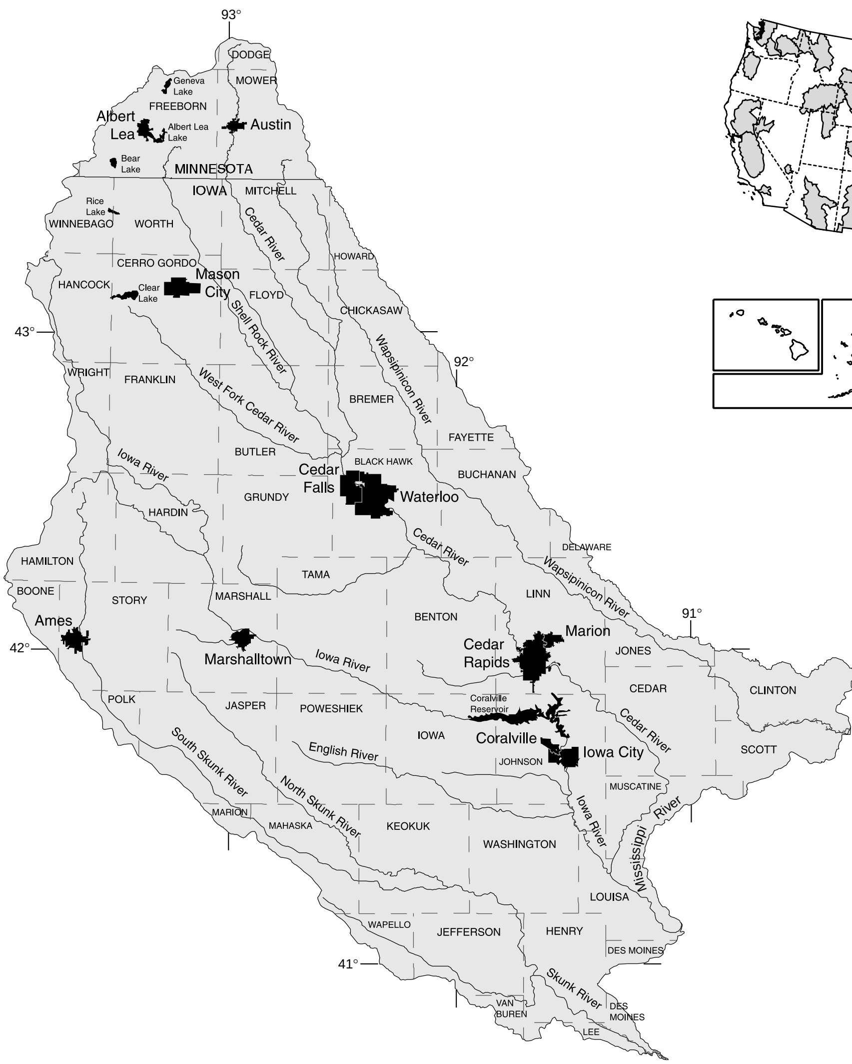
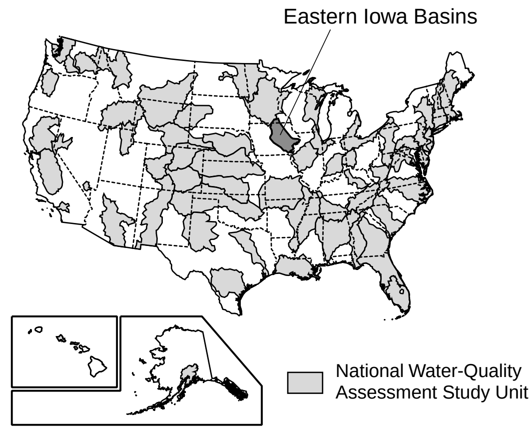
U.S. Department of the Interior
U.S. Geological Survey
National Water-Quality Assessment Program

# Fish Communities and Their Relation to Environmental Factors in the Eastern Iowa Basins in Iowa and Minnesota, 1996

**Water-Resources Investigations Report 00–4194**

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**U.S. DEPARTMENT OF THE INTERIOR**
**U.S. GEOLOGICAL SURVEY**

# Fish Communities and Their Relation to Environmental Factors in the Eastern Iowa Basins in Iowa and Minnesota, 1996

By Daniel J. Sullivan

Water-Resources Investigations Report 00–4194

Iowa City, Iowa
2000

# 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
Chief Hydrologist

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# Fish Communities and Their Relation to Environmental Factors in the Eastern Iowa Basins in Iowa and Minnesota, 1996

*By* Daniel J. Sullivan

## Abstract

Fish community data were collected by the U.S. Geological Survey (USGS) at 12 sites in 1996 in the Wapsipinicon, the Cedar, the Iowa, and the Skunk River Basins in eastern Iowa. The study was done as part of the National Water-Quality Assessment (NAWQA) Program of the USGS. This report presents an evaluation of the fish communities, the composition and conditions of the fish communities, and by relating these compositions and conditions to a variety of habitat and water-quality factors.

A total of 56 fish species representing 13 families were collected from among the 12 sites in 1996. The family with the most species represented were the minnows with 20. The number of individuals of all species collected in one sampling pass ranged from 472 at the Iowa River near Rowan to 2,072 at Wolf Creek near Dysart.

Fish community composition was similar among many of the stream sites. The fish community at 4 of the 5 stream sites, as well as at 2 of the large-river sites, was similar to the reference site, the Wapsinicon River near Tripoli, an indication that fish communities across the study unit are similar. The sites that were the least similar to any of the other sites include Flood Creek, a stream site, and the Skunk River at Augusta large-river site. The fish communities at both of these sites were dominated by relatively few species, many of which are tolerant or represent degraded environmental conditions.

Biplots of detrended correspondence analysis ordinations indicate a gradient from the stream sites to the large-river sites. The detrended correspondence analysis ordination also indicates that the stream sites are more closely clustered than the large-river sites. The large-river sites were more likely to have their ordination driven by one or two dominant species, while several species occurred in similar relative abundance at many of the stream sites.

Several indexes of biotic integrity (IBI) based on fish community were applied to the data and results were generally comparable. In general, the IBIs indicate higher biotic integrity at the stream sites than the large-river sites. Based on IBI classifications, fish communities at most sites were degraded compared to reference conditions.

The fish communities at the 12 study sites appear to be related to a number of environmental factors. Obvious differences in fish communities occur between the stream sites and the large-river sites, the result of differences in both physical and chemical characteristics of the streams. Important physical factors related to fish communities included several directly related to stream size as well as human population density and percent of rowcrops in the watershed. Chemical factors that were important included median total phosphorus, suspended-sediment, and dissolved organic carbon concentrations.

## INTRODUCTION

Human activities have caused dramatic changes to our Nation’s landscape for more than a century. Changes in aquatic habitat as a result of land-use practices that increase runoff and erosion, direct alteration such as channel dredging and filling of riverine wetlands, and reduction of the canopy due to forest clearing are a few of the ways human activities have changed aquatic habitats, often to the detriment of the organisms that live in the streams. Water quality has also been affected by direct dumping of wastes into rivers, as well as runoff from agricultural and urban areas that contributes sediments and toxic substances to rivers and streams.

The U.S. Geological Survey (USGS) began the National Water-Quality Assessment (NAWQA) Program in 1991 to describe the status and trends in the quality of a large part of the Nation's surface- and ground-water resources, and to identify the major factors that affect the quality of those resources. The Eastern Iowa Basins NAWQA study unit was selected as an important hydrologic system representative of an agricultural area in the Midwest. NAWQA assessment activities in the Eastern Iowa Basins study unit (Kalkhoff, 1994), which includes the Wapsipinicon, Iowa, Cedar, and Skunk River Basins, began in 1994. Aquatic ecological investigations are a basic part of the overall assessment of the health of the study unit's streams and rivers.

This report presents an evaluation of fish communities at six stream sites and six large-river sites, the composition and conditions of the fish communities, and by relating these compositions and conditions to a variety of environmental factors. The scope of this report is limited to data collected during 1996 as part of the assessment activities in the Eastern Iowa Basins study unit.

## Background

Accounts of the historical condition of Iowa surface waters in relation to their present condition indicates major changes in the fish communities of Iowa streams due to changes wrought by the introduction of row crop agriculture and human settlement to the prairies of Iowa. Menzel (1981) cites many reports that indicate that European settlement has had a deep and lasting negative impact on the quality of fish communities in Iowa streams. These changes began with the earliest European settlers to the region in the mid-1800's.

Although historical accounts indicate that people of the mid-1800's seemed to be aware of the decline of the fisheries of the state, laws and regulations passed to protect the streams from overfishing and from habitat restrictions caused by dams were difficult to enforce with the limited resources of the State Fish Commission. As a result, as lands were cleared, plowed, and drained, as streams were ditched for agricultural uses, and as urban centers flushed sewage into waterways, deterioration of conditions for aquatic life occurred with startling rapidity (Menzel, 1981). Other factors that contributed to the decline of the state's fish fauna were more than 1,000 low-head dams that impeded the seasonal migration of fish, the introduction and rapid spread of the common carp from Asia, and unlimited fishing.

Meek (1892) wrote that Iowa streams that were "formerly deep and narrow, and abounding in pickerel, bass, and catfishes, have since grown wide and shallow, while the volume of water in them varies greatly in different seasons, and they are inhabited only by bullheads, suckers, and a few minnows." Meek (1893) further explained that the change in streams' character was because "The soil, since loosed with the plow, is much more easily washed into the streams than when it was covered with the stiff native sod. The more thorough underdraining and the surface ditches enables the water, after heavy rains, to find its way at once into the large creeks and rivers. Thus the water in the streams is muddier than formerly; in wet weather is deeper, and in dry weather is more shallow. These features, together with the fact that the rivers are becoming, to some extent, the sewers for the large cities, is a probable cause for diminution of some of the food fishes".

The environmental problems associated with agricultural and urban development intensified during the first 3 decades after 1900 (Menzel, 1981). A major portion of Iowa's wetlands were drained by the end of this time (Bishop, 1981), and more than 1,000 miles of stream were eliminated through channelization of streams (Bulkley, 1975). Sediment and sewage constituted serious water-quality problems over much of the state (Menzel, 1981).

The 1930's marked the beginning of the modern era of resource conservation in Iowa. Provisions of the 25-Year Conservation Plan (Crane and Olcott, 1933) for the fisheries of the state included fisheries surveys, research on fish ecology and management, improved fish stocking, and programs for habitat improvement, land acquisition, public education, and erosion and pollution control.

