Physical, Chemical, and Biological Responses to Urbanization in the Fox and Des Plaines River Basins of Northeastern Illinois and Southeastern Wisconsin

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U.S. Department of the Interior
U.S. Geological Survey

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Cover photos, clockwise from top left:

1. Des Plaines River near Russell, Illinois, north of Russell Road, July 18, 2000.
2. Green sunfish, from Des Plaines River near Riverside, Illinois, September 7, 2000.
3. Willow Creek and water tower in Rosemont, Illinois, May 1, 2001.
4. Filtering algae sample for chlorophyll and ash-free dry-mass analysis, July 18, 2000.

FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity and quality, even more critical to the long-term sustainability of our communities and ecosystems.

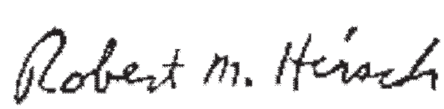
The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Associate Director for Water

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Conversion Factors, Abbreviated Water-Quality Units, and Other Abbreviations

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
micrometer (µm)	0.00003937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
	Hydraulic gradient	
meter per kilometer (m/km)	5.27983	foot per mile (ft/mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

< Less than

≤ Less than or equal to

> Greater than

≥ Greater than or equal to

Physical, Chemical, and Biological Responses to Urbanization in the Fox and Des Plaines River Basins of Northeastern Illinois and Southeastern Wisconsin

By Mitchell A. Harris, Barbara C. Scudder, Faith A. Fitzpatrick, and Terri L. Arnold

Abstract

Physical, chemical, and biological responses to urbanization were examined along an agricultural to urban watershed land-cover gradient of 45 stream sites in the Fox and Des Plaines River Basins in northeastern Illinois and southeastern Wisconsin, including the Chicago metropolitan area. The study was conducted during 2000–01 as part of the U.S. Geological Survey's National Water-Quality Assessment Program, upper Illinois River Basin study. Correlation, nonparametric analysis of variance, and multivariate analyses were used to assess interactions among the watershed characteristics. Physical characteristics of stream sites were affected by landscape characteristics and land-use practices, as well as by urbanization. Bankfull-channel area was smaller and less variable for stream sites with 10 percent or less watershed urban land, than for stream sites with more watershed urban land. Concentrations of chloride and sodium in water increased, whereas concentrations of calcium and magnesium decreased with increasing percent watershed urban land. Concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc in streambed sediment increased with increasing percent watershed urban land. Indices representing benthic algal, macroinvertebrate, and fish biological communities declined as urban land cover increased. Indices of macroinvertebrate and fish communities initially declined sharply from 0 to 30 percent urban land cover. Urban indicator variables and variables correlated with urban land cover were important on the first axis of all indirect and direct ordinations of all three biological communities. Environmental variables that were correlated to biological communities included urban land-use indicators, concentrations of trace elements in streambed sediment, and dissolved ions in water. Other important environmental variables were related to stream slope, stream power and the transport index, percent fines in the substrate, canopy cover and nutrients.

Introduction

Urbanization has been cited as one of the major causes of stream impairment in the United States and Europe and it is recognized as a growing threat to stream water quality and biological integrity as land area that is covered by urban development increases (House and others, 1993; U.S. Environmental Protection Agency, 2000; Paul and Meyer, 2001). Resource managers, engineers, and scientists have been concerned about urban development since at least the 1960s (Leopold, 1968; American Society of Civil Engineers, 1969; Spieker, 1970; The H. John Heinz III Center, 2002). Streams in urban and urbanizing areas are subjected to physical and chemical changes, which in turn can affect aquatic habitat and biological communities.

Physical effects of urbanization include direct channel modification, as well as indirect effects on hydrology, geomorphology, and temperature (House and others, 1993; Paul and Meyer, 2001). Urban development modifies land surfaces and increases the amount of impervious surface in the watersheds. Some researchers have cited increasing impervious cover, and the hydrologic and geomorphic changes that result, as an important cause of decline in biological community integrity (Schueler, 1994; Booth and Jackson, 1997). Investigators have examined the "total impervious area" as well as the "effective impervious area" – impervious areas that have direct hydraulic connection to the stream system (Booth and Jackson, 1997). Altered stream fluvial dynamics that result from increased impervious area include increased surface runoff; modified peak-flow characteristics, modified sediment erosion and deposition characteristics; modified flood characteristics; and reduced infiltration and lower base flows (House and others, 1993; Leopold, 1968; Booth and Jackson, 1997; Konrad, 2003). In northeastern Illinois, Allen and Bejcek (1979) found that urban development of rural area streams increased streamflow for the 2-year flood by a factor of three. Channel enlargement typically occurs from increases in the peak and volume of stream runoff (Leopold, 1994). Geomorphic changes can be highly variable and are dependent on local conditions.

The changes in stream and sediment chemistry induced by urban development vary depending on the type and extent of development in a watershed (House and others, 1993; Paul and Meyer, 2001). Point sources include domestic and industrial wastewater discharges. Nonpoint-sources include runoff from parking lots and roads, which may contain petroleum derivatives, metals, and deicing salts, and runoff from residential areas, parks and golf courses, which may contain nutrients and pesticides. In urban areas, both point and nonpoint sources can contribute chemical contaminants to streams. In general, there is an increase in concentrations of nutrients and other ions, metals, pesticides, and organic contaminants with increasing urban land (Porcella and Sorenson, 1980; U. S. Geological Survey, 1999). Pharmaceuticals, hormones, and other organic wastewater contaminants that have not been widely examined were the focus of recent studies that examined stream sites downstream of intense urbanization (Kolpin and others, 2002). Little is known about potential synergistic interactions that may occur in the environment from complex mixtures of organic contaminants in wastewater effluent (Kolpin and others, 2002).

Aquatic biological communities integrate the state of and changes in hydrology, water chemistry, geomorphology, habitat, food source, and biotic interactions (Karr, 1991; Yoder and Rankin, 1995). Decreases in biotic diversity and integrity of invertebrate and fish communities have been related to urbanization (Klein, 1979; Dreher, 1997; Wang and others, 1997; Kennen, 1999; Yoder and others, 1999; Wang and others, 2001). Less work has been done on microbes, algae, and macrophytes (Paul and Meyer, 2001).

Agriculture is the predominant land use in northeastern Illinois and southeastern Wisconsin in terms of land area, but the metropolitan areas of Chicago, Illinois and Milwaukee, Wisconsin are large and expanding rapidly (fig. 1). Watersheds are being converted from agricultural to urban land and, therefore, stream conditions may reflect both land uses. The percent watershed agricultural land has been shown to be a major factor affecting fish, macroinvertebrate, and habitat integrity in previously forested watersheds (Richards and others, 1996; Roth and others, 1996; Cuffney and others, 1997; Wang and others, 1997; Fitzpatrick and others, 2001). Ruhl (1995) working in Chicago-area streams found that fish-community structure, water quality, streambed sediments, and habitat were strongly related to the watershed land use. Many agricultural streams near the Chicago area, however, still support high-quality fish assemblages (Dreher, 1997; Wang and others, 1997; Fitzpatrick and others, 2004). Geologic setting has been suggested as an important factor in moderating the biological response of streams to agriculture and urbanization (Wang and others, 1997). Comparing fish collections in the 1980s to collections in the 1990s, Fitzpatrick and others (2004) found improvement in IBI scores and increases in numbers of intolerant fish species in streams in the Fox and Des Plaines River Basins. Surficial deposits and population characteristics probably affected the relative amount of improvement in fish populations at different sites. Improvements to wastewater-treatment plants and other point sources in recent decades have lead to some improvement of biotic integrity of urban, urbanizing, and rural streams in northeastern Illinois (Illinois Environmental Protection Agency, 1987; Dreher, 1997; Fitzpatrick and others, 2004). Nevertheless, biotic integrity continues to decrease as watersheds are converted from agricultural to urban land.

Understanding the effects of urbanization on the physical, chemical, and biological conditions of streams in northeastern Illinois and southeastern Wisconsin was determined to be a major issue for the U.S. Geological Survey (USGS) study of the upper Illinois River Basin (UIRB) as part of the National Water-Quality Assessment Program (NAWQA) (Arnold and others, 1999). Historical biotic index data from the Illinois Environmental Protection Agency and the Illinois Department of Natural Resources and sediment trace-element data from the U.S. Geological Survey for 43 stream sites in the Fox and Des Plaines River Basins from the 1980s and 1990s were examined within the context of an agricultural to urban land-cover gradient (Fitzpatrick and others, 2004). This study illustrated the potentially complex spatial and temporal relations among biotic integrity, sediment chemistry, watershed urban land, and geologic setting. In the 1980s, stream sites in agricultural settings had a range of biotic integrity from low to high based on fish and invertebrate indices, but streams with more than 10-percent watershed urban land consistently had low biotic integrity. Copper concentrations in sediment above background levels occurred in stream sites with greater than 40 percent watershed urban land and the fish and invertebrate indices correlated with urban-associated sediment trace-element concentrations. The number of intolerant fish species and biotic integrity increased in some rural, urbanizing, and urban streams from the 1980s to 1990s, with the largest increases occurring in rural streams with loamy/sandy surficial deposits. However, smaller increases also occurred in urban streams with clayey surficial deposits and over 50-percent watershed urban land (Fitzpatrick and others, 2004).

In 2000–01, as part of the UIRB-NAWQA study, physical, chemical, and biological data were collected from sites in the Fox and Des Plaines River Basins along an agricultural to urban land-cover gradient (figs. 1, 2). Many of the sites overlapped with sites used for the historical analysis described above. These new data were collected with the main purpose of determining if ecological responses to urbanization varied among different biological communities and indicators within the context of their geologic setting. Specific data from this study are available from various sources, including Adolphson and others (2002), the USGS Illinois Water Science Center Web site (*http://il.water.usgs.gov*), and the USGS NAWQA site *(http://water.usgs.gov/nawqa/*).

Purpose and Scope

This report presents the results of a study to determine how urbanization of the areas of northeastern Illinois and southeastern Wisconsin, especially surrounding the Chicago metropolitan area, affects physical, chemical, and biological conditions of streams. The study included 45 stream sites along an agricultural to urban land-cover stream gradient, using a space-for-time substitution (described in the Methods section later in the report). Data were collected during 2000–01; sites were located in two river basins in the greater Chicago area. The study was part of the upper Illinois River Basin study of the USGS NAWQA Program.

How geomorphic, hydrologic, habitat, and chemical stream characteristics, and algal, invertebrate and fish communities change as stream basins are converted to urban land use from agricultural land use and the major factors affecting aquatic biological communities in northeastern Illinois and southeastern Wisconsin are summarized in this report. The report includes a description of field and analytical methods, evaluates patterns of the representative physical, chemical, and biological variables, and lists the algal, macroinvertebrate, and fish assemblages sampled. Data and more detailed methodology from this study were reported in Adolphson and others (2002).

Study Area

Study watersheds are located in the Fox and Des Plaines River Basins of northeastern Illinois and southeastern Wisconsin (fig. 2). The combined drainage area of the study area is approximately 12,400 km^2 (4,770 mi^2). The Chicago River, the Calumet River system, and the Du Page River are included in the Des Plaines River Basin (fig. 1). The Fox and Des Plaines Rivers are major tributaries of the Illinois River.

The Chicago metropolitan area, one of the largest urban areas in the United States, lies largely within these basins (fig. 1). In the 2000 census, the population of Cook County alone was 5,377,000 and the population of the Chicago Combined Metropolitan Statistical Area (includes Chicago, Ill., Kenosha, Wis., Gary, Ind., and Kankakee, Ill.) was 9,158,000 (U.S. Bureau of the Census, 2001). The northern part of the study area includes urbanizing areas around Milwaukee, Wis. These areas contain important farmland, and conversion of agricultural land to urban land is a concern. The amount of land being developed is disproportionate to the increase in population, as low density residential land use has increased in proportion to other land uses (Arnold and others, 1999). Agricultural and urban land are the dominant land uses in the Fox and Des Plaines River Basins (fig. 1), with small amounts of forest and wetland, mainly occurring in county forest preserves (Vogelmann and others, 2001). Forest preserves are common along rivers in the Chicago area and extensive flood-plain areas in the preserves are, in part, used for flood control.

The environmental setting of the study area is described in detail in Arnold and others (1999) and summarized below. The climate is humid continental with an average annual temperature (1961–90) of about 9°C (48°F) and average annual precipitation of about 890 mm (35 in.). Two physiographic sections cover the study area. The Great Lakes Section encompasses the entire Des Plaines River Basin and the northern half of the Fox River Basin; and the Till Plains Section covers the southern half of the Fox River Basin (Fenneman, 1938; Leighton and others, 1948). The topography in the study area is relatively flat and studied watersheds have slopes that range from 0.2 to 3.4 percent (Adolphson and others, 2002). The distribution of Quaternary deposits is highly variable and complex, but the deposits generally consist of clayey till in the Des Plaines River Basin, glacial lake clay in the Chicago River and Calumet Basins, sandy and loamy till and outwash sand and gravel in the upper Fox River Basin, and loamy till in the lower Fox River Basin (Willman, 1971; Lineback and others, 1983).

A variety of stormwater-control techniques are used in the study area. Wet and dry stormwater-detention ponds of various sizes are numerous. Combined-sewer systems are used in Chicago and in many of the suburbs. Historically, the capacity of combined-sewer systems was often exceeded during summer thunderstorms resulting in the release of untreated sewage directly to streams. To avoid this release, Chicago's Tunnel and Reservoir Plan (TARP) system was developed (Metropolitan Water Reclamation District of Greater Chicago, 1999). The TARP is a system of drop shafts, tunnels, and reservoirs designed to capture and hold overflows from combined sewers and convey the overflows to a wastewater-treatment plant for treatment (Terrio, 1994). Six streams in this study are in part of TARP: Willow Creek, Salt Creek, Addison Creek, Flag Creek, North Creek, and Midlothian Creek (map reference numbers [nos.] 5, 6, 7, 8, 15, 16, respectively, fig. 2). There are five major wastewater-treatment plants operated by the Metropolitan Water Reclamation District of Greater Chicago. Two of the plants are located upstream of the sampled reaches on Willow Creek and Salt Creek.

Methods

This study was conducted as part of the upper Illinois River Basin study of the U.S. Geological Survey National Water-Quality Assessment Program. The complete data set and methods are provided in Adolphson and others (2002). Urbanization indicators and watershed-scale characteristics were calculated for each stream site. Two major physiographic settings were sampled: clayey surficial deposits (full gradient) and loamy/sandy deposits (partial gradient). Water chemistry, sediment chemistry, geomorphic, flow, habitat, algae, invertebrate, and fish data were collected from 45 stream sites in the Fox and Des Plaines River Basins in 2000–01 (tables 1 and 2). Correlation, nonparametric analysis of variance, and multivariate analyses were used to assess interactions among the characteristics.

The urban-gradient approach, where multiple watersheds representing different levels of urbanization are used in a space-for-time substitution, was used to examine biologi-

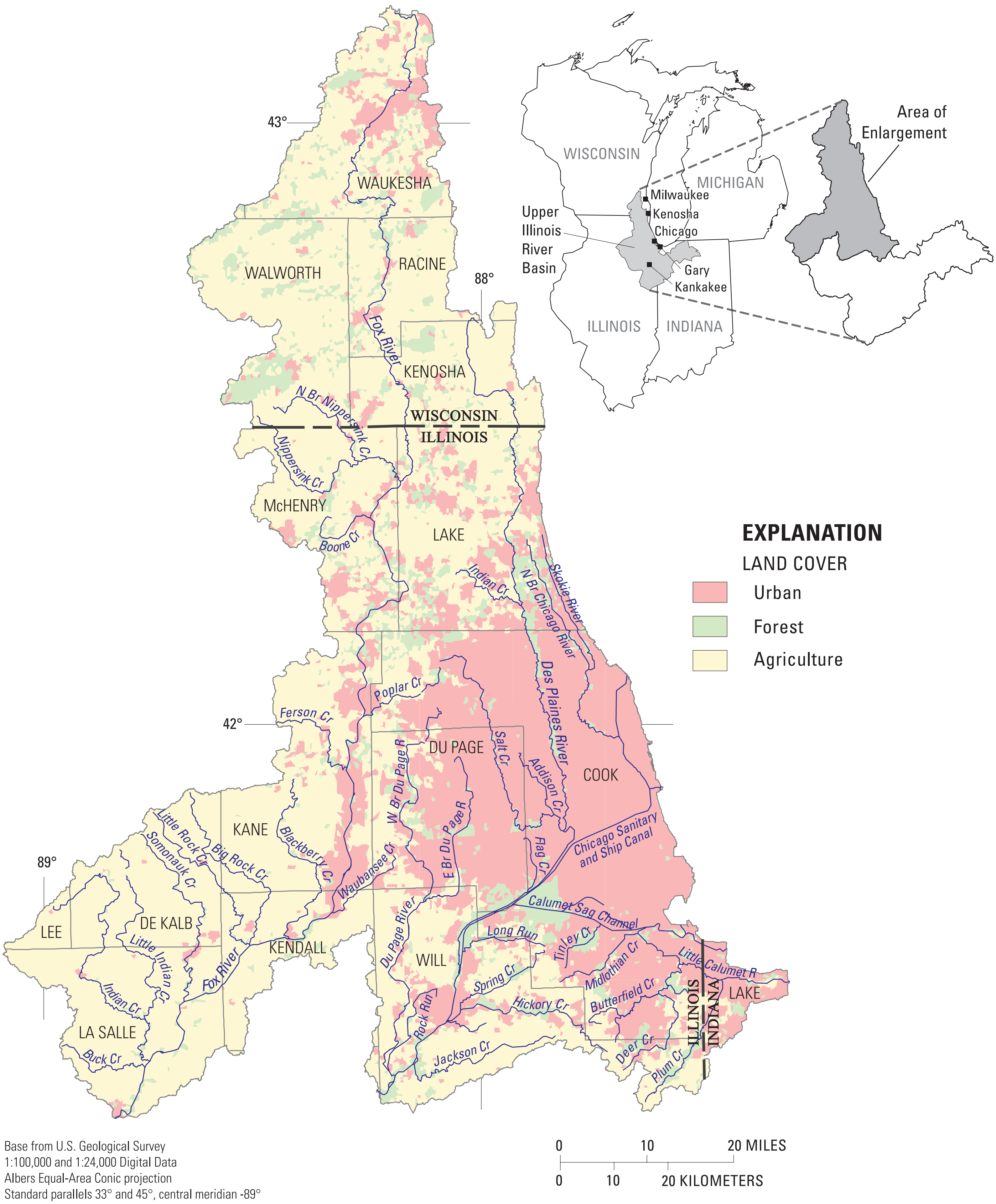


Figure 1. Location of study area and land cover in northeastern Illinois and southeastern Wisconsin, 2000-01 (Land cover from Vogelmann and others, 2001).

