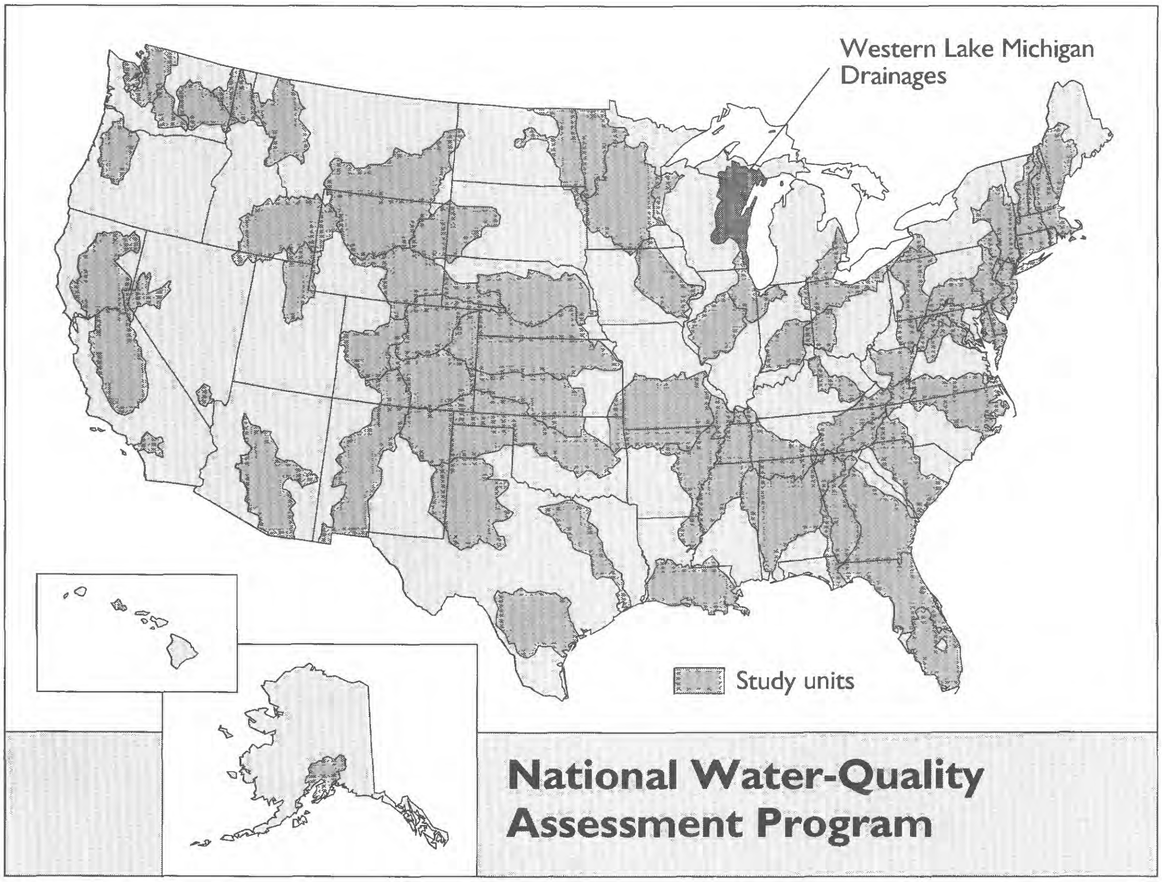
U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4211-C

Fish Communities of Fixed Sites in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95



FISH COMMUNITIES OF FIXED SITES IN THE WESTERN LAKE MICHIGAN DRAINAGES, WISCONSIN AND MICHIGAN, 1993–95

By Daniel J. Sullivan

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4211-C

National Water-Quality Assessment Program
Western Lake Michigan Drainages

Middleton, Wisconsin
1997

USGS
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For additional information write to:

District Chief
U.S. Geological Survey
8505 Research Way
Middleton, WI 53562

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

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 59 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 59 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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FIGURES

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
kilometer	0.6214	mile (mi)
square kilometer	.3861	square mile (mi^2)
hectare	2.471	acre

MISCELLANEOUS ABBREVIATIONS

CCA	Canonical correspondence analysis
DCA	Detrended correspondence analysis
IBI	Index of Biotic Integrity
NAWQA	National Water-Quality Assessment
RHU	Relatively homogeneous unit
STATSGO	State Soil Geographic Data Base
TWINSPAN	Two Way Indicator Species Analysis
USGS	United States Geological Survey
WDNR	Wisconsin Department of Natural Resources

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Dr. William LeGrande, Professor of Ichthyology, University of Wisconsin-Stevens Point, Stevens Point, Wis.
Dale M. Robertson, Research Hydrologist, U.S. Geological Survey, Middleton, Wis.
David A. Saad, Hydrologist, U.S. Geological Survey, Middleton, Wis.

Technical Reviewers

Peter M. Ruhl, Hydrologist, U.S. Geological Survey, Raleigh, N.C.
Robert J. Waschbusch, Hydrologist, U.S. Geological Survey, Middleton, Wis.
Charles A. Peters, Supervisory Hydrologist, U.S. Geological Survey, Middleton, Wis.

Editorial and Graphics

Michelle M. Greenwood, Cartographer, U.S. Geological Survey, Middleton, Wis.
Morgan A. Schmidt, Hydrologic Technician, U.S. Geological Survey, Middleton, Wis.
Janice A. Fuller, Editorial Assistant, U.S. Geological Survey, Middleton, Wis.
Chester A. Zenone, Reports Inprovement Advisor, Reston, VA

Fish Communities of Fixed Sites in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95

By Daniel J. Sullivan

Abstract

Fish communities were surveyed at 20 wadable stream sites during 1993–95 as part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program's assessment of the Western Lake Michigan Drainages. Part of the NAWQA design is to incorporate ecological data into an overall environmental assessment. Collection of fish-community data was part of this ecological assessment.

The Western Lake Michigan Drainages study area is located in eastern Wisconsin and parts of the Upper Peninsula of Michigan. To isolate the effects of individual factors on stream quality, the study area was subdivided into 28 environmental settings, or relatively homogeneous units (RHUs), on the basis of land use/land cover, texture of surficial deposits, and bedrock geology. A fixed monitoring site was established on a wadable stream within 8 of these RHUs to determine the status and trends of water quality in a representative stream. Water-quality characteristics, ecological-community data, and stream-habitat factors were measured at these sites during 1993–95.

Fish communities were sampled at the 8 wadable fixed sites once a year during 1993–95. At three of these sites, multiple-reach samples were collected in 1994 to determine within-site variation. Fish communities also were sampled at an additional 12 sites, 11 in 1993 and one in 1995, within the 6 largest RHUs. The sites, 1–3 per each of the 6 RHUs, were located on streams with drainage basins of similar size as the fixed sites within the same RHUs.

A total of 44 fish species from 12 families were collected at the 20 sites. The family with the most species represented were the minnows. The number of species per site ranged from one at a small urban site (Lincoln Creek) in 1995 to 21 at an agricultural site (North Branch Milwaukee River) in 1995. The number of individuals collected in one sampling pass ranged from 21 at a stream in the forested northwest part of the study area (Peshekee River) in 1995 to 498 at an agricultural site (East River) in 1995. White sucker *(Catostomus commersoni)* were collected at 17 sites, the most of any species. Species that are indicative of a coldwater environment were collected at 12 sites.

Detrended correspondence analysis (DCA) of multiple-reach and multiple-year data indicated that species composition at each of these sites were fairly consistent between reaches and years. Thus, for simplicity, most analyses were done using 1993 data only.

Index of Biotic Integrity (IBI) scores on 1993 data ranged from very poor at a channelized urban site to excellent at 3 sites; 2 in primarily agricultural areas and 1 in a forested area. Seven sites each scored good or fair, and two sites scored poor. Sites with multiple-year or multiple-reach data did not vary significantly within the error factor of the IBI.

DCA of fish-community data from 19 sites indicated that coldwater sites were tightly grouped, whereas warmwater sites showed a larger gradient. This was expected, given the potential for greater diversity among warmwater sites. Fixed sites were shown to be representative of the study area as a whole, while specific fish communities could not be attributed to particular RHUs.

Cluster analysis revealed two major groups of sites and two outlier sites. The two groups represented coldwater and warmwater streams, while the outlier sites were the urban site and a species-

rich site with high biotic integrity that drains primarily agricultural land.

Canonical correspondence analysis (CCA) revealed that soil erodibility was a significant predictor of species composition. Though not statistically significant, land use, soil permeability, and bedrock permeability also were indicated as predictors of fish-species composition by CCA.

INTRODUCTION

In 1991, the first 20 study units of the National Water-Quality Assessment (NAWQA) Program began investigations. The NAWQA study-unit design for examining surface-water quality includes the collection of ecological data, including fish community information, at all fixed sites.

This report describes the fish communities at the eight wadable fixed sites and twelve comparison sites in the Western Lake Michigan Drainages NAWQA study unit. An Index of Biotic Integrity is calculated for each sample. Multivariate statistics are used to determine differences, or gradients, between stream sites, as well as to determine environmental variables that may be associated with observed patterns in species composition. The scope of this report is limited to analysis of fish-community data collected at the 8 wadable fixed sites and 12 comparison sites during 1993–95.