Bailey (1956) speculated that "it is doubtful that any other state has experienced such extensive reduction in its original fish fauna." Possibly the most impacted from the degradation of Iowa's streams are the non-game fishes. A list of endangered and threatened species in Iowa (Roosa, 1977) identifies 34 species as threatened, extirpated, or of undetermined status—nearly one-quarter of all native species. Of these, 23 are fishes that primarily inhabit interior waters. Minnows are the largest contributor to this group (12 species); darters (3 species) and suckers (3 species) also are prominent.

Point sources of nutrients have been gradually reduced due to improved wastewater treatment. Nonpoint-source contributions have thus become of greater concern in regard to improving environmental conditions for fishes and other aquatic life in Iowa.

Currently, the Iowa Department of Natural Resources (DNR) lists 148 fish species within the state (Iowa DNR World Wide Web site “Fishes of Iowa” at URL http://www.state.ia.us/government/dnr/organiza/fwb/fish/iafish/iafish.htm). Of these, 139 species are considered native to Iowa waters.

## Description of the Study Unit

The Eastern Iowa Basins study unit encompasses the Wapsipinicon, Iowa, Cedar, and Skunk River Basins and covers about 19,500 $mi^2$ (square miles) (fig. 1) in eastern Iowa and southern Minnesota (Kalkhoff, 1994). The four major rivers in the study unit generally flow in a southeasterly direction. The Wapsipinicon River originates in southeastern Minnesota and is about 225 mi long. The Wapsipinicon River Basin averages about 10 mi in width and has a drainage area of 2,540 $mi^2$. The Iowa River originates in north-central Iowa. The Iowa River Basin is long and narrow with an average width of about 20 mi and a maximum width of about 40 mi. The Cedar River joins the Iowa River about 30 mi upstream of the mouth of the Iowa River. The Cedar River originates in southern Minnesota. The Cedar River Basin also is long and narrow. The Iowa and the Cedar River Basins cover 12,640 $mi^2$, more than 90 percent of which is in Iowa. The Skunk River originates in central Iowa and drains about 4,350 $mi^2$. Mean width of the Skunk River Basin is about 24 mi. The mouths of the Wapsipinicon, Iowa, and Skunk share a common confluence in the Mississippi River.

About 93 percent of the land area in the Eastern Iowa Basins is used for agriculture (fig. 2); most of this is for the production of row crops. Only about 2 percent of the study unit is urban land. About 40 percent of the area’s population of over 1 million is concentrated in cities with populations of greater than 20,000 people; the remainder are scattered throughout rural areas. Forested areas cover less than 4 percent of the study unit and are primarily confined to the immediate riparian zone along streams, especially larger streams. Wetlands cover less than 1 percent of the land in the Eastern Iowa Basins.

The Eastern Iowa Basins study unit is divided into three major physiographically distinct landform regions and one subregion—the Des Moines Lobe, Iowan Surface, Iowan Karst (subregion), and Southern Iowa Drift Plain (Prior, 1991) (fig. 1). The Des Moines Lobe is characterized by low relief with some distinct ridges near the eastern boundary and occasional depressions that form lakes, ponds, and swamps. Glacial till is the dominant surficial material, with alluvium along the streams. The Iowan Surface has gently rolling topography with long slopes, low relief, and a mature drainage pattern. The surficial material is primarily glacial drift, with thin layers of windblown loess on the ridges and alluvium near the streams. A subregion of the Iowan Surface, the Iowan Karst, has near-surface bedrock and karst-type geological features. In the Southern Iowa Drift Plain, streams have eroded deeply into the loess mantle and the glacial drift to produce a steeply rolling terrain with broad, flat drainage divides.

Although all the landforms in the study unit are of glacial origin, the ages of the landforms vary greatly. The Des Moines Lobe is the youngest landform in the Eastern Iowa Basins, and lies along the western border of the study unit. The area is relatively flat and has an immature drainage that historically had shallow undrained depressions, or potholes, in many areas, that have since been largely drained for agriculture. Many of the streams in this area have been channelized, and ditches added to drain wet areas. The soils typically developed from glacial till. Large animal feeding operations are more prevalent in this landform area than in other parts of the study unit (fig. 2).

The Iowan Surface and Iowan Karst landforms are also relatively flat, but have a mature drainage system. The soils were developed from glacial till. The Iowan Karst landform has near-surface bedrock and karst-type geological features, which may have some effect on stream quality. Many streams in both the Iowan Surface and Iowan Karst landforms have been channelized, especially in the northern parts.

The Southern Iowa Drift Plain is the oldest landform in the study unit, and has the steepest topography, especially near streams. These steep slopes are commonly wooded, and form larger riparian zones than streams in most of the rest of the study unit. Soils in the Southern Iowa Drift Plain are formed from thick layers of loess which overlay the glacial drift. Streams in the Southern Iowa Drift Plain have not been as heavily