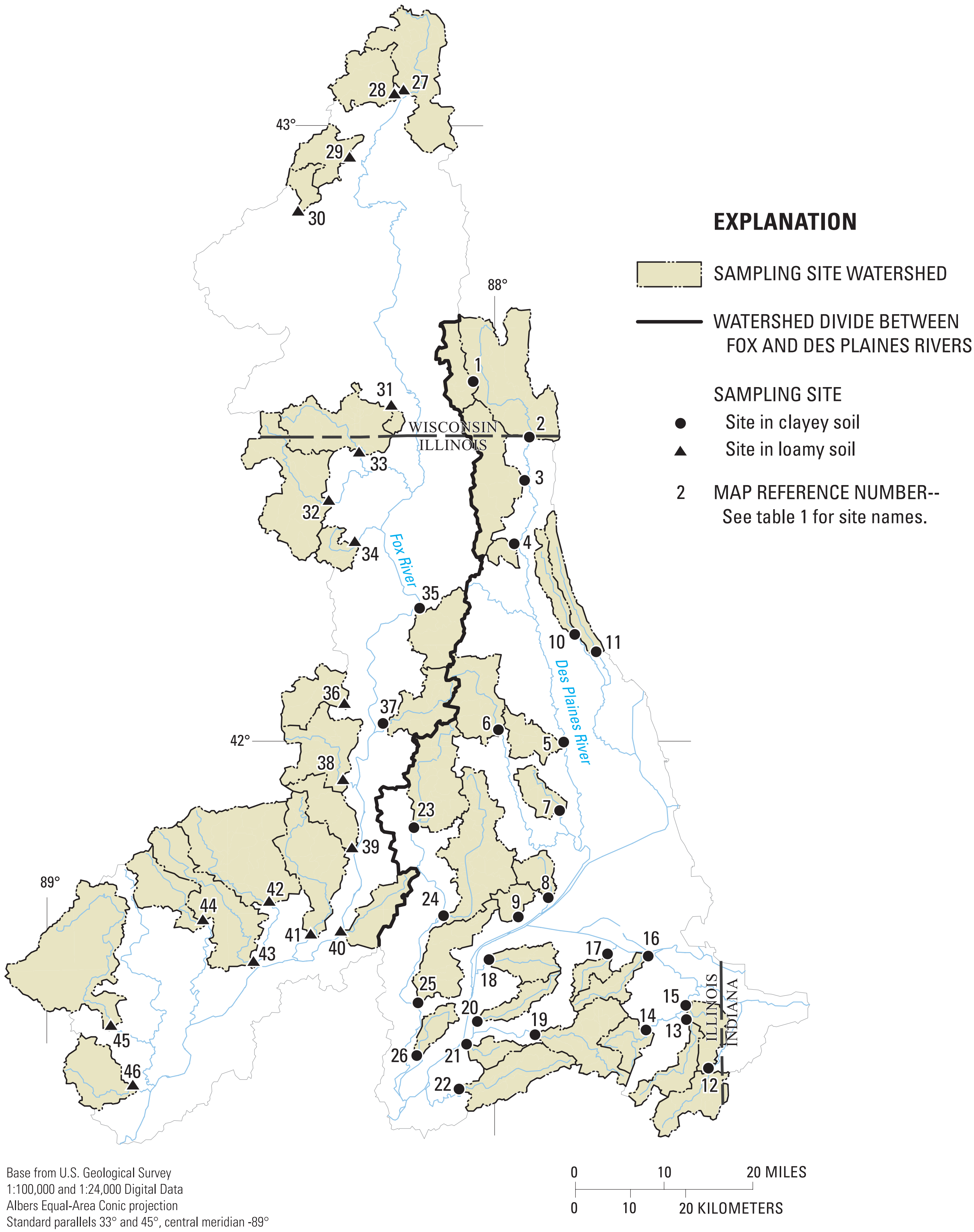


Figure 2. Location of stream sites sampled in northeastern Illinois and southeastern Wisconsin, 2000-01.

cal community responses to urbanization. Percent-watershed urban land cover was used to represent the urban gradient. Urban land cover in the watersheds of the studied sites ranged from 0.03 percent to 92-percent urban land (fig. 3). Agricultural land use in the watersheds of the studied sites ranged from 0-percent to 99-percent agricultural land.

Drainage areas for the stream sites ranged from 20 to 326 km^2 (8 to 126 mi^2). Stream sites without point sources were preferred but point sources could not be avoided in highly urbanized areas. One site (Basset Creek, map reference number [no.] 31), in a rural area, was dropped from the analysis because a sewage-treatment plant was discovered upstream after the sampling was conducted. Stream sites with historical streamflow collected by the USGS or biological data collected by the Illinois Department of Natural Resources (IDNR) and those that represented an agricultural to urban land-cover gradient were preferentially selected.

Sites were originally grouped into two surficial-deposit categories based on texture of surficial deposits in their watersheds. Sites were classified as clayey if they had surficial deposits in their watersheds consisting of greater than 50-percent clayey till, lake clay, and silt. Typically, the soils in these watersheds have low permeability. Sites were classified as loamy if they had greater than 50-percent loam, sand, and gravel deposits in their watersheds, and the soils in these watersheds have relatively moderate to high permeability. All sites in the Des Plaines River Basin and three eastern tributaries to the Fox River were classified as clayey. The rest of the sites in the Fox River Basin were classified as loamy. Urban land cover at clayey sites ranged from 3 to 92 percent and at loamy sites ranged from 0 to 30 percent. Thus, a full urban gradient was represented by clayey sites and a partial gradient by loamy sites.

Characterization of Urban Indicators and Landscape Features

Watershed-scale data for urban indicators, land cover, and landscape-scale geologic and geomorphic characteristics were derived from overlays of thematic maps with watershed boundaries by use of a geographic information system (GIS) (table 2). Watershed percent land-cover was calculated from 30 m Multi-Resolution Land Cover (MRLC) data (Vogelmann and others, 2001). Urban land cover was defined as the sum of four categories: low-density residential, high-density residential, commercial/industrial/transportation, and urban/recreational grasses. Population density data included information from the U.S. Bureau of Census 1980, 1990, and 2000 population data (U.S. Bureau of the Census, 1985; 1991; 2001). An area around the streams was created by drawing a polygon with a boundary 60 m from the stream on each side to calculate percentages of soil permeability, surficial deposits, and depth to bedrock.

In addition to watershed urban land cover, road density and estimated impervious area were used to represent urban

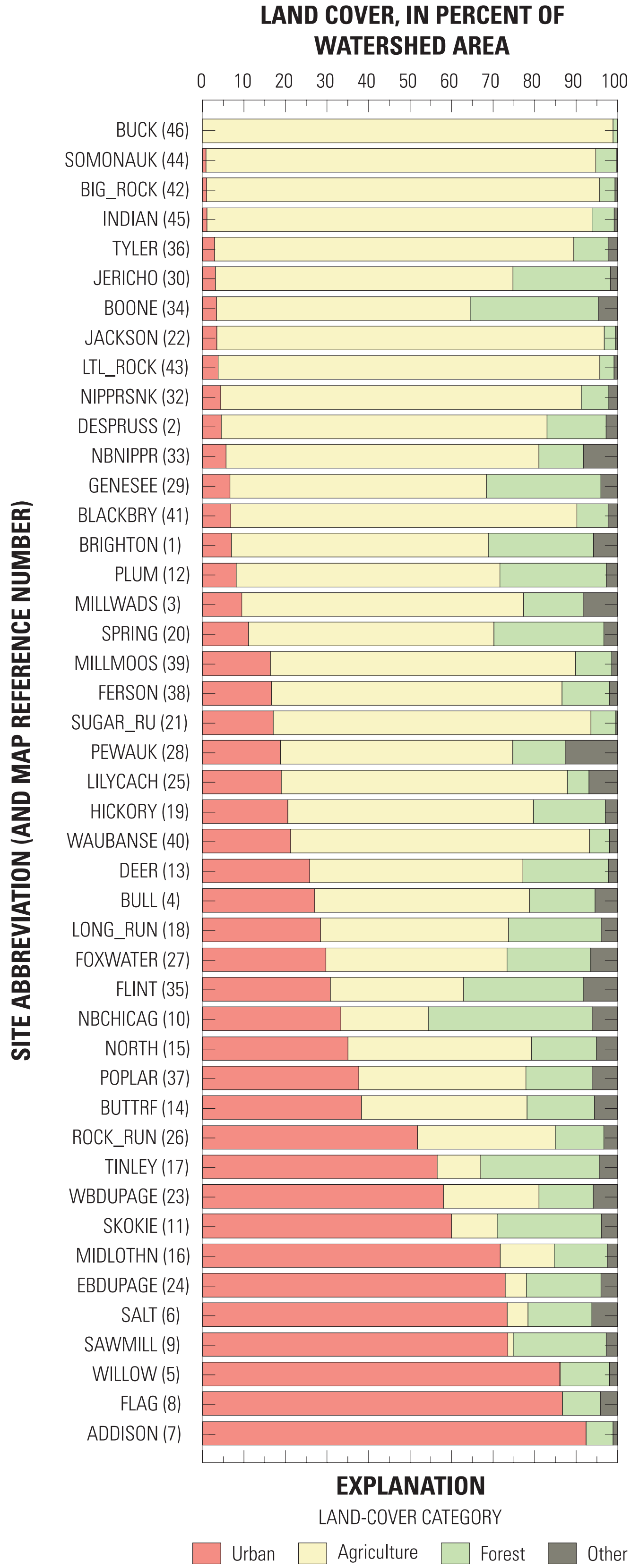


Figure 3. Land cover in drainage basins of 45 stream sites sampled in northeastern Illinois and southeastern Wisconsin, 2000-01, ordered by percent urban land. Site abbreviations are listed in table 1. Site locations are shown on figure 2.

area. The 1999 Topologically Integrated Geographic Encoding and Referencing (TIGER) system line files (U.S. Bureau of the Census, 1999) representing roads were used to estimate road density. To obtain an estimate of overall impervious area based on urban land cover, U.S. Department of Agriculture (1986) estimates of percent impervious area provided by different urban land-cover categories were used in calculations. Impervious area of roads was estimated by assigning various widths depending on the road type.

Landscape-scale geologic and geomorphic data included surficial Quaternary deposits, bedrock geology, depth to bedrock, soil permeability, drainage area, average basin slope, drainage density, basin relief ratio, cumulative stream length, and a transport index (drainage density times relief ratio) (table 2). The 1:24,000-scale National Elevation Data Set (NED) Digital Elevation Model (DEM) (U.S. Geological Survey, 2001), GIS, and the Basinsoft Program were used to calculate selected watershed-scale geomorphic characteristics (Adolphson and others, 2002; Fitzpatrick and others, 1998; Harvey and Eash, 1996). Climatic data for air temperature, precipitation, snowfall, and degree days were also compiled (National Oceanic and Atmospheric Administration, 1995). Latitude was included as a variable to account for any possible gradient related to location.

Geomorphology and Hydrology

Channel geometry, roughness, and slope characteristics were calculated from data collected from reach-scale surveys of channel cross sections and longitudinal profiles (table 2). Surveys were conducted from November 2000 through May 2001. Each reach was surveyed at three cross sections, located near the top, middle, and bottom of each reach sampled for habitat. Methods described in Fitzpatrick and others (1998) were used to determine bankfull channel indicators. Bankfull and channel flow, and unit-area stream power was simulated with U.S. Army Corps of Engineers' HEC-RAS (v. 3.0) computer program (Brunner, 2001). Bankfull flows were simulated in HEC-RAS by adjusting discharge to match observed bankfull stage indicators (as described in Harrelson and others, 1994). Bankfull-channel area was normalized by drainage area prior to analysis because of its dependence on stream size. Details on methods used may be found in Fitzpatrick and others (in press, 2005).

Stream competence and erosivity for bankfull flow was estimated (Fitzpatrick and others, in press, 2005). Competence was based on shear stress calculations for bankfull flow from HEC-RAS and describes the maximum particle size that a stream is capable of transporting under a given flow. Bankfull erosivity was calculated as the ratio of stream competence (mm) at bankfull flow divided by the average particle size (mm). Average particle size was taken from the reach-scale habitat measurements.

Hydrologic data used in this study included streamflow measurements at the time of ecological sampling in July 2000, daily streamflow data collected at 15 out of the 45 sites at USGS streamflow-gaging stations from 1985 to 2000, and HEC-RAS estimated base flow determined from water-surface data collected during channel cross-section surveys. The ecological sampling was done at some stream sites during falling stages following summer thunderstorms; therefore, streamflow measurements collected during the sampling were not always a good representation of base flow. The HEC-RAS estimates were compared to discharge measurements collected during the July 2000 ecological sampling. Flow variability was calculated as the ratio of bankfull flow to base flow. Flow data also were normalized by drainage area to avoid the effects of watershed size obscuring relations to other watershed and geomorphic characteristics.

Reach-Scale Habitat

Reach-scale habitat characteristics were collected at each site concurrently with biological sampling during July 2000. Methods followed USGS protocols (Fitzpatrick and others, 1998), and included channel, substrate, and bank measurements. Reach lengths ranged from 150 to 300 m. Measurements were made at 11 equidistant transects within each reach. At each transect, channel depth and substrate measurements were made at the thalweg and at two other points equally spaced along the transect within the channel. Data for land cover within a 15-m buffer at the endpoints, open-canopy angle, and channel aspect were collected at each transect. Segment slope and sinuosity for a segment encompassing the sampled reach was measured from 1:24,000-scale NED DEM data (U.S. Geological Survey, 2001); these characteristics were calculated as in Fitzpatrick and others (1998). Bank stability was classified using a bank-stability index (BSI), also described in Fitzpatrick and others (1998). The bank-stability index is calculated from bank angle, vegetative cover, height, and substrate measurements. To help quantify bank erosion and overall sedimentation, two measurements additional to those listed in the USGS protocols were used: the length of bank erosion occurring along the transect line and silt depth at each transect point.

Two habitat indices were calculated, the U.S. Environmental Protection Agency (USEPA) Rapid Bioassessment Protocol (RBP) and Wisconsin Department of Natural Resources (WDNR) habitat index (Barbour and others, 1999; Simonson and others, 1994; respectively). Each index contained multiple metrics that are combined to give a cumulative assessment of habitat quality for the stream site. Some modifications were made to the calculation of the metrics because data-collection techniques varied among the USGS, USEPA, and WDNR protocols. All deviations from published versions were systematically recorded and archived, along with any errors that may have resulted during data collection.

Metrics of channel shape and variability were calculated from the habitat data. A channel-shape index (CHANSH) was calculated for each transect by the equation

CHANSH = $(W/D)^{(D/Dmax)}$, where W = wetted width and D = average depth, and Dmax = maximum depth. This index provides a measure of relative occurrence of macrohabitat conditions (Terry Short, U.S. Geological Survey, written commun., 2003). The coefficient of variation of the channel-shape index (CHANSHCO) provides of measure of variability in the shape of the wetted channel. Bankfull area and bankfull width/depth ratios were calculated for each transect and, subsequently, averaged for the reach. The coefficient of variation of bankfull width/depth ratio also gives an indication of variability in the channel shape.

Water Chemistry

Water-chemistry samples were collected once at each site during July 2000. Samples were analyzed for concentrations of nutrients, major ions, and for municipal organic wastewater compounds (table 2). All water samples with sufficient water depths were depth- and width-integrated following USGS protocols (U.S. Geological Survey, variously dated). At wadable sites having insufficient water depths, dip samples were collected at the center of flow. Most samples were taken during stable low-flow conditions; however, sites sampled during the first few days (July 10–12, 2000) of the study were taken during falling stages following summer thunderstorms. Water temperature, air temperature, pH, specific conductivity, and dissolved oxygen concentrations were measured in the field at the time of sampling. Streamflow was measured at sites that were not near a streamflow-gaging station.

Samples for nutrients and major ions were analyzed at the U.S. Geological Survey National Water-Quality Laboratory (NWQL) using methods described in Fishman and Friedman (1989) and Fishman (1993). Total phosphorus, nitrate plus nitrite as N, and total Kjeldahl nitrogen (TKN) are discussed in this report.

Water samples also were tested for presence of 45 compounds that are often detected in wastewater, including antioxidants (5 compounds), detergent and disinfectants (7), flame retardants (2), Polycyclic Aromatic Hydrocarbons (PAHs) (11), pesticides (7), pharmaceuticals (3), plasticizers (6), and steroids and hormones (4). Organic wastewater compounds were analyzed at the NWQL using a custom method described in Brown and others (1999). Data are presented only as detected or not detected because samples may not meet standard NWQL data-quality acceptance criteria for organic analytes of 60-percent recovery with a standard deviation of 15 percent for approved methods. An additional pesticide (not included above), N,N-diethyl-meta-toluamide (DEET), was found in blank samples and was not used in analysis. The sample from one site, Flag Creek (no. 8; fig. 2), was lost in processing.

Trace Elements in Streambed Sediment

Streambed-sediment samples were collected for analyses of trace elements in July 2000 using USGS protocols (U.S. Geological Survey, variously dated). Five to 10 samples of fine-grained sediment were collected by hand with a Teflon scoop from each of 5 to 10 depositional zones that were submerged during low flow. Samples were collected from the upper 2 cm, which is the most recently deposited sediment layer. The sample was composited and homogenized, and a portion of the sample was removed for analysis of particle size. The remainder of the composite was wet-sieved with native water through a 63 μm-plastic mesh, and collected for trace-element analysis. Samples were analyzed for 46 major and trace elements using total digestion at NWQL in Denver, Colorado (Fishman, 1993); however, this report discusses selected trace elements that are of most concern in the UIRB.

Sediment trace-element concentrations for arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc were compared to the consensus-based sediment quality guidelines of MacDonald and others (2000). Harmful effects on sediment-dwelling organisms are expected in sediments where concentrations exceed the Probable Effect Concentrations (PEC), and harmful effects are not expected where contaminant concentrations are less than Threshold Effect Concentrations (TEC).

Algae and Chlorophyll

Benthic algal (periphyton) collections followed USGS protocols (Porter and others, 1993) and were collected between July 10 and July 26, 2000. In each reach, periphyton was collected from either cobble riffles or submerged woody snags. Each cobble sample was a composite of five subsamples collected from each of five locations in the stream reach (total sampling area about 75 cm^2). Where cobble riffles were unavailable, woody snags were used for periphyton samples and two snag sections were composited from each of five locations in the stream reach (sampling area of about 500 cm^2). For comparison, cobble riffles or woody snags were concurrently sampled for periphyton at three sites where both substrates were available: Butterfield Creek, Pewaukee River, and Ferson Creek (nos. 14, 28, 38, respectively).

From each composite periphyton sample, aliquots were removed for chlorophyll *a*, pheophytin *a*, and ash-free drymass (AFDM) analysis, and immediately frozen on dry ice. Similarly, aliquots for chlorophyll *a* in phytoplankton were split from water samples that were collected for nutrient analyses. The NWQL fluorometrically analyzed for chlorophyll *a* and pheophytin *a* (Arar and Collins, 1997) and analyzed for AFDM gravimetrically (Britton and Greeson, 1987). The remainder of each composite periphyton sample was preserved in 5-percent buffered formalin for taxonomic identification and enumeration at the Academy of Natural Sciences in Philadelphia, Pennsylvania.

Analysis of periphyton data included basic summaries of algal groups (green, blue-green, yellow-green, red, diatoms, dinoflagellates, and euglenoids) at sites and comparison among sites using cell densities and biovolumes. Algal metrics included taxa richness and diatom-based metrics such as pollution tolerance, siltation, and diversity. The diatom pollution-tolerance index and percent sensitive and tolerant diatoms were computed based on tolerances in Bahls (1993) and Lange-Bertalot (1979). The diatom pollution-tolerance index and siltation index were computed according to Bahls (1993) and calibrated as described in Scudder and Stewart (2001). The diatom pollution-tolerance index values can range from 3.00, all sensitive diatoms, to 1.00, all most-tolerant diatoms. The diatom pollution-tolerance index value of 2.4 is the threshold below which sites are rated as having at least "minor pollution." Values greater than 2.4 are rated as having "no pollution". Diatom growth-form guilds based on Molloy (1992) were computed based on morphological characteristics of cells: (1) small and monoraphid (*Achnanthes* spp.), (2) concave and monoraphid (*Cocconeis* spp.), (3) centric and non-filamentous, (4) filamentous, (5) adnate, (6) erect, (7) biraphid, prostrate, and nonmotile, (8) biraphid, prostrate, and motile (*Navicula* spp.), (9) stalked, and (10) araphid (*Eunotia* spp.).

Macroinvertebrates

Benthic macroinvertebrate community collections followed USGS protocols (Cuffney and others, 1993) and were concurrent with algal and habitat sampling. In each reach, a benthic macroinvertebrate sample was collected from cobble riffles, or, if no cobble riffles were present, samples were collected from submerged woody snags. In order to compare results from the different methods, at three sites, two samples were collected, one from cobble riffle and the other from submerged woody snags.

When a cobble riffle was present, a Hess sampler was used to collect macroinvertebrates, except at one site where a modified kick net was used, and five or six subsamples were obtained from two riffles and were combined for a single sample. Invertebrates from about 10 snags were combined to form a sample from each study reach. A 425-μm mesh net was used for all samples.

The USGS National Water-Quality Laboratory Biology Unit sorted the invertebrate samples using a 500-organism count method and identified the organisms according to the Standard Taxonomic Assessment as provided by Moulton and others (2000). When possible, mollusks, crustaceans, and insects were identified to either genus or species level, and other benthic macroinvertebrate groups were identified to higher taxonomic levels.

For invertebrates, descriptive statistics, including richness measures, composition (relative abundance) measures, tolerance indices, diversity indices, and functional-feeding group composition, were calculated. Taxa that are not normally considered part of the benthic fauna were excluded from calculations; these taxa included neustonic taxa (for example, the true bug families Gerridae and Veliidae), and terrestrial taxa (for example, adult midges).