DESCRIPTION OF THE WESTERN LAKE MICHIGAN DRAINAGES

The Western Lake Michigan Drainages study area encompasses 51,540 square kilometers in eastern Wisconsin and parts of the Upper Peninsula of Michigan (fig. 1, inset map). A brief discussion of selected study-area features follows; see Robertson and Saad (1996) for a more complete discussion. The study area, 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.

The bedrock of the study area consists of igneous and metamorphic rocks in the northwest, sandstone in the southwest, and carbonate rocks in the east. A small area of shale underlies the East River and the North Branch of the Manitowoc River near the city of Green Bay.

The overall population of the study area is 2,435,000 (U.S. Bureau of Census, 1991), with urban land use accounting for less than 4 percent of the study area. The major cities and their populations are Milwaukee, 628,000; Green Bay, 96,000; Racine, 84,000; Kenosha, 80,000; and Appleton, 66,000. About 40 percent of the study area is forested, primarily in the northwestern part. Streams and lakes abound in this area and offer excellent fishing, boating, and other recreation. Agriculture accounts for 37 percent of the land use. Cropland and pastureland used for the dairy industry are the major agricultural activities. Cropland predominates in the southern part of the study area, and most of the major urban areas are also in the southern part of the study area. Wetlands account for about 15 percent of the land use. Lake Winnebago, a 55,440-hectare lake in the Fox River Basin, is a major surface-water feature of the study area. The Milwaukee River Basin in the southeastern part of the study area has the largest human population.

STUDY DESIGN AND METHODS

Study Design

To isolate the effects of individual factors on stream quality, the Western Lake Michigan Drainages study area was subdivided into 28 environmental settings, called relatively homogenous units (RHUs), on the basis of bedrock geology, texture of surficial deposits, and land use/land cover (Robertson and Saad, 1995; 1996). A total of eight fixed sites were established on wadable streams within the study area. Additional sites were sampled within the six largest RHUs that contained fixed sites to better understand the variation of species composition among streams of similar sizes in the same RHU. These comparison sites were located in different drainage basins and the same or, in one case, similar RHUs (fig. 1). For the two smallest RHUs with fixed sites, it was not possible to locate a comparison site in a different drainage basin.

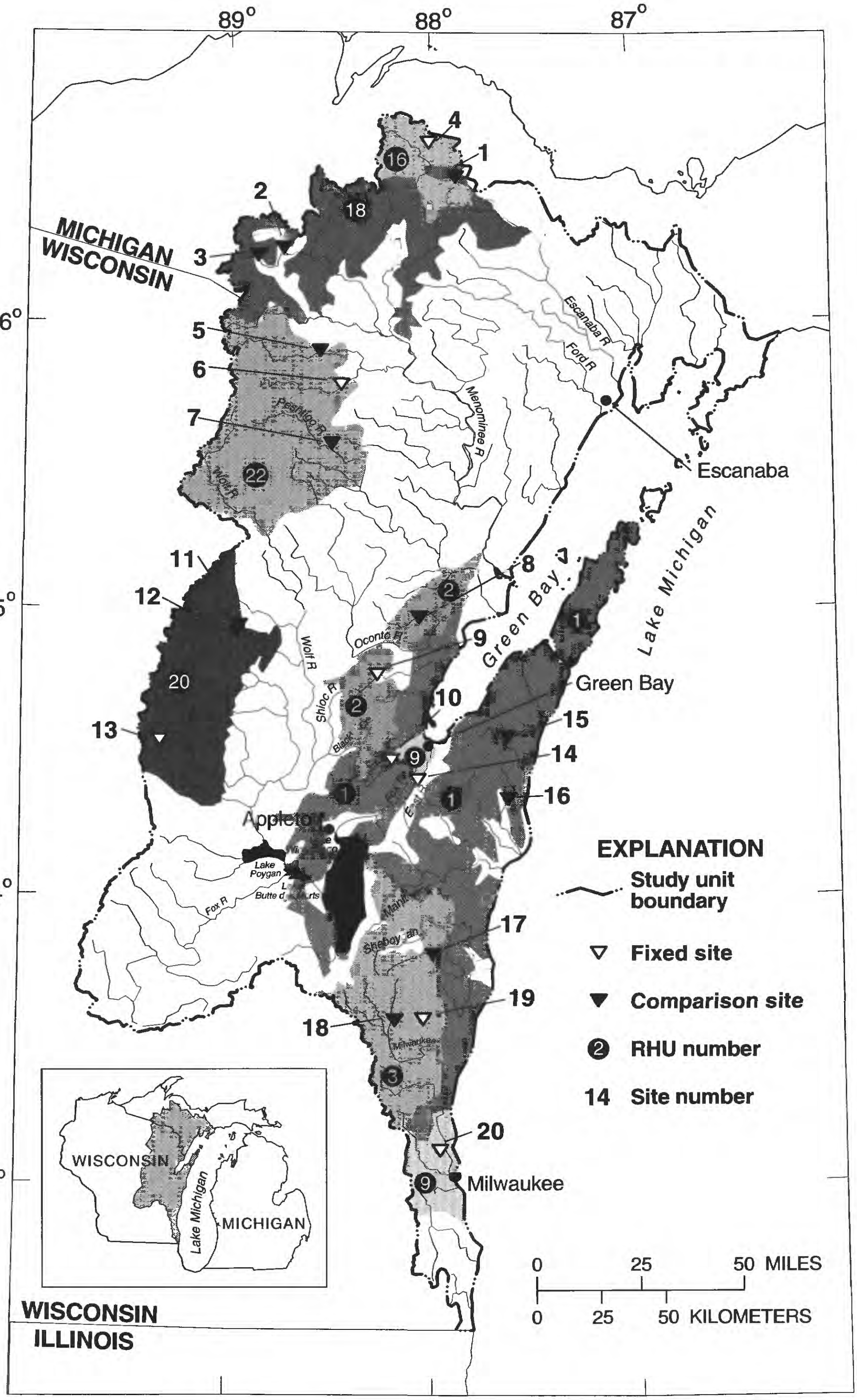

Figure 1. Locations of 8 fixed sites and 12 comparison sites in the Western Lake Michigan Drainages.

As part of the Western Lake Michigan Drainages NAWQA study, three additional fixed sites on larger streams were established. These large-river fixed sites were sampled to characterize the water quality of a large portion of the study area. However, these large-river fixed sites were not sampled intensively for fish communities.

General characteristics of the fixed sites, including exact locations, detailed land-use information, and general water-quality characteristics, can be found in Sullivan and others (1995). The 20 fixed and comparison sites drain areas that range from 25 to 543 sq km (square kilometers), with an average of 166 sq km. Land-use/land-cover types within the 20 basins are agriculture, forest, urban, and combinations of these. Surficial deposits are either clayey, loamy, sandy, or sand and gravel. Bedrock types are either igneous/metamorphic, shale, or carbonate. Information about the environmental settings of the 20 sites are in table 1.

The 8 fixed sites were sampled once each year during 1993–95. Three of these sites were sampled at three reaches in 1994 to gain an estimate of within-stream variation. The 12 comparison sites, with the exception of the East Branch Milwaukee River, were sampled in 1993 only. Due to high flow conditions in 1993 that made obtaining a representative sample difficult, the East Branch Milwaukee River was resampled in 1995 and these data are used in this report. Habitat data were collected at the fixed sites but not at all of the comparison sites. Therefore any references to habitat data will be qualitative and limited to those sites where it was collected.

The fish species composition at the 8 fixed sites and 12 comparison sites is described and characterized to provide baseline information for trends studies. An Index of Biotic Integrity is calculated for the 20 sites and the scores compared to established ranges of biotic health of streams. Species-composition data for the 20 sites are compared on the basis of RHU variables in an attempt to determine the importance of RHU variables in predicting species composition. Beyond the scope of this report, the fish data complement algal, benthic-invertebrate, and water-chemistry data and can be used in conjunction with these data in an integrated assessment of overall water quality at the fixed sites. Finally, the data will be part of a national NAWQA ecological data base.

Data-Collection Methods

The fish-collection protocol for the NAWQA program is detailed in Meador and others (1993). Fish-community samples were collected during July and August, 1993; August, 1994; and June–September, 1995. The sites were sampled using either backpack-mounted or a towed barge direct-current electrofishing unit.

The length of the sampling reach was determined on the basis of the following criteria: (1) at least 2 types of geomorphic units (pools, riffles, or runs) occur repetitively in the selected reach, (2) minimum reach length is the lesser of 150 m (meters) or 20 times the average stream width, and (3) maximum reach length is 300 m. An attempt was made to select reaches that were upstream from bridges to limit effects from roads and channel modifications. If upstream reaches were inaccessible or not representative of the stream, downstream reaches were selected.

The multiple-reach sampling that was done at three sites in 1994 consisted of sampling three similar-length reaches that contained no major tributaries or known point sources of contamination between them. Each reach was separated from the adjacent reach(es) by sufficient stream length so that sampling in one reach did not disturb the fish in another.

