relative to axes 1 and 2, only the first two axes are interpreted here.

Three groupings can be inferred from the station-ordination diagram (fig. 5). Lines drawn to separate

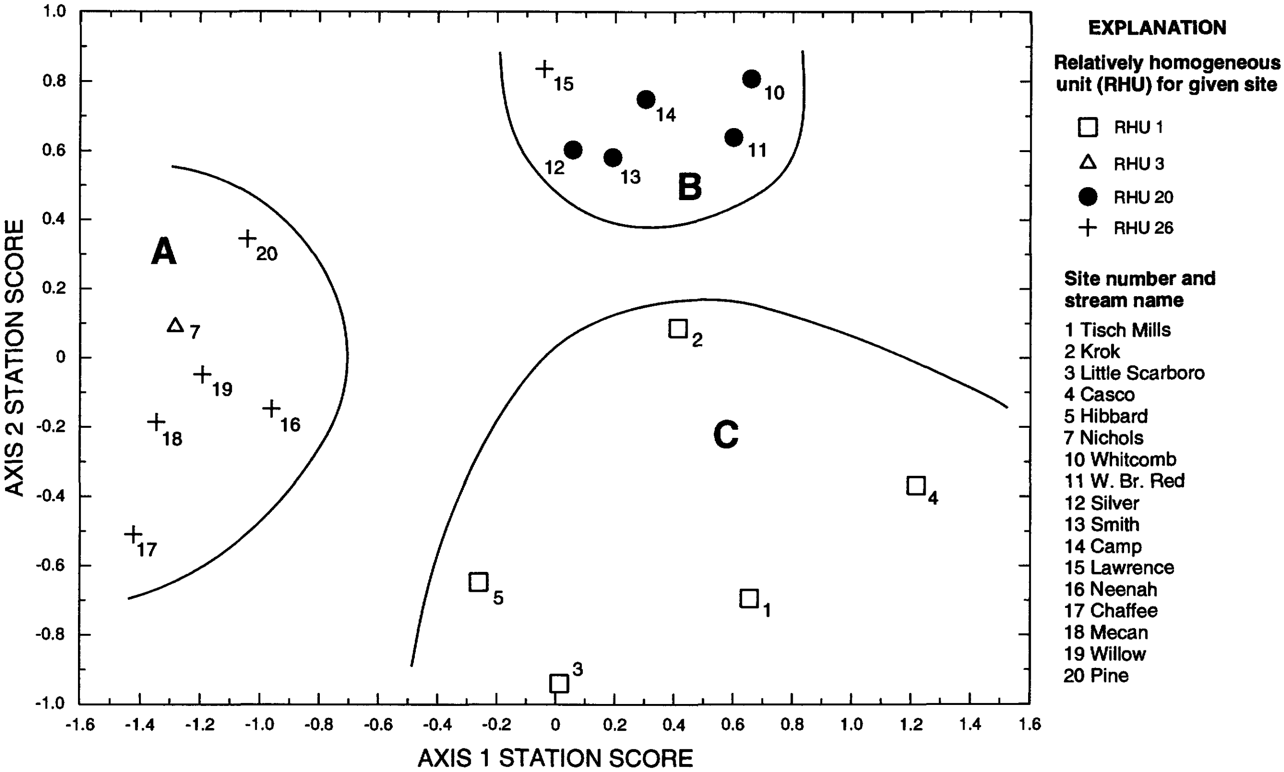

Figure 5. Station-ordination diagram from detrended correspondence analysis of 17 agricultural benchmark streams in the Western Lake Michigan Drainages.

these three groups are also shown in the species-ordination diagram (fig. 6), which displays the position of the 15 species that have the greatest influence (weighting) in the calculation of the station scores. For this discussion, these groups are labeled A, B, and C.

The most obvious characteristic of the groupings is that they seem to follow RHU divisions: group A sites are primarily in RHU 26, group B sites in RHU 20, and group C sites in RHU 1. The three down-weighted sites that are not shown are in RHU 3; thus, sites in this RHU did not show a grouping. Each of these groupings has a trout species associated with it: brown trout with group A, brook trout with group B, and rainbow trout with group C. Mottled sculpin, the species with the highest weighting (most abundant species overall), falls between the three groups in the ordination, the result of its presence at all 17 sites. Group C sites are not as tightly grouped as those in A and B, a result of a wider variety of fish species, including most of the minnows important in the ordination, present at these sites. There also appears to be a gradient of increasing species richness from the upper left to the lower right of the species-ordination diagram.