Fish

Fish-community data were collected by three agencies: the USGS (two sites sampled in 2000 and 22 sites sampled in 2001), the IDNR (17 sites sampled during the period from 1995 to 1999), and the WDNR (5 sites sampled in July 1997). The USGS used a barge or backpack electroshocker to sample one pass of the entire stream reach and then conducted supplementary riffle kicks and seine hauls (Meador and others, 1993). The IDNR collected fish in a single pass using a backpack electroshocker, electric seine, or boat electroshocker (Bertrand and others, 1996) to sample a 91- to 213-m reach (including a riffle-pool sequence, if present). The WDNR used a barge or backpack electroshocker to sample all major habitats in a stream reach. The reach length for WDNR sampling was determined by stream size, which is based on stream width (Lyons, 1992). Fish data for the Addison Creek at Bellwood, Ill. (no. 7) site were collected near but not at the same reach as the other types of samples.

A revised Index of Biotic Integrity (IBI) is being reviewed for use in Illinois (Roy Smogor, Illinois Environmental Protection Agency, written commun., 2003). A draft version of the revised Illinois IBI was used in this analysis. The IBI is scored on a scale of 0 to 60. Ten metrics were used, of which six are based on richness, three on trophic- or reproductive-structure, and one on tolerance. Metric values were scaled according to geographic region, and stream size and slope.

Univariate and Multivariate Data Analyses

Spearman rank correlation was used to correlate environmental variables to urban indicators. Variables representing various data types were plotted against percent watershed urban land cover. Trends are indicated in the scatterplots with a lowess smooth line. Sites were divided into four categories based on amount of urban watershed land—low (LO): 0 to 10 percent (17 sites); middle-low (ML): > 10 to 25 percent (8 sites); middle-high (MH): > 25 to 50 percent (9 sites); and high (HI): > 50 to 100 percent (11 sites) (table 3). The Kruskal-Wallis nonparametric analysis of variance was used to test significant differences between pairs of urban land-cover categories using Data Desk 6 software (Data Description, Inc., 1997). Linear regression was used to highlight the linear relation between nitrate and agricultural land cover. The adjusted r-squared (coefficient of dermination) was used as a measure of the strength of the relation.

Indirect gradient analysis (Detrended correspondence analysis (DCA)) and direct gradient analysis (canonical correspondence analysis (CCA)) were used to examine relations between environmental variables and biological communities using the CANOCO 4.5 program (ter Braak, and Smilauer, 2002). Covariables were selected to reduce the effect of sampling variability. Sampling substrate was used as a covariable for algae and macroinvertebrate sample analyses and sampling agency was used as a covariable for analysis of fish samples. Algae data were analyzed at the species level, data were square-root transformed, and analyses were examined with rare taxa without downweighting. Macroinvertebrate taxa were analyzed at the genus level (Cuffney, 2003), data were square-root transformed, and only taxa that appeared at least 10 percent of the sites were used. All fish species were used in the analyses; fish-species data were log transformed, and rare species were downweighted. Environmental variables were then correlated to the DCA axes for algae, invertebrates, and fish. For CCA analysis, the number of environmental variables was reduced to 45, using principal-component analysis and correlation to identify correlated variables. Forward selection was used to select the environmental variables in the CCA model for invertebrates and fish and for assistance in selection of environmental variables in CCA for algae.

Relations Among Urban Indicators

The major urban indicators of watershed urban land (URBANLU), road density (ROADDEN), estimated impervious surface (IMPERV), and 2000 population density (POPDEN00)) were correlated highly with each other; correlation coefficients ranged from 0.95 to 0.99 (table 4). Watershed urban land was used as the main urban indicator in subsequent analysis of urban effects on physical, chemical, and biological data. Percent agricultural land was negatively correlated with urban land (rho = -0.94). The three sites with the most urban land, Addison Creek (92 percent), Flag Creek (87 percent), and Willow Creek (86 percent) (nos. 7, 8, 5, respectively; fig. 2), had the least agricultural land, each with less than 0.25 percent (fig. 3). The most agricultural sites, Buck Creek (99 percent), Somonauk Creek (94 percent), and Big Rock Creek (95 percent) (nos. 46, 44, 42, respectively), all had less than 1-percent urban land (fig. 3).

Examination of population density change in the watershed from 1990 to 2000 gives some indication of the spatial distribution and urbanization rates. Median population growth of 45 watersheds between 1990 and 2000 was 20 percent (table 2). Growth exceeded 60 percent in six watersheds in the rapidly growing perimeter of the Chicago metropolitan area. For example, population density doubled in the Waubansee Creek (no. 40) watershed, from 317 people/km^2 to 646 people/km^2, and in the Ferson Creek (no. 38) watershed, populations increased 70 percent, from 76 people/km^2 to 133 people/km^2. Watersheds with the lowest growth rates included both mostly rural and mostly urban areas. Rural watersheds that were not growing rapidly in 2000 included Buck Creek (no. 46) and Big Rock Creek (no. 42) with about 5 and 24 people/km^2, respectively. Likewise, the most urban sites did not have high growth rates; all but one of the sites with over 70-percent urban land cover had less than 10-percent growth rates. The Addison Creek (no. 7) watershed with the highest percent urban land cover had the highest population density and grew from 1,597 people/km^2 to 1,689 people/km^2.

Physical Responses to Urbanization

Stream hydrology and geomorphology develop from the underlying physical landscape (long time scale, from hundreds to thousands of years) and the overlying land use (recent, short time scale, several years to tens of years) of a stream watershed. Reach-scale habitat characteristics represent the conditions under which biological communities are sampled.

Landscape Characteristics

Urban indicators and other landscape characteristics were highly correlated (table 4), often because of site selection. Soil-permeability variables (including percent clayey surficial deposits (WATCLAY)) and stream size (including drainage area (DRAIN)) correlated to urban land cover because of the sampling design of having a full gradient (0–100 percent urban land) of streams in the clayey deposits and a partial gradient of streams in loamy deposits. As a result, only 4 of the 16 sites classified as loamy had greater than 7-percent urban watershed land. More variability in stream size was found at sites with lower percent urban land use. Streams with higher percent urban land cover also had smaller watersheds. The amount of forest and wetland in the 60-m stream-network buffer was not correlated with watershed urban land.

Based on results from Fitzpatrick and others (in press, 2005), relations among landscape characteristics were a reflection of watershed size, geologic setting, and riparian buffer characteristics of the sampled streams. Stream sites with larger drainage areas had lower reach-scale slopes, less watershed clayey deposits, less forest/wetland in the stream-network buffer, and more open canopy. Stream sites with steep watershed slopes had high transport indices, high drainage density, and more forest/wetland in the stream-network buffer.

Geomorphology and Hydrology

For the geomorphic variables, bankfull-channel area adjusted for drainage area (AREABFDA) had the highest Spearman rank correlation (0.59) with watershed urban land (table 4, fig. 4a). This variable was also correlated with watershed clayey surficial deposits, indicating that clayey, urban streams have larger bankfull-channel areas than loamy/sandy, rural streams (Fitzpatrick and others, in press, 2005). Bankfull-channel area (adjusted for drainage area) at sites in the LO urban land-cover category (between 0- and 10-percent urban land) was significantly lower than in the three higher land-cover categories (fig. 5a).

Three hydrologic variables, bankfull flow normalized by drainage area (BFLOWDA), base flow including point source contributions, and flow variability (FLOWVAR2), correlated with similar landscape and geomorphic variables (Fitzpatrick and others, in press, 2005). Stream sites with large bankfull flows and high flow variability had small drainage areas, large bankfull areas, and high stream power. In contrast, stream sites with high base flow (including point-source contributions), had large drainage areas, small bankfull areas, and low stream power. However, if the estimated average point-source component of flow was subtracted from the estimated base flow, then the difference was negatively correlated with the amount of urban land, indicating that ground-water contributions to base flow are less at urban stream sites (Fitzpatrick and others, in press, 2005).

The size of 2-year flood peaks increased as urban land cover increases from 0 to about 30 percent, but above 30-percent watershed urban land, the relation becomes more complex and is possibly related to watershed relief, drainage density, and stormwater-control practices (Fitzpatrick and others, in press, 2005). The transport index (TRANSIN) had the highest correlation with 2-year flood, indicating that streams in urban areas with relatively high watershed relief and drainage density still have larger floods than streams with low watershed relief and drainage density, regardless of the extent or type of hydrologic modifications implemented such as combined sewers and stormwater detention.

Reach-Scale Habitat

Six reach habitat variables had small but significant ($p < 0.05$) negative correlations with watershed urban land (table 4). These variables included coefficient of variation of stream aspect (ASPCO), coefficient of variation of canopy closure (RIPCLOCO), average bankfull-channel width/depth ratio in runs (BWDRATRU), average bankfull-channel width/depth ratio (BWDRAT), coefficient of variation of wetted width/depth ratio (WDRATCO), and coefficient of variation of shape index (CHANSHCO).

There was no significant correlative relation between RBP Habitat Index scores (RBPHABIN) and urban land cover, however, a difference by category resulted (fig. 4b). Sites between 10- and 25-percent urban land cover (ML) had better habitat scores than sites with higher watershed urban land (categories MH and HI) (fig. 5b). The RBP correlated with other urban, landscape, and reach-scale geomorphic and habitat characteristics (table 4). Stream sites with high habitat index scores had low percent disturbed land cover in reach-scale riparian buffer, steep reach-scale slope, low potential for erosion of the channel bed, less fine substrate, high variability in bankfull width/depth ratios, and high percent riffle. Most of these correlated characteristics are used in the calculation of metrics included in both indices. High RBP habitat index scores also were related to high transport index, steep watershed slope, high percent coarse deposits in the stream-network buffer, high stream power, wide channels, and little bank erosion (Fitzpatrick and others, in press, 2005).

Various habitat variables were correlated to stream slope (table 5). Greater slope (SLOPELO) was strongly correlated ($rho > 0.48$, $p < 0.001$) to larger substrate size (SUBST, ROUGH, GRAVEL), amount of riffle in the reach (RIFFLE), and coefficient of variation of mean depth (DEPCO). The two habitat quality indices, RBP habitat index (RBPHABIN) and Wisconsin habitat index (WIHABIN), and two variables, coefficient of variation of aspect (ASPCO) and average riparian canopy closure (RIPCLO), were also positively correlated with stream slope ($p < 0.05$). Additionally, stream shape was apparently more variable at sites with greater stream slopes. Lower stream slope was correlated with greater embeddedness (EMBED), percent substrate as fines (FINES), and amount of runs (RUN). Stream size (DRAIN) and other variables related to stream size, were negatively correlated to stream slope. These variables included wetted cross-sectional area (WETXSAR), bankfull cross-sectional area (BKFXSAR), wetted stream volume (WETVOL), mean depth (DEPAVG), mean maximum depth (DEPMAX), bankfull stream-surface area (BKFSURAR), wetted stream-surface area (WETSURAR).

Correlations (or lack of correlations) among forest in the stream-network buffer (BUFFOWE), canopy angle (CANOPY), and percent disturbed land cover in the reach buffer (RIPLU) illustrate the importance of collecting multiple spatial scales of riparian buffer data (Fitzpatrick and others, 2001). Canopy angle did not correlate with the percent disturbed land cover in the reach buffer, possibly because open-canopy streams may have undisturbed land cover such as wetland or grassy areas. Forest/wetland in the stream-network buffer was more prevalent in smaller, clayey watersheds with relatively steep watershed slopes; and also was associated with narrower channels. Disturbed land cover in the reach buffer did not correlate with any reach-scale geomorphic or habitat characteristics. The correlation of disturbed land cover in the reach buffer with the habitat indices is present because quality of the riparian zone is a metric in the index.

Chemical Responses to Urbanization

Increases in concentrations of nutrients and other ions, metals, pesticides and organic contaminants have been observed with increasing watershed urbanization (Porcella and Sorenson, 1980; U. S. Geological Survey, 1999). Both agricultural and urban land uses have been shown to be sources of nutrients to streams (Herlihy and others, 1998; U. S. Geological Survey, 1999).

Nutrients and Major Ions in Water

The six sites with the highest total phosphorus concentrations (fig. 4c) were Salt Creek, West Branch Du Page River, Flag Creek, East Branch Du Page River, Addison Creek, and

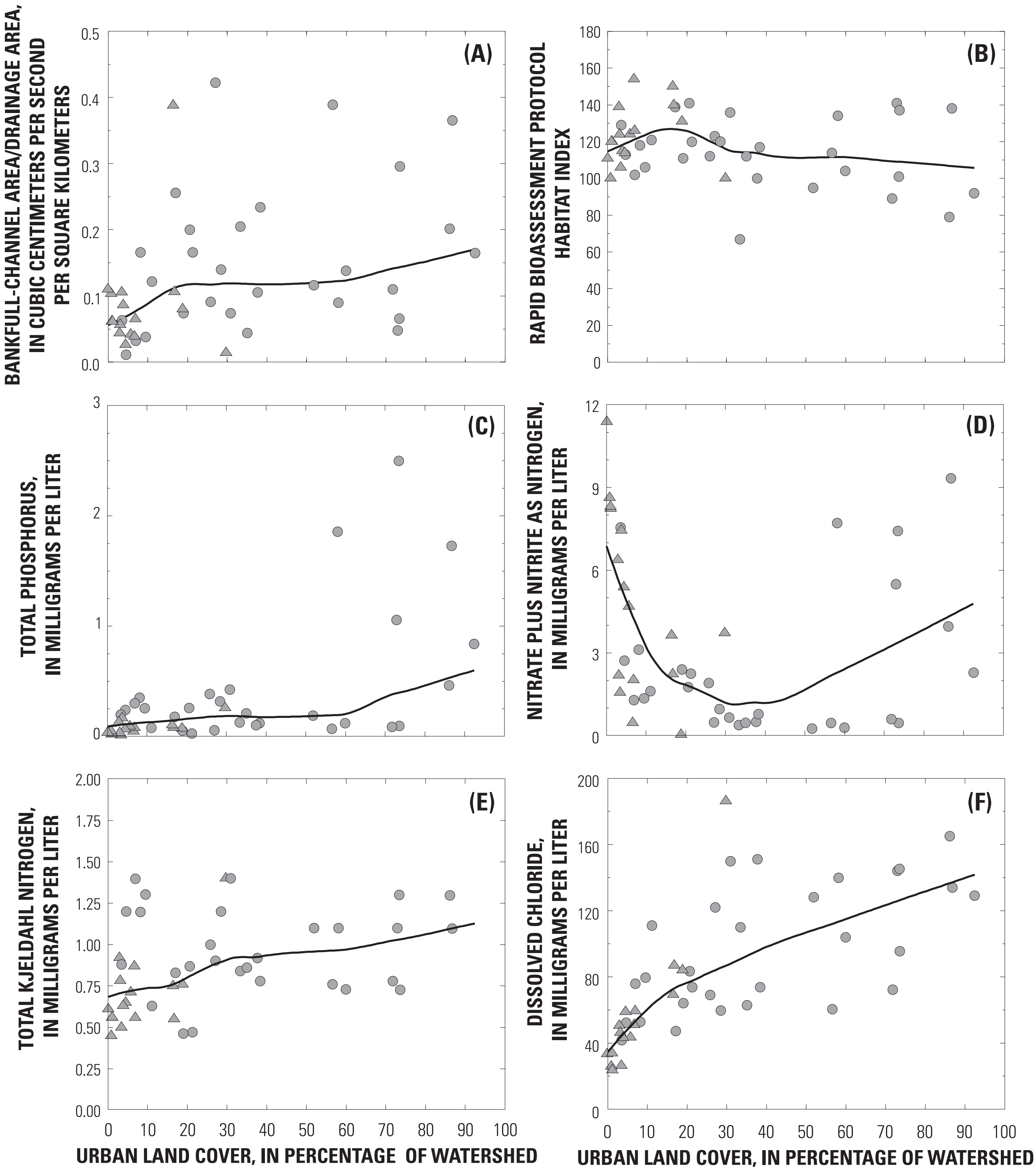
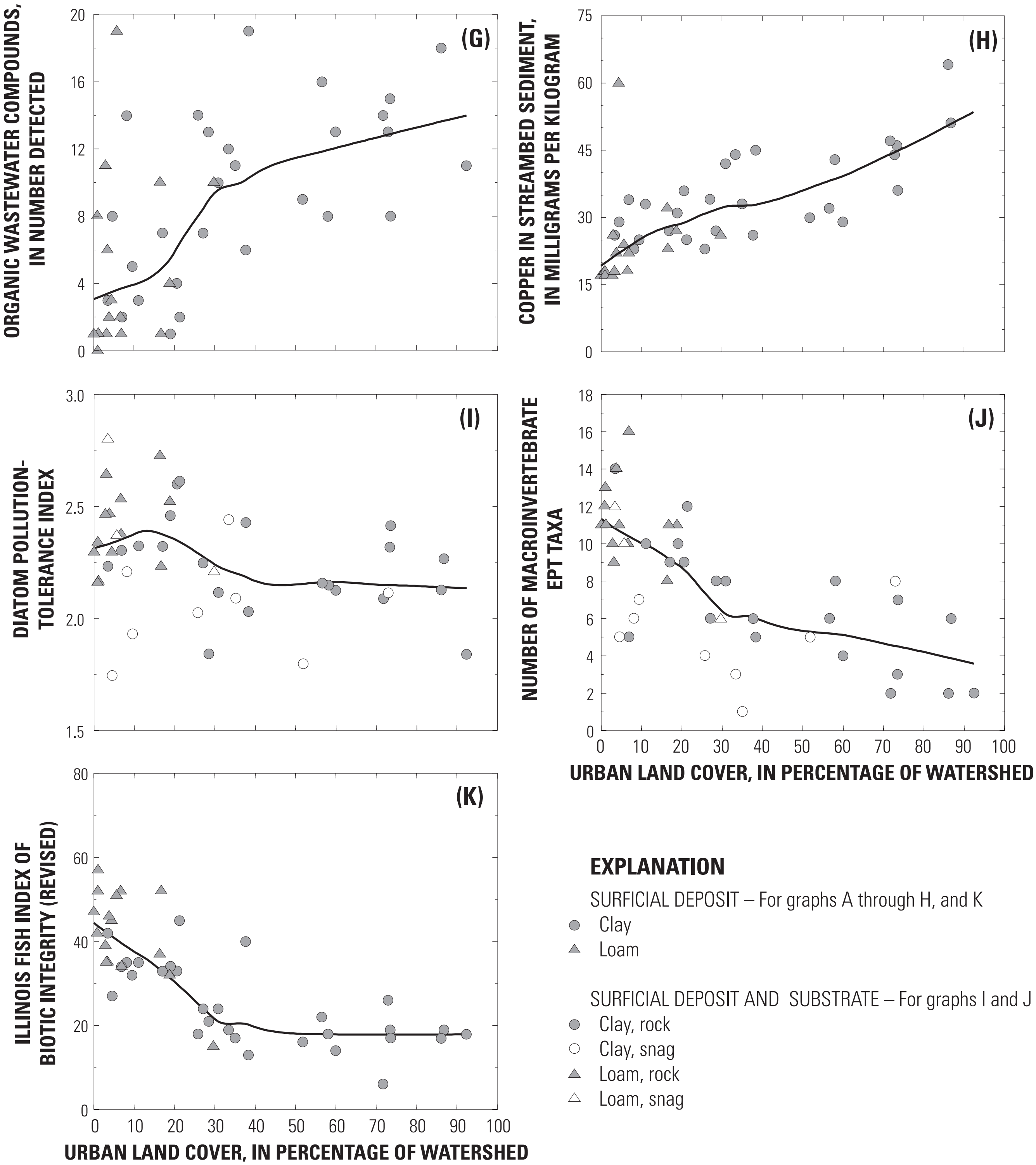


Figure 4. Scatterplots of selected variables along the urban gradient, percent watershed urban land, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. Lowess smooth trend line is drawn. (A) Bankfull-channel area/drainage area; (B) Rapid Bioassessment Protocol (RBP) Habitat Index; (C) Phosphorus, total, milligrams per liter; (D) Nitrate + nitrite, as N, milligrams per liter; (E) Total Kjeldahl nitrogen, milligrams per liter; (F) Chloride, dissolved, milligrams per liter; (G) Organic wastewater compounds, number detected; (H) Copper in streambed sediment, milligrams per kilogram; (I) Diatom Pollution Index; (J) Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa; (K) Fish Index of Biotic Integrity.