Data-Analysis Methods

Samples were collected over multiple years at the eight fixed sites. These data, while too few to analyze for temporal trends, were analyzed by detrended correspondence analysis (DCA), an ordination procedure used to identify and describe patterns in community structure based on species composition and relative abundance at each site (Gauch, 1982). The DCA was applied by using the CANOCO computer program (Ter Braak, 1988) that plots sites and species in an ordination diagram. A plot of DCA axis 1 and axis 2 station scores (fig. 2) indicate that samples from multiple years and multiple reaches at a given site generally group more closely together than do samples from different sites. This indicates that species composition did not vary widely between sample years and reaches. Thus for simplication, all further statistical analyses will be done using 1993 data only. For the East Branch Milwaukee River, a sample collected in 1995 is used because high flow made it difficult to collect a representative sample in 1993.

Table 1. Watershed and landscape characteristics of 8 fixed sites and 12 comparison sites in the Western Lake Michigan Drainages

[Fixed sites are listed in bold print; km^2, square kilometers; D.A., drainage area; RHU, relatively homogeneous unit; m/km, meters per kilometer; Ag, agriculture]

Map reference number	Site name	D.A. (km^2)	RHU	Ecoregion[1]	Bedrock[2]	Erodibility[3]	Gradient[4] (m/km)	Permeability[3]	Percentage of basin in:			
									Ag	Forest	Urban	Wetland[5]
1	**Peshekee River near Martins Landing, Mich.**	114	16	NLF	5.0	0.132	3.95	3.15	0	88	0	10
2	Middle Br. Escanaba River near Humboldt, Mich.	116	16	NLF	5.0	.129	5.37	3.35	1.6	94	0.21	1.8
3	N. Branch Paint River near Gibbs City, Mich.	204	18	NLF	5.0	.157	2.89	3.16	0	84	0	11
4	S. Branch Paint River near Gibbs City, Mich.	65.8	18	NLF	5.0	.201	3.79	1.83	0	86	0	12
5	**Popple River near Fence, Wis.**	362	22	NLF	5.0	.157	3.11	5.74	3.0	61	.13	35
6	Pine River near Tipler, Wis.	543	22	NLF	5.0	.170	2.59	4.72	0.83	60	.09	36
7	Peshtigo River near Armstrong Creek, Wis.	526	22	NLF	5.0	.158	4.50	5.50	8.2	60	.19	31
8	**Pensaukee River near Krakow, Wis.**	86.7	2	NCHF	9.8	.262	5.80	3.18	86	4.4	.23	9.3
9	Kelly Brook at Jagiello Rd. near Laona, Wis.	194	2	NCHF	6.9	.247	3.12	3.78	64	19	.04	15
10	**Duck Creek near Oneida, Wis.**	247	1	SEWTP	9.8	.274	1.68	1.67	89	4.6	.59	4.8
11	Casco Creek near Casco, Wis.	38.8	1	SEWTP	10	.267	7.13	2.79	89	7.0	1.5	2.2
12	Tisch Mills Creek at Tisch Mills, Wis.	42.2	1	SEWTP	10	.249	4.71	5.61	81	7.6	0	11
13	**Tomorrow River near Nelsonville, Wis.**	114	20	NCHF	5.0	.163	3.99	6.43	58	31	.21	8.8
14	W. Branch Red River near Bowler, Wis.	95.8	20	NCHF	5.0	.164	5.94	6.04	39	50	.53	10
15	Silver Creek near Bowler, Wis.	40.9	20	NCHF	5.0	.161	5.43	6.09	35	45	0	19
16	**East River near De Pere, Wis.**	122	9	SEWTP	4.1	.290	5.67	2.06	92	5.0	2.81	2.5
17	**N. Branch Milwaukee R. near Random Lake, Wis.**	133	3	SEWTP	10	.281	5.68	3.11	88	6.4	1.1	4.0
18	Mullet River near Plymouth, Wis.	115	3	SEWTP	10	.234	3.92	5.86	73	15	2.4	7.7
19	E. Branch Milwaukee River near New Fane, Wis.	138	3	SEWTP	10	.202	2.92	8.33	56	32	2.2	7.8
20	**Lincoln Creek at 47th Street at Milwaukee, Wis.**	24.8	9	SEWTP	10	.327	3.86	1.02	3.2	0	97	0

[1]NLF, Northern Lakes and Forests; NCHF, North Central Hardwood Forests; SEWTP, Southeastern Wisconsin Till Plain. Based on Omernik and Gallant, 1988.

[2]Bedrock permeability was classified on basis of average bedrock properties.

[3]Obtained from data available through the State Soil Geographic Database (U.S. Department of Agriculture, 1991).

[4]Basin gradient = change in elevation divided by length of the basin.

[5]Includes only non-forested wetlands; forested wetlands are included in forests category because of overlap.

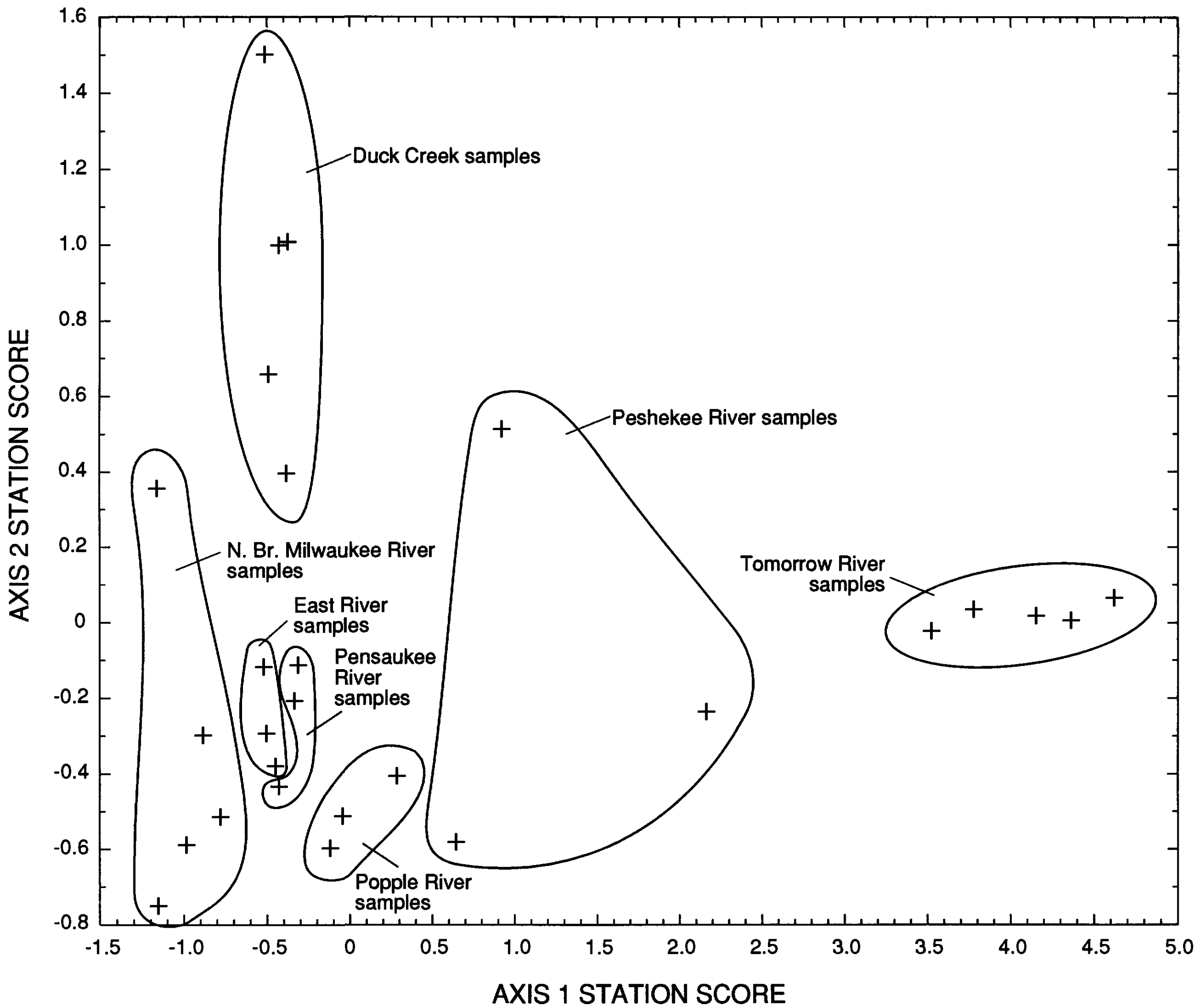

Figure 2. Station-ordination diagram from detrended correspondence analysis of fish-community data from fixed sites in the Western Lake Michigan Drainages.

An Index of Biotic Integrity (IBI) has been developed for both coldwater (Lyons and others, 1996) and warmwater (Lyons, 1992) streams in Wisconsin. Several features, or metrics, of the fish assemblage are rated as good, fair or poor and then combined to assign an overall score. Major differences exist between species composition in streams with different water-temperature regimes, so it is important to use the appropriate index. Six of the eight small-stream fixed sites are warmwater streams. The Popple and the Tomorrow Rivers are classified as trout fisheries, and thus coldwater streams, by the Wisconsin Department of Natural Resources (WDNR) (Wisconsin Department of Natural Resources, 1980; 1996). Ten of the twelve comparison sites are coldwater streams; only Kelly Brook and the East Branch Milwaukee River are warmwater streams. The IBI may behave erratically and not accurately reflect biotic integrity and ecosystem health when very small numbers of fish are captured; at warmwater sites, at least 50 fish and at coldwater sites, at least 25 fish need to be captured to ensure an accurate IBI (Lyons, 1992; Lyons and others, 1996). For this report, the IBI was calculated for all sites; the IBI for sites with fewer than the recommended catch level should be considered tentative pending additional sample collection.