Intolerant species are associated with each grouping, a reflection of the good water quality at these sites. Although these species may not be present at every site in these groups, coolwater lamprey (family Petromyzontidae) is associated with group A, coldwater brook trout with group B, and rock bass *(Ambloplites rupestris)*, which can survive in a range of temperature conditions, with group C.

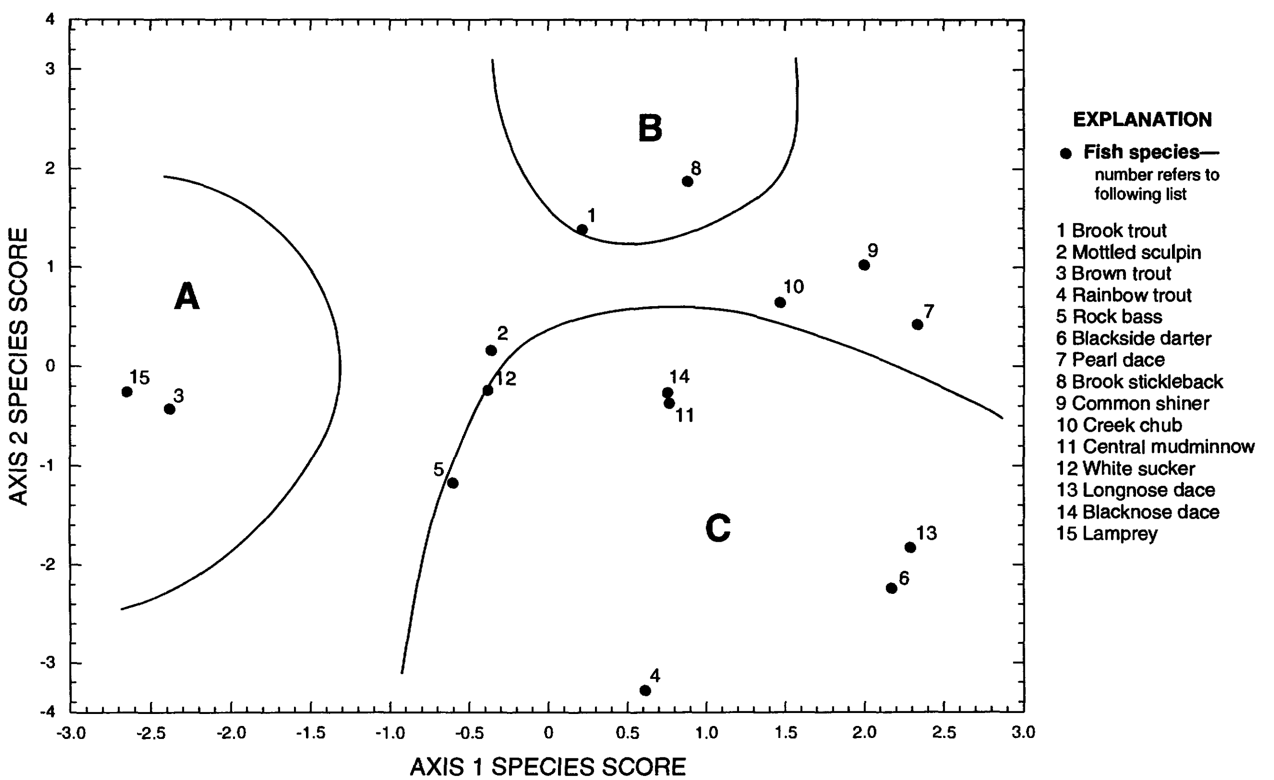

Figure 6. Species-ordination diagram from detrended correspondence analysis of 17 agricultural benchmark streams in the Western Lake Michigan Drainages.

Four tolerant species appear on the ordination diagram: blacknose dace *(Rhinichthys atratulus)*, central mudminnow *(Umbra limi)*, creek chub, and white sucker *(Catostomus commersoni)*. White sucker were found at sites in each group and each RHU but appear in group C. Creek chub appears to be most closely associated with sites in group C and was found at only three sites in groups A and B combined. Blacknose dace and central mudminnow were found at sites in groups B and C only and were most abundant at group C sites, and appear within that group in the ordination diagram.

A Wilcoxon rank-sum test was run to determine whether these groupings also showed differences with respect to habitat indices or IBI scores. The results indicate no significant differences in habitat indices scores or IBI between the three groups ($p < 0.05$). Because this study targeted streams of good water quality within a relatively limited geographic area, this finding is expected.