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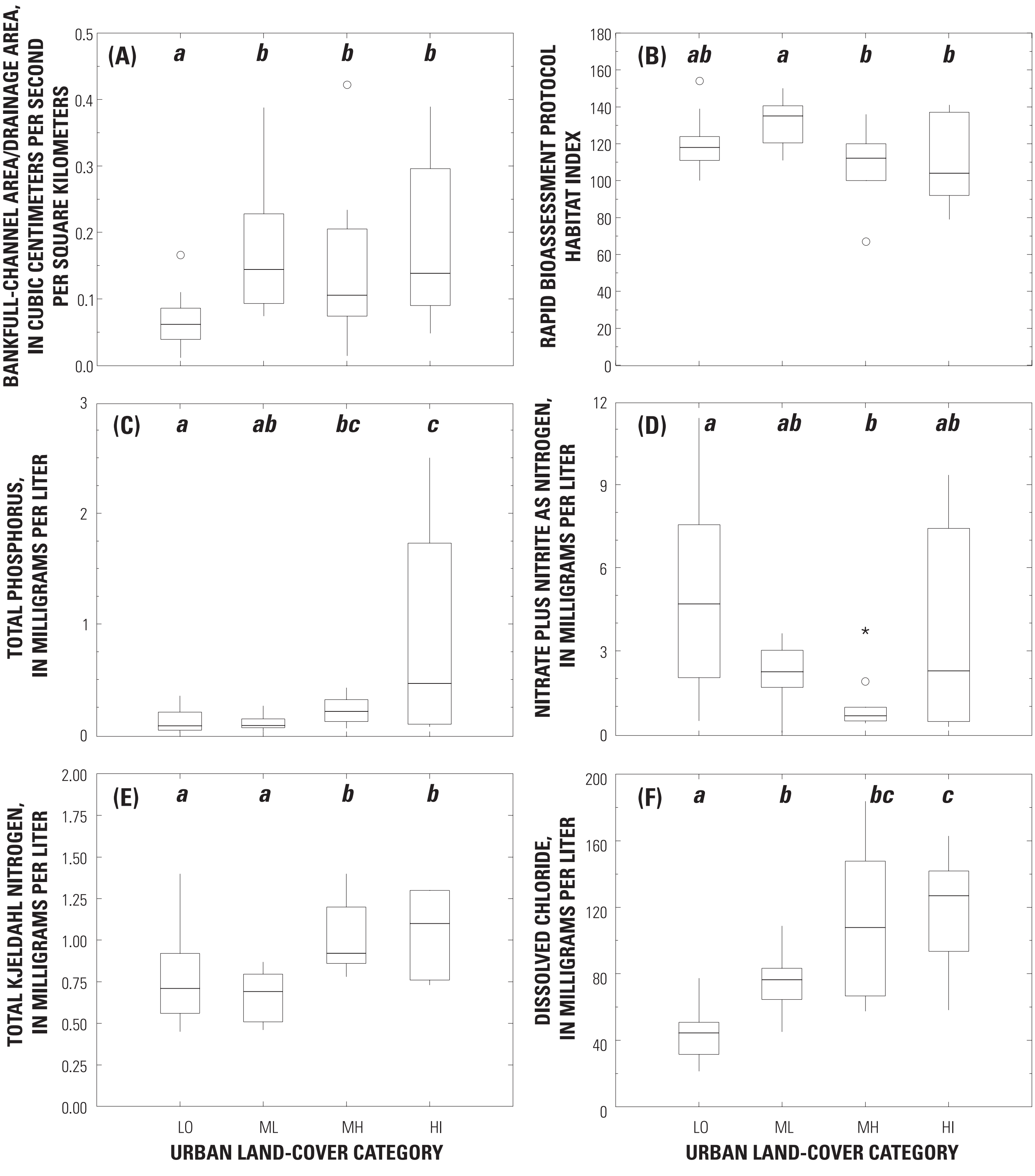

Figure 5. Box plots of selected variables in four urban watershed land-cover categories for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. Watershed land-cover categories are LO: 0 percent to 10 percent (17 sites); ML: >10 percent to 25 percent (8 sites); MH: >25 percent to 50 percent (9 sites); HI: >50 percent to 100 percent (11 sites). Kruskal-Wallis test was used to test significant differences between pairs of land-cover categories; different letter signify differences at $p < 0.05$. (A) Bankfull-channel area/drainage area; (B) Rapid Bioassessment Protocol (RBP) Habitat Index; (C) Phosphorus, total, milligrams per liter; (D) Nitrate + nitrite, as N, milligrams per liter; (E) Total Kjeldahl nitrogen, milligrams per liter; (F) Chloride, dissolved, milligrams per liter; (G) Organic wastewater compounds, number detected; (H) Copper in streambed sediment, milligrams per kilogram; (I) Diatom Pollution Index; (J) Number of Ephemeroptera , Plecoptera, and Trichoptera (EPT) taxa; (K) Fish Index of Biotic Integrity; >, greater than; <, less than.

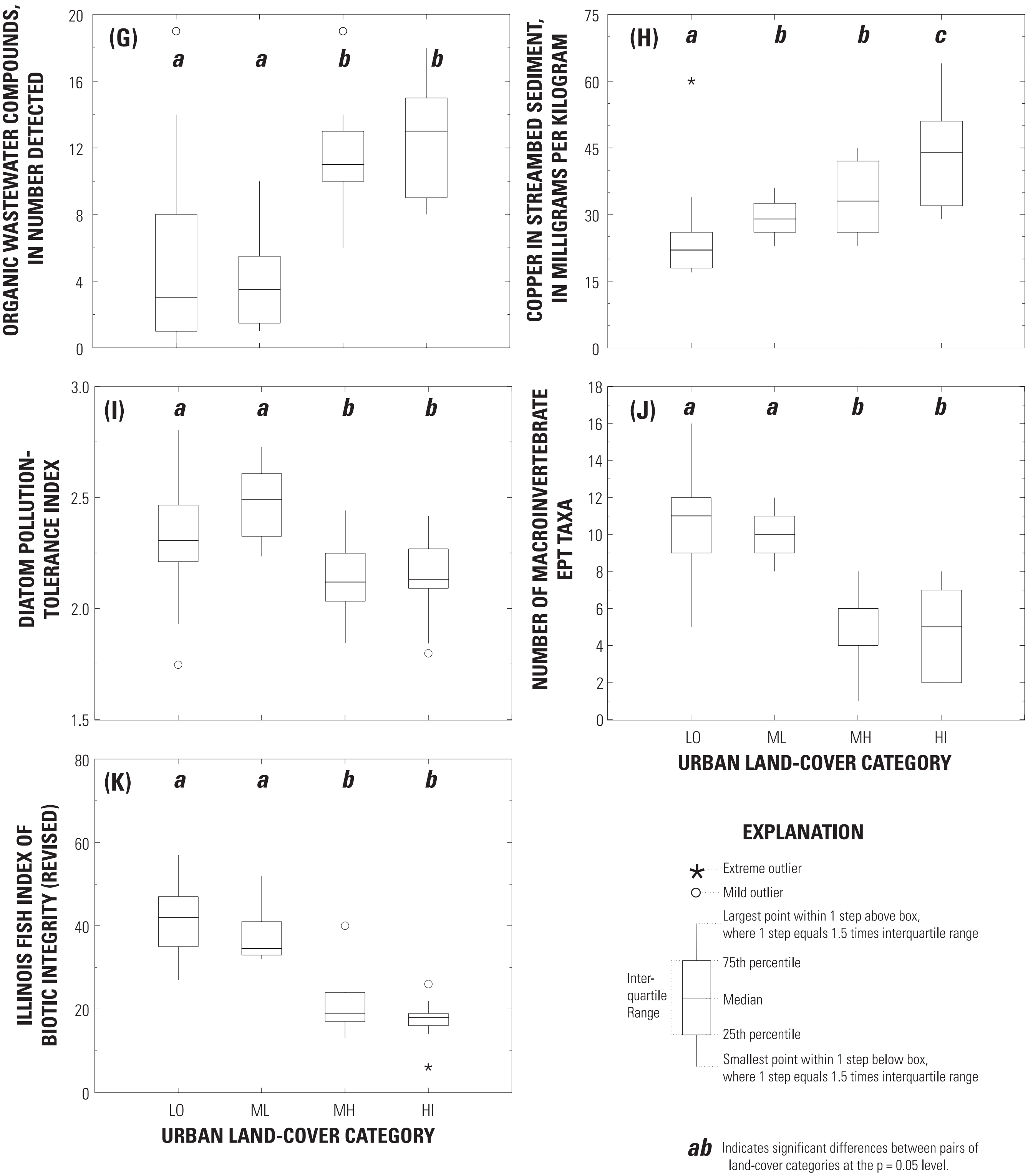

Figure 5. Continued.

Willow Creek (nos. 6, 23, 8, 24, 7, 5, respectively; fig. 2). These highest total phosphorus concentrations ranged from 0.46 mg/L (Willow Creek) to 2.5 mg/L (Salt Creek), and five of these values were outliers on a standard box plot (exceeding 1.5 times the interquartile distance + upper quartile) (NIST/SEMATECH, 2002). These sites all had among the highest amounts of urban land cover in the watershed; West Branch Du Page River, had 58-percent urban land and the other five sites had greater than 72-percent watershed urban land. Total phosphorus concentrations at the other 39 sites, including 5 sites with greater than 50-percent watershed urban land, had no correlation with urban land cover. Total phosphorus in the LO urban land-cover category was significantly lower than total phosphorus in the MH and HI categories (fig. 5c).

Agricultural and urban land uses have been demonstrated to contribute to elevated phosphorus concentrations above background levels in streams (Herlihy and others, 1998; U. S. Geological Survey, 1999). Osborne and Wiley (1988) found that urban areas, compared to agricultural areas, contribute disproportionately larger amounts soluble reactive phosphorus to streams in an agricultural watershed. Wastewater and fertilizers are important contributors of phosphorus in urban areas (La Valle, 1975).

Nitrate (nitrate + nitrite as N) was significantly higher in the LO urban land-cover category than in the MH category (fig. 5d). The correlation of nitrate with land cover was significant with both agricultural land cover and urban land cover, but greater with agricultural land. Nitrate concentrations at sites with less than 50-percent urban land were linearly related to the amount of agricultural area in the basin. Considering only sites with greater than 50-percent agricultural land, the adjusted r-squared with nitrate and percent agricultural land was 0.62 ($p \leq 0.001$). One site, Sugar Run (no. 21), which was sampled on the first day of sampling after a storm, had the highest nitrate concentrations measured during this study. Removing Sugar Run from the regression raised the adjusted r-squared to 0.81 ($p \leq 0.001$).

Of the sites with greater than 50-percent watershed urban land, six sites had high nitrate concentrations relative to most other sites. These are the same sites with elevated total phosphorus concentrations—Flag Creek, West Branch Du Page River, Salt Creek, East Branch Du Page River, Willow Creek, and Addison Creek. Nitrate concentrations at these sites ranged from 2.3 mg/L to 9.3 mg/L. Nitrate concentrations at the other five sites with greater than 50-percent urban land (Rock Run, Skokie River, Sawmill Creek, Tinley Creek, and Midlothian Creek; nos. 26, 11, 9, 17, 16, respectively) were all 0.6 mg/L or lower.

Evidence is present for both point and nonpoint sources of nutrients along the urban gradient in northeastern Illinois and southeastern Wisconsin. Urban sites typically have multiple point and nonpoint sources. Three of the six highly urbanized sites with higher phosphorus and nitrate concentrations had six or greater permitted discharge facilities in their watersheds: East Branch Du Page River (11 facilities); West Branch Du Page River (8); and Willow Creek (6) (nos. 24, 23, 5, respectively). The other three sites had either two or three facilities. The five highly urban sites with lower phosphorus and nitrate concentrations had either two or fewer discharge facilities reported. In contrast, all but one of the five highly urbanized stream sites with lower phosphorus and nitrate concentrations had higher percent forest and wetland within a 60-m buffer along the stream length (median = 25 percent, range from 16 to 35 percent) than the six other sites (median = 15 percent, range from 7 to 21 percent). Nitrate was negatively correlated to (rho = -0.61) percent forest and wetland within a 60-m buffer along the stream length. Herlihy and others (1998) found increasing nitrate concentrations associated with both agriculture and urban land uses, but found nitrate to be an especially good indicator of agricultural land use.

TKN was correlated with total phosphorus (rho = 0.83), but not correlated (rho = -0.10) with nitrate. The relations between TKN and land cover were not clear. TKN (NITTKN_W) correlated more highly with agricultural land (rho = -0.52) than with urban land (rho = 0.46) (table 4). The relation between TKN and land cover was driven by the majority of the loamy sites (all Fox River Basin sites) with relatively low (0.6 mg/L) TKN (fig. 4e) as compared to the other sites. TKN concentrations were lower in the LO and ML land-cover categories than in the MH and HI categories (fig. 5e).

Specific conductivity was only weakly correlated to urban land cover (table 4). This weak correlation resulted because of opposing patterns for some major ions. Sodium, chloride, and potassium concentrations were positively correlated with urban land; however, calcium and magnesium concentrations were negatively correlated. Sodium and chloride concentrations had a highly positive correlation with each other (rho = 0.86), and calcium and magnesium were highly correlated with each other (rho = 0.98). Ruhl (1995) commented that concentrations of calcium and magnesium tend to be high in the upper Illinois River Basin because of glacial till deposits, and underlying limestone and dolostone bedrock. Leland and Porter (2000) found that calcium and magnesium ions were dominant in the upper Fox River Basin compared to other basins in the upper Illinois River Basin.

Chloride concentrations in the LO urban land-cover category were significantly lower than in the other land-cover categories, but increased with increasing land cover (figs. 4f, 5f). Elevated sodium and chloride concentrations, above background or natural levels, often have been associated with road deicing, but municipal and industrial sewage discharges, and fertilizers are other sources. In Canada, elevated chloride concentrations were found in areas of intense road salt loadings (Environment Canada, 2001). Herlihy and others (1998) found chloride ion concentrations to be a “surrogate for general human disturbance in the watershed” in the Mid-Atlantic region.

Organic Wastewater Compounds

The number of wastewater compounds detected at sites with greater than 25-percent urban land was significantly greater than at sites with less than 25-percent urban land (figs. 4g, 5g). At sites with greater than 25-percent urban land, the median number of compounds detected was 12 (mean = 12; range from 6 to 19). In contrast, the 25 sites with less than 25-percent urban land, the median was only 3 compounds detected (mean = 5; range from 0 to 19).

Overall, the number of wastewater compounds detected at a site ranged from 0 at Big Rock Creek to 19 at North Branch Nippersink Creek and Butterfield Creek (nos. 42, 33, 14, respectively). Of the 10 sites where the greatest number of wastewater compounds was detected, 8 had greater than 25-percent urban land, but 2, North Branch Nippersink Creek and Plum Creek (no. 12), had less than 25-percent urban land.

A variety of types of compounds were most commonly detected, including a detergent, diethoxy-Octylphenol (31 detections); PAHs (naphthalene (30), fluoranthene (24), and pyrene (22)); an insecticide, diazinon (26); a flame retardant, Tri(2-chloroethyl)phosphate (26); and a plasticizer, phthalic anhydride (24) (table 6). All of these compounds were found more commonly at sites with greater than 25-percent urban land than at sites with less than 25-percent urban land. Diazinon and fluoranthene were detected at all 19 sites with greater than 25-percent urban land compared to only 7 of 25 sites with less than 25-percent urban land. Two other most common PAHs (fluoranthene and pyrene) were found at 18 of the 19 most urbanized sites compared to 5 and 4, respectively, out of the 25 least urbanized sites.

Low concentrations of many organic wastewater compounds were found in streams with urban sources across the United States during a recent reconnaissance study (Kolpin and others, 2002). Triclosan, an antibacterial ingredient in soaps, detergents, and toothpastes, and Tris (2-chloroethyl) phosphate, a flame retardant in plastics, were some of the commonly found compounds in the Kolpin and others (2002) study.

Sources of these compounds detected in the UIRB streams are varied. Diazinon is an insecticide used to control cockroaches, silverfish, ants, and fleas in buildings and it is used on home gardens and farms to control a wide variety of insects. Diazinon is probably transported to streams in nonpoint overland flow. Diazinon has been found more commonly in urban streams than in agricultural streams (U. S. Geological Survey, 1999; Groschen and others, 2004). Industrial byproducts, including some PAHs, can be derived from regulated and unregulated industrial effluent, and household chemicals and pharmaceuticals have been reported from wastewater-treatment plants or domestic septic systems that do not remove them from the effluent (Paul and Meyer, 2001; Kolpin and others, 2002).

Trace Elements in Streambed Sediment

Sediment concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc substantially increased with increasing urban land in the study area. The strongest correlation was between lead and urban land (rho = 0.87), followed by zinc (0.81), and copper (0.76) (table 4, fig. 4h.) Copper concentrations in the LO urban land-cover category were significantly lower than copper concentrations in the other categories; copper concentrations in the HI urban land-cover category were significantly higher than copper concentrations in other land-cover categories (fig. 5h).

Similar to the trace elements described above, lead, zinc, cadmium, nickel, and mercury concentrations in the LO or LO and ML land-cover categories were lower than the HI land-cover category and concentrations in the MH and HI land-cover categories were higher than concentrations in the LO land-cover category. Concentrations of various trace elements were lower at urban land cover of less than 10 percent. Copper, lead, zinc and arsenic concentrations were lower in the LO land-cover category than in the ML category.

Consensus-based Threshold Effect Concentrations (TEC) of MacDonald and others (2000) were exceeded for chromium at 93 percent of the sites and for nickel at 70 percent of the sites. Cadmium and mercury TEC were exceeded the least often. The TEC for cadmium was exceeded at only three of the most urbanized sites (Addison Creek, Salt Creek and Willow Creek; nos. 7, 6, 5, respectively). The TEC for mercury was exceeded at two sites (Butterfield Creek (no. 14) and Pewaukee River (no. 28)). Concentrations of four other trace metals exceeded TEC standards at between 35 and 44 percent of the sites.

Consensus-based Probable Effects Concentrations (PEC) of MacDonald and others (2000) were exceeded at two sites: Addison Creek (no. 7) and Nippersink Creek (no. 32). Sediment concentrations of chromium, lead, and nickel exceeded PEC at Addison Creek, the site with the most watershed urban land and the highest population density. Sediment concentrations exceeded PEC for both chromium and nickel in Nippersink Creek, a primarily agricultural watershed. Nippersink Creek was also a high outlier for copper concentrations.

Groschen and others (2000) found that concentrations of chromium, copper, lead, mercury, nickel, selenium, and zinc decreased in the Illinois River in a downstream direction away from the Chicago metropolitan area. Fitzpatrick and others (1995), summarizing USGS and other historical data (1975–92) in the UIRB, found that sediment concentrations of chromium, copper, mercury and zinc were enriched in urban streams relative to agricultural streams, and concentrations of many trace elements decreased in the Illinois River with increasing distance from the Chicago metropolitan area. Rice (1999), Mathis and Cummins (1973), and Colman and Sanzolone (1992) also found relations between urban land use, or a surrogate, and sediment trace-element concentrations.

Biological Responses to Urbanization

Algae, macroinvertebrate, and fish communities are often sampled for monitoring water quality (Barbour and others, 1999). These communities represent multiple trophic levels and each may be expected to respond differently to changes in watershed urbanization and changes in stream physical and chemical characteristics.

Algae and Chlorophyll

A total of 263 unique algal taxa were identified in samples from the 45 sites (table 7). The most taxa (65) were found on woody snags from Plum Creek (no. 12; fig. 2), and the least taxa (19) were found on rocks from Sawmill Creek (no. 9). Both sites were in watersheds with clayey surficial deposits. Over half the algal taxa were found at only 1 or 2 sites, and 70 percent of the algal taxa were found at 5 or fewer of the 45 sampled sites. Algal abundance ranged from a minimum of 41,224 cells per cm^2 at Deer Creek (no. 13) to a maximum of 4,697,531 cells per cm^2 at Little Rock Creek (no. 43).