The warmwater IBI for Wisconsin (Lyons, 1992) has 10 metrics and two correction factors: (1) total number of native species; (2) number of darter species; (3) number of sucker species; (4) number of sunfish 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.

The coldwater IBI for Wisconsin (Lyons and others, 1996) has five metrics: (1) number of intolerant species; (2) percent of all individuals that are tolerant species; (3) Percent of all individuals that are top carnivore species; (4) percent of all individuals that are stenothermal coolwater and coldwater species, and (5) percent of salmonid individuals that are brook trout. This IBI is based on patterns in fish assemblage that are likely to be similar in coldwater streams in areas adjacent to Wisconsin (Lyons and others, 1996) and thus was used for Michigan streams as well.

Species composition is compared among the sites by use of DCA. In addition, the Two Way Indicator Species Analysis (TWINSPAN) clustering program (Hill, 1979) is used and the results compared to those from DCA. TWINSPAN was done using the CANOCO computer program (Ter Braak, 1988) and classifies sites and constructs an ordered two-way table from a sites-by-species matrix. Sites are grouped on the basis of a series of divisions that are in turn based on the frequency of species at given sites. These divisions continue for several iterations, and with each iteration, sites grouped together are more similar. For clustering analyses, abundance data were transformed to percentages so that groupings would be more dependent on species composition and less susceptible to influence from abnormally large numbers of an individual species at a site.

Environmental variables for which data were available at all sites and that are perceived as important factors that affect overall water quality include drainage area, land use/land cover (represented by percent forested land), two measures of surficial deposit characteristics (soil permeability and erodibility), basin gradient, and a bedrock permeability factor. Environmental data were converted to standard *z*-scores to account for differences in units of measurement. A *z*-score is a standardized value calculated for each observation by subtracting the average of the entire data set and dividing the result by the standard deviation of the data.

Soil permeability and erodibility were obtained from data available through the State Soil Geographic Database (STATSGO) (U.S. Department of Agriculture, 1991). Basin gradient was determined from U.S. Geological Survey 1:24000-scale topographic maps by dividing the total elevation change in each basin by the length of the basin. Bedrock permeability was classified on the basis of average properties of each bedrock type.

Canonical correspondence analysis (CCA) was used to determine the degree to which environmental variables are associated with species distribution and abundance (Ter Braak, 1986). CCA is a type of multivariate direct gradient analysis in that ordination axes are chosen on the basis of both species and environmental data. The CCA was applied using the CANOCO computer program (Ter Braak, 1988) that plots sites and species in an ordination diagram. Fish abundance data were log-transformed for these analyses. In the ordination diagram, environmental gradients are displayed as vectors. A Monte Carlo test of 99 random permutations tested the significance of each envi-

Table 2. Selected information for fish-community sites in the Western Lake Michigan Drainages

[Sites listed in bold are fixed sites; * = count may be low because the holding net was torn by animals before the sample was processed and some individuals may have escaped]

Site name	Number species collected			Number individuals collected			Coldwater species Collected
	93	94	95	93	94	95	
Peshekee River near Martins Landing, Mich.	7	4	6	24	26	21	N
Middle Br. Escanaba River near Humboldt, Mich.	6	--	--	23	--	--	Y
North Branch Paint River near Gibbs City, Mich.	14	--	--	134	--	--	Y
South Branch Paint River near Gibbs City, Mich.	12	--	--	158	--	--	Y
Popple River near Fence, Wis.	5	10	9	66	97	49	Y
Pine River near Tipler, Wis.	13	--	--	206	--	--	Y
Peshtigo River near Armstrong Creek, Wis.	9	--	--	44	--	--	Y
Pensaukee River at Krakow, Wis.	18	14	11	242	339	70	N
Kelly Brook at Jagiello Road near Laona, Wis.	16	--	--	136	--	--	N
Duck Creek near Oneida, Wis.	11	11	8	320	105	293	N
Casco Creek near Casco, Wis.	14	--	--	264	--	--	Y
Tisch Mills Creek at Tisch Mills, Wis.	10	--	--	95	--	--	Y
Tomorrow River near Nelsonville, Wis.	8	5	6	65	35	99	Y
West Branch Red River near Bowler, Wis.	9	--	--	135	--	--	Y
Silver Creek at Silver Creek Road near Bowler, Wis.	5	--	--	107	--	--	Y
East River near De Pere, Wis.	10	10	10	209	267	498	N
North Branch Milwaukee River near Random Lake, Wis.	20	15	21	90*	135	416	N
East Branch Milwaukee River near New Fane, Wis.	--	--	11	--	--	152	N
Mullet River near Plymouth, Wis.	13	--	--	146	--	--	Y
Lincoln Creek at 47th Street at Milwaukee, Wis.	6	2	1	34	23	30	N

ronmental variable during the forward selection process (Ter Braak, 1988).

FISH COMMUNITIES OF FIXED AND COMPARISON SITES

A total of 44 fish species from 12 families were collected from among the 20 wadable stream sites. Of these, 37 species were collected at the fixed sites. The family with the most species represented (14) were the minnows (see appendix for scientific names). The number of species collected per site ranged from one at Lincoln Creek in 1995 to 21 at the North Branch Milwaukee River in 1995 (table 2). The number of individuals collected in one sampling pass ranged from 21 at the Peshekee River in 1995 to 498 at the East River in 1995.

White suckers were collected at 17 sites, the most of any species. The white sucker is probably the most widespread of all fishes in Wisconsin (Becker, 1983). Other species commonly collected were blacknose dace (16 sites), common shiner (15 sites), creek chub (14 sites), and mottled sculpin, central mudminnow, and longnose dace (12 sites each). The species collected in the greatest abundance at a given site was the johnny darter—360 were collected in a single pass at the East River in 1995.

Of the 20 stream sites sampled, coldwater indicator species were collected at 12 sites. In all cases, this was a species from the trout family.

Table 3. Index of Biotic Integrity scores and habitat evaluation results for fish communities at 8 fixed sites and 12 comparison sites in the Western Lake Michigan Drainages

[sites listed in bold are fixed sites; Index of Biotic Integrity (IBI) rating is for coldwater IBI unless in ( ) then is warmwater IBI score; * indicates total number of individuals was below recommended level for calculation of IBI and thus IBI score may not accurately reflect the biotic integrity in these cases; Habitat evaluation results: GLEAS, Great Lakes Environmental Assessment Section; WDNR, Wisconsin Department of Natural Resources; ●, excellent; ◓, good; ⊖, fair; ⊙, poor; ○, very poor.]

Stream name	Index of Biotic Integrity			Habitat evaluation[a]	
	1993	1994	1995	GLEAS	WDNR
Peshekee River	(◓)	(⊖)	(◓)	◓	◓
M. Br. Escanaba River	⊖				
N. Br. Paint River	⊖				
S. Br. Paint River	⊖				
Popple River	⊙	⊙	⊙	◓	◓
Pine River	⊖				
Peshtigo River	◓				
Pensaukee River	(◓)	(◓)	(⊖)	◓⊖	⊖
Kelly Brook	(●)				
Duck Creek	(◓)	(◓)	(⊖)	⊖	⊖
Casco Creek	⊖			◓	◓
Tisch Mills Creek	◓			◓	◓
Tomorrow River	◓	◓	◓	◓	◓
West Branch Red River	◓			◓	◓
Silver Creek	●			◓●	●
East River	(⊖)	(⊖)	(⊖)	⊖	⊙
N. Br. Milwaukee River	(●)	(◓)	(●)	⊖◓	⊖
Mullet River	⊙			⊖◓	◓
E. Br. Milwaukee River	(⊖)			◓	◓
Lincoln Creek	(○)	(○)	(○)	⊙⊖	⊖

[a]Habitat evaluation results from Fitzpatrick and Giddings, 1997.

Index of Biotic Integrity

The IBI scores for the eight fixed sites covered the range from very poor to excellent biotic integrity (table 3). In general, the IBI scores for the comparison sites were in the fair to good range. Two streams, Kelly Brook and Silver Creek, had IBI scores that indicated excellent biotic integrity, while one comparison stream, Mullet River, had a score that indicated poor biotic integrity. The results indicate that the fixed sites do represent the range of biotic integrity in the study area.

Lincoln Creek, the urban fixed site, was expected to have an IBI score that indicated poor biotic integrity, because of habitat and water-quality limitations. The Popple River's relatively low coldwater IBI score was unexpected, given that this stream drains a heavily forested watershed and is known for its good water quality. The IBI for the Popple River also was calculated using the warmwater IBI, and the results indicated only fair biotic integrity. One possible explanation for this apparently low IBI is that many streams in northern Wisconsin and Michigan have temperature regimes that are too warm for coldwater species and too cool for warmwater species. Thus, the species composition of these streams are not typical of either warmwater or coldwater streams. These streams may be better defined as coolwater. At present an IBI has not been developed for these in-between streams. Thus, IBI scores for some of the northern sites in this study should not be used as a basis for concluding that environmental degradation exists at these sites. Other sites that may fall into the category of coolwater streams include the East Branch Milwaukee River and Casco Creek. The Mullet River's low coldwater rating is probably due, at least in part, to a temporary influx of warmwater species during a high-flow event that occurred before and during sampling.