Correlations of Fish-Community Structure with Selected Environmental Factors

The structure of the fish communities in benchmark streams, as determined by DCA, was checked for correlation with various habitat variables (table 4) as well as the Wisconsin fish-habitat rating and IBI scores. Only DCA scores from the 17 streams used for the DCA ordinations were used. The 30 environmental variables used are listed in table 4, and discussed in Fitzpatrick and others (1996).

Table 4. Environmental variables used in correlation analysis with detrended correspondence analysis axes 1 and 2 station scores and Index of Biotic Integrity

Variable name	Variable name	Variable name	Variable name	Variable name
Bedrock	Basin relief	Erodibility factor	Average substrate	Average aspect
Drainage area	Basin storage	Percent sandy surficial deposits	Average velocity	Average canopy cover
Percent agricultural land use	Channel sinuosity	Soil drainage	Average width:depth ratio	Amount of woody debris
Percent forest	Drainage density	Soil permeability	Bank stability	Macrophyte coverage
Percent wetland	Drainage shape	2-year flood discharge	Percent pool	Riffle embeddedness
	Segment slope	Measured discharge divided by 2-year flood discharge	Percent riffle	Undercut banks
	Stream order			

Table 5. Selected variables from agricultural benchmark streams in the Western Lake Michigan Drainages that are significantly correlated ($p < 0.05$) with detrended correspondence analysis axes 1 and 2 station scores and Index of Biotic Integrity

[DCA, detrended correspondence analysis; IBI, Index of Biotic Integrity]

DCA Score 1		DCA Score 2		IBI Score	
Environmental variable or property	rho	Environmental variable or property	rho	Environmental variable or property	rho
Average velocity	-0.67	Percent wetland	0.66	Stream order	-0.67
Soil drainage	-.58	Percent pool	-.59		
Permeability	-.57	Percent agriculture	-.58		
Percent sandy surficial deposits	-.48	Bedrock	.56		
		Bank stability	-.49		
		Erodibility factor	-.47		

A number of these variables (bedrock, percent agriculture, percent forest, percent wetland, and percent sandy surficial deposits) are directly related to the environmental factors that define the RHU determination. Because the DCA groupings were closely related to the RHU that the sites were in, it was expected that these factors would be highly correlated with DCA axis scores. Although these correlations and related habitat correlations (soil drainage, permeability, erodibility, and bank stability) showed strong correlations (table 5), other nonrelated habitat variables were the most strongly related. Plots of selected correlated variables are shown in figure 7.

In general, average velocity was highest at group A sites, while percent pool was highest at group B and C sites. The correlation with average velocity is due to high velocities at three of the largest benchmark sites in group A (Mecan River, Neenah Creek, and Willow Creek). Percent pool appears to be inversely related to percent sandy surficial deposits, with the exception of Chaffee Creek, which possessed high percentages of both characteristics.

The usefulness of ordination methods used in conjunction with more traditional methods of defining biotic integrity (IBI) has been noted in previous studies (Ruhl, 1994). In this study, however, perhaps because of the relative homogeneity of the benchmark streams, IBI scores and DCA axis scores were not correlated with similar variables. The only variable that the IBI did correlate with was stream order, and since there was little variation in stream order, this correlation is probably not very meaningful.

SUITABILITY OF STUDIED STREAM REACHES AS BENCHMARK SITES

To be useful as indicative of benchmark conditions, the fish-community data collected during this study need to be qualified in the following manner. Because 19 of the streams support primarily coldwater species, comparisons with other streams should be