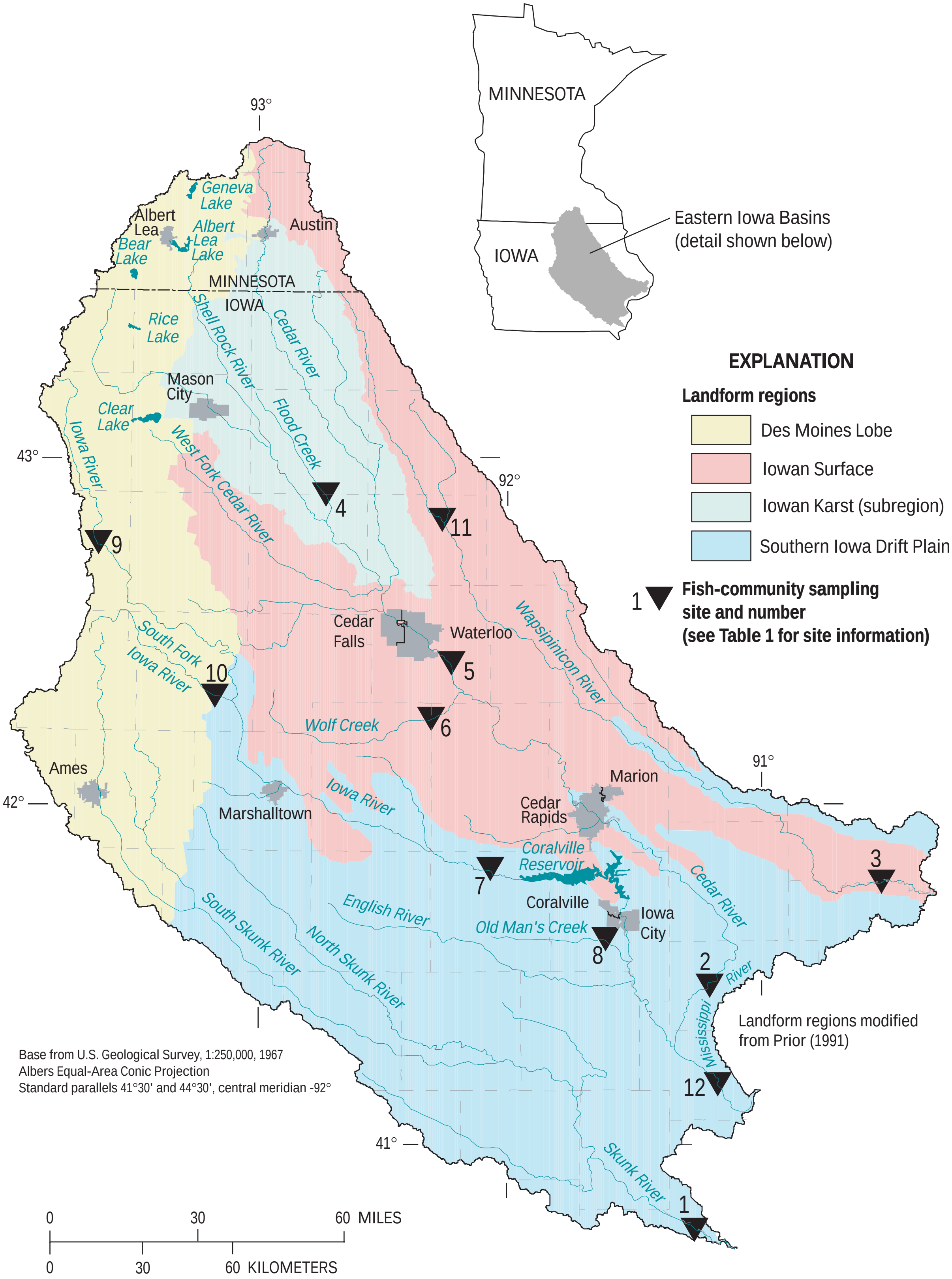


**Figure 1.** Location of fish-community sampling sites in the Eastern Iowa Basins study unit, 1996.

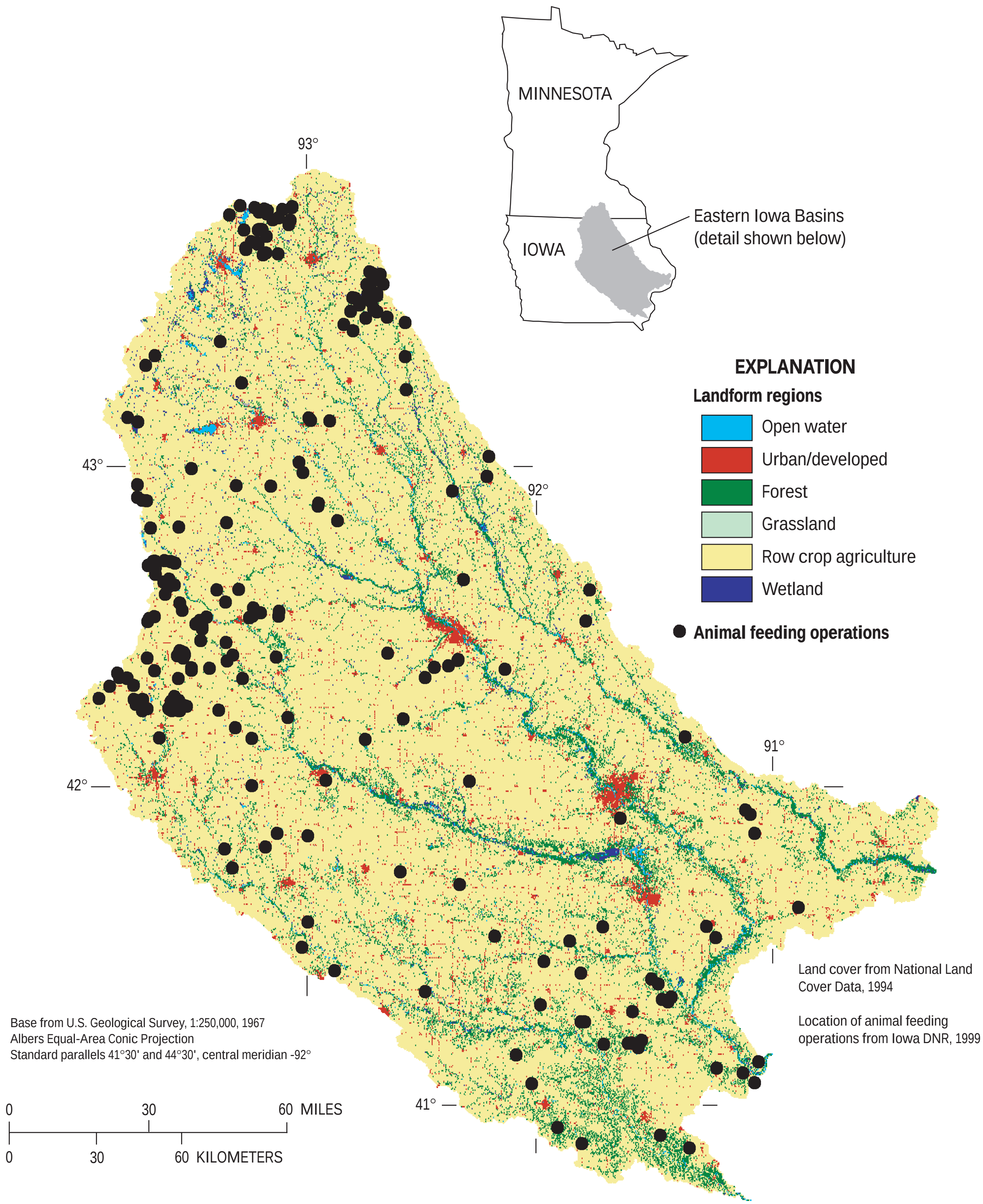


**Figure 2.** Land use in the Eastern Iowa Basins study unit.

channelized as those in other parts of the study unit, probably because the steep topography provides effective drainage of the uplands without the need for additional measures.

Water in the study unit generally originates as rainfall in late spring to late fall and as snow during winter and early spring. Average annual precipitation (1961–90) in the basin ranges from about 30 inches (in.) in the northwestern part of the study unit to about 36 in. in the southeastern part (Wendland and others, 1992). The greatest rainfall typically occurs during the growing season in spring and summer. The mean April-to-October precipitation (1961–90) is about 25 in. The most intense 24-hour rainfall (5-year recurrence interval) can be more than 4 in. Snowfall has been recorded from September to May. The greatest 24-hour snowfall seldom (less than 25 percent of the time) exceeds 10 in.

Excess precipitation, that does not infiltrate into the soil and does not evaporate, enters streams as overland runoff. Overland flow and ground-water discharge are the major sources of streamflow. Overland runoff to streams averages about 25 percent of the annual precipitation and ranges from less than 7 in. in the northern part of the study unit to about 9 in. in the southeastern part. Yearly streamflow from the study unit averages about 9.2 million acre-feet. Surface water is an important source for public-water supplies for about 6 percent of the population and for power generation. About 272 million gallons per day are used instream to produce 2.1 gigawatt-hours of hydroelectric power.

Major water-quality issues in the study unit include eutrophication, toxic contamination, and soil erosion and sedimentation (Kalkhoff, 1994). Eutrophication is from agricultural and urban runoff of fertilizers and industrial and municipal sewage effluent that results in increased biological production in streams and reservoirs, which causes reduced species diversity and altered fish communities. Toxic contamination is a result of movement of chemicals such as pesticides to surface and ground water and has endangered public-water supplies. Large quantities of soil are being transported in streams, resulting in increased turbidity and siltation and thus a degradation of aquatic habitats and the aesthetic quality of the streams.

## Study Design and Methods

The NAWQA Program study design includes the collection of ecological data as well as water-chemistry data. These data act as mulitple lines of evidence to use in an overall assessment of stream and river health.

### Study Design

Water-chemistry data, ecological-community data, and data on stream-habitat features were collected at 12 sites in the study unit. Six sampling sites were selected on reaches of streams that were generally wadable at normal flow and will be referred to as “stream sites”. Four stream sampling sites were established in watersheds in each of the four landforms in the study unit (table 1, fig. 1). Another stream site was selected to represent an area with a large number of animal feeding operations. The sixth stream site was selected as a background or reference site for water quality (site 11). The drainage area of this site overlaps two of the landform regions. The upper Wapsipinicon River watershed, where this site is located, contains the largest and least disturbed riparian zone of all the sites sampled in this study. Abundant bottomland hardwood forests line the river corridor. In addition, sampling sites were established near the mouths of the four large rivers in the study unit (table 1, fig. 1). An additional site was located upstream of the Coralville Reservoir on the Iowa River. A final site (site 5), was operated for only 1 year, and was located downstream of Waterloo on the Cedar River, with the intent of gathering information on the effects of an urban area on an otherwise agricultural stream.

### Data-Collection Methods

The fish-collection protocol for the NAWQA Program is detailed in Meador and others (1993a). Fish-community samples were collected during September and October, 1996. The sites were sampled using direct-current electrofishing equipment mounted on either a backpack, towed barge, or boat, depending on the stream depth. Shallow riffle areas were sampled using a bag seine.

Environmental data were collected according to NAWQA protocols. Water samples were depth- and width-integrated samples as described in Shelton (1994). Stream and riparian habitat data were collected according to methods outlined in Meador and others (1993b).

**Table 1.** Description of fish-community sampling sites in the Eastern Iowa Basins study unit

[$mi^2$, square miles; --, no USGS station number]

| Site number (fig.1) | USGS station number | Site name | Drainage area ($mi^2$) | Site description |
|---|---|---|---|---|
| | | **Stream sites** | | |
| 4 | 05461390 | Flood Creek near Powersville, Iowa | 150 | Row-crop agriculture on Iowan karst |
| 6 | 05464220 | Wolf Creek near Dysart, Iowa | 327 | Row-crop agriculture on Iowan Surface |
| 9 | 05449500 | Iowa River near Rowan, Iowa | 418 | Row-crop agriculture on Des Moines Lobe |
| 8 | 05455100 | Old Man's Creek near Iowa City, Iowa | 201 | Row-crop agriculture on Southern Iowa Drift Plain |
| 10 | 05451210 | South Fork Iowa River northeast of New Providence, Iowa | 224 | Row-crop agriculture and concentrated animal feeding operations on Des Moines Lobe |
| 11 | 05420680 | Wapsipinicon River near Tripoli, Iowa | 346 | Row-crop agriculture on Iowan surface; "Reference" site |
| | | **Large-river sites** | | |
| 1 | 05474000 | Skunk River at Augusta, Iowa | 4,310 | Mouth of the Skunk River Basin |
| 2 | 05465000 | Cedar River near Conesville, Iowa | 7,790 | Mouth of the Cedar River Basin |
| 3 | 05422000 | Wapsipinicon River near De Witt, Iowa | 2,340 | Mouth of the Wapsipinicon River Basin |
| 5 | -- | Cedar River at Gilbertville, Iowa | 5,240 | Combined effects of row-crop agriculture and urban |
| 7 | 05453100 | Iowa River at Marengo, Iowa | 2,790 | Iowa River Basin upstream of the Coralville Reservoir |
| 12 | 05465500 | Iowa River at Wapello, Iowa | 12,500 | Mouth of the Iowa River Basin |

## Data-Analysis Methods

Researchers have developed indexes of biotic integrity (IBI) that can be used to calculate a score based on features of the fish assemblage in a given stream. These features, or metrics, are rated as good, fair, or poor and then combined to assign an overall score to a stream reach. Personnel from the Iowa DNR are in the preliminary stages of producing an IBI calibrated to streams of the state (Thomas Wilton, Iowa Department of Natural Resources, oral commun., 1999). Several other IBIs were compared to that version, including several that include slight modifications of Karr's original metrics (Karr, 1981). These include an IBI developed for warmwater streams in Wisconsin (Lyons, 1992), and an IBI used in a Minnesota study (Bailey and others, 1992). For the large-river sites, two IBIs were compared: a draft version of a large-river IBI for Wisconsin (John Lyons, Wisconsin Department of Natural Resources, written commun., 2000), and a large-river IBI developed by the Ohio Environmental Protection Agency (OEPA) (Ohio Environmental Protection Agency, 1987).

Species-composition data were compared among the sites by the use of detrended correspondence analysis (DCA) and Bhattacharyya's coefficient of similarity (Smith and others, 1990). DCA is 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 use of the CANOCO computer program (Ter Braak, 1988) that enables plots of sites and species in an ordination diagram. Species abundance data were log-transformed for DCA. On a DCA biplot, sites that plot near other sites in space indicate similar species composition and abundance. Conversely, sites that plot far from each other have different fish communities. Nonparametric Spearman rank correlation (Iman and Conover, 1983; Johnson and Wichern, 1992) was used to check for relations between DCA scores and environmental factors.

Interpretation of the results of the DCA is limited because so few samples contain a relatively large number of species; thus, the degrees of freedom are less than the number of variables and the pooled covariance matrix is singular. Because of the large number of species typically absent in some samples and present at others, the normality assumption cannot be met. While transformation may help in dealing with skewed data (for DCA, species data were log transformed), problems still exist in using these types of analyses. Thus, a measure of community similarity (Bhattacharyya, 1946), was also used in an attempt to determine the relative similarity of the fish communities at the fixed sites. Bhattacharyya's coefficient of similarity ($S_{ij}$) is calculated as follows:

$$S_{ij}=\Sigma(P_{ik}P_{jk})^{1/2}$$

**Table 2.** Summary of fish-community data collected in the Eastern Iowa Basins study unit, 1996

[See figure 1 and table 1 for site descriptions.]

| Site number (fig. 1) | Site name | Date sampled | Number of fish collected | Number of species collected |
|---|---|---|---|---|
| | | **Stream sites** | | |
| 4 | Flood Creek near Powersville, Iowa | 09/26/1996 | 1,277 | 14 |
| 6 | Wolf Creek near Dysart, Iowa | 10/01/1996 | 2,072 | 22 |
| 8 | Old Man's Creek near Iowa City, Iowa | 09/16/1996 | 1,689 | 21 |
| 9 | Iowa River near Rowan, Iowa | 09/24/1996 | 472 | 19 |
| 10 | South Fork Iowa River northeast of New Providence, Iowa | 09/23/1996 | 900 | 24 |
| 11 | Wapsipinicon River near Tripoli, Iowa | 09/26/1996 | 1,170 | 25 |
| | | **Large-river sites** | | |
| 1 | Skunk River at Augusta, Iowa | 10/03/1996 | 1,429 | 17 |
| 2 | Cedar River near Conesville, Iowa | 09/18/1996 | 1,512 | 20 |
| 3 | Wapsipinicon River near Dewitt, Iowa | 10/02/1996 | 930 | 24 |
| 5 | Cedar River at Gilbertville, Iowa | 09/30/1996 | 1,938 | 26 |
| 7 | Iowa River at Marengo, Iowa | 09/17/1996 | 1,161 | 15 |
| 12 | Iowa River at Wapello, Iowa | 09/19/1996 | 1,953 | 17 |

Where $P_{ik}$ and $P_{jk}$ refer to the proportion of species $k$ at sites $i$ and $j$, respectively.