A comparison of IBI and habitat ratings may give an indication of whether habitat was a limiting factor for a given stream's ability to support a healthy fish community (table 3). In general, both IBI and habitat ratings are similar for a given site among both the fixed sites and the comparison sites.

Comparison of Fish Species Composition

Initial DCA ordinations on all 20 sites indicated that Lincoln Creek was a far outlier. Thus, DCA was done on the remaining 19 sites. The major patterns in fish-community structure are expressed by the first and second DCA axes, with eigenvalues of 0.547 and 0.305, respectively. Because eigenvalues for additional axes were small relative to axes 1 and 2, only the first two axes are interpreted here.

The DCA station-ordination diagram (fig. 3) shows a relatively small gradient among coldwater sites on the right side of the diagram, while the warmwater sites plot across a relatively large gradient to the left. Other factors that relate to the 2 DCA axes include percent of forested land, which increases in sites that plot to the right of the ordination. The three furthest outlier sites—East Branch Milwaukee, Peshekee, and North Branch Milwaukee Rivers—each have unique fish species that influence their location. Although some groupings of sites by RHU are suggested, particularly sites in RHUs 2, 20, 22, there does not appear to be any overall grouping by RHUs. This indicates that other RHU-independent factors such as stream temperature regime and quality of habitat may be more important to determining the type of fish community that can exist in a given stream than landscape-scale RHU factors.

The DCA station-ordination diagram illustrates that the fixed sites (shown in bold in fig. 3) are spread out along the entire gradient of sites. Thus, even though most of the RHUs contain streams with a diversity of fish communities and may not be typified by any one type, the fixed sites do seem to capture the range of fish communities present in small streams in the Western Lake Michigan Drainages.

TWINSPAN cluster analysis of the 1993 data set gave similar results to the DCA ordination. Two outlier sites are indicated—Lincoln Creek and North Branch Milwaukee River (fig. 4). These sites represent extremes in the study—Lincoln Creek is a concrete-channel, urban stream with few species and flow consisting of shallow ground-water recharge and urban runoff. It is subject to rapid changes in water stage following storms or snowmelt as well as very low flow in dry periods. Only one species was captured at Lincoln Creek in 1995. The North Branch Milwaukee River drains an agricultural area of permeable, sandy surficial deposits that buffer both high and low flow extremes. This site supports the most species of all the sites, with a diverse number of warmwater fishes, with numerous larger fishes, including common carp, northern pike, and several species of suckers that makes it unique among the warmwater streams in this study.

The remaining 18 sites divided nearly along coldwater/warmwater lines, with the exception of the Mullet and Popple Rivers. Although classified as coldwater, these streams group with warmwater streams. The Mullet River was sampled during elevated flow, however, and the typical species mix at this site may have been altered by migration of warmwater fish. The Popple River may fall into the previously-mentioned category of coolwater streams, especially in the late summer, when the samples were collected. At this time, warmer temperatures may force many coldwater species to migrate to cooler refuges. The Peshekee River grouped with coldwater streams even though it is not classified as a coldwater stream. However, species typically associated with coldwater streams, such as mottled sculpin, were collected at the Peshekee River.

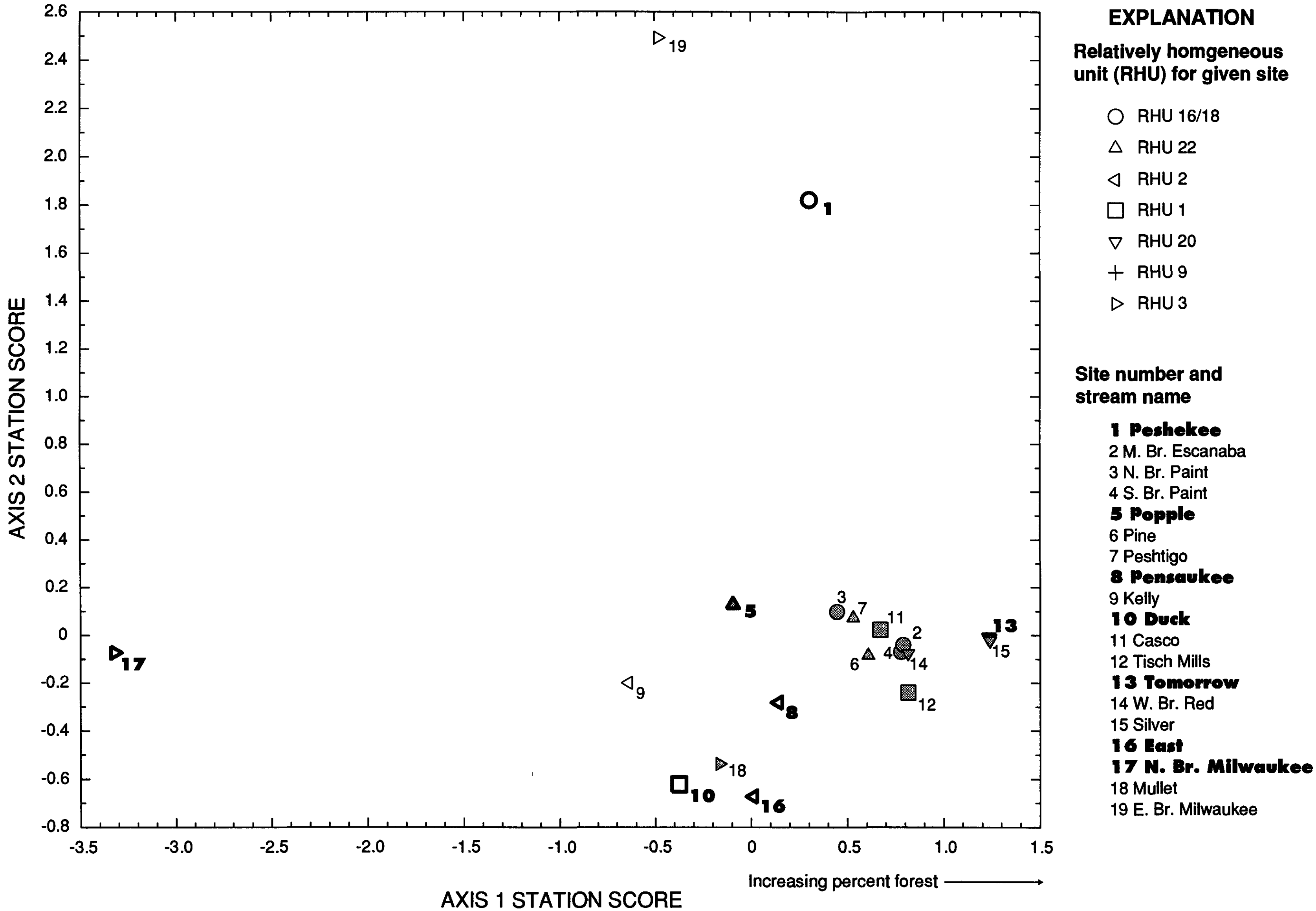

Figure 3. Station-ordination diagram from detrended correspondence analysis of fish-community data from 7 fixed sites and 12 comparison sites in the Western Lake Michigan Drainages. (Fixed sites shown in bold; shaded symbols indicate stream has coldwater species.)