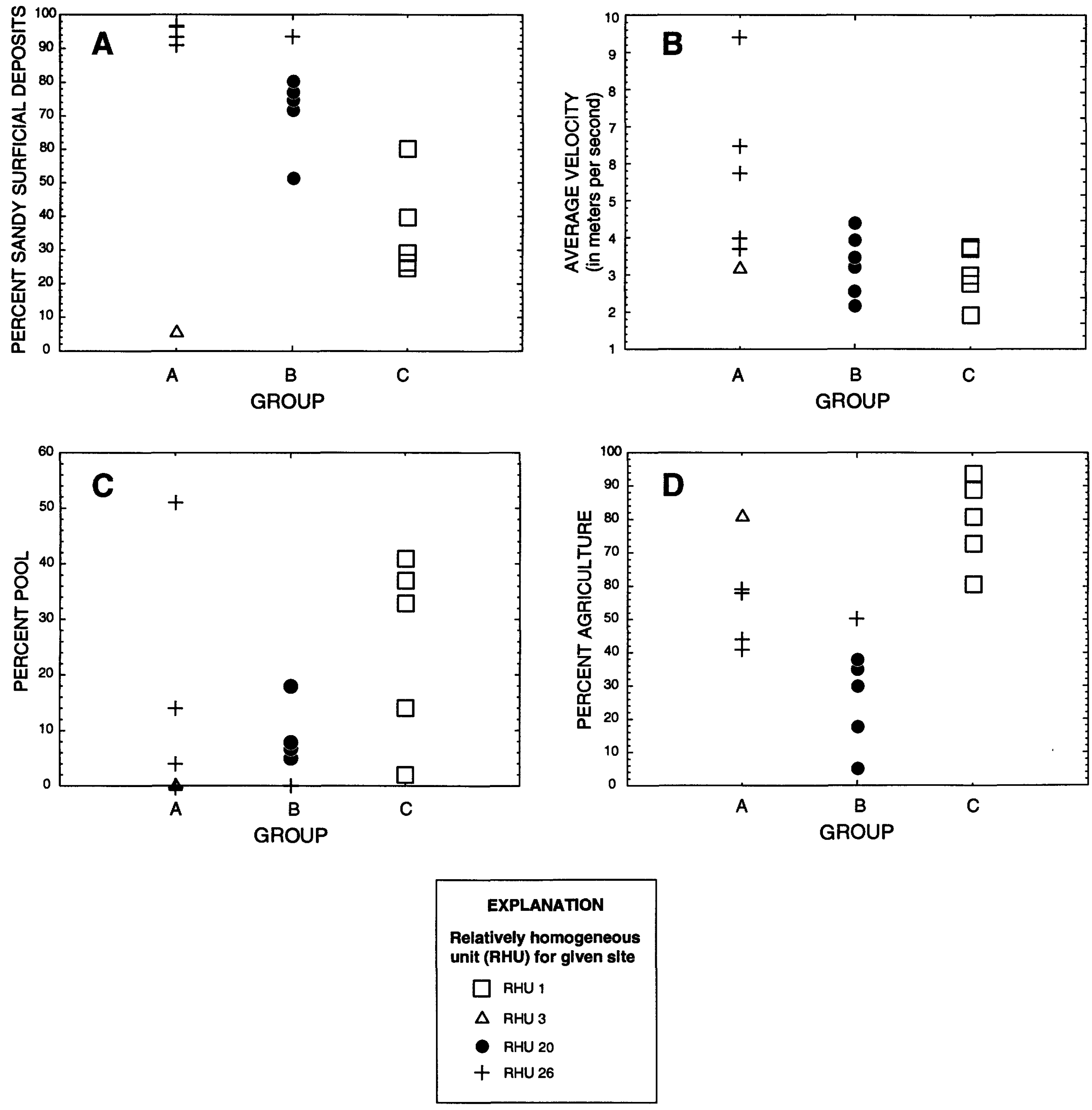

Figure 7. Plots of (A) percent sandy surficial deposits, (B) average velocity, (C) percent pool, and (D) percent agriculture for sites within three groups of the station-ordination diagram for benchmark streams in the Western Lake Michigan Drainages.

restricted to coldwater streams. This restriction is of concern because many streams in southeastern Wisconsin are not coldwater streams. In few cases, a degraded stream that currently supports warmwater species could become a coldwater stream if the proper conditions exist and restoration activities result in increased stream shading, increased velocity, and decreased average width-to-depth ratios. However, stream improvement measures do not guarantee that a warmwater stream will become a coldwater fishery.

In addition to limiting comparison to coldwater streams, the DCA ordination plots indicate differences between RHU's on the basis of the fish communities. This finding indicates that investigators who wish to compare fish communities in other streams to these benchmark streams should pick a benchmark site that is near their site, and preferably within the same RHU.

It is unclear if IBI scores are suitable for determining the overall environmental quality of the smallest sites. Low IBI scores and habitat ratings at Krok and Watercress Creeks resulted from low base flow and limited habitat. However, these low ratings don't necessarily indicate environmental degradation, and it is possible that these streams may be suitable reference sites for streams with limited base flow. Analyses of algal, benthic-invertebrate, and water-chemistry data collected at these sites may help to determine the overall environmental quality at these sites.