Most of the algal taxa (greater than or equal to 74 percent) and most of the algal cells (median 66 percent) at all sites consisted of diatoms. In order of percent occurrence across all sites, the diatoms *Amphora pediculu*s, *Rhoicosphenia curvata*, *Navicula minima*, *Cocconeis placentula* var. *lineata*, and *Navicula cryptotenella*, *Nitzschia frustulum*, *Cocconeis placentula* var. *euglypta*, *Cocconeis placentula*, and *Achnanthes lanceolata* were the most common taxa. Of these species, only *Navicula minim*a is considered to be pollution tolerant and the others are considered to be less tolerant or sensitive to pollution (Lange-Bertalot, 1979; Bahls, 1993).

Diatoms accounted for the majority of the biovolume at many but not all sites, because of abundant green or red algae. For example, although green algae accounted for less than 1 percent of the total algal biomass and 5 percent or less of the total algal cells at most sites (absent at 16 sites), 98 percent of the total algal biovolume at Long Run (no. 18) consisted of the green alga *Cladophora glomerata*, a species generally considered to indicate high nutrient concentrations when abundant. Other species of green algae contributed more than one-quarter of the total algal biovolume at Indian Creek, Nippersink Creek, Little Rock Creek and Big Rock Creek (nos. 45, 32, 43, 42, respectively). The abundance of green algae increased with increasing concentrations of the nutrient phosphorus in sediment (rho = 0.38) and dissolved solids (0.41) (table 8). At 23 sites, a red alga (Unknown Rhodophyte Florideophycidae (chantransia)) made up at least half of the algal biovolume; however, red algae were absent from 13 of 45 sites. Yellow-green algae were present only at Bull Creek, West Branch Du Page River, Rock Run, and Big Rock Creek (nos., 4, 23, 26, 42, respectively) but abundance of this algal group was 1 percent or less of the total algal abundance at these four sites. The yellow-green alga *Dinobryon divergens* was found at three of these sites. This colonial phytoplankton is important in water supplies because it may cause disagreeable taste and odor (Prescott, 1978; Terrell and Perfetti, 1989). Blue-green algae never accounted for more than 16 percent of the algal biovolume, although this group was present at most sites and in relatively high abundance (from 40 to 65 percent) at some sites. Although various species of blue-green algae are known to fix nitrogen, none of those found in this study are known nitrogen-fixers. The most common blue-green algae were *Amphithrix janthina*, a suspected nitrogen-fixing alga, and the filamentous *Oscillatoria granulate* and *Oscillatoria prolifica*. Euglenoids were found at just three sites and a different species was present at each site, whereas dinoflagellates were found only at Salt Creek (no. 6) and were represented by only one species. The dinoflagellate *Glenodinium pulvisculus* was found with abundance and biovolume less than 1 percent on rocks at Salt Creek.

The diatom pollution-tolerance index indicates degrading water quality with lower values and the index showed a significant relation to increasing percent urban land (fig. 4i). This index relation indicated that at sites with more urban land in the drainage, the algal assemblages became more dominated by pollution-tolerant diatoms. Although index values for more sites indicated some pollution stress for diatom assemblages, no values greater than 2.4 for sites with greater than about 25-percent urban land were determined during this study. Sites in the LO and ML urban land-cover categories had higher diatom pollution-tolerance index values than the two categories of sites with greater than 25-percent urban land (fig 5i).

The median percent pollution-sensitive diatoms at sites was 44 percent. Many silt-tolerant taxa also are pollution-tolerant. The highest percent pollution-sensitive diatoms and the lowest diatom silt index for all sites were found at Boone Creek (no. 34) and Mill Creek at Mooseheart, Ill. (no. 39) (81 percent sensitive taxa and $\leq$ 20 percent silt-tolerant taxa). In contrast, the algal assemblage at Rock Run (no. 26) was represented by the lowest percent pollution-sensitive diatoms (5.3 percent) and the second highest (75 percent) silt index. Higher values of the silt index indicate a greater abundance of silt-tolerant diatom taxa. The diatom silt index was correlated (rho = -0.39) to one urban indicator, percent change in population density from 1990 to 2000 (POPDENCH). Increased fine sediment, such as silt, in streams is a common result of construction and adverse effects on streams can be severe (Waters, 1995). Soil loss from construction sites can be much greater than from either agricultural or forest sources.

The median percent pollution-tolerant diatoms was 17 percent, and algal assemblages at Des Plaines River at Russell, Addison Creek, and Long Run (nos. 2, 7, 18, respectively) included much higher percent pollution-tolerant diatoms relative to other sampled sites (from 43 to 45 percent). The percent pollution-tolerant diatoms increased with increasing percent urban land and other indicators of urbanization (table 4) such as increasing industrial land use, population density, impervious surface, dissolved sodium in water, concentrations of various metals (chromium, copper, nickel, zinc) in streambed sediment, as well as with indicators of eutrophication–

increasing TKN and total phosphorus in water. Fitzpatrick and others (2001) found that the percent pollution-tolerant diatoms showed the strongest relations to environmental variables of all algal metrics evaluated for their study of agricultural streams in Wisconsin.

Diatom diversity ranged from a low of 2.50 on rocks at Sawmill Creek (no. 9) to a high of 4.97 and 5.13 on woody snags at Deer Creek (no. 13) and Butterfield Creek (no. 14), respectively. The rock sample at Butterfield Creek did not have a similarly high value at 3.04. Diatom diversity index values for Addison Creek, Sawmill Creek (no. 9), and Jackson Creek (no. 22) showed that diatom assemblages in these stream sites were under high stress (values < 2.7). Diversity at 11 stream sites indicated no stress on the diatom assemblages from contamination; however, diversity may be high with moderate levels of some types of contamination.

Diatom guilds showed few relations with environmental characteristics (table 4). The abundance of *Achnanthes* spp. (guild 1) decreased and stalked diatoms (guild 9) increased with agricultural land cover. Neither guild showed any relation with urban land cover; however, the abundance of diatom guild 3 (non-filamentous centric diatoms) and guild 4 (filamentous centric diatoms) correlated with urban land cover. Guild 4 diatoms decreased with increasing urban land, road density, impervious cover, and population density, and the relation with urban land improved when woody snag samples were excluded. Guild 3 diatoms increased with urban land when woody snags alone were considered (table 8); however, this increase may simply reflect more slowly moving streams where these generally planktonic algae are more abundant.

Chlorophyll *a* in phytoplankton was weakly correlated to the urban-indicator variables (table 4). Chlorophyll *a* in periphyton was not correlated to any urban indicators, however, pheophytin, a degradation product of chlorophyll, was weakly correlated to all but one urban indicator.

The eigenvalues for DCA axes 1 through 4 are shown in table 9 and together the first four axes explained 17.3 percent of the variance in the algal data set. The taxa with high scores on the algal DCA axis 1 were the diatoms *Achnanthes affinis*, *A. minutissima*, *Gomphonema minutum*, *Navicula capitato-radiata*, and *N. reichardtiana*, and the blue-green alga *Oscillatoria granulata* (fig. 6). The sites that were scored highest on axis 2 were Little Rock Creek, Buck Creek, Jericho Creek, Boone Creek, and Indian Creek (nos. 43, 46, 30, 34, 45, respectively); all these sites were in watersheds with less than 5-percent urban land. The sites that scored lowest on the algal DCA axis 1 were Salt Creek, Addison Creek, and Flag Creek (nos 6, 7, 8, respectively). All these sites had greater than 70-percent urban land. The taxa which scored lowest on the algal DCA axis 1 were all diatoms: *Achnanthes pinnata*, *Navicula ingénue*, *N. seminulum*, *N. tantula*, and *N. recens*. The species *Navicula*, as a group, are generally motile and tend to be associated with higher silt conditions in streams (Molloy, 1992; Bahls, 1993).

DCA ordination indicated that urban land and other urban indicators were the major variables affecting the overall abundance and distribution of benthic algae in the studied stream sites (table 10a). The strongest correlations (rho $\geq$ 0.6) to DCA axis 1 scores were all negative, and these included urban indicators, dissolved ions in water, and sediment metals, and percent clayey surficial deposits in the watershed (WATCLAY). Positive correlations to DCA axis 1 included dissolved magnesium (MG_W) and calcium ions (CA_W), and soil-permeability variables (WATMOPER, BUFMOPER). Fewer environmental variables were correlated to DCA axis 2 and many of these variables were more highly correlated to DCA axis 1.

The eigenvalues for the first four axes of the algal CCA were 0.242, 0.209, 0.189, and 0.166, respectively. The first four axes explained 16 percent of the cumulative percent variance of the algal species data and 39.3 of the cumulative percent variance of the algal species-environment relation. The variable URBANLU was selected as a representative variable for CCA because it was highly correlated with many other variables, such as CL_W, CU_S, and Pb_S.

The most important environmental variables indicated by CCA were total phosphorus in water (PHOTOT_W) and the percent urban land (URBAN_LU), mean watershed slope (WATSLOP2), substrate variability (SUBSTCO), the percent clayey surficial deposits in the watershed (WATCLAY), nitrogen as nitrate plus nitrite (NITRAT_W), and the total number of detections of organic wastewater compounds (WWTPDET) (fig. 7; table 11). Additional important variables were arsenic in streambed sediment (AS_S), average wetted width/depth ratio (WDRAT), the amount of forest/wetland within the 60-m buffer (BUFFOWE), the slope of the low-flow water surface (SLOPELO), the percent habitat cover (HABCOVER), the average erosion length of stream banks (EROSION), the Wisconsin Habitat Index (WIHABIN), and average open-canopy angle (CANOPY). Algal species highly associated with increasing percent urban land in the watershed (URBANLU) were the green algae *Scenedesmus opoliensis* and *Scenedesmus acuminatus*, blue-green alga *Merismopedia tenuissima*, and motile diatoms including *Nitzschia thermaloides*, *Nitzschia intermedia*, *Nitzschia clausii*, *Navicula microcephala*, *Navicula gastrum*, and *Luticola goeppertiana*.

Macroinvertebrates

The macroinvertebrate genera most commonly identified were the midges *Polypedilum* sp. (44 sites), and *Ablabesmyia* sp. (42), and the caddisfly *Cheumatopsyche* sp. (41) (table 12). Other commonly identified taxa were *Turbellaria* (39 sites), Tubificidae (39), *Baetis* sp. (38), *Hydropsyche* sp. (37), *Stenelmis* sp. (37). The most abundant taxa in terms of mean percent of sample were *Stenelmis* sp. (10.6 percent), *Cheumatopsyche* sp. (10.2 percent), and Tubificidae (9.8 percent). Taxa that also averaged more than 5 percent of sample composition were *Polypedilum* sp. (8.0 percent), *Baetis* sp. (7.3), *Hydropsyche* sp. (6.6 percent), and *Caecidotea* sp. (6.6 percent).

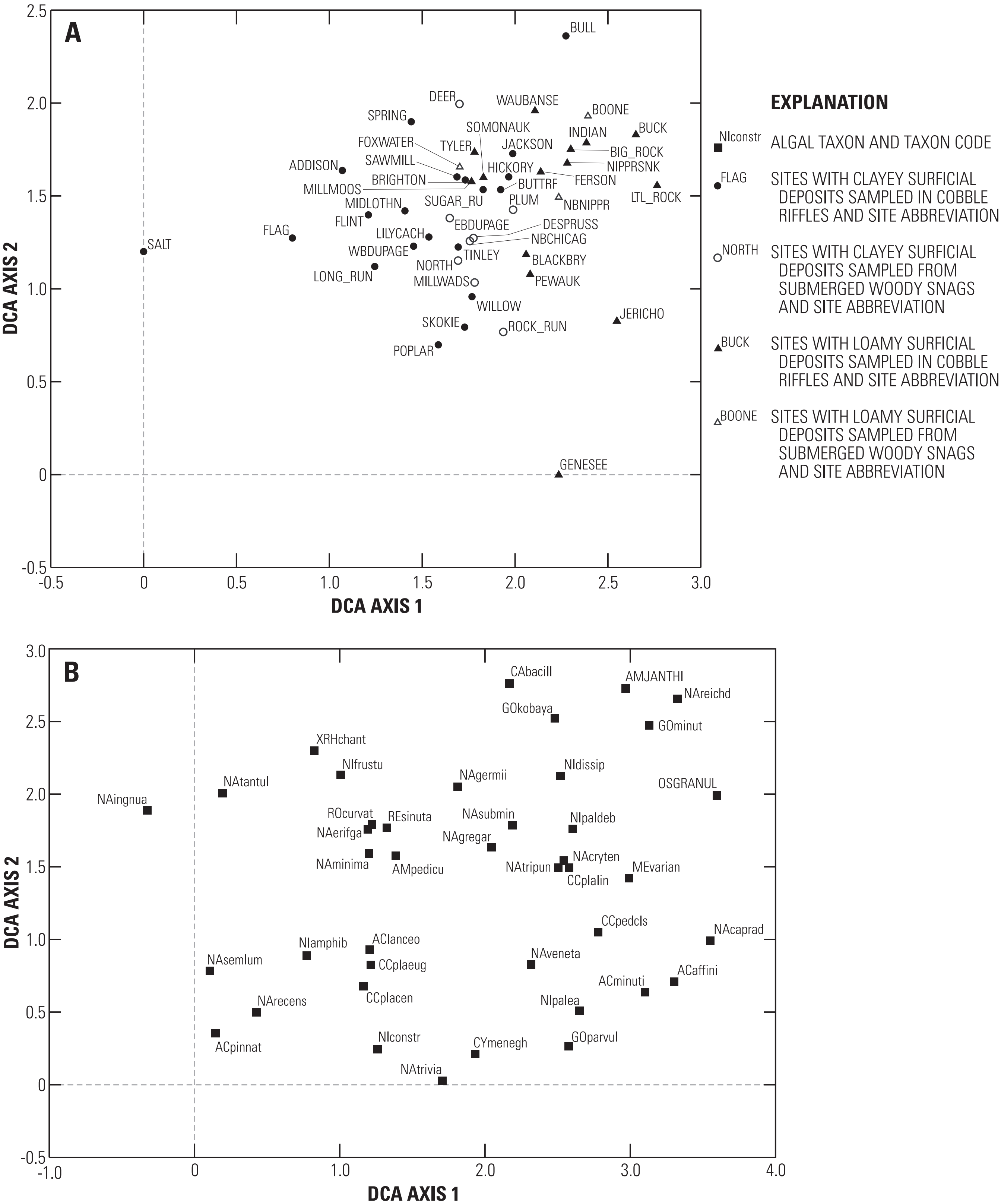

Figure 6. Algal partial detrended correspondence analysis (DCA) by A) site and by B) species for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Site abbreviations and species codes are listed in tables 1 and 7, respectively. Only species with a weight greater than 100 (42 of 263 taxa) are displayed.

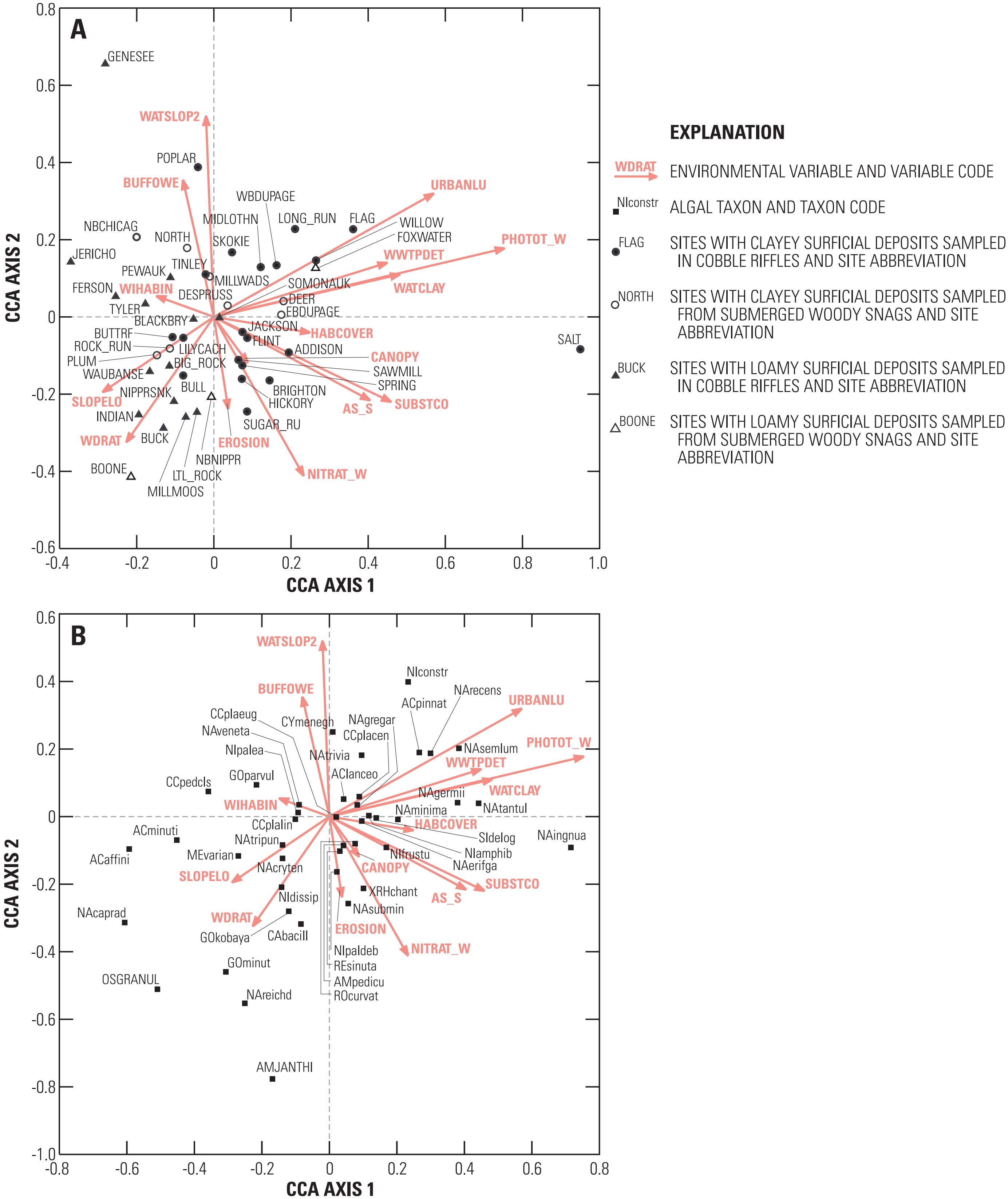

Figure 7. Algal partial canonical correspondence analysis (CCA) biplots of the relations of environmental variables to A) stream sites and to B) species, in northeastern Illinois and southeastern Wisconsin, 2000–01. Site abbreviations, environmental variable codes, and species codes are listed in tables 1, 2, and 7, respectively. Environmental variable arrow vectors represent the importance and direction of influence. Only species with a weight greater than 100 (42 of 263 taxa) are displayed.

The most total taxa were identified from Boone Creek (no. 34) (3.4-percent watershed urban land cover), with 48 taxa collected from the snag substrate. Additionally, the highest number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa on snags (12 taxa) was identified from Boone Creek. The sites with the next highest numbers of total taxa were Somonauk Creek (45 taxa; no. 44) and Little Rock Creek (41; no. 43). The seven stream sites with the highest numbers of total taxa (from 35 to 48) were all sites in the Fox River Basin, and all but one of these sites was classified as having loamy surficial deposits. Waubansee Creek (37), Jackson Creek (34), East Branch Du Page River (34), and Spring Creek (33) (nos. 40, 22, 24, 20, respectively), had the highest number of taxa for stream sites in clayey deposits. Of these sites, only the Boone Creek sample was collected from snag substrate. The highest number of EPT taxa was 16 at Blackberry Creek (no. 41), 14 at Little Rock Creek and Jackson Creek, and 13 at Big Rock Creek (no. 42); samples at these sites were collected from rocks, and these three sites had less than 7-percent watershed urban land cover. The lowest number of macroinvertebrate taxa, 15, was collected from Willow Creek (no. 5) and North Creek (no. 15). The lowest number of EPT taxa was identified from North Creek (one EPT taxon) and there were three sites with only two EPT taxa identified: Willow Creek, Addison Creek (no. 7) and Midlothian Creek (no. 16).