## FISH COMMUNITIES OF STREAM SITES IN THE EASTERN IOWA BASINS

Fish community data are summarized in table 2. Data on species, relative abundance, and number of fish collected are shown in table 3. A total of 56 fish species representing 13 families were collected from among the 12 sites in 1996. The family with the most species represented were the minnows, with 20. Only one exotic species was collected in 1996—the common carp.

### Fish Community Composition

The number of individuals of all species collected in one sampling pass ranged from 472 at the Iowa River near Rowan (site 9) to 2,072 at Wolf Creek near Dysart (site 6). The number of individuals collected at large-river sites increased, in general, as drainage area increased (fig. 3); however, no correlation was indicated between the number of individuals collected and drainage area at the stream sites. The number of species collected at a given site seemed to be independent of drainage area. The number of species at the stream sites ranged from 14 to 25, and at the large-river sites from 17 to 26.

Minnows accounted for over 50 percent of the total number of individual fish collected at 10 of the 12 sites. Suckers accounted for 68 and 45 percent, respectively, of the total number of individual fish collected at the Iowa River at Wapello (site 12) and the Cedar River 15 percent of the fish collected at the Iowa River near Rowan (site 9).

Most species accounted for less than 5 percent of the total number of fish collected at a given site. Species that accounted for more than 5 percent of the fish collected at more than one site included spotfin shiner (9 sites), sand shiner (6), bluntnose minnow (6), river carpsucker (4), bigmouth shiner (4), bullhead minnow (2), emerald shiner (2), and common shiner (2).

In general, most species were rare (herein defined as less than 5 percent of the total number of fish collected) at most sites. Species that were common (5–20 percent of the total number of fish collected) or abundant (greater than 20 percent of the total number of fish collected) at more than one site included spotfin shiner (abundant at 5 sites, common at 4 sites), bluntnose minnow (abundant at 5, common at 1), sand shiner (common at 6), river carpsucker (abundant at 2, common at 2), bullhead minnow (abundant at 2), bigmouth shiner (abundant at 1, common at 3), emerald shiner (abundant at 1, common at 1), and common shiner (common at 2).

A number of species were collected that are intolerant, or sensitive to environmental degradation, and thus may be indicative of good water-quality condi-

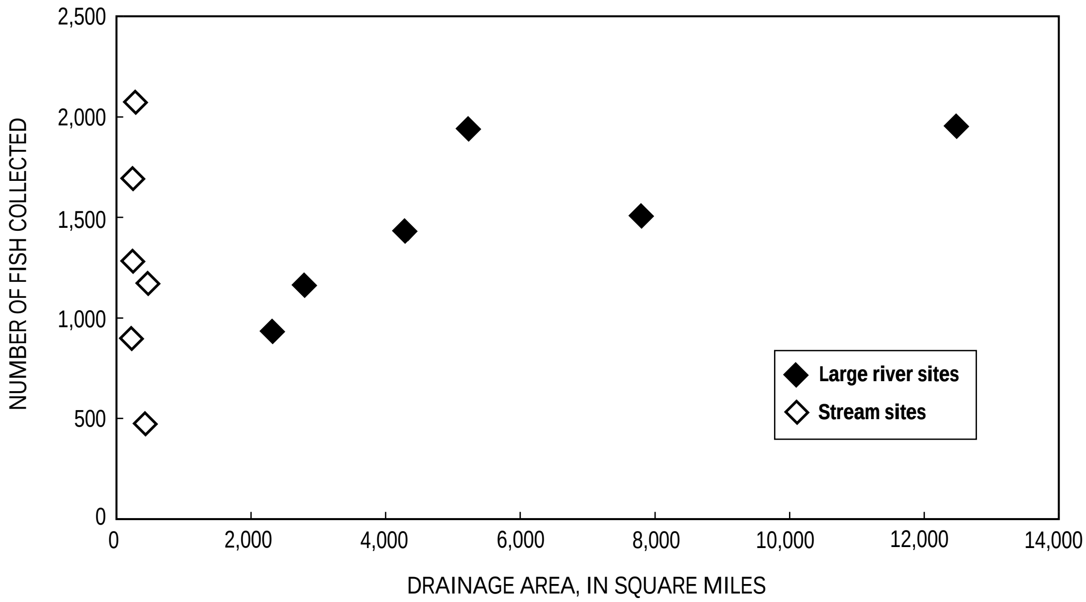


**Figure 3.** Number of fish collected as a function of drainage area, at 12 sites in the Eastern Iowa Basins study unit, 1996.

tions. The sites at which the highest number of intolerant species collected were the South Fork Iowa River northeast of New Providence (8 species—largescale stoneroller, hornyhead chub, northern hogsucker, slender madtom, smallmouth bass, blackside darter, banded darter, and slenderhead darter) and the Wapsipinicon River near Tripoli (6 species—American brook lamprey, northern pike, northern hogsucker, smallmouth bass, rock bass, and blackside darter). The sites with the highest percentage of tolerant, or less sensitive to environmental degradation, species were Old Man's Creek near Iowa City (site 8) and the Iowa River at Marengo (site 7), where about 66 and 58 percent, respectively, of all fish captured at those sites in 1996 were tolerant species. This suggests degraded environmental quality at these two sites.

On the basis of observed abundance, several species exhibited a preference for either large-river or stream environments. For example, river carpsucker was common or abundant at 4 of 6 large-river sites, but were rare at 5 of 6 stream sites, and not found at one site. This is consistent with this species' known preference for larger river environments (Harlan and others, 1987). Other species more prevalent at large-river sites included gizzard shad, emerald shiner, bullhead minnow, channel and flathead catfish, and freshwater drum. These species are considered large-river species (Harlan and others, 1987) and thus their distribution in these streams is reasonable. A number of minnow and sucker species were collected in greater abundance at stream sites, including white sucker, golden redhorse, and several darters. White sucker are ubiquitous in streams, and the more frequent observations of this species at stream sites may be due to greater sampling efficiency at stream sites. However, it is likely that the occurrence of golden redhorse and the darter species is related to water-quality and habitat conditions that favor these species at the stream sites. The presence of johnny darter in the absence of other darter species, as was the case at three of the large-river sites (sites 3, 5, and 7) and at three of the stream sites (sites 4, 6, and 8), is an indicator of degraded conditions (Karr, 1981).

The relative similarity of the fish communities at the 12 sampling sites was calculated by the use of Bhattacharyya's coefficient of similarity (Smith and others, 1990). The coefficients indicate that the fish community at many of the sites in the study unit are similar (table 4). In general, a similarity coefficient of 60 percent or greater indicates similar species composition and abundance among samples.

Fish community composition was similar among many of the stream sites. The fish community at 4 of 5 stream sites, as well as at two of the large-river sites, was similar to the reference site, the Wapsipinicon

**Table 3.** Species, relative abundance, and number of fish collected in the Eastern Iowa Basins study unit, 1996

[See figure 1 and table 1 for site descriptions; top number (in shaded area) is relative abundance in percent, lower number is number of individuals]

| Fish species by family | | Site number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Large-river sites | | | | | | Stream sites | | | | | |
| Common name | Scientific name | 1 | 2 | 3 | 5 | 7 | 12 | 4 | 6 | 8 | 9 | 10 | 11 |
| **Lampreys** | ***Petromyzontidae*** | | | | | | | | | | | | |
| American brook lamprey | *Lampetra appendix* | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | | 23 |
| **Gars** | ***Lepisosteidae*** | | | | | | | | | | | | |
| Longnose gar | *Lepisosteus osseus* | | <0.1 | 0.1 | | | <0.1 | | | | | | |
| | | | 1 | 1 | | | 1 | | | | | | |
| Shortnose gar | *Lepisosteus platostomus* | | .06 | | | | | | | 0.1 | | | |
| | | | 1 | | | | | | | 1 | | | |
| **Herrings** | ***Clupeidae*** | | | | | | | | | | | | |
| Gizzard shad | *Dorosoma cepedianum* | 0.4 | .9 | .3 | | 2 | 2 | | | 8 | | | |
| | | 5 | 14 | 3 | | 22 | 29 | | | 133 | | | |
| **Pikes** | ***Esocidae*** | | | | | | | | | | | | |
| Northern pike | *Esox lucius* | | | | | | | | | | 0.6 | | .8 |
| | | | | | | | | | | | 3 | | 10 |
| **Minnows** | ***Cyprinidae*** | | | | | | | | | | | | |
| Central stoneroller | *Campostoma anomalum* | | | .5 | 0.2 | | | 3 | 0.7 | | | 2 | |
| | | | | 5 | 3 | | | 44 | 14 | | | 22 | |
| Largescale stoneroller | *Campostoma oligolepis* | | | | | | | | | | | 0.11 | |
| | | | | | | | | | | | | 1 | |
| Red shiner | *Cyprinella lutrensis* | 65 | .1 | | | | | | | .06 | | | |
| | | 935 | 2 | | | | | | | 1 | | | |
| Spotfin shiner | *Cyprinella spiloptera* | 1 | 8 | 22 | 39 | 15 | .46 | | 58 | 8 | 34 | 15 | 48 |
| | | 16 | 127 | 204 | 749 | 175 | 9 | | 1,193 | 130 | 161 | 138 | 559 |
| Common carp | *Cyprinus carpio* | .7 | 1 | .5 | 1 | 1 | .6 | 0.2 | .5 | .3 | 4 | .2 | .1 |
| | | 10 | 22 | 5 | 24 | 11 | 12 | 2 | 11 | 5 | 22 | 2 | 1 |
| Brassy minnow | *Hybognathus hankinsoni* | | | | .1 | | | | | | | .9 | .1 |
| | | | | | 1 | | | | | | | 8 | 1 |
| Mississippi silvery minnow | *Hybognathus nuchalis* | 1 | | 11 | | | | | | | | | |
| | | 17 | | 100 | | | | | | | | | |
| Common shiner | *Luxilus cornutus* | | | | | | | 16 | | | | 8 | .3 |
| | | | | | | | | 206 | | | | 68 | 4 |
| Silver chub | *Macrhybopsis storeriana* | | | .1 | | | | | | | | | |
| | | | | 1 | | | | | | | | | |
| Hornyhead chub | *Nocomis biguttatus* | | | | | | | .1 | <.1 | | | .8 | |
| | | | | | | | | 1 | 1 | | | 7 | |
| Emerald shiner | *Notropis atherinoides* | 22 | .5 | 11 | | | <.1 | | | .8 | | | |
| | | 314 | 7 | 104 | | | 1 | | | 14 | | | |
| River shiner | *Notropis blennius* | | | | | 4 | | | | .5 | | | |
| | | | | | | 51 | | | | 9 | | | |
| Bigmouth shiner | *Notropis dorsalis* | .3 | .1 | .2 | 3 | 3 | | 53 | 9 | 8 | | 19 | 2 |
| | | 4 | 2 | 2 | 61 | 38 | | 674 | 191 | 136 | | 169 | 26 |
| Sand shiner | *Notropis stramineus* | .6 | .4 | 2 | 7 | 2 | <.1 | 10 | 14 | 4 | 13 | 14 | 12 |
| | | 8 | 6 | 20 | 130 | 20 | 1 | 123 | 285 | 72 | 60 | 127 | 140 |