The reasons for the low percentage of trout at and resultant low IBI score for Casco Creek is unknown. As stated earlier, it may be the result of summer migration of species more typical of warmwater streams. Finally, additional fish collection would need to be done at the Mullet River site before any final conclusions can be made regarding the suitability of this site as a benchmark site. In addition, as at the small stream sites, analyses of other biological and water-chemistry data at these sites may be necessary to determine their potential as benchmark sites.

Finally, the IBI for the East Branch Milwaukee River, the only non-coldwater stream in this study, may be misleading. This stream, though too warm to support trout, may be cooler than many warmwater streams and thus support lower diversity than a typical high-quality warmwater stream. Researchers are currently working to develop a classification system for coolwater streams in Wisconsin (John Lyons, Wisconsin Department of Natural Resources, oral commun., 1995). An IBI can then be developed for coolwater streams.

SUMMARY

Fish-community data were collected at 20 sites in 1993 and 1995 during an ecological survey of agricultural streams in eastern Wisconsin as part of National Water-Quality Assessment (NAWQA) Program. These streams, designated "benchmark streams," were selected for study because of their potential use as regional references for healthy streams in agricultural areas, based on aquatic communities, habitat, and water chemistry. The agricultural benchmark streams were selected from four physical settings, or relatively homogeneous units (RHU's), that differ in bedrock type, texture of surficial deposits, and land use. Additional data were collected along with the fish-community data, including measures of habitat, water chemistry, and population surveys of algae and benthic invertebrates.

Data were analyzed to (1) describe fish communities, (2) determine whether the fish communities are suitable as reference standards for comparison to other agricultural streams in similar geographic settings, (3) determine whether differences exist between relatively homogeneous units (RHU's), subunits of the study area divided on the basis of bedrock geology, surficial deposits, and land use, and (4) determine important environmental and habitat variables that can be used to predict fish communities at agricultural streams in similar geographic settings.

Of the 20 sites, 19 are classified as coldwater trout streams. Fish species that require cold or cool water conditions were the most commonly collected. At least one species of trout was collected at 18 sites, and trout were the most abundant species at 13 sites. The species with the greatest collective abundance at the 20 sites were mottled sculpin, followed by brown trout, brook trout, creek chub, and longnose dace. In all, 31 species of fish were collected. The number of species per stream ranged from 2 to 14. The number of individuals collected at a single site ranged from 19 to 264.

On the basis of Index of Biotic Integrity (IBI) scores, 15 of the 20 stream sites rated good or better; 5 sites rated excellent, 10 sites good, 4 fair, and 1 poor. The ratings of the five sites in the fair to poor range were low for various reasons. Two sites appeared to have a higher percentage of warmwater species than is typical for a high-quality coldwater stream. One site was sampled during high flow and the results may not be valid for periods of normal flow; at the other, warmwater species may have migrated from warmwater habitat. Two additional sites appear to lack deep-water habitat needed to support large numbers of fish, especially top carnivores. Finally, one stream may have scored low because it is too cool to support many warmwater species and too warm to support trout; thus, neither IBI used may be suited for it.

In general, habitat rankings of the sites indicate that, with two exceptions, habitat is not a limiting factor for fish communities. Krok and Watercress Creeks, two sites with fair IBI ratings, were rated as fair according to both habitat evaluation methods. Two sites that rated below good according to one habitat evaluation method rated good or excellent according to the other rating.

Detrended correspondence analysis (DCA) of 17 sites showed three station groupings. Thes groupings fell along RHU divisions and each group was associated with one of three trout species. A species-richness gradient also was evident on the station-ordination diagram. Intolerant species were associated with each grouping, a reflection of the generally excellent water quality at the benchmark stream sites. The DCA axis 1 and 2 scores correlated with average velocity and percent pool as well as RHU factors including percent sandy surficial deposits, percent wetland, percent agriculture, and bedrock. Average velocity was highest at three sites which also had among the highest measured flows and largest drainage areas. Percent pool was generally lower at sites with smaller percentages of sandy surficial deposits, with one exception. Several other factors related to surficial deposits also were correlated. Three sites were not included in the ordination; all rated fair or worse on the IBI, and fish communities at the sites included rare species that could bias statistical analyses.

The usefulness of ordination methods in conjunction with more traditional methods of defining biotic integrity (IBI) has been noted in previous studies. In this study, however, perhaps because of the relative homogeneity of the benchmark streams, the IBI did not correlate with the same variables as the DCA axis scores did.