Sites in the LO and ML urban land-cover categories had higher numbers of EPT taxa than the two categories of sites with greater than 25-percent urban land (fig. 5j). This pattern was also found for number of macroinvertebrate taxa, tolerance value based on richness, number of Ephemeroptera taxa, number of Trichoptera taxa, and percent Ephemeroptera. Of the 7 sites with 12 or more EPT taxa, 6 had less than 7-percent urban land and Waubansee Creek (no. 40) had 21-percent urban land (fig. 4j). The greatest range of EPT scores and the highest standard deviation of EPT scores was in the LO land-cover category.

Various macroinvertebrate indices had strong correlations with percent watershed urban land cover (tables 4 and 8). In order of strength of correlation, these indices were the number of EPT taxa (rho = -0.72), the number of macroinvertebrate taxa (rho = -0.68), and the tolerance value based on richness (rho = 0.66). Other indices that were strongly negatively correlated ($p < 0.001$) with increasing urban land included number of Ephemeroptera taxa, percent Ephemeroptera, number of Trichoptera taxa, and all three macroinvertebrate diversity indices. The dominance of the top three taxa in a sample was positively correlated with increasing urban land.

Considering only the 34 samples where rock substrate was sampled (as opposed to woody snags), some correlations between macroinvertebrate indices and percent urban land were higher than correlations when both rock and woody snag samples were used (table 8). The strongest correlations ($p < 0.001$) were number of EPT taxa (rho = -0.80), number of taxa (rho = -0.82), and tolerance value based on richness (rho = 0.74). Other indices that decreased with increasing urban land were number of Ephemeroptera taxa, percent Ephemeroptera, number of Trichoptera taxa, and Margalef and Shannon diversity. Indices that increased with increasing urban land were dominance of the top three taxa and percent noninsects.

In samples that were collected off only woody snags (14 samples, Spearman significance level 0.538, $p = 0.05$), the percent Coleoptera (rho = -0.60) decreased with percent urban land. The smaller sample size of number of snag samples compared to other data sets may have some effect on the ability to detect trends in macroinvertebrate indices.

For a sampler comparison (data not shown), at three sites, two samples were collected, one from cobble and the other from submerged woody snags (Bassett Creek (no. 31), dropped from analyses, was a fourth site where two samples were collected). Density was at least twice as great in the rock samples as in the woody snag samples. (At Bassett Creek, the opposite was true). The number of EPT taxa in the rock samples was equal to or greater than in the woody snag samples; however, the total number of taxa identified in the woody snag samples was greater than or equal to the number of taxa in the rock samples. This result was mostly due to a greater number of chironomid taxa collected in the woody snag samples.

Eigenvalues for the first three DCA axes were 0.23, 0.15, and 0.10, respectively (table 9), and the cumulative variance explained was 13, 21, and 27 percent, respectively. The sites that were scored highest on the axis were North Branch Nippersink Creek, Blackberry Creek, Big Rock Creek and Little Rock Creek (fig. 8; nos. 33, 41, 42, 43, respectively); all these sites had less than 7-percent urban watershed land. The taxa that had high scores on the macroinvertebrate DCA axis 1 were: the mayflies *Tricorythodes* and *Isonychia*; the midges *Tvetenia* and *Rheotanytarsus*; and the caddisfly *Ceratopsyche*. The sites that were scored lowest on the macroinvertebrate DCA axis 1 were North Creek, North Branch Chicago River, Addison Creek, and Willow Creek (nos. 15, 10, 7, 5, respectively). All these sites had greater than 33-percent urban watershed land. The taxa that scored low on the macroinvertebrate DCA axis 1 were: the snail *Ferrissia*; the isopod *Caecidotea*; the fingernail clams, *Pisidium*; the annelid worms Tubifididae; and the flatworm *Turbellaria*.

Macroinvertebrate DCA axis 1 had strong negative correlations ($p < 0.001$) with sediment metal variables and urban land-use variables (table 10b). The bankfull-channel area area divided by drainage area (AREABFDA) and instantaneous discharge/estimated low flow (FLOWVAR2) was also negatively correlated to the macroinvertebrate DCA axis 1. Sodium and potassium in water were negatively correlated with this axis, and calcium and magnesium ion concentrations were positively correlated to this axis. Higher soil permeability was positively related to the axis by various variables (percent moderately permeable soils in the watershed (WATMOPER) and in a stream buffer (BUFMOPER), and percent outwash (WATOUT)) and variables indicating larger drainage size (drainage area (DRAIN) and cumulative stream length (CSTLE)) were positively related to the axis.

The highest macroinvertebrate DCA axis 2 score was at Jericho Creek (no. 30). Variables indicating higher basin relief and runoff were correlated with higher DCA axis 2 scores. These variables included a higher transport index (TRANSIN) (calculated by multiplying the relief by the drainage density and indicates how fast the runoff is drained), higher basin relief ratio (RELIEF), and higher slope (WATSLOP1, WATSLOP2, SLOPEBF, SLOPELO). The midge *Tvetenia* and the net-spinning caddisflies *Ceratopsyche* and *Cheumatopsyche* had high macroinvertebrate DCA axis 2 scores. Des Plaines River (no. 2) and Jackson Creek (no. 22) had the lowest macroinvertebrate DCA axis 2 scores. Larger channel size, indicated by higher bankfull-channel area and bankfull cross-sectional area (AREABF, BKFXSAR), and higher concentrations of the trace elements aluminum, chromium, and nickel in sediment were correlated with lower scores on the axis. The mayfly *Tricorythodes* had low macroinvertebrate DCA axis 2 scores.

Macroinvertebrate CCA axis 1 was negatively correlated with urban land use (URBANLU) and percent clay (WATCLAY) in the watershed, and positively correlated with drainage area, (DRAIN), the transport index (TRANSIN), and periphyton chlorophyll (chlper_a) (fig. 9). The second axis negatively related to stream size and amount of clay in the basin. Variables related to the third axis were standing crop of periphyton (chlper_a) and urban land cover.

The loamy surficial deposit sites scored highly on the macroinvertebrate CCA axis 1 and were separated from the clayey surficial deposit sites. The loamy sites were characterized by high transport index values (TRANSIN), high standing crop of periphyton (chlper_a), and low urban land cover. The loamy sites were characterized by the mayflies *Isonychia* and *Tricorythodes*, the midges *Tvetenia and Rheotanytarsus*, and the net-spinning caddisflies *Ceratopsyche*. The macroinvertebrates associated with negative axis 1 scores were the snail *Ferrissia*; the isopod *Caecidotea*; the fingernail clams *Musculium*, and the annelid worms Tubificidae.

Fish

Seventy fish species from 16 families were identified at the 45 sites. Four of these species were not native to the UIRB. The number of native fish species identified at a particular site ranged from a low of 2 at Midlothian Creek (no. 16) to a high of 31 at Genesee Creek (no. 29). The median number of native fish at a site was 13.

Green sunfish (Centrarchidae) was the species identified from the most sites; it was present at 39 sites (table 13). The bluntnose minnow (Cyprinidae) and white sucker (Catostomidae) were the next most commonly encountered species, at 36 and 35 sites, respectively. Other species that were found at more than one-third of the sites were the sunfish (Centrarchidae) bluegill (27 sites) and largemouth bass (26); a darter (Percidae), johnny darter (30); a bullhead catfish (Ictaluridae) yellow bullhead (25); and seven other minnows (Cyprinidae). In addition to bluntnose minnow, the most common minnows were creek chub (31 sites), central stoneroller (25), hornyhead chub (24), spotfin shiner (21), common carp (21), sand shiner (20), and common shiner (17).

Common carp is a widespread non-native species and was identified at 21 sites. Three other non-native species were identified during fish sampling. The oriental weatherfish was found at Midlothian Creek (72-percent urban land in basin; no. 16) and the western mosquitofish and goldfish were identified from the Skokie River (60-percent urban land cover; no. 11).

Of the three biological components, fish metrics and indices had the strongest correlations with urban land cover. The revised Illinois IBI was strongly negatively correlated (rho = -0.81) with amount of watershed urban land (fig. 4k). Only one site with less than 25-percent urban land had a score less than 30; Des Plaines River at Russell (no. 2), a low-gradient site, scored 27. Only one site with greater than 25-percent urban land had a score of greater than 26; Poplar Creek (no. 37), 38-percent urban land, had a score of 40. Of the nine sites that scored 45 or better, seven had less than 7-percent urban land; all these sites were in basins with loamy surficial deposits.

In the revised Illinois IBI, eight metrics are expected to decrease with disturbance and two are expected to increase. With respect to urban land cover, 9 of the 10 metrics were consistent with this hypothesis. Eight metrics had Spearman rho values greater than ± 0.48 ($p < 0.001$), and the ninth, proportion of generalist feeders, had a Spearman rho of 0.44 ($p < 0.01$) (table 4). The number of native sunfish species metric showed no correlation with the urban gradient. The IBI itself had a higher correlation value with urban land than any of the individual metrics.

Sites in the LO and ML urban land-cover categories had higher Illinois IBI scores than the two categories of sites with greater than 25-percent urban land (fig. 5k).The following metrics had a similar pattern: number of native intolerant species; number of native benthic invertivore species; proportion of obligate coarse-mineral-substrate spawners; and proportion of tolerant species (data not shown). The number of native minnow species followed a similar pattern, but, in addition, the LO was higher than ML. The number of native fish was higher in the LO category than in the other categories. The proportion of specialist benthic invertivores in the HI category was lower than in all the other categories. The proportion of individuals of species that are generalist feeders was lowest in the ML category. The greatest variability in IBI scores was in the LO (from 0- to 10-percent urban land) category (interquartile range = 13; standard deviation = 8.5), and the lowest variability of IBI scores was found in the greater than 50-percent urban land category (interquartile range = 3; standard deviation = 4.9) (fig. 5k).

Eigenvalues for the first three fish DCA axes were 0.30 0.20, and 0.10, respectively (table 9), and the cumulative variance explained was 14, 24, and 29 percent, respectively. The lowest fish DCA axis 1 scores were found at North Branch Chicago River, Deer Creek, Salt Creek, Des Plaines River,

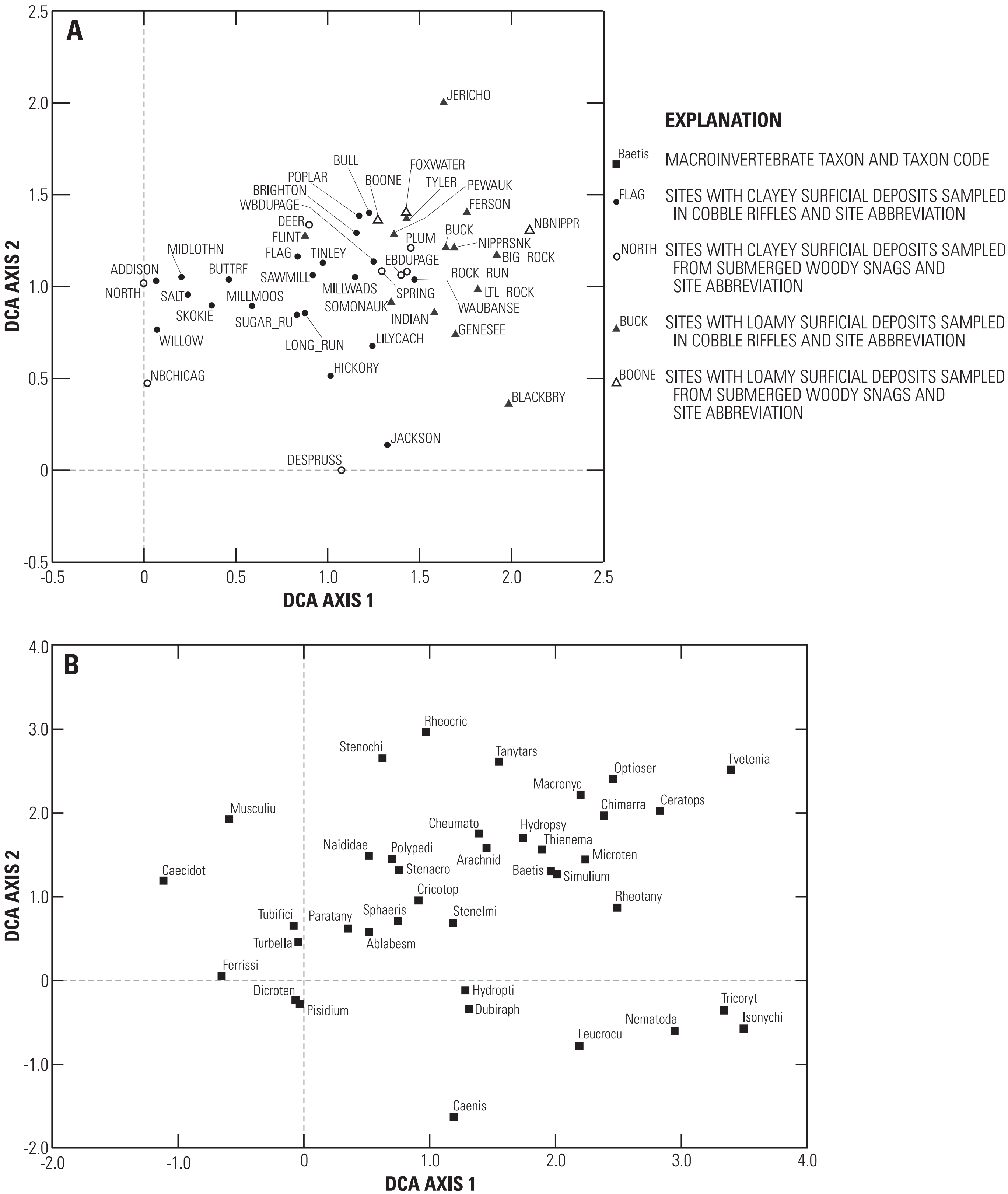

Figure 8. Macroinvertebrate partial detrended correspondence analysis (DCA) by A) site and by B) taxon for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Site abbreviations and taxa codes are listed in tables 1 and 12, respectively. Only taxa with a species weight greater than 11 (38 of 61 taxa) are displayed.

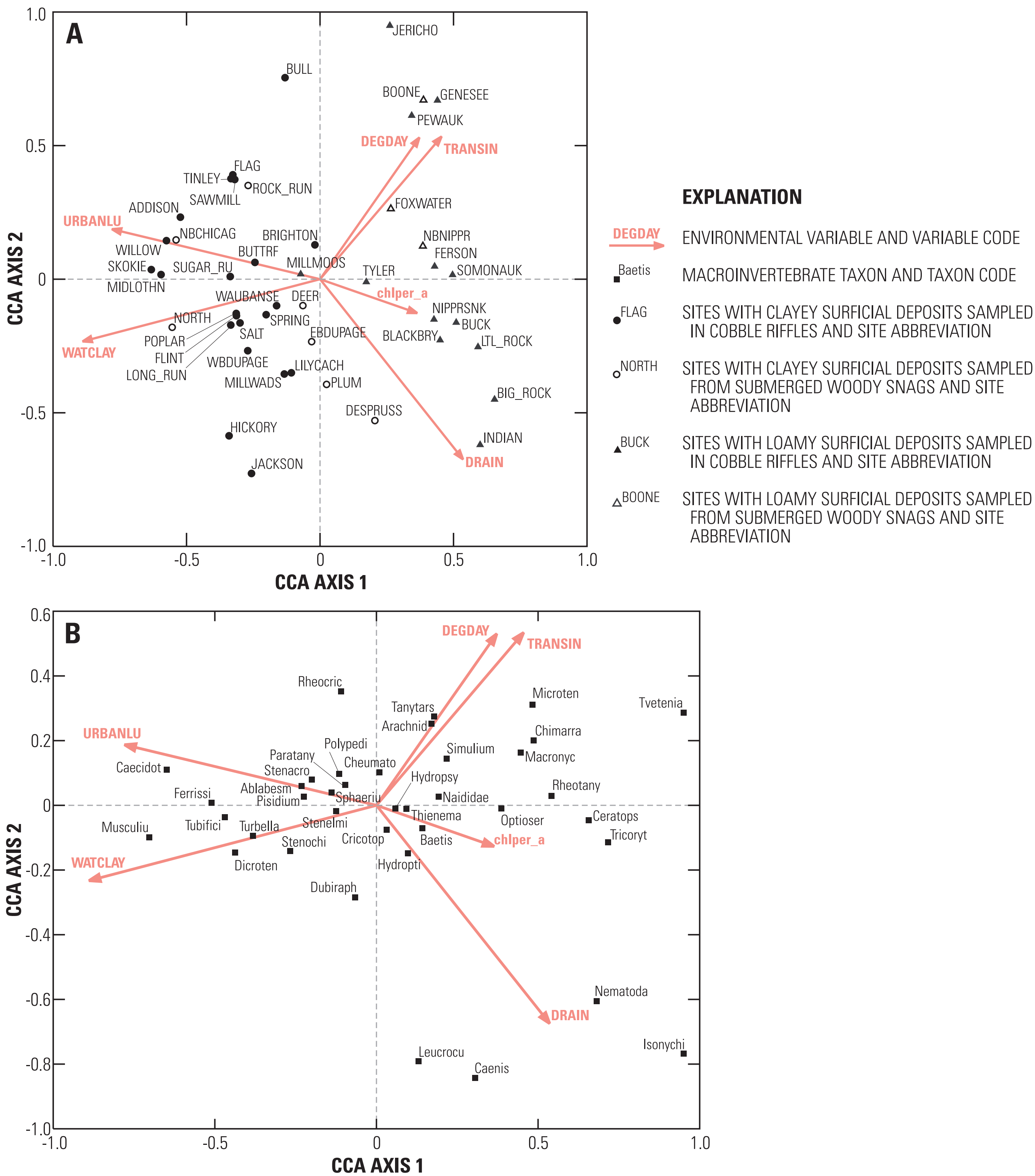

Figure 9. Macroinvertebrate partial canonical correspondence analysis (CCA) biplots of the relations of environmental variables to A) stream sites and B) species in northeastern Illinois and southeastern Wisconsin, 2000–01. Site abbreviations, environmental variable codes, and taxa codes are listed in tables 1, 2, and 12, respectively. Environmental variable arrow vectors represent the importance and direction of influence. The environmental variables shown are significantly related to one or more of the CCA axes (table 11). Only taxa with a species weight greater than 11 (38 of 61 taxa) are displayed.

and Skokie River (fig. 10; nos. 10, 13, 6, 2, 11, respectively). Of these sites, four had greater than 25-percent urban land cover, and all of these sites were among the sites with the lowest stream slopes. Black bullhead (Amei mel), blackstripe topminnow (Fund not), and bluegill (Lepo mac) scored low on the DCA axis 1. Conversely, the highest scoring sites on the DCA axis 1, including Buck Creek, Spring Creek, and Sugar Run (nos. 46, 20, 21, respectively), had less than 20-percent urban watershed land and relatively medium to high slopes (SLOPESE $\geq$ 0.0029). Among the fish with high axis 1 scores were striped shiner (Luxi chr), orangethroat darter (Ethe spe), fantail darter (Ethe fla), and northern hogsucker (Hype nig).

Associated with fish DCA axis 1 were environmental variables associated with land use, ions, sediment metal, substrate composition, and stream slope and power (table 10c). Lower fish DCA axis 1 scores were correlated with higher urban land use indicators, higher concentrations of sodium, potassium, and chloride ions, higher concentrations of TKN and total phosphorus, and concentrations of various sediment trace elements (including chromium, zinc, mercury, nickel and cadmium). Higher scoring sites were associated with larger substrate particles (roughness, ROUGH; average substrate size/depth SUBST; and amount of gravel, GRAVEL). Higher scoring sites also were correlated with many variables indicating greater slopes and stream power (including three slope variables and stream power, stress and competence variables).

The highest scoring sites on fish DCA axis 2 were Indian Creek, Mill Creek (Fox Basin), Big Rock Creek, Mill Creek (Des Plaines Basin), and Jackson Creek (nos. 45, 39, 42, 39, 22, respectively). These sites were all among the larger sites sampled. The lowest scoring sites on the DCA axis 2 were Bull Creek, Spring Creek, Boone Creek, Midlothian Creek, Jericho Creek, and Sugar Run (nos. 4, 20, 34, 16, 30, 21, respectively). High values on fish DCA axis 2 were correlated to environmental variables indicating large stream size, including drainage area (DRAIN), cumulative stream length (CSTLE), and bankfull cross-sectional area (BKSURAR). Variables related to canopy cover were also correlated to the DCA axis 2 and lower correlation values were found for variables related to urban land use and slope.