**Table 3.** Species, relative abundance, and number of fish collected in the Eastern Iowa Basins study unit, 1996—Continued

[See figure 1 and table 1 for site descriptions; top number (in shaded area) is relative abundance in percent, lower number is number of individuals]

| Fish species by family | | Site number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Large-river sites | | | | | | Stream sites | | | | | |
| Common name | Scientific name | 1 | 2 | 3 | 5 | 7 | 12 | 4 | 6 | 8 | 9 | 10 | 11 |
| Suckermouth minnow | *Phenacobius mirabilis* | | .1 | .1 | | 1 | | | | .8 | | | |
| | | | 2 | 1 | | 15 | | | | 13 | | | |
| Bluntnose minnow | *Pimephales notatus* | 5 | | 4 | 27 | 50 | | 5 | 10 | 62 | 5 | 20 | 20 |
| | | 67 | | 35 | 527 | 582 | | 60 | 202 | 1,045 | 23 | 183 | 235 |
| Fathead minnow | *Pimephales promelas* | | | | | 7 | | .3 | | 2 | 2 | | .1 |
| | | | | | | 77 | | 4 | | 26 | 11 | | 1 |
| Bullhead minnow | *Pimephales vigilax* | .1 | 32 | 41 | 4 | | 1 | | | | | | |
| | | 1 | 485 | 385 | 77 | | 25 | | | | | | |
| Blacknose dace | *Rhinichthys atratulus* | | | | | | | .6 | .1 | | | .1 | |
| | | | | | | | | 8 | 2 | | | 1 | |
| Creek chub | *Semotilus atromaculatus* | .1 | | | .3 | | | 5 | .9 | 3 | | 2 | |
| | | 1 | | | 6 | | | 63 | 19 | 43 | | 22 | |
| **<u>Suckers</u>** | ***<u>Catastomidae</u>*** | | | | | | | | | | | | |
| River carpsucker | *Carpoides carpio* | 2 | 44 | 3 | 15 | 13 | 68 | .2 | 2 | .3 | | .9 | .1 |
| | | 33 | 665 | 24 | 293 | 154 | 1,332 | 2 | 31 | 5 | | 8 | 1 |
| Quillback carpsucker | *Carpoides cyprinus* | | | | <.1 | | | | .1 | | .8 | 4 | |
| | | | | | 1 | | | | 2 | | 4 | 33 | |
| Highfin carpsucker | *Carpoides velifer* | | | | <.1 | | | | <.1 | | | | |
| | | | | | 1 | | | | 1 | | | | |
| White sucker | *Catostomus commersoni* | | | | <.1 | | | 2 | .5 | <.1 | 5 | | |
| | | | | | 1 | | | 24 | 11 | 1 | 23 | | |
| Northern hogsucker | *Hypentelium nigricans* | | | | | | | | .7 | | | 3 | 2 |
| | | | | | | | | | 15 | | | 27 | 20 |
| Smallmouth buffalo | *Ictiobus bubalus* | | .1 | .3 | .1 | | | | | <.1 | | | |
| | | | 1 | 3 | 2 | | | | | 1 | | | |
| Silver redhorse | *Moxostoma anisurum* | | | | <.1 | | | | | | | | 3 |
| | | | | | 1 | | | | | | | | 29 |
| Golden redhorse | *Moxostoma erythrurum* | | | .2 | .3 | | | | 2.4 | .2 | 2 | 7 | 2 |
| | | | | 2 | 6 | | | | 49 | 4 | 9 | 60 | 24 |
| Shorthead redhorse | *Moxostoma macrolepidotum* | | .7 | .3 | <.1 | .2 | | | 1 | .4 | 3 | .2 | 3 |
| | | | 11 | 3 | 1 | 2 | | | 23 | 7 | 16 | 2 | 36 |
| **<u>Catfish</u>** | ***<u>Ictaluridae</u>*** | | | | | | | | | | | | |
| Black bullhead | *Ameiurus melas* | | | | | | | | | | 6 | | |
| | | | | | | | | | | | 28 | | |
| Yellow bullhead | *Ameiurus natalis* | | | | | | | | | | .8 | | .8 |
| | | | | | | | | | | | 4 | | 9 |
| Channel catfish | *Ictalurus punctatus* | .5 | 9 | 2 | .5 | .5 | .6 | | <.1 | .2 | | | .1 |
| | | 7 | 137 | 19 | 10 | 6 | 12 | | 1 | 3 | | | 1 |
| Flathead catfish | *Pylodictus olivaris* | .1 | .1 | | <.1 | | | | | | | | |
| | | 1 | 1 | | 1 | | | | | | | | |
| Slender madtom | *Noturus exilis* | .1 | | | | | | | | | .4 | .1 | |
| | | 1 | | | | | | | | | 2 | 1 | |

**Table 3.** Species, relative abundance, and number of fish collected in the Eastern Iowa Basins study unit, 1996—Continued

[See figure 1 and table 1 for site descriptions; top number (in shaded area) is relative abundance in percent, lower number is number of individuals]

| Fish species by family | | Site number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Large-river sites | | | | | | Stream sites | | | | | |
| Common name | Scientific name | 1 | 2 | 3 | 5 | 7 | 12 | 4 | 6 | 8 | 9 | 10 | 11 |
| Stone cat | *Noturus flavus* | | | | | | | | .1 | | | | |
| | | | | | | | | | 2 | | | | |
| **Silversides** | ***Atherinidae*** | | | | | | | | | | | | |
| Brook silversides | *Labidesthes sicculus* | | | | | | 22 | | | | | | |
| | | | | | | | 434 | | | | | | |
| **Sticklebacks** | ***Gasterosteidae*** | | | | | | | | | | | | |
| Brook stickleback | Culea inconstans | | | | | | | .6 | | | | | |
| | | | | | | | | 8 | | | | | |
| **Temperate basses** | ***Percichthyidae*** | | | | | | | | | | | | |
| White bass | *Morone chrysops* | | .2 | | | | .7 | | | | | | |
| | | | 3 | | | | 14 | | | | | | |
| **Sunfishes** | ***Centrarchidae*** | | | | | | | | | | | | |
| Northern rock bass | *Ambloplites rupestris* | | | | | | | | | | | | .2 |
| | | | | | | | | | | | | | 3 |
| Green sunfish | *Lepomis cyanellus* | | .2 | | .5 | | <.1 | | .1 | | 13 | | .2 |
| | | | 3 | | 7 | | 1 | | 3 | | 63 | | 3 |
| Orangespotted sunfish | *Lepomis humilus* | | | .3 | .1 | | 3 | | | | .6 | | |
| | | | | 3 | 2 | | 51 | | | | 3 | | |
| Bluegill | *Lepomis macrochirus* | .1 | | .1 | <.1 | .5 | .1 | | <.1 | | .4 | .1 | |
| | | 1 | | 1 | 1 | 6 | 2 | | 1 | | 2 | 1 | |
| Smallmouth bass | *Micropterus dolomieui* | | 1 | .2 | .8 | | | | .4 | | | 1 | .4 |
| | | | 19 | 2 | 16 | | | | 9 | | | 13 | 5 |
| Largemouth bass | *Micropterus salmoides* | | | .4 | .5 | | .4 | | | .1 | .6 | | .3 |
| | | | | 4 | 9 | | 7 | | | 2 | 3 | | 4 |
| Black crappie | *Pomoxis nigromaculatus* | | | | .1 | | | | | | | | .1 |
| | | | | | 2 | | | | | | | | 1 |
| White crappie | *Pomoxis annularis* | | | | | | .5 | | | | | | .1 |
| | | | | | | | 10 | | | | | | 10 |
| **Perches** | ***Percidae*** | | | | | | | | | | | | |
| Johnny darter | *Etheostoma nigrum* | | | .1 | .3 | .1 | | 5 | .3 | 2 | 6 | .1 | 2 |
| | | | | 1 | 6 | 1 | | 58 | 6 | 38 | 26 | 1 | 28 |
| Banded darter | *Etheostoma zonale* | | | | | | | | | | | .1 | |
| | | | | | | | | | | | | 1 | |
| Blackside darter | *Percina maculata* | | | | | | | | | | 2 | .4 | .4 |
| | | | | | | | | | | | 9 | 4 | 5 |
| Slenderhead darter | *Percina phoxocephala* | | | | | | | | | | | .1 | |
| | | | | | | | | | | | | 1 | |
| Walleye | *Stizostedion vitreum* | | | | | .1 | | | | | | | |
| | | | | | | 1 | | | | | | | |
| **Drums** | ***Sciaenidae*** | | | | | | | | | | | | |
| Freshwater drum | *Aplodinotus grunniens* | .6 | .2 | .2 | | | .6 | | | | | | |
| | | 8 | 3 | 2 | | | 12 | | | | | | |

**Table 4.** Correlation matrix of Bhattacharyya's coefficient of similarity for fish-community data collected in the Eastern Iowa Basins study unit, 1996

[See figure 1 and table 1 for site descriptions; all coefficients in percent; coefficients of 60 or greater shown in bold]

| Site number (fig. 1) | Large-river sites | | | | | | Stream sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 5 | 7 | 12 | 4 | 6 | 8 | 9 | 10 | 11 |
| **1** | 100 | 26 | 36 | 29 | 29 | 17 | 12 | 22 | 33 | 16 | 21 | 21 |
| **2** | | 100 | **71** | **62** | 42 | **69** | 8 | 37 | 20 | 25 | 24 | 28 |
| **3** | | | 100 | **67** | 44 | 29 | 15 | 54 | 41 | 42 | 40 | 51 |
| **5** | | | | 100 | **84** | 42 | 38 | **88** | **74** | **66** | **74** | **84** |
| **7** | | | | | 100 | 36 | 36 | **68** | **87** | 51 | **64** | **69** |
| **12** | | | | | | 100 | 4 | 17 | 11 | 9 | 12 | 9 |
| **4** | | | | | | | 100 | 47 | 52 | 26 | **72** | 37 |
| **6** | | | | | | | | 100 | **67** | **75** | **83** | **91** |
| **8** | | | | | | | | | 100 | 50 | **72** | **71** |
| **9** | | | | | | | | | | 100 | 56 | **77** |
| **10** | | | | | | | | | | | 100 | **78** |
| **11** | | | | | | | | | | | | 100 |

River near Tripoli (site 11), an indication that fish communities across the study unit are similar. The sites that were the least similar to any of the other sites include the stream site Flood Creek near Powersville (site 4), and the large-river site Skunk River at Augusta (site 1). The fish communities at both of these sites were dominated by relatively few species, many of which are tolerant of degraded environmental conditions.