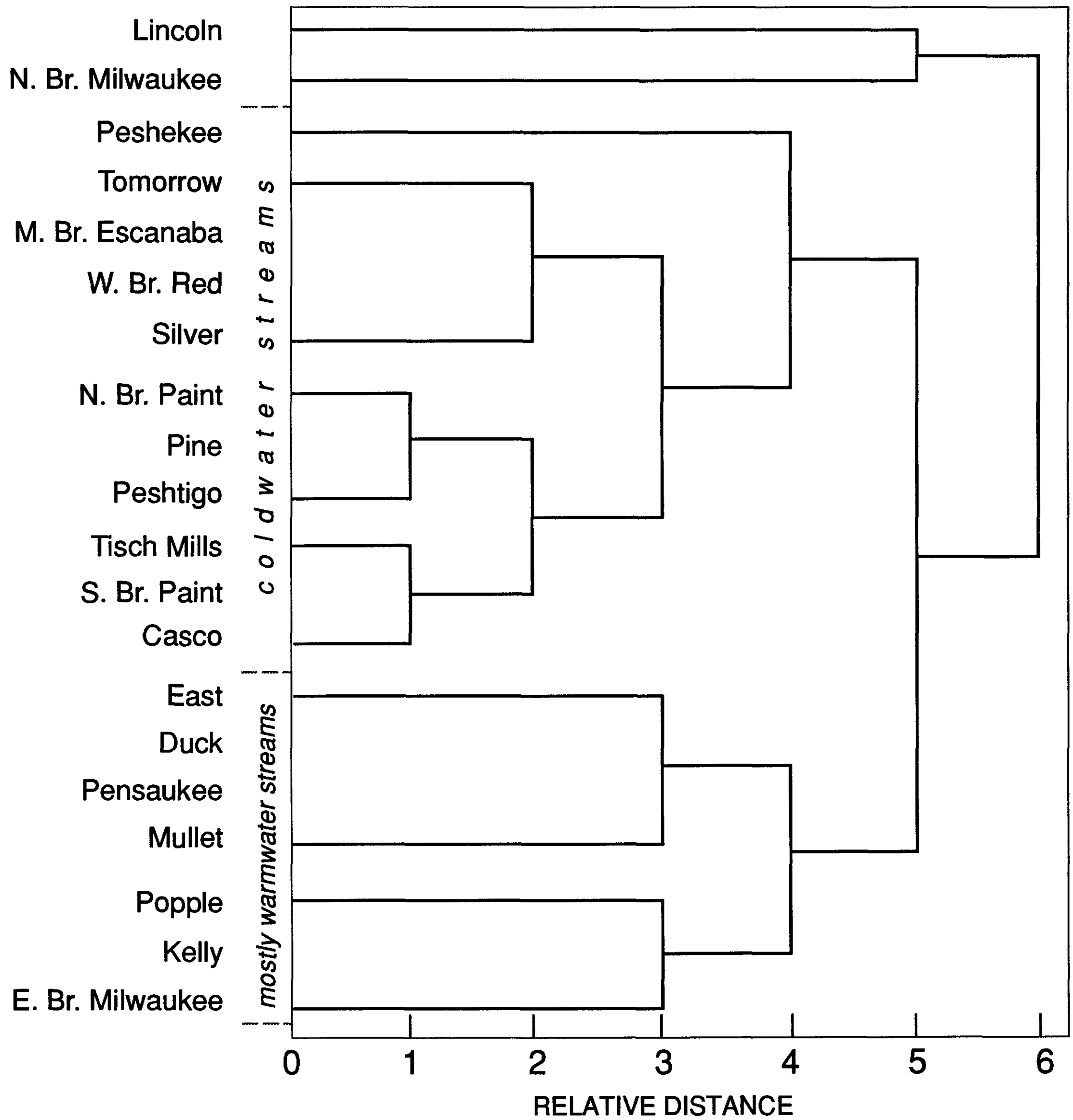

Figure 4. Similarity of fish-species composition as shown by cluster analysis of species percentage. (Relative distance is a unitless measure of site similarity. Sites that connect at "1" are more similar than sites that connect at "4", etc.)

RELATIONS BETWEEN FISH-SPECIES COMPOSITION AND ENVIRONMENTAL FACTORS

Lincoln Creek was an outlier in initial canonical correspondence analysis (CCA) ordination diagrams and thus was deleted from further analyses so as not to mask gradients among other streams. Results of the CCA of fish species composition and environmental variables at the remaining 19 sites are shown in figure 5. Analysis of the CANOCO output, however, indicated that only soil erodibility was a significant variable ($p<0.05$). Other influences, including land use/land cover, were indicated but not statistically significant. Soil erodibility is related to land use in the study area in that areas of more-erodible soils are generally

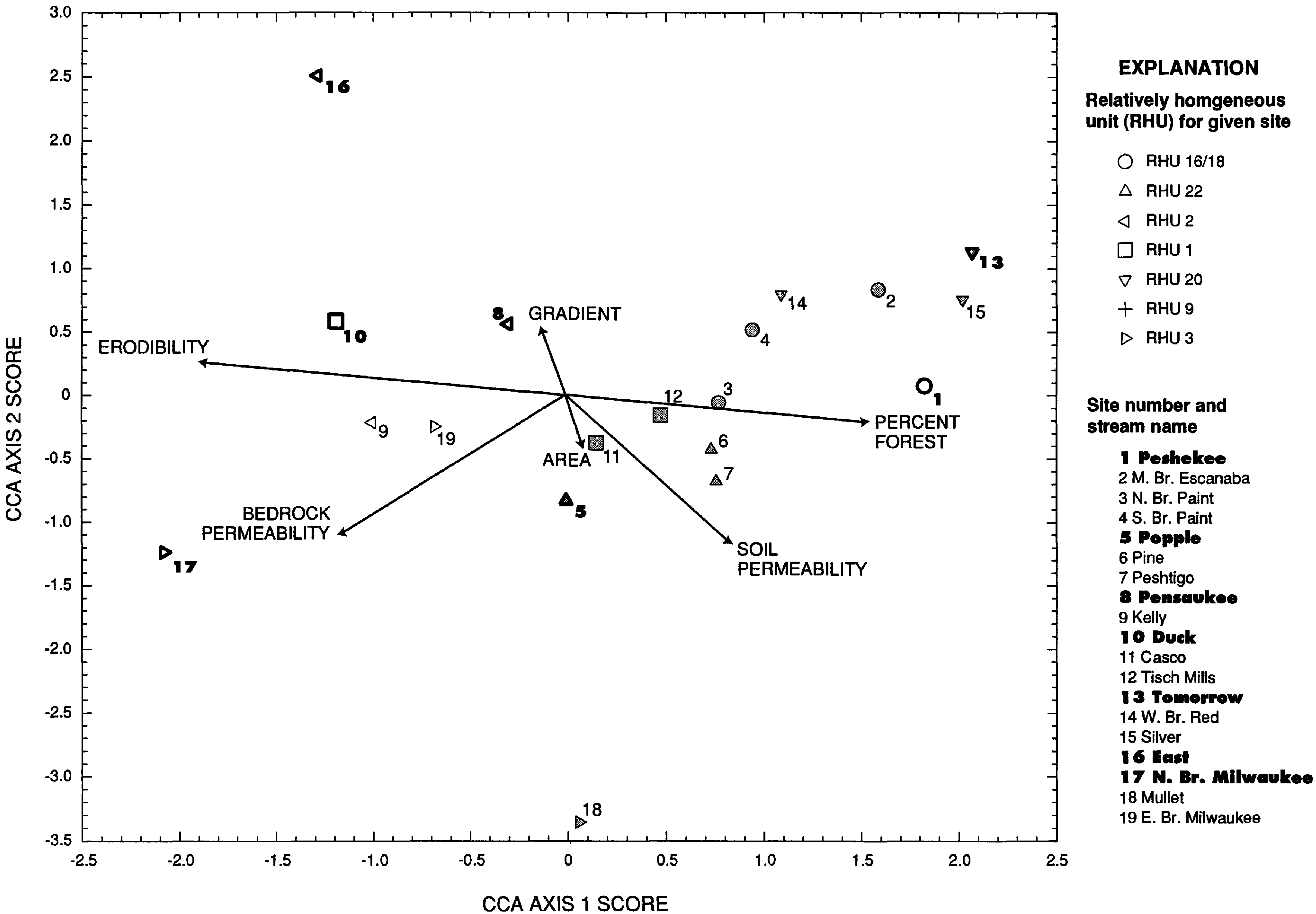

Figure 5. Results of canonical correspondence analysis showing 7 fixed sites and 12 comparison sites based on fish species abundance and selected environmental factors. (Fixed sites shown in bold; environmental vectors are shown at twice their actual length for clarity; shaded symbols indicate stream has coldwater species.)