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APPENDIX

Appendix. Site-by-site summary of fish collected at agricultural benchmark streams in the Western Lake Michigan Drainages, 1993 and 1995

[--, not collected]

Family name Common name *Scientific name*	Tisch Mills Creek	Krok Creek	Little Scarboro Creek	Casco Creek	Hibbard Creek	East Branch Milwaukee River	Nichols Creek	Mullet River	Watercress Creek	Whitcomb Creek	West Branch Red River	Silver Creek	Smith Creek	Camp Creek	Lawrence Creek	Neenah Creek	Chaffee Creek	Mecan River	Willow Creek	Pine River
Petromyzontidae																				
Lamprey ammocoete	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	8	--	6	--	--
Salmonidae																				
Rainbow trout *Oncorhynchus mykiss*	11	--	23	9	9	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--
Brook trout *Salvelinus fontinalis*	8	1	3	3	11	--	3	--	1	48	98	86	5	48	63	--	--	--	1	34
Brown trout *Salmo trutta*	1	1	2	--	3	--	41	--	1	--	--	--	--	--	--	127	61	92	34	75
Umbridae																				
Central mudminnow *Umbra limi*	1	6	5	--	1	--	--	--	--	3	4	1	3	3	--	--	--	--	--	--
Cyprinidae																				
Stoneroller *Campostoma* sp.	--	--	--	2	--	51	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Common carp *Cyprinus carpio*	--	--	--	--	--	--	--	7	--	--	--	--	--	--	--	--	--	--	--	--
Common shiner *Luxilus cornutus*	--	1	--	7	--	45	--	1	--	1	2	--	--	--	--	--	--	--	--	--
Pearl dace *Margariscus margarita*	--	--	--	9	--	--	--	--	11	--	--	--	--	1	--	--	--	--	--	--
Hornyhead chub *Nocomis biguttatus*	--	--	--	--	--	19	--	6	1	--	--	--	--	--	--	--	--	--	--	--
Blacknose shiner *Notropis heterolepis*	--	--	--	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--	--	--
Redbelly dace *Phoxinus* sp.	--	--	--	3	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--
Bluntnose minnow *Pimephales notatus*	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Fathead minnow *Pimephales promelas*	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--
Blacknose dace *Rhinichthys atratulus*	6	25	--	22	--	--	--	31	--	2	4	1	--	--	--	6	--	2	--	--
Longnose dace *Rhinichthys cataractae*	19	--	--	76	--	--	--	16	--	--	--	0	--	--	--	--	--	--	--	--
Creek chub *Semotilus atromaculatus*	4	4	--	34	--	11	--	48	1	18	11	--	--	--	--	2	--	--	--	--

Appendix. Site-by-site summary of fish collected at agricultural benchmark streams in the Western Lake Michigan Drainages, 1993 and 1995—Continued

Family name Common name *Scientific name*	Tisch Mills Creek	Krok Creek	Little Scarboro Creek	Casco Creek	Hibbard Creek	East Branch Milwaukee River	Nichols Creek	Mullet River	Watercress Creek	Whitcomb Creek	West Branch Red River	Silver Creek	Smith Creek	Camp Creek	Lawrence Creek	Neenah Creek	Chaffee Creek	Mecan River	Willow Creek	Pine River
Catostomidae																				
White sucker *Catostomus commersoni*	4	1	--	16	--	1	--	9	--	--	4	2	--	--	--	32	--	14	2	--
Northern hogsucker *Hypentelium nigricans*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	--	--
Ictaluridae																				
Tadpole madtom *Noturus gyrinus*	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gasterostidae																				
Brook stickleback *Culaea inconstans*	--	--	--	--	--	--	--	--	1	--	2	--	1	3	--	--	--	--	--	--
Cottidae																				
Mottled sculpin *Cottus bairdi*	40	12	10	78	7	--	8	--	13	10	9	17	10	44	28	70	10	35	16	6
Centrarchidae																				
Rock bass *Ambloplites rupestris*	--	--	--	--	8	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Green sunfish *Lepomis cyanellus*	--	--	--	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--
Bluegill *Lepomis macrochirus*	--	--	--	--	--	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Largemouth bass *Micropterus salmoides*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
Percidae																				
Johnny darter *Etheostoma nigrum*	--	--	--	1	--	1	--	10	--	--	1	--	--	--	--	--	--	--	--	--
Fantail darter *Etheostoma flabellare*	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Yellow perch *Perca flavescens*	--	--	--	--	--	--	--	--	39	--	--	--	--	--	--	--	--	--	--	--
Logperch *Percina caprodes*	--	--	--	--	--	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Blackside darter *Percina maculata*	3	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--