The fish community composition of Flood Creek near Powersville (site 4) was similar to only one other site, the South Fork Iowa River northeast of New Providence (site 10). Several sites near the mouths of the major river systems were similar, including those on the Cedar, Wapsipinicon, and Iowa Rivers (sites 2, 3, and 12). The similarity between sites 2 and 12 is likely due to their close geographical proximity. Reasons for similarities between these two sites and site 3 are not as obvious; however, there are several ways that fishes could migrate between the two watersheds, including via their common confluence in the Mississippi River. The other site, Skunk River at Augusta (site 1), is located near the confluence of the Mississippi River, and was dissimilar to all the other sites in the study unit. A very large percentage of red shiners (65 percent of the total catch) as well as the fewest number of several minnow species were collected at the Skunk River at Augusta (site 1). The red shiner is a species that is able to establish itself in polluted, turbid, or unstable waters (Harlan and others, 1987).

The fish community at site 8 was similar to the fish community at sites 10 and 11. This result may be due to the presence of several minnow species (bigmouth shiner, spotfin shiner, sand shiner, and bluntnose minnow) at all three sites in similar abundance.

Gizzard shad, primarily a large-river species (Harlan and others, 1987), was found at one stream site, Old Man's Creek near Iowa City (site 8). This site is located near the Iowa River and these fish may migrate from that large river.

Two sites that had similar fish communities were sites 7 and 8, which are separated by the Coralville Reservoir on the mainstem of the Iowa River. These data suggest that the fish communities at these sites were established before the dam was completed (in 1958) and the general fish community has not been greatly changed since then.

An illustration of the overall similarity can be seen in a biplot of a DCA ordination on samples collected in 1996. The biplot indicates a gradient from the stream sites to the large-stream sites along DCA axis 1 (fig. 4). The DCA ordination also indicates that the stream sites are more closely clustered than the large-river sites. The large-river sites were more likely to have their ordination affected by one or two dominant species, whereas several species occurred in similar relative abundance at many of the stream sites.

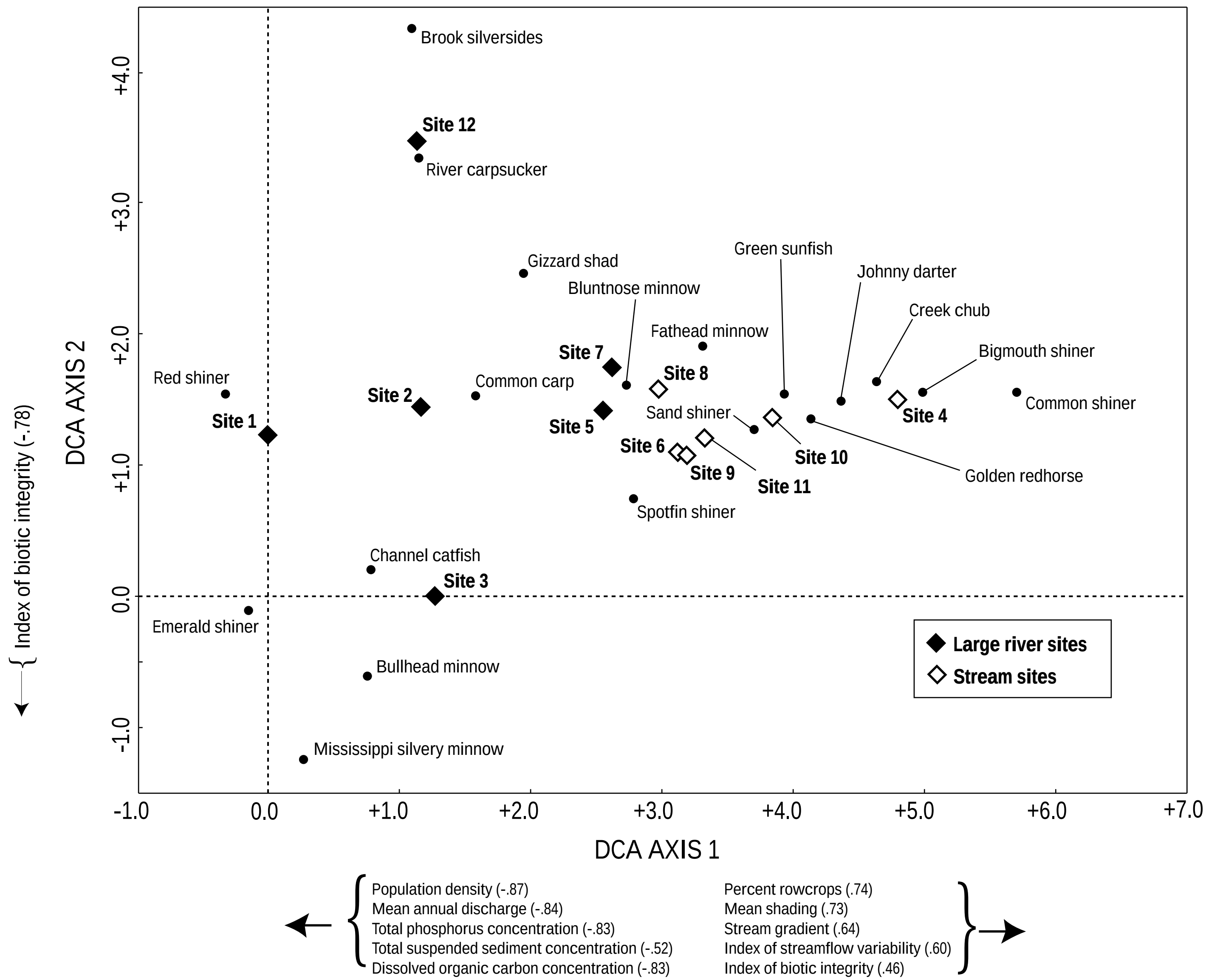


**Figure 4.** Patterns in fish communities shown by Detrended Correspondence Analysis (DCA) of 56 fish species at stream sites in the Eastern Iowa Basins study unit, 1996.

## Fish Community Conditions

The condition of fish communities can be evaluated by use of an IBI, which is based on species composition, trophic composition, and fish abundance and condition (Karr, 1981). Data collected at a given site are evaluated in relation to what might be expected at an unimpacted or relatively unimpacted site located in a similar geographical region and on a stream of comparable size. The strength of an IBI rating is that it integrates information from individual, population, community, zoogeographic, and ecosystem levels into a single ecologically based index of the health of the fish community (Karr and others, 1986).

The IBI was originally developed for application in warmwater rivers and streams in Illinois (Karr, 1981). It was quickly accepted and modified for other areas, and used by state and federal agencies including OEPA (1987), U.S. Environmental Protection Agency (Simon, 1991), Illinois EPA (Hite and Bertrand, 1989), Wisconsin Department of Natural Resources (Lyons, 1992), and the National Park Service (Fausch, 1986).

The State of Iowa has recently developed an IBI for small streams based on fish community, for streams with watersheds ranging from 10 to 500 $mi^2$ (Thomas Wilton, Iowa Department of Natural Resources, written commun., 2000). Because the Iowa IBI is still in development, scores derived from it were compared to several other IBIs that were previously developed and have defined categories related to biotic integrity. The other stream IBIs used for this report are the Wisconsin IBI (Lyons, 1992), one developed for streams in Minnesota (Bailey and others, 1992). Large-river IBIs used were the Ohio EPA large-river IBI (Ohio Environmental Protection Agency, 1987) and a recently developed version for Wisconsin (John Lyons, Wisconsin Department of Natural Resources, written commun., 2000).

Results of the calculated IBIs are in table 5. For the stream sites, ratings ranged from very poor to good. At this writing, the Iowa DNR had not yet developed classification ratings for their IBI system.

The stream site with the highest IBI score according to two of the three IBIs used was the reference site, the Wapsipinicon River near Tripoli (site 11). Partially as a result of the extensive riparian zone along this stretch of stream, the stream itself contains an abundance and variety of habitats including deep pools and snags of downed trees. The South Fork Iowa River northeast of New Providence (site 10) ranked highest on the Iowa IBI and among the three highest on the other two. These results were somewhat surprising given that the South Fork Iowa River has had several fish kills in recent years, with a major kill occurring in 1995 (Thomas Wilton, Iowa Department of Natural Resources, oral commun., 2000). However, samples collected by the Iowa DNR at a similar location on the South Fork Iowa River indicate that the scores achieved in this sample were not unusual. Possible reasons that the fish kills did not seem to decimate the fish community at this site are that (1) it was downstream far enough that the fish kills did not affect the sampled reach, and/or (2) fish may be recruited from the nearby Iowa River and thus the population was able to quickly reestablish itself. The other site that scored “good” on the IBI was Wolf Creek near Dysart (site 6).

The “good” IBI rating and relatively high scores for the South Fork Iowa River northeast of New Providence (site 10) and “fair” to “poor” rating and lower scores on the other sites in the Iowa River Basin (sites 7, 8, 9, and 12) suggest that the rest of the Iowa River Basin has a lower overall water quality than the South Fork Iowa River subbasin, and that water quality degrades as one proceeds downstream in the watershed.