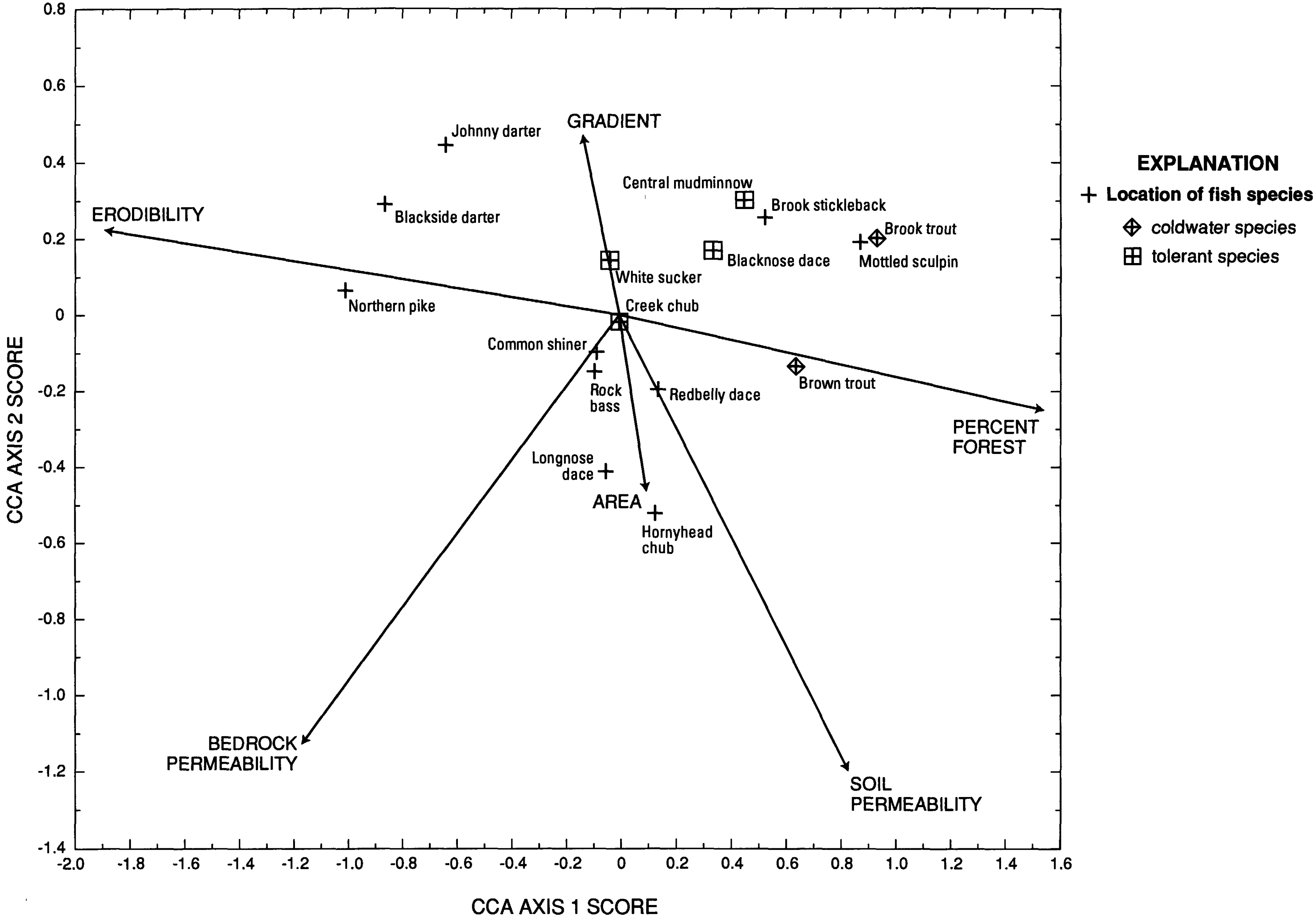

Figure 6. Results of canonical correspondence analysis showing 16 most abundant species collected at 7 fixed sites and 12 comparison sites in the Western Lake Michigan Drainages. (Environmental vectors are shown at twice their actual length for clarity.)

better suited to agriculture. Thin, coarse-textured soils of the northern part of the study area are less erodible and at the same time are not productive enough for row-crop agriculture, but instead are suited primarily to silviculture and some grazing.

The CCA of the 16 most common fish species to environmental factors (fig. 6) indicates that, as expected, coldwater species are related to higher percent forest. Tolerant species clustered near the center of the ordination, indicating the ability of these species to exist under a variety of environmental conditions.

SUMMARY

The Western Lake Michigan Drainages NAWQA study began in 1991. The study area encompasses 51,540 square kilometers in eastern Wisconsin and part of the Upper Peninsula of Michigan.

The study area was subdivided into 28 environmental settings, or relatively homogeneous units (RHU's), on the basis of land use/land cover, texture of surficial deposits, and bedrock geology. A fixed monitoring site was established on a wadable stream within 8 of these RHUs to determine the status and trends of water quality in a representative stream. Part of the NAWQA design is to incorporate ecological data into an overall environmental assessment. Collection of fish-community data were part of this ecological assessment.

Fish-community surveys were done at the 8 wadable fixed sites once each year from 1993–95. At three of these sites, multiple-reach samples were collected in 1994 to determine within-site variation. Within the 6 largest RHUs sampled, an additional 1–3 comparison sites were sampled in 1993 to determine if fish species composition was similar in streams of similar watershed size and physical characteristics to the fixed sites.

Analyses of data collected at multiple reaches and over multiple years indicated that species composition was generally consistent at a given site. Thus, for simplicity, most analyses were done on the 1993 data only.

A total of 44 fish species from 12 families were collected at the 20 sites. The family with the most species represented were the minnows. The number of species per site ranged from 1 at Lincoln Creek in 1995 to 21 at the North Branch Milwaukee River in 1995. The number of individuals collected in one sampling pass ranged from 21 at the Peshekee River in 1995 to 498 at the East River in 1995. The most commonly collected species was white sucker, collected at 17 sites. Coldwater species were collected at 12 sites.

Index of Biotic Integrity (IBI) scores on 1993 data ranged from very poor at a channelized urban site to excellent at 3 sites; 2 in primarily agricultural areas and 1 in a forested area. Seven sites each scored good or fair, while 2 sites scored poor. At sites where multiple-year and multiple-reach data were collected, IBI scores did not vary significantly within the error factor of the IBI. Results of habitat evaluations generally were similar to the IBI rating for a given site.

Detrended correspondence analysis of 19 sites indicated that coldwater sites were tightly grouped, while warmwater sites showed a larger gradient. This was expected given the potential for greater diversity among warmwater sites. Fixed sites were shown to be representative of the study area as a whole, while specific fish communities could not be attributed to particular RHUs.

Cluster analysis revealed two major groups of sites and two outlier sites. The groups represented coldwater and warmwater streams, while the outlier sites were a degraded urban site and a high biotic integrity, species-rich site draining mostly agricultural land.

Canonical correspondence analysis (CCA) revealed that soil erodibility was a significant predictor of species composition. Land use, soil permeability, and bedrock permeability were suggested as predictors of fish-species composition by CCA.

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APPENDIXES 1–2

Appendix 1. Fish species collected at wadable fixed sites in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95

[93A, 94A, 94B, and 94C refer to reach sampled; number in parentheses indicates number of fish collected in second of two consecutive sampling passes]

Family Common name *Scientific name*	Peshekee River	Popple River	Pensaukee River	North Branch Milwaukee River			Lincoln Creek	Duck Creek			East River	Tomorrow River		
	93	93	93	93A			93	93A			93	93A		
Year collected	94	94	94	94A	94B	94C	94	94A	94B	94C	94	94A	94B	94C
	95	95	95	95A			95	95A			95	95A		
Petromyzontidae														
Lamprey ammocoete	--	--	--	--			--	--			--	(3)		
	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--			--	--			--	1		
Salmonidae														
Brook trout	--	--	--	--			--	--			--	22(20)		
Salvelinus fontinalus	--	--	--	--	--	--	--	--	--	--	--	10	4	8
	--	--	--	--			--	--			--	22		
Brown trout	--	1	--	--			--	--			--	7(2)		
Salmo trutta	--	1	--	--	--	--	--	--	--	--	--	5	4	3
	--	--	--	--			--	--			--	9		
Umbridae														
Central mudminnow	1(2)	--	39(9)	--			--	24(9)			--	1(2)		
Umbra limi	--	3	50	--	--	--	--	14	3	4	--	--	--	--
	1	3	--	3			--	0			--	1		
Esocidae														
Northern pike	--	--	(2)	4(3)			--	8(1)			1	--		
Esox lucius	--	--	--	2	4	2	--	2	--	--	--	--	--	--
	--	--	--	7			--	--			--	--		
Cyprinidae														
Central stoneroller	--	--	--	--			--	--			--	--		
Campostoma anomalum	--	--	8	--	--	--	--	1	1	--	--	--	--	--
	--	--	--	14			--	--			--	--		
Common carp	--	--	--	26(17)			--	--			4	--		
Cyprinus carpio	--	--	--	4	8	13	--	--	--	--	4	--	--	--
	--	--	--	11			--	--			--	--		
Spotfin shiner	--	--	--	2(4)			--	--			--	--		
Cyprinella spiloptera	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	--	--	--	--			--	--			--	--		

Appendix 1. Fish species collected at wadable fixed sites in the Western Lake Michigan drainages, Wisconsin and Michigan, 1993–95—Continued

Family Common name *Scientific name*	Peshekee River	Popple River	Pensaukee River	North Branch Milwaukee River			Lincoln Creek	Duck Creek			East River	Tomorrow River		
Year collected	93 94 95	93 94 95	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C
Common shiner *Luxilus cornutus*	-- -- 5	11 20 14	69(33) 17 16	-- 24 96	6	5	-- -- --	4 3 17	--	--	-- 10 12(1)	-- -- --	--	--
Redfin shiner *Lythrurus umbratilus*	-- -- --	-- -- --	(1) -- --	-- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Hornyhead chub *Nocomis biguttatus*	-- -- --	41 24 14	1(2) 4 5	5(8) 28 76	--	--	-- -- --	-- -- --	--	--	19 -- --	-- -- --	--	--
Sand shiner *Notropis ludibundus*	-- -- --	-- -- --	-- -- --	2(3) 8 92	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Northern redbelly dace *Phoxinus eos*	-- -- --	-- -- 3	(3) -- 2	-- -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Bluntnose minnow *Pimephales notatus*	-- -- --	-- 1 --	1(1) -- --	-- 6 --	4	--	-- -- --	-- -- --	--	--	-- 19 19	-- -- --	--	--
Fathead minnow *Pimephales promelas*	-- -- --	-- -- --	-- 1 1	-- -- --	--	--	10 15 --	-- -- --	--	--	2 2 30(14)	-- -- --	--	--
Blacknose dace *Rhinichthys atratulus*	1(1) 9 2	-- 1 --	8(4) 14 4	-- -- --	--	--	-- -- --	-- -- 11	--	--	6 16 10(7)	1 -- --	--	--
Longnose dace *Rhinichthys cataractae*	-- -- 9	-- 7 2	8(3) 38 --	-- -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Creek chub *Semotilus atromaculatus*	7(4) 1 1	-- 32 8	32(16) 28 19	(1) 14 17	--	--	-- -- --	2 25 121	13	8	7 36 28(12)	-- -- --	--	--
Pearl dace *Margariscus margarita*	-- -- --	-- -- 1	1 -- 1	-- -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--