Urban land (URBANLU), percent clayey surficial deposits (WATCLAY), and percent fines (FINES) were the most important significant variables on the fish CCA axis 1 (fig. 11). Five sites with over 30-percent urban land scored highest on this axis. Also scoring highly were stream sites associated with more fines (FINES), lower stream slope, and lower current velocity, such as Des Plaines River, Fox River, and Mill Creek (Des Plaines Basin) (nos. 2, 27, 3, respectively). Representative species included black bullhead (Amei mel), blackstripe topminnow (Fund not), fathead minnow (Pime pro), and three sunfishes, bluegill (Lepo mac), green sunfish (Lepo cya), and largemouth bass (Micr sal). Lower scoring sites were low urban sites, such as Somonauk Creek (no. 44) and Buck Creek (no. 46), and moderately urban, higher gradient sites, such as Hickory Creek, and characterized by species such as striped shiner (Luxi chr), golden redhorse (Moxo ery), stonecat (Notu fla), northern hogsucker (Hype nig), banded darter (Ethe zon), and smallmouth bass (Micr dol).

High scoring sites on the second axis were associated with larger stream size. These sites, such as Des Plaines River (no. 2) and Indian Creek (no. 45), were characterized by species such as blackstripe topminnow (Fund not), black bullhead (Amei mel), channel catfish (Icta pun), golden redhorse (Moxo ery), and banded darter (Ethe zon). The third axis was primarily related to periphyton (chlper_a) (table 11).

Comparison of Biological Community Reponses to Urbanization

The macroinvertebrate EPT index and fish IBI both declined with increasing urbanization, whereas the urbanization effects on the diatom pollution-tolerance index were more complex (figs. 4i-k). The macroinvertebrate EPT index and fish IBI trend lines parallel each other, each having a steep initial decline from 0- to 30-percent urban land, an inflection point at about 30-percent watershed urban land, and then a shallow decline or no trend at higher percent urban land. In this study, 30-percent urban land was roughly equivalent to 9-percent impervious surface, 0.035 km^2/km^2 road density, and 500 people/km^2 (1,300 people/mi^2). An initial decline in the diatom pollution-tolerance index was present but there was more scatter about the trend line than there was for the other two community indices.

The steep decline in the biotic indices at the low end of the land-cover gradient is similar to other studies that found large decreases in biotic integrity with increasing urban indicators (Klein, 1979; Dreher, 1997; Wang and others, 1997). Some studies have suggested specific levels of urbanization where appreciable impairment occurs. Near the Chicago area, for example, fish Index of Biotic Integrity (IBI) scores tended to be low in watersheds with greater than 10- to 20-percent urban land and 200 people/m^2 (Dreher, 1997; Wang and others, 1997; Fitzpatrick and others, 2004). Other studies have suggested that biotic integrity degrades at about 10-percent effective impervious area (for example, Booth and Reinelt, 1993; Booth and Jackson, 1997; Maxted and Shaver, 1997; Wang and others, 2000, 2001). Some researchers have identified a second threshold where stream-quality impairments are severe (Klein, 1979; Kennen and Ayers, 2002); the inflection point of the macroinvertebrate EPT index and fish IBI trend lines in this study may reflect this second threshold.

Values for the diatom pollution-tolerance index, number of macroinvertebrate EPT taxa, and the fish IBI were lower in watershed urban land-cover categories LO and ML than in MH and HI (fig. 5). For both the fish IBI and macroinvertebrate EPT indices, the majority of the highest scores were found in samples from sites with less than 10-percent urban land (LO watershed land -cover category). In both of these cases, however, the variability of the scores in the LO category were greater than that of the ML category. Beyond 20 to 25-percent urban land, macroinvertebrate and fish index values were uniformly low, with a few exceptions. These findings are similar to Fitzpatrick and others (2004) for historic fish and macroinvertebrate indices.

Summary

Urbanization is one of the major causes of stream impairment in the United Sates and Europe. Urban development modifies land surfaces and increases the amount of impervious surface in watersheds. Altered stream channels in urban areas result in increased surface runoff; modified peak-flow characteristics; modified sediment erosion and deposition characteristics; modification of annual flooding; and reduced infiltration and lower base flows. Point and nonpoint sources in urban areas contribute chemical contaminants to streams and, in general, concentrations of nutrients and other ions, metals, pesticides, and organic compounds increase with increasing urban land. Decreases in biotic diversity and integrity of invertebrate and fish communities have been related to urbanization.

Agriculture is the predominant land use in northeastern Illinois and southeastern Wisconsin in terms of land area, but the populated areas of Chicago, Ill. and Milwaukee, Wis. are large and rapidly expanding. Watersheds are being converted from agriculture to urban and stream conditions may reflect these changes in land use. As part of the USGS UIRB - NAWQA study, physical, chemical, and biological data were collected from sites in the Fox and Des Plaines River Basins along an agricultural to urban land-cover gradient to better understand the effects of urbanization on the physical, chemical, and biological condition of streams in northeastern Illinois and southeastern Wisconsin. Forty-five stream sites in the study area were sampled. Urbanization indicators and watershed characteristics were calculated for each stream site. Correlation, nonparametric analysis of variance, and multivariate analyses were used to assess interactions among the watershed characteristics.

Study watersheds are located in the Fox and Des Plaines River Basins of northeastern Illinois and southeastern Wisconsin. The study area is approximately 12,400 km^2. The climate is humid with an average temperature of 9°C and average annual precipitation of about 890 mm. Topography is relatively flat. Quaternary deposits are highly variable and complex but generally consist of till and outwash sand and gravel. A variety of stormwater-control techniques are used in the study area. Historically, the capacity of combined sewer systems was often exceeded during summer thunderstorms resulting in the release of untreated sewage directly to streams.

Physical characteristics of stream sites were affected by landscape characteristics, including stream slope, land-use practices, such as different kinds of stormwater-control techniques, as well as by urbanization. Sites with greater stream slope were positively correlated with substrate size, amount of riffle area, and stream depth variation. Bankfull-channel area was smaller and less variable for stream sites with 10-percent or less watershed urban land, than for stream sites with more watershed urban land. Results from a concurrent study found that the size of 2-year flood peaks increased as urban land cover increased from 0 to about 30 percent. The RBP Habitat Index was not correlated to percent urban land cover, but stream sites with 10- to 25-percent urban land had higher scores than stream sites with less than 10-percent urban land and stream sites with greater than 25-percent urban land.

Concentrations of dissolved chloride and sodium, number of organic wastewater compounds detected, and concentrations of various metals in sediment all had strong positive correlations with increasing urban land. Concentrations of nutrients were related to urban and agricultural land use, and possibly point sources. Chloride concentrations increased along the entire gradient, and would serve as a good surrogate as an urban land indicator. Conductivity, which has been used as an urban indicator in other studies, was only weakly correlated to urban land cover in the study area. Number of detections of wastewater compounds was more variable at sites with less than 25-percent urban land cover than at sites with greater than 25-percent urban land. The number of detections ranged from 0 to 19 compounds, but no sites with greater than 25-percent watershed urban land had fewer than 6 detections. A variety of types of compounds were commonly detected, including PAHs, detergents, disinfectants, insecticides, plasticizers and a flame retardant. The sediment trace-element concentrations with highest correlations with urban land use were lead, zinc, and copper. Concentrations of these trace elements, in particular, appeared to rapidly increase at lower urban levels, level off, and then rapidly increase at higher urban land-cover percentages. Nitrate concentrations decreased as agricultural land cover decreased and urban land cover increased; this result contrasts with some other urban gradient studies that examined urban development in undeveloped areas. Total phosphorus and nitrate concentrations were particularly high at 6 of 11 sites with greater than 50-percent urban land cover, indicating point-source contributions.

Biological indices, such as the diatom pollution-tolerance index, percent pollution-tolerant diatoms, number of EPT taxa, number of macroinvertebrate taxa, and tolerance value based on richness, and fish IBI and most of its component metrics, indicated decreasing water quality with increasing urban land. The majority of the highest scores of the macroinvertebrate EPT and the fish IBI indices were found in samples from sites with less than 10-percent urban land. More variability of the values of these two indices were found at the sites with less than 10-percent urban land cover compared to sites with between 10 and 25 percent and sites with greater than 25-percent urban land cover. At sites with greater than about 25-percent urban land cover, these index values were uniformly low, with a few exceptions.

The algal diatom pollution-tolerance index, macroinvertebrate EPT index, and fish IBI all declined with increasing urban land cover. Macroinvertebrate EPT index and fish IBI values declined sharply from 0- to 30-percent urban land cover. The steep decline in the biotic indices at the low end

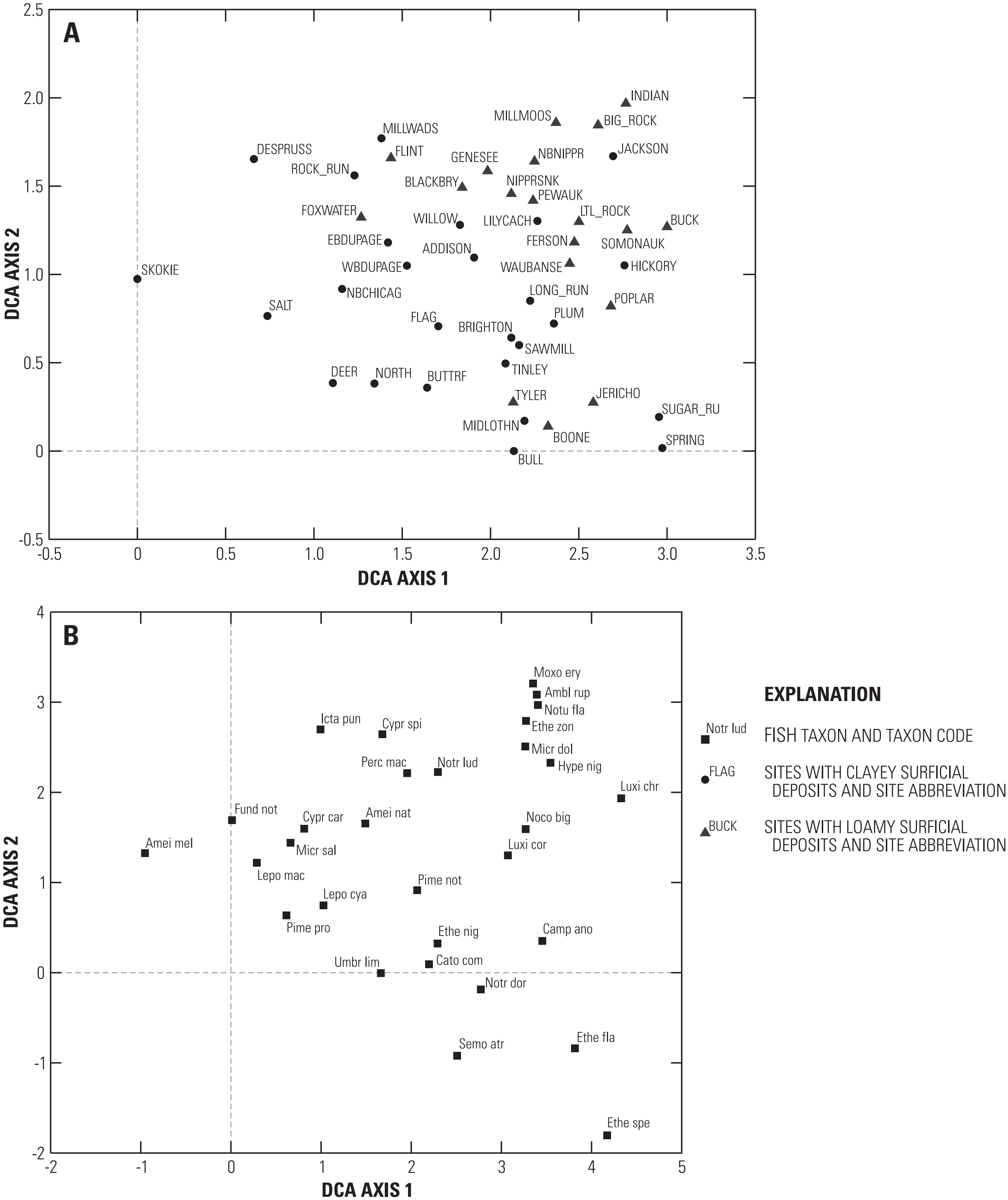

Figure 10. Fish partial detrended correspondence analysis (DCA) by A) stream site and by B) species in northeastern Illinois and southeastern Wisconsin, 1995–2001. Site abbreviations and species codes are listed in tables 1 and 13, respectively. Only species with a species weight greater than 5 (30 of 72 species) are displayed.

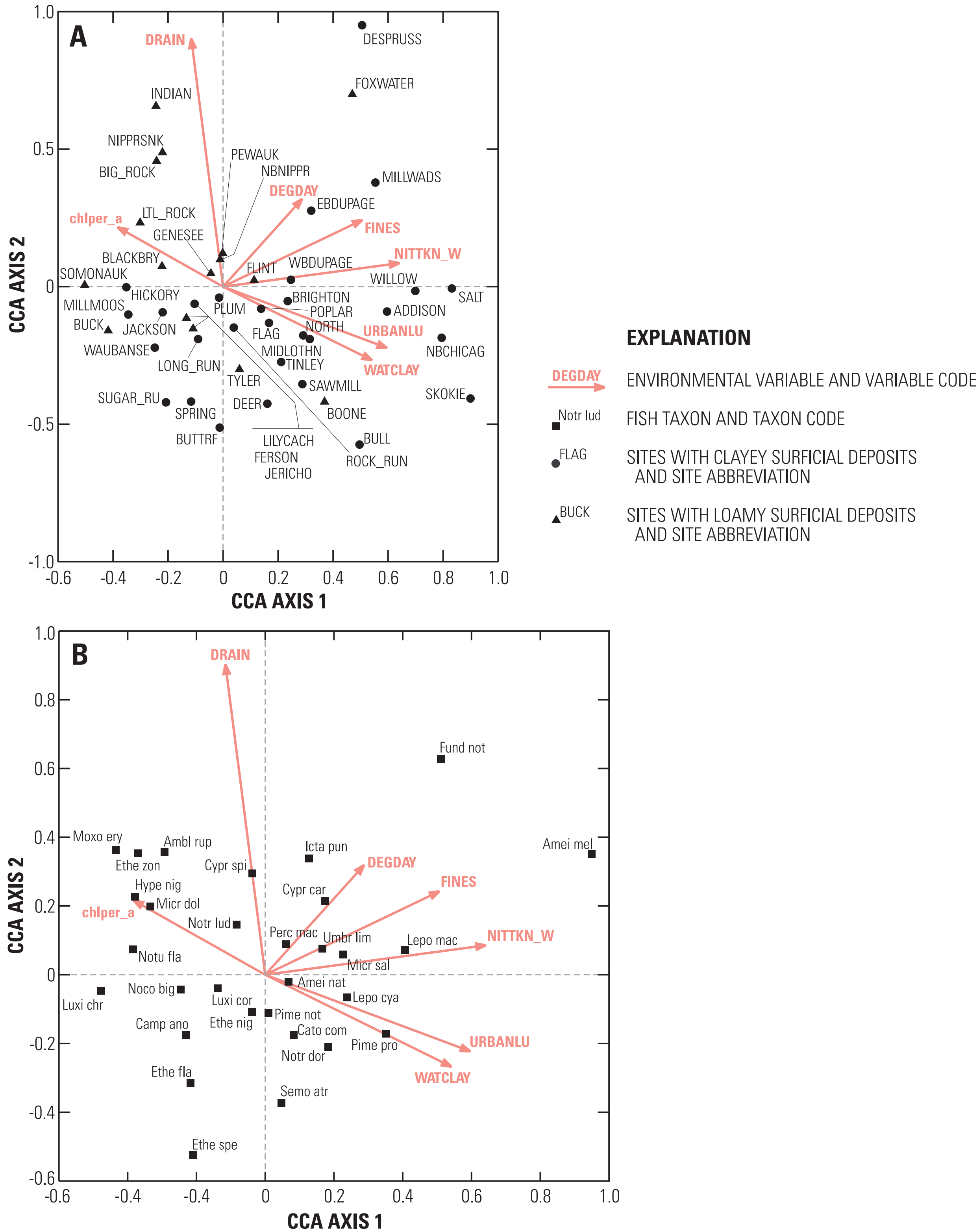

Figure 11. Fish partial canonical correspondence analysis (CCA) biplots of the relations of environmental variables to A) stream sites and to B) species, in northeastern Illinois and southeastern Wisconsin, 1995–2001. Site abbreviations, environmental variable codes, and species codes are listed in tables 1, 2, and 13, respectively. Environmental variable arrow vectors represent the importance and direction of influence. The environmental variables shown are significantly related to one or more of the CCA axes (table 11). Only species with a species weight greater than 5 (30 of 72 species) are displayed.

of the gradient is similar to other studies that found large decreases in biotic integrity with increasing urban indicators. The change in slope of the macroinvertebrate EPT index and fish IBI trend lines is similar to a second threshold reported in other studies, where stream-quality impairments are severe. In comparison to macroinvertebrate and fish responses to urbanization, algal community indices often were highly variable at lower levels of urbanization as some algal species increase with urban development; however, at sites with higher amounts of watershed urban land, the percent pollution-tolerant diatoms appeared to respond similarly to invertebrates and fish.

Primary axes defined in indirect gradient analysis (DCA) and direct gradient analysis (CCA) were largely related to urban indicators and variables associated with urban indicators, such as concentrations of trace elements in streambed sediment and dissolved ions in water. Percent clay in watershed and stream size were correlated with urban land because of the site selection and patterns of urban development. Other environmental variables important to biological communities were related to stream slope, stream power and the transport index, percent fines in the substrate, canopy cover, and nutrient concentrations.

Physical, chemical, and biological stream attributes are altered concurrently as predominantly agricultural lands are urbanized; however, there are different patterns of changes in these attributes. In general, whereas chloride and sediment trace-element concentrations increased over the entire urban gradient, increased point sources (contemporaneous with urban development) affected nutrient concentrations and the presence of wastewater compounds. Pattern of nitrate concentrations reflect both the decrease of watershed agricultural land cover as well as site-specific sources in urban areas. Many macroinvertebrate and fish community indices declined rapidly with urban development in the study area, but then reached a threshold beyond which indices at most sites reflected high community impairment. Variability was highest for the macroinvertebrate EPT index and the fish IBI at low levels of watershed urban land cover (and high amount of agricultural land cover), but the variability of bankfull-channel area/drainage area at sites with less than 10-percent watershed urban land cover was lower than at sites with higher amount amounts of urban land cover.

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TABLES 1–13

Table 1. Sampling sites, locations, drainage area, percent watershed urban land, and population density for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01.