The two highest-scoring large-river sites were the Wapsipinicon River near its mouth (site 3) and the Cedar River at Gilbertville (site 5), the site selected to represent the water quality of the upper Cedar River watershed (fig. 1). These sites were rated as having “fair” biotic integrity based on IBI scores depending on the IBI method used. The three lowest-scoring large-river sites were sites near the mouth of the Skunk and Iowa Rivers (sites 1 and 12) and at site 7 on the Iowa River upstream of Coralville Reservoir.

A direct comparison between stream and large-river IBI scores is not possible due to the different metrics used in assigning scores for different size streams. However, on the basis of IBI classifications, it appears the stream sites have higher quality fish communities and better water quality than the large-river sites.

# RELATIONS BETWEEN FISH COMMUNITY COMPOSITION AND CONDITIONS AND ENVIRONMENTAL FACTORS

A summary of selected physical habitat and water-quality data is shown in table 6. Median concentrations of water-quality constituents collected during the 1996 water year (Akers and others, 1999) were used to repre-

**Table 5.** Index of biotic integrity scores for fish-community data collected in the Eastern Iowa Basins study unit, 1996

[See figure 1 and table 1 for site descriptions; DNR, Department of Natural Resources; MRAP, Minnesota River Assessment Project; WDNR, Wisconsin Department of Natural Resources; EPA, Environmental Protection Agency]

| | | Index of Biotic Integrity | | | | |
|---|---|---|---|---|---|---|
| | | Stream sites | | | Large-river sites | |
| Site number | Stream name | Iowa DNR[1] | MRAP[2] | WDNR[3] | Ohio EPA[4] | WDNR[5] |
| | **Stream sites** | | | | | |
| 4 | Flood Creek near Powersville, Iowa | 39 | 35 – fair | 35 – fair | -- | -- |
| 6 | Wolf Creek near Dysart, Iowa | 40 | 44 – good | 60 – good | -- | -- |
| 8 | Old Man’s Creek near Iowa City, Iowa | 26 | 30 – fair | 12 – v. poor | -- | -- |
| 9 | Iowa River near Rowan, Iowa | 40 | 34 – fair | 47 – fair | -- | -- |
| 10 | South Fork Iowa River near New Providence, Iowa | 48 | 42 – good | 62 – good | -- | -- |
| 11 | Wapsipinicon River near Tripoli, Iowa | 46 | 48 – good | 64 – good | -- | -- |
| | **Large-river sites** | | | | | |
| 1 | Skunk River at Augusta, Iowa | -- | -- | -- | 30 – fair | 25 – poor |
| 2 | Cedar River near Conesville, Iowa | -- | -- | -- | 32 – fair | 40 – fair |
| 3 | Wapsipinicon River near DeWitt, Iowa | -- | -- | -- | 36 – fair | 50 – fair |
| 5 | Cedar River at Gilbertsville, Iowa | -- | -- | -- | 36 – fair | 45 – fair |
| 7 | Iowa River at Marengo, Iowa | -- | -- | -- | 22 – poor | 15 – poor |
| 12 | Iowa River at Wapello, Iowa | -- | -- | -- | 30 – fair | 15 – poor |

[1]Iowa IBI maximum score = 100, minimum = 0. Classifications have not been developed as of this writing (Thomas Wilton, Iowa Department of Natural Resources, written commun., 2000).

[2]Highest overall score possible is 60. Scores are classified as 50–60 (excellent), 40–49 (good), 30-39 (fair), 20–29 (poor), and 12–20 (very poor) (Bailey and others, 1992).

[3]Highest overall score possible is 100. Scores are classified as 65–100 (excellent), 50–64 (good), 30-49 (fair), 20–29 (poor), and 0-19 (very poor) (Lyons, 1992).

[4]Highest overall score possible is 60. Scores are classified as 50–60 (exceptional), 40–48 (good), 26–38 (fair), 16–24 (poor), and less than 16 (very poor) (Ohio EPA, 1988).

[5]Highest overall score possible is 100. Scores are classified as 36–65 (good) and less than 36 (poor) (John Lyons, Wisconsin Department of Natural Resources, written commun., 2000).

**Table 6.** Characteristics of reach level physical habitat and water quality for sites where fish-community data were collected in the Eastern Iowa Basins study unit, 1996

[See figure 1 and table 1 for site descriptions; water-quality data were collected during the 1996 water year; water year is defined as the period beginning October 1 and ending September 30; $mi^2$, square miles; ft/mi, feet per mile; ft/s, feet per second; $ft^3/s$, cubic feet per second; mg/L, milligrams per liter]

| | Large-river sites | | | | | | | Stream sites | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Characteristic** | **1** | **2** | **3** | **5** | **7** | **12** | **Mean** | **4** | **6** | **8** | **9** | **10** | **11** | **Mean** |
| Population density[1] (person/$mi^2$) | 18.5 | 28.2 | 13.2 | 24.9 | 13.3 | 24.6 | 20.4 | 6.9 | 9.2 | 12.9 | 10.7 | 4.0 | 9.5 | 8.9 |
| Stream gradient (ft/mi) | .8 | 1.7 | 2.6 | 1.9 | 1.6 | 1.4 | 1.7 | 4.1 | 3.1 | 3.0 | .9 | 6.3 | 1.9 | 3.2 |
| Mean channel width (ft) | 290 | 436 | 320 | 341 | 328 | 702 | 404 | 27 | 97 | 54 | 98 | 48 | 51 | 62 |
| Mean channel depth (ft) | 2.4 | 1.8 | 3.1 | 3.1 | 4.6 | 4.7 | 3.3 | .49 | .98 | .69 | 1.94 | 1.2 | 1.3 | 1.1 |
| Mean velocity (ft/s) | 1.2 | 1.6 | 1.4 | 1.5 | 1.7 | 1.1 | 1.4 | .8 | .9 | 1.1 | .8 | 1.1 | .9 | .9 |
| Mean shading (percent) | 26 | 13 | 33 | 14 | 33 | 9.3 | 22 | 86 | 26 | 65 | 66 | 48 | 73 | 61 |
| Percent rowcrops | 59 | 66 | 70 | 72 | 67 | 54 | 65 | 82 | 82 | 56 | 82 | 87 | 64 | 76 |
| Mean annual discharge ($ft^3/s$) | 1,280 | 3,280 | 928 | 2,160 | 1,120 | 5,160 | 2,320 | 9.9 | 88 | 25 | 136 | 50 | 102 | 68 |
| Index of streamflow variability[2] | 31 | 7.2 | 9.0 | 7.5 | 12 | 8.0 | 12 | 16,300 | 15 | 44 | 17 | 36 | 18 | [3]**26** |
| Median total nitrogen (mg/L) | 5.5 | 5.5 | 3.7 | 4.1 | 3.5 | 4.2 | 4.4 | 8.1 | 7.2 | 3.0 | 5.6 | 7.8 | 2.9 | 5.8 |
| Median total phosphorus (mg/L) | .28 | .26 | .26 | .21 | .37 | .27 | 0.28 | .06 | .10 | .09 | .13 | .06 | .10 | .09 |
| Median suspended sediment (mg/L) | 128 | 78 | 110 | 46 | 220 | 87 | 112 | 32 | 47 | 18 | 98 | 26 | 16 | 40 |
| Median nitrate (mg/L) | 4.97 | 3.44 | 2.68 | 3.645 | 2.87 | 3.67 | 3.54 | 7.45 | 6.64 | 2.30 | 5.16 | 7.34 | 2.62 | 5.25 |
| Median dissolved organic carbon (mg/L) | 3.2 | 4.5 | 3.0 | 2.6 | 3.4 | 4.9 | 3.6 | .4 | .95 | .8 | 1.4 | .9 | 1.2 | .94 |

[1]U.S. Department of Commerce, Bureau of the Census, 1994.

[2]Index of streamflow variability is defined herein as the ratio of the 90th percentile of flow to the 10th percentile of flow.

[3]Mean index of variability at the stream sites does not include data for site 4, where periods of zero flow skewed the index.

sent typical water-quality conditions which fish were exposed to in the study-unit streams.

Mean suspended-sediment concentrations were almost three times higher at the large-river sites than the stream sites. Total phosphorus concentrations were also higher at the large-river sites. Relatively high suspended-sediment and phosphorus concentrations may partially contribute to relatively low biotic integrity at large-river sites. Human population density in the large-river basins on average is more than twice that in the stream site watersheds, due to one or more large cities located in the large-river basins. Mean annual discharge at all the large-river sites is much greater than at all the stream sites. The index of streamflow variability is also lower at most of the large-river sites, with the exception of the Skunk River at Augusta (site 1).

These data also give an indication of why fish communities are similar among the stream sites and among the large-river sites, but less so between the two groups. In general, water-quality and stream and river physical characteristics are similar among streams of similar size, though differences are evident between the two groups of sites. For example, fish in the large rivers have to contend with higher suspended-sediment concentration as well as higher velocities, conditions that favor more tolerant fish with more fusiform body shape, such as some sucker species.

Madejczyk (1998) found few relations between Iowa fish communities and environmental factors. This finding was attributed to the homogeneous land use (rowcrop agriculture) in Iowa and relatively harsh hydrologic conditions. These factors caused fish communities to lack many of the strong structural patterns and environmental relations found in studies conducted in more pristine or heterogeneous settings.

The results of a Spearman's rank correlation test of DCA axis 1 and 2 scores with environmental factors (fig. 4) indicates that DCA axis 1 is strongly related to factors associated with stream size. However, it is difficult to separate characteristics that are due to stream size, such as mean channel width, from factors that are influenced by human activity, such as total phosphorus concentration. Because human activity is often situated along large rivers, many of these factors are interrelated.

Correlations between IBI scores and environmental factors were weak, an indication that factors other than those measured affected biotic integrity. However, the correlations do indicate that IBI scores decreased with factors such as increased human population density and higher total phosphorus concentrations, both factors associated with large-river sites.

## SUMMARY AND CONCLUSIONS

Fish community data were collected at 12 sites in 1996 in eastern Iowa streams by the U.S. Geological Survey (USGS). This report presents an evaluation of fish communities at six stream sites and six large-river sites, the composition and conditions of the fish communities, and by relating these compositions and conditions to a variety of environmental factors. The study was part of the water-quality assessment of the Eastern Iowa Basins, a part of the National Water-Quality Assessment Program of the USGS. Of the 12 sites, four were selected on small streams to be indicative of water-quality conditions in each of the various landforms present in the study unit. In one of the landforms, an additional site with a large number of animal feeding operations upstream was selected. An additional stream site was selected as a reference site for water quality. The upper Wapsipinicon River watershed, where this site is located, contains the largest and least disturbed riparian zone of all the sites sampled in this study. Abundant bottomland hardwood forests line the river corridor. Four sites were located near the mouths of major river basins in the study unit to serve as integrators of water-quality conditions in the basin as a whole. The final two sites selected were on large rivers and were sampled in an attempt to determine the effects of combined urban and rowcrop agriculture on water quality and to determine the effect of a major reservoir on water quality, respectively.