Appendix 1. Fish species collected at wadable fixed sites in the Western Lake Michigan drainages, Wisconsin and Michigan, 1993–95—Continued

Family Common name *Scientific name*	Peshekee River	Popple River	Pensaukee River	North Branch Milwaukee River			Lincoln Creek	Duck Creek			East River	Tomorrow River		
Year collected	93 94 95	93 94 95	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C
Catostomidae														
White sucker *Catostomus commersoni*	-- -- --	11 4 3	25(6) 9 --	3(3) 22 28	6	--	1 -- --	21(6) 4 21	3	6	18 12 29(13)	6(2) 2 1	2	12
Golden redhorse *Moxostoma erythrurum*	-- -- --	-- -- --	-- -- --	11(4) 5 5	12	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Greater redhorse *Moxostoma valenciennesi*	-- -- --	-- -- --	-- -- --	10(5) -- 6	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Ictaluridae														
Black bullhead *Ameiurus melas*	-- -- --	2 --	(7) -- --	(2) -- 1	na -- na	na -- na	2 -- --	1 -- --	na -- na	na -- na	1 -- 1(0)	-- -- --	na -- na	na -- na
Yellow bullhead *Ameiurus natalis*	-- -- --	-- -- --	-- -- --	(2) 2* --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Gadidae														
Burbot *Lota lota*	2(2) 1 --	-- -- --	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Gasterostidae														
Brook stickleback *Culaea inconstans*	-- -- --	-- 1 --	46(61) 27 8	-- -- --	--	--	-- -- --	-- 1 1	--	--	-- -- --	1(1) -- --	--	--
Centrarchidae														
Rock bass *Ambloplites rupestris*	6(2) -- --	-- -- --	2 1 2	1(1) -- --	--	--	-- -- --	39(17) 4 16	12	9	-- -- --	-- -- --	--	--
Green sunfish *Lepomis cyanellus*	-- -- --	-- -- --	-- -- 2	3(1) -- 1	1	--	16 8 30	15(1) -- --	4	1	-- 4 5(0)	-- 1 --	--	--

Appendix 1. Fish species collected at wadable fixed sites in the Western Lake Michigan drainages, Wisconsin and Michigan, 1993–95—Continued

Family Common name *Scientific name*	Peshekee River	Popple River	Pensaukee River	North Branch Milwaukee River			Lincoln Creek	Duck Creek			East River	Tomorrow River		
Year collected	93 94 95	93 94 95	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C	93 94 95	93A 94A 95A	94B	94C
Pumpkinseed *Lepomis gibbosus*	-- -- --	-- -- --	(1) -- --	12(7) -- 8	5	1	5 -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Bluegill *Lepomis macrochirus*	-- -- --	-- -- --	-- -- --	8(6) -- 1	--	--	-- -- --	-- 1 --	--	--	-- -- --	-- -- --	--	--
Largemouth bass *Micropterus salmoides*	-- -- --	-- -- --	-- -- --	-- 2 4	6	1	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Black crappie *Pomoxis nigromaculatus*	-- -- --	-- -- --	-- -- --	1(2) -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Percidae														
Johnny darter *Etheostoma nigrum*	-- -- --	-- 1 --	22(25) 132 10	(1) 3 11	2	--	-- -- --	177(23) 38(82)	8	8	142 154 360(215)	-- -- --	--	--
Yellow perch *Perca flavescens*	-- -- --	-- -- --	-- -- --	2(4) 1 5	2	--	-- -- --	1 -- --	--	--	-- -- --	-- -- --	--	--
Logperch *Percina caprodes*	1(7) -- --	-- -- --	-- -- --	(1) 10 17	2	--	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--
Blackside darter *Percina maculata*	-- -- --	-- -- --	11(2) 10 --	(1) 4 8	--	--	-- -- --	28(7) 12 24	14	9	5 10 4	-- -- --	--	--
Cottidae														
Mottled sculpin *Cottus bairdi*	6(11) 15 3	-- 4 1	-- -- --	-- -- --	--	--	-- -- --	-- -- --	--	--	-- -- --	26(23) 17 65	16	16

Appendix 2. Fish species collected at fish comparison sites in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95

Family / Common name / *Scientific name*	Middle Br. Escanaba R.	N. Br. Paint R.	S. Br. Paint R.	Pine R.	Peshtigo R.	Kelly Brook	Casco Creek	Tisch Mills Creek	W. Br. Red R.	Silver Creek	Mullet R.	E. Br. Milwaukee R.
Salmonidae												
Brook trout *Salvelinus fontinalus*	1	3 (2)	33	4 (10)	--	--	3	8 (4)	98 (41	86 (25	--	--
Brown trout *Salmo trutta*	--	--	--	6 (8)	--	--	--	(1)	--	--	--	--
Rainbow trout *Oncorhynchus mykiss*	--	--	--	--	--	--	9 (5)	11 (1)	--	--	--	--
Umbridae												
Central mudminnow *Umbra limi*	5	30 (6)	2	--	--	1	--	(2)	4 (3)	1	--	--
Esocidae												
Northern pike *Esox lucius*	--	--	--	--	--	2 (4)	--	--	--	--	--	--
Cyprinidae												
Central stoneroller *Campostoma anomalum*	--	--	--	--	--	--	2 (1)	--	--	--	--	51
Common carp *Cyprinus carpio*	--	--	--	--	--	--	--	--	--	--	7 (4)	--
Common shiner *Luxilus cornutus*	--	(13)	5	(3)	--	4 (12)	7 (6)	--	2 (1)	--	1	45
Blacknose shiner *Notropis heterolepis*	--	--	--	--	--	--	--	--	--	--	9	--
Hornyhead chub *Nocomis biguttatus*	--	53 (50)	1	47 (31)	--	57 (67)	--	--	--	--	--	19
Northern redbelly dace *Phoxinus eos*	--	5	5	(2)	--	--	3 (1)	--	--	--	4	--
Fathead minnow *Pimephales promelas*	--	--	1	--	--	--	1	--	--	--	1	--
Blacknose dace *Rhinichthys atratulus*	10	4	44	2 (8)	--	--	22 (7)	6	4 (3)	1 (2)	31 (11)	--
Longnose dace *Rhinichthys cataractae*	--	(1)	2	103 (61)	--	3 (10)	76 (46)	19 (12)	--	(1)	16 (13)	--
Creek chub *Semotilus atromaculatus*	--	2 (6)	15	4 (5)	--	10 (1)	34 (11)	4 (9)	11 (8)	--	48 (20)	11
Pearl dace *Margariscus margarita*	--	--	--	2 (1)	--	--	9 (1)	--	--	--	--	--
Catostomidae												
White sucker *Catostomus commersoni*	--	14 (3)	28	3 (3)	--	(5)	16 (9)	4 (7)	4 (7)	2	9 (3)	1

Appendix 2. Fish species collected at fish comparison sites in the Western Lake Michigan Drainages, Wisconsin and Michigan, 1993–95—Continued

Family Common name *Scientific name*	Middle Br. Escanaba R.	N. Br. Paint R.	S. Br. Paint R.	Pine R.	Peshtigo R.	Kelly Brook	Casco Creek	Tisch Mills Creek	W. Br. Red R.	Silver Creek	Mullet R.	E. Br. Milwaukee R.
Ictaluridae												
Tadpole madtom *Noturus gyrinus*	--	--	--	--	--	--	--	--	--	--	--	2
Gasterostidae												
Brook stickleback *Culaea inconstans*	1	11 (2)	2	--	--	--	--	--	2	--	--	--
Centrarchidae												
Smallmouth bass *Micropterus dolomieui*	--	--	--	--	--	3 (1)	--	--	--	--	--	--
Warmouth *Lepomis gulosus*	--	--	--	--	--	1	--	--	--	--	--	--
Rock bass *Ambloplites rupestris*	--	5 (3)	--	--	--	20 (3)	--	--	--	--	--	11
Green sunfish *Lepomis cyanellus*	--	--	--	--	--	1	--	--	--	--	4	--
Pumpkinseed *Lepomis gibbosus*	--	--	--	--	--	(1)	--	--	--	--	--	--
Bluegill *Lepomis macrochirus*	--	--	--	--	--	2 (1)	--	--	--	--	--	2
Black crappie *Pomoxis nigromaculatus*	1	--	--	1 (1)	--	--	--	--	--	--	--	--
Percidae												
Johnny darter *Etheostoma nigrum*	--	--	--	5	--	18 (15)	1 (1)	--	1 (3)	--	10 (7)	1
Fantail darter *Etheostoma flabellare*	--	--	--	--	--	--	--	--	--	--	--	6
Yellow perch *Perca flavescens*	--	--	--	--	--	2	--	--	--	--	--	--
Logperch *Percina caprodes*	--	--	--	--	--	--	--	--	--	--	--	7
Blackside darter *Percina maculata*	--	--	--	--	--	12 (11)	3 (1)	3	--	--	--	--
Cottidae												
Mottled sculpin *Cottus bairdi*	5	7 (13)	20	29 (26)	--	--	78 (29)	40 (36)	9 (1)	17 (8)	--	--