A total of 56 fish species representing 13 families were collected at the 12 sites in 1996. Species in the minnow family were the most commonly collected, followed by suckers and sunfish. The number of individuals collected at a single site ranged from 472 at the Iowa River near Rowan (site 9) to 2,072 at Wolf Creek near Dysart (site 6). Minnows accounted for over 50 percent of all fish collected at 10 of the 12 sites.

Most species accounted for less than 5 percent of the total number of fish collected at a given site. Species that accounted for more than 5 percent of the fish collected at more than one site included spotfin shiner (9 sites), sand shiner (6), bluntnose minnow (6), river carpsucker (4), bigmouth shiner (4), bullhead minnow (2), emerald shiner (2), and common shiner (2).

The largest number of intolerant, or sensitive to environmental degradation, species was collected at the

South Fork Iowa River northeast of New Providence (site 10) and the Wapsipinicon River near Tripoli (site 11), with 8 and 6 intolerant species collected, respectively. The sites with the most tolerant, or less sensitive to environmental degradation, species were Old Man's Creek near Iowa City (site 8) and the Iowa River at Marengo (site 7).

Fish community composition was similar among many sites in the study unit. The fish community composition at the Wapsipinicon River near Tripoli (site 11) was similar to 6 of the other sampling sites, including 4 of the 5 other stream sites. Flood Creek near Powersville (site 4) was the only stream site where the fish community composition was not similar to that of the Wapsipinicon River reference site.

Biplots of detrended correspondence analysis (DCA) ordinations indicate a gradient from the stream sites to the large-river sites. The DCA ordination also indicates that the stream sites are more closely clustered than the large-river sites. The large-river sites were more likely to have their ordination driven by one or two dominant species, while several species occurred in similar relative abundance at many of the stream sites.

The sites at which the fish community composition was least similar to other sites in the study unit were the three sites near the mouths of the major rivers, just upstream of their confluence with the Mississippi River. At these sites, the presence of one or more unique-to-the-site large-river species set them apart from the other sites.

The stream with the best overall IBI was the Wapsipinicon River near Tripoli (site 11), the site selected as the reference site for the study. The South Fork Iowa River northeast of New Providence (site 10) also scored well, despite a large fish kill in the stream in 1995. This site's "good" IBI classification was in contrast to other sites in the Iowa River Basin which ranged from fair to poor. The lowest IBI classifications were given to three large-river sites: Skunk River at Augusta (site 1); and 2 sites on the Iowa River, at Marengo (site 7) and Wapello (site 12), respectively. The fish community at the stream site with the lowest IBI score, Old Man's Creek near Iowa City (site 8), was similar to that at the stream sites with the highest IBI scores, due to the co-presence of many minnow and sucker species at these three sites.

Fish communities at most sites, especially the large-river sites, are somewhat degraded compared to reference conditions. These results are not unexpected given the large degree of disturbance to the landscape in Iowa and southern Minnesota caused by the conversion of prairie to row-crop agriculture and the settlement of large numbers of people along the rivers of the state.

The fish communities at the 12 study sites appear to be related to a number of environmental factors. Obvious differences in fish communities occur between the stream sites and the large-river sites, the result of differences in both physical and chemical characteristics of the streams. Important physical factors related to fish communities included several directly related to stream size as well as human population density and percent of rowcrops in the watershed. Chemical factors that were important included median total phosphorus, suspended-sediment, and dissolved organic carbon concentrations.

## REFERENCES CITED


Akers, K.K.B., Schnoebelen, D.J., Savoca, M.E., Roberts, L.R., and Becker, K.D., 1999, Water-quality assessment of the Eastern Iowa Basins—Hydrologic and biologic data, September 1995 through September 1996: U.S. Geological Survey Open-File Report 99–66, 154 p.

Bailey, R.M., 1956, A revised list of the fishes of Iowa, with keys for identification, *in* Harlan, J.R., and Speaker, E.B., Iowa fish and fishing (rev. Ed.): Iowa State Conservation Commission, p. 313–365.

Bailey, P.A., Enblom, J.W., Hanson, S.R., Renard, P.A., Schmidt, Konrad, 1992, Minnesota River Assessment Project, 1990–92: A fish community analysis of the Minnesota River Basin, 211 p.

Bhattacharyya, A., 1946, On a measure of divergence between two multinomial populations: Sankya, v. 7, p. 401–406.

Bishop, R.A., 1981, Iowa's wetlands: The Proceedings of the Iowa Academy of Sciences, vol. 88, no. 1, p. 11–16.

Bulkley, R.V., 1975, A study of the effects of stream channelization and bank stabilization on warm water sport fish in Iowa, subproject no. 1, Inventory of major stream alterations in Iowa: Completion Report, U.S. Fish and Wildlife Service Contract no. 14–16–0008–745, 373 p.

Crane, J.L., Jr., and Olcott, G.W., 1933, Report on the Iowa Twenty-Five Year Conservation Plan: Iowa Board of Conservation and Iowa Fish and Game Commission, 176 p.

Fausch, K.D., 1986, Development and use of the index of biotic integrity to monitor fish communities in the St. Croix National Scenic Riverway: Colorado State University, 41 p.

Gauch, H.G., 1982, Multivariate analysis in community ecology: New York, Cambridge University Press, 298 p.

Harlan, J.R., Speaker, E.B., and Mayhew, James, 1987, Iowa Fish and Fishing: Iowa Department of Natural Resources, 323 p.

Hite, R.L., and Bertrand, W.A., 1989, Biological stream characterization (BSC)—Biological assessment of Illinois stream quality: Special Report #13 of the Illinois State Water Plan Task Force, Illinois Environmental Protection Agency, IEPA/AC/89–275, 42 p.

Kalkhoff, S.J., 1994, National Water-Quality Assessment Program—Eastern Iowa Basins: U.S. Geological Survey Fact Sheet FS–94–031, 1 sheet.

Karr, J.R., 1981, Assessment of biotic integrity using fish communities: Fisheries, v. 6, no. 6, p. 21–27.

Karr, J.R., Fausch, K.D., Angermeier, P.L., Yant, P.R., and Schlosser, I.J., 1986, Assessing biological integrity in running waters—a method and its rationale: Illinois Natural History Survey Special Publication 5, 27 p.

Lyons, John, 1992, Using the Index of Biotic Integrity (IBI) to measure environmental quality in warmwater streams of Wisconsin: USDA Forest Service General Technical Report NC–149, 51 p.

Madejczyk, J.C., 1998, Fish community relationships with hydrological and landscape characteristics in Iowa rivers and streams: Iowa State University Master’s Thesis ISU 1998 M33.

Meador, M.R., Cuffney, T.F., and Gurtz, M.E., 1993a, Methods for sampling fish communities as part of the National Water-Quality Assessment program: U.S. Geological Survey Open-File Report 93–104, 40 p.

Meador, M.R., Hupp, C.R., Cuffney, T.F., and Gurtz, M.E., 1993b, Methods for characterizing stream habitat as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93–408, 48 p.

Meek, S.E., 1892, Report upon the fishes of Iowa, based upon observations and collections made during 1889, 1890, and 1891: Bulletin of the U.S. Fish Commission, 10(1890), p. 217–248.

Meek, S.E., 1893, Fishes of the Cedar River Basin: The Proceedings of the Iowa Academy of Sciences, vol. 1, p. 105–112.

Menzel, B.W., 1981, Iowa’s waters and fishes—A century and a half of change: The Proceedings of the Iowa Academy of Sciences, vol. 88, no. 1, p. 17–23.

Ohio Environmental Protection Agency, 1987, Biological criteria for the protection of aquatic life—Vol. I, II, and III: Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

Prior, J.C., 1991, Landforms of Iowa: Iowa City, University of Iowa Press, 153 p.

Roosa, D.M., 1977, Endangered and threatened fish of Iowa: Iowa State Preserves Board, Special Report 1, 626 p.

Simon, T.P., 1991, Development of the Index of Biotic Integrity expectations for the ecoregions of Indiana—v. I, Central Corn Belt Plain: U.S. Environmental Protection Agency, Region V, Environmental Sciences Division, Monitoring and Quality Assessment Branch, Ambient Monitoring Section, Chicago, Ill., EPA 905/9–91/025, 105 p.

Smith, E.P., Pontasch, K.W., and Cairns Jr., John, 1990, Community similarity and the analysis of multispecies environmental data—A unified statistical approach: Water Resources, v. 24, no. 4, p. 507–514.

Ter Braak, C.J.F., 1988, CANOCO—A FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, and redundancy analysis (version 2.1): Wageningen, The Netherlands, Ministry of Agriculture and Fisheries Agricultural Mathematics Group, 95 p.

U.S. Department of Commerce, Bureau of the Census, 1994, Census of population and housing, 1990 Public Law 94–171 data (United States): Washington D.C., Bureau of the Census.

Wendland, W.M., Kunkel, K.E., Conner, Glen, Decker, W.L., Hillaker, Harry, Naber-Knox, Pam, Nurnberger, F.V., Rogers, Jeffery, Scheeringa, Kenneth, and Zandlo, James, 1992, Mean 1961–1990 temperature and precipitation over the upper Midwest: Midwest Climate Center, Illinois State Water Survey Research Report 92–01, 27 p.

## CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATED WATER-QUALITY UNITS, AND MISCELLANEOUS ABBREVIATIONS

| Multiply | By | To Obtain |
|---|---|---|
| inch (in) | 2.54 | centimeter |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 2.590 | square kilometer |
| cubic foot per second ($ft^3/s$) | .02832 | cubic meter per second |

Temperature, in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by use of the following equation:

°F = 9/5 (°C) + 32.

Temperature, in degrees Celsius (°F) can be converted to degrees Fahrenheit (°C) by use of the following equation:

°C = 5/9 (°F-32).

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

**Abbreviated water-quality units**: Chemical concentrations of subtances in water are given in metric units of milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as mass (milligrams) of solute per unit volume (liter) of water. One milligram per liter is equivalent to one thousand micrograms per liter.

### Miscellaneous Abbreviations

| | |
|---|---|
| DCA | Department Correspondence Analysis |
| DNR | Department of Natural Resources |
| EPA | Environmental Protection Agency |
| IBI | Index of Biotic Integrity |
| NAWQA | National Water-Quality Assessment Program |
| USGS | U.S. Geological Survey |

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