[USGS, U.S. Geological Survey; km^2, square kilometers]

Map reference number (see fig. 2)	Site name	Site abbreviation	USGS Station Number	Drainage area (km^2)	Watershed urban land cover (percent)	Road density (km^2/ km^2)	Estimated impervious cover (percent)	Population density (people/ km^2)
1	Brighton Creek at State Highway 45 near Bristol, Wis.	BRIGHTON	05527675	66	6.9	0.014	1.5	100
2	Des Plaines River at Russell, Ill.	DESPRUSS	05527800	318	4.5	.015	.9	70
3	Mill Creek at Wadsworth, Ill.	MILLWADS	05527960	169	9.5	.029	2.7	311
4	Bull Creek below Milwaukee Ave near Libertyville, Ill.	BULL	05528032	20	27	.035	7.1	453
5	Willow Creek at Des Plaines R Rd near Rosemont, Ill.	WILLOW	05530510	56	86.1	.043	41.1	510
6	Salt Creek at Elk Grove Village, Ill.	SALT	05531045	128	73.4	.062	23.3	1,240
7	Addison Creek at Bellwood, Ill.	ADDISON	05532000	47	92.4	.079	38	1,690
8	Flag Creek near Willow Springs, Ill.	FLAG	05533000	43	86.7	.081	22.2	1,300
9	Sawmill Creek near Lemont, Ill.	SAWMILL	05533400	33	73.6	.061	20.9	900
10	N Br Chicago River at Deerfield Rd at Deerfield, Ill.	NBCHICAG	05534460	48	33.3	.039	9.5	334
11	Skokie River at Glencoe, Ill.	SKOKIE	05535100	62	60	.05	18.4	756
12	Plum Cr at Richton Rd near Sauk Village, Ill.	PLUM	05536176	85	8.1	.016	1.7	88
13	Deer Creek near Glenwood, Ill.	DEER	05536236	62	25.8	.031	5.7	311
14	Butterfield Cr at Country Club Rd near Flossmoor, Ill.	BUTTRF	05536248	48	38.3	.045	11.4	667
15	North Creek Below 183rd Street near Thornton, Ill.	NORTH	05536272	58	35	.041	11.4	710
16	Midlothian Creek at Blue Island, Ill.	MIDLOTHN	05536355	51	71.7	.072	25.1	1,450
17	Tinley Creek near Palos Park, Ill.	TINLEY	05536500	29	56.5	.055	18.7	1,120
18	Long Run Cr at Smith Rd near Lemont, Ill.	LONG_RUN	05537550	61	28.5	.038	4.7	473
19	Hickory Creek at Schmuhl Rd near New Lenox, Ill.	HICKORY	05538270	127	20.6	.034	6.2	352
20	Spring Creek near Joliet, Ill.	SPRING	05538490	47	11.1	.026	2.2	204
21	Sugar Run at Mills Road at Joliet, Ill.	SUGAR_RU	05539335	33	17	.026	4.4	253
22	Jackson Cr at Manhattan Rd near Elwood, Ill.	JACKSON	05539632	113	3.5	.017	.9	133
23	W Br DuPage R at Garys Mill Rd near W Chicago, Ill.	WBDUPAGE	05540032	157	58.1	.056	17.1	1,290
24	East Branch Du Page River near Naperville, Ill.	EBDUPAGE	05540260	206	72.9	.062	20.8	1,300
25	Lily Cache Creek above Caton Farm Rd near Lily Cache, Ill.	LILYCACH	05540440	114	19	.04	5.6	636
26	Rock Run near Shorewood, Ill.	ROCK_RUN	05540660	37	51.8	.054	16.6	909

Table 1. Sampling sites, locations, drainage area, percent watershed urban land, and population density for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[USGS, U.S. Geological Survey; km^2, square kilometers]

Map reference number (see fig. 2)	Site name	Site abbreviation	USGS Station Number	Drainage area (km^2)	Watershed urban land cover (percent)	Road density (km^2/ km^2)	Estimated impervious cover (percent)	Population density (people/ km^2)
27	Fox River at Watertown Rd near Waukesha, Wis.	FOXWATER	05543800	203	29.7	0.031	7.7	320
28	Pewaukee River near Pewaukee, Wis.	PEWAUK	055438135	98	18.8	.032	4.3	290
29	Genesee Creek at Saylesville, Wis.	GENESEE	055438845	72	6.6	.021	1	110
30	Jericho Creek near Jericho, Wis.	JERICHO	05544080	32	3.1	.019	.6	96
31	Basset Creek near Twin Lakes, Wis.				Site Dropped			
32	Nippersink Creek above Wonder Lake, Ill.	NIPPRSNK	05548105	219	4.4	.014	1.4	100
33	North Branch Nippersink Creek near Richmond, Ill.	NBNIPPR	05548200	167	5.7	.017	1.3	83
34	Boone Creek near McHenry, Ill.	BOONE	05549000	40	3.4	.016	.4	56
35	Flint Creek near Fox River Grove, Ill.	FLINT	05549850	96	30.8	.036	6.8	341
36	Tyler Creek at Randall Road near Elgin, Ill.	TYLER	05550290	81	2.9	.013	1	49
37	Poplar Creek at Elgin, Ill.	POPLAR	05550500	94	37.7	.044	10.7	881
38	Ferson Creek near St. Charles, Ill.	FERSON	05551200	134	16.6	.025	3.1	242
39	Mill Creek at Mooseheart, Ill.	MILLMOOS	05551340	80	16.4	.029	3.4	311
40	Waubansee Creek at Oswego, Ill.	WAUBANSE	05551548	77	21.2	.037	6.9	646
41	Blackberry Cr at Bristol Ridge Rd near Bristol, Ill.	BLACKBRY	05551695	174	6.8	.021	1.7	155
42	Big Rock Creek at Jericho Road near Sugar Grove, Ill.	BIG_ROCK	05551931	273	1	.011	.3	24
43	Little Rock Creek at Milhurst Road near Plano, Ill.	LTL_ROCK	05551939	196	3.8	.013	1	60
44	Somonauk Creek at Somonauk Rd near Sandwich, Ill.	SOMONAUK	05551985	96	.9	.01	.3	18
45	Indian Creek below Shabbona County Park near Harding, Ill.	INDIAN	05552190	326	1.1	.01	.3	16
46	Buck Creek near Wedron, Ill.	BUCK	05552450	103	0	.008	0	5

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01.

[km^2, square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m^2, square meters; N/m s, Newtons per meters per second; m^3/s, cubic meters per second; mm, millimeters; m^3, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm^2, square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m^2, milligrams per square meters; g/m^2, grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Urban Indicators				
Watershed urban land (percent)	URBANLU	19	0	92
Road density (km^2/km^2)	ROADDEN	.031	.008	.081
Estimated impervious cover (percent)	IMPERV	5	0	41
2000 population density (people/km^2)	POPDEN00	311	5	1,690
Agricultural land (percent)	AGRICUL	59	0	99
Industrial land (percent)	INDUSLU	2	0	47
1990 population density (people/km^2)	POPDEN90	252	5	1,600
1990-2000 population density change (percent)	POPDENCH	20	3	104
1980 population density, estimated (people/km^2)	POPDEN80	196	6	1,610
1980-2000 population density change, estimated (percent)	POPDENC2	39	-27	215
1999 housing unit density (houses/km^2)	HOUSE	94	2	574
Landscape Characteristics				
Drainage area (km^2)	DRAIN	81	20	326
Drainage density (km^2/km^2)	DRAINDEN	1.34	1.08	1.44
Basin relief ratio	RELIEF	.004	.001	.007
Very low and low permeability (percent)	WATLOPER	99	2	100
Moderate permeability (percent)	WATMOPER	1	0	98
Average basin slope from Basinsoft (feet/mile)	WATSLOP1	111	38.3	240
Mean slope in watershed from DEM data (percent)	WATSLOP2	1.31	.2	3.36
Percent of basin with ≤1 percent slope (percent)	TOPOFLAT	68	36	98
Cumulative stream length (km)	CSTLE	112	27	470
Clayey surficial deposits (clay till + lake clay/silt) (percent)	WATCLAY	71.2	0	100
Outwash (percent)	WATOUT	2	0	86
Transport index	TRANSIN	.005	.001	.01
Depth of bedrock <50 ft, within 60-m buffer (percent)	BUFBEDRO	3.8	0	98.2
Depth of bedrock <50 ft in watershed (percent)	WATBEDRO	5.3	0	93.9
Soil permeability high-moderate, within 60-m buffer (percent)	BUFMOPER	.8	0	99.6
Forest/wetland within 60-m buffer (percent)	BUFFOWE	19.1	2.4	49.3
Coarse Quaternary deposits within 60-m buffer (outwash, alluvium, lake S/G, ice contact S/G, and sand) (percent)	BUFCOARS	1.8	0	96.1
Latitude (degrees,minutes,seconds)	LATITU	41°44’20”	41°25’47”	43°03’12”
Degree days	DEGDAY	6,612	6,260	7,415
Geomorphology and Hydrology				
Slope, segment (m/m)	SLOPESE	.0015	0	.0098
Sinuosity (m/m)	SINUOS	1.3	1.1	2
Slope, low-flow water surface (m/m)	SLOPELO	.002	.0001	.0079
Slope, bankfull water surface (m/m)	SLOPEBF	.002	.0001	.0079

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[km^2, square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m^2, square meters; N/m s, Newtons per meters per second; m^3/s, cubic meters per second; mm, millimeters; m^3, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm^2, square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m^2, milligrams per square meters; g/m^2, grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Geomorphology and Hydrology (cont.)				
Bankfull-channel area (m^2)	AREABF	10	2	24
Bankfull-channel area/drainage area (m^2/km^2)	AREABFDA	.11	.03	.43
Stream power (N/m s)	POWERBF	12.1	.1	149
Manning's n for bankfull flow	MANNBF	.035	.030	.045
Bankfull flow (m^3/s)	BFLOW	8.5	1.8	31.1
Bankfull flow/drainage area (m^3/s / km^2)	BFLOWDA	.103	.011	.422
Stream competence, bankfull (mm)	COMPETBF	19.8	1	108
Erosivity potential at bankfull flow (ratio)	EROSBF	1.5	.3	88.7
Instantaneous discharge at time of biological sampling (m^3/s)	FLOW	.59	.06	3.51
Estimated base flow at time of cross-section surveys (m^3/s)	FLOWXS	.4	.1	2.4
Estimated base flow/drainage area (m^3/s / km^2)	FLOWXSDA	.0044	.0006	.030
Bankfull flow/estimated low flow (ratio)	FLOWVAR1	24	2	154
Instantaneous discharge/estimated low flow	FLOWVAR2	1	.7	23.2
Reach-Scale Habitat				
Riffle (percent)	RIFFLE	20	0	59
Run (percent)	RUN	74	28	100
Habitat cover (percent)	HABCOVER	24	0	75
Woody debris (percent)	WOODDEBR	11	0	71
Microhabitat heterogeniety	MICHETER	93	33	326
Average wetted width/depth ratio (m/m)	WDRAT	25	12	72
Coefficient of variation of wetted width/depth ratio	WDRATCO	33	15	95
Channel-shape index	CHANSH	14	7	29
Coefficient of variation of shape index	CHANSHCO	36	13	87
Average bankfull channel width/depth ratio (in runs only) (m/m)	BWDRATRU	10	3	31
Coefficient of variation of bankfull channel width/depth ratio in runs	BWDRUCO	23	8	67
Average bankfull channel width/depth ratio (m/m)	BWDRAT	11	3	31
Coefficient of variation of bankfull channel width/depth ratio	BWDRATCO	25	9	86
Bankfull stream surface area (m^2)	BKFSURAR	2,140	923	8,130
Wetted stream surface area (m^2)	WETSURAR	1,620	617	7,370
Wetted stream volume (m^3)	WETVOL	672	161	4,290
Wetted cross sectional area (m^2)	WETXSAR	4	1	17
Bankfull cross sectional area (m^2)	BKFXSAR	13	4	43
Mean maximum depth (m)	DEPMAX	.49	.29	1.1
Mean depth (m)	DEPAVG	.39	.22	.98
Coefficient of variation of mean depth	DEPCO	39	15	103
Mean velocity at biological sampling points (m/s)	VELBIO	2	0	3
Number of transect points with substrate particle size > gravel	GRAVEL	23	0	32

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[km^2, square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m^2, square meters; N/m s, Newtons per meters per second; m^3/s, cubic meters per second; mm, millimeters; m^3, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm^2, square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m^2, milligrams per square meters; g/m^2, grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Reach-Scale Habitat (cont.)				
Average embeddedness (percent)	EMBED	42	6	100
Average embeddedness in gravel (percent)	EMBEDGR	23	0	67
Average substrate (with 1 as small) (mm)	SUBST	22	0	105
Coefficient of variation of substrate (with 1 as small)	SUBSTCO	123	0	454
Average substrate (with 1 as large) (mm)	SUBSTMOD	37	0	553
Coefficient of variation of substrate (with 1 as large)	SUBSTMCO	120	0	454
Percent of fine substrate (percent)	FINES	27	3	100
Percent sand (percent)	SAND	15	0	77
Average silt depth (cm)	SILTDEP	0	0	22
Coefficient of variation of silt depth	SILTDEPCO	147	0	574
Roughness	ROUGH	.07	.00	.36
Average erosion length of banks (m)	EROSION	1	0	3
Bank-stability index	BSI	12	10	16
Flow stability (m/m)	FLOWSTAB	0	0	1
Average open-canopy angle (degrees)	CANOPY	48	2	145
Coefficient of variation of open canopy angle	CANOPYCO	56	13	332
Average riparian canopy closure (percent)	RIPCLO	63	9	95
Coefficient of variation of canopy closure	RIPCLOCO	30	5	140
Disturbed riparian land use index (percent)	RIPLU	5	0	100
Wisconsin habitat index	WIHABIN	45	20	68
USEPA rapid bioassessment protocol index	RBPHABIN	118	67	154
Coefficient of variation of aspect	ASPCO	20	0	160
Water Chemistry				
Phosphorus, total (mg/L)	PHOTOT_W	.12	.02	2.5
Nitrogen, nitrite and nitrate, dissolved (mg/L)	NITRAT_W	2.6	.7	13.6
Nitrogen, Kjeldahl, total (mg/L)	NITTKN_W	.8	.5	2.2
Sodium, dissolved (mg/L)	NA_W	38	7	108
Chloride, dissolved (mg/L)	CL_W	72	24	186
Potassium, dissolved (mg/L)	K_W	3	1.2	12.9
Calcium, dissolved (mg/L)	CA_W	65	36	100
Magnesium, dissolved (mg/L)	MG_W	33	17	45
Specific conductance (µS/cm at 25 degrees Celsius)	COND_W	760	548	1,250
Fluoride, dissolved (mg/L)	F_W	.2	.05	.8
Silica, dissolved (mg/L)	SI_W	7	2.8	15.1
Sulfate, dissolved (mg/L)	SO4_W	52.7	17.7	154
Iron, dissolved (mg/L)	FE_W	10	5	60
Manganese, dissolved (mg/L)	MN_W	18	2	93

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[km^2, square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m^2, square meters; N/m s, Newtons per meters per second; m^3/s, cubic meters per second; mm, millimeters; m^3, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm^2, square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m^2, milligrams per square meters; g/m^2, grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Water Chemistry (cont.)				
Number of wastewater compounds detected	WWTPDET	8	0	19
Trace Elements in Streambed Sediment				
Lead (mg/kg)	PB_S	28	15	160
Zinc (mg/kg)	ZN_S	120	68	330
Copper (mg/kg)	CU_S	29	17	85
Cadmium (mg/kg)	CD_S	.4	.2	1.7
Nickel (mg/kg)	NI_S	28	16	110
Mercury (mg/kg)	HG_S	.07	.02	.25
Chromium (mg/kg)	CR_S	59	36	150
Arsenic (mg/kg)	AS_S	9	3.5	18
Standardized sum of Cd, Cr, Cu, Hg, Ni, Pb, Ag, Zn	METSUM_S	2.2	1.3	6.2
Algae and Chlorophyll				
Diatom pollution tolerance index	pollut_d	2.3	1.7	2.8
Diatom siltation index	silt_d	55	18	80
Diatom diversity (Shannon-Wiener) index	divers_d	3.7	2.5	5.0
Diatom – Pollution Sensitive (percent)	psens_d	44	5	81
Diatom – Pollution Tolerant (percent)	ptoler_d	17	1	48
Algal abundance (cells/cm^2)	aalltx_a	545,000	41,200	4,698,000
Diatom abundance (percent)	adiatm_a	64	22	100
Yellow-green algae abundance (percent)	aylgrn_a	0	0	1
Blue-green algae abundance (percent)	ablugr_a	16	0	65
Green algae abundance (percent)	agreen_a	1	0	21
Red algae abundance (percent)	ared_a	11	0	39
Euglenoid algae abundance (percent)	aeugld_a	0	0	0
Diatom biovolume (percent)	bdiatm_a	40	0	100
Yellow-green algae biovolume (percent)	bylgrn_a	0	0	0
Blue-green algae biovolume (percent)	bblugr_a	1	0	16
Green algae biovolume (percent)	bgreen_a	0	0	98
Red algae biovolume (percent)	bred_a	45	0	90
Algae Biovolume Euglenoid (percent)	beugld_a	0	0	5
Dinoflagellates biovolume (percent)	bdino_a	0	0	0
Algal taxa richness	taxa_a	37	19	65
Diatom taxa richness	diatax_a	34	16	62
Diatom – Molloy Guild 1 (percent)	gild1_d	1	0	8
Diatom – Molloy Guild 2 (percent)	gild2_d	9	0	68
Diatom – Molloy Guild 3 (percent)	gild3_d	1	0	23
Diatom – Molloy Guild 4 (percent)	gild4_d	4	0	70

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[km², square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m², square meters; N/m s, Newtons per meters per second; m³/s, cubic meters per second; mm, millimeters; m³, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm², square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m², milligrams per square meters; g/m², grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Algae and chlorophyll (cont.)				
Diatom – Molloy Guild 5 (percent)	gild5_d	25	0	94
Diatom – Molloy Guild 6 (percent)	gild6_d	0	0	30
Diatom – Molloy Guild 7 (percent)	gild7_d	10	1	41
Diatom – Molloy Guild 8 (percent)	gild8_d	20	2	65
Diatom – Molloy Guild 9 (percent)	gild9_d	2	0	11
Diatom – Molloy Guild 10 (percent)	gild10_d	0	0	5
Chlorophyll-a, periphyton (mg/m²)	chlper_a	27	1.1	262
Ash-free dry mass, periphyton (g/m²)	afdm_a	14	1.8	62.4
Pheophytin-a, periphyton (mg/m²)	pheper_a	14	.75	190
Chlorophyll-a, phytoplankton (µg/L)	chlphy_a	5.4	.3	99.7
Pheophytin-a, phytoplankton (µg/L)	phephy_a	5.2	1	27
Macroinvertebrates				
Density (number organisms/m²)	dens_i	10,600	2,630	60,900
Organisms (number)	invno_i	3,950	1,260	26,000
Invertebrate taxa richness	taxa_i	28	15	48
EPT taxa richness	ept_i	8	1	16
Mayfly (Ephemeroptera) taxa richness	ephem_i	3	0	9
Caddisfly (Trichoptera) taxa richness	trich_i	4	0	8
True-fly (Diptera) taxa richness	dipt_i	10	3	20
Midge (Chironomidae) taxa richness	chir_i	8	3	17
Non-insect taxa richness	nonins_i	7	3	13
EPT (percent)	eptp_i	37	0	83
Mayflies (percent)	ephemp_i	9	0	49
Caddisflies (percent)	trichp_i	20	0	69
Beetles (Coleoptera) (percent)	coleop_i	9	0	42
True flies (percent)	diptp_i	21	1	84
Midges (percent)	chirp_i	16	1	84
Orthoclad midges (percent)	orthop_i	3	0	40
Tanytarsini midges (percent)	tanyp_i	1	0	18
Non-insects (percent)	nninsp_i	18	1	92
Aquatic worms (Oligochaeta) (percent)	oligop_i	5	0	80
Non-chironomid dipterans (percent)	nchdip_i	3	0	21
Non-chironomid dipterans and noninsects (percent)	nchnip_i	20	4	92
Mollusks and crustaceans (percent)	mlcrp_i	6	0	70
EPT/Chironomidae abundance ratio	eptchr_i	3	0	27
Orthocladiinae/Chironomidae abundance ratio	ortchr_i	0	0	1
Tanytarsini/Chironomidae abundance ratio	tnychr_i	0	0	1

Table 2. Variables, abbreviations, and median, minimum, and maximum of variables used in analysis of effects related to urbanization, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[km^2, square kilometers; DEM, digital elevation model; ≤, less than or equal to; km, kilometers; <, less than; m, meters; S/G, sand and gravel; m^2, square meters; N/m s, Newtons per meters per second; m^3/s, cubic meters per second; mm, millimeters; m^3, cubic meters; m/s, meters per second; >, greater than; cm, centimeters; cm^2, square centimeters; USEPA, U.S. Environmental Protection Agency; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; mg/kg, milligrams per kilogram; mg/m^2, milligrams per square meters; g/m^2, grams per square meters; µg/L, micrograms per liter; EPT, Ephemeroptera, Plecoptera, Trichoptera]

Variable	Abbreviation	Median	Minimum	Maximum
Macroinvertebrates (cont.)				
Predator (percent)	predp_i	6	1	16
Omnivores (percent)	omnp_i	11	0	49
Collector-gatherer (percent)	cgp_i	27	1	87
Collector-filterer (percent)	cfp_i	27	0	70
Scraper (percent)	scrp_i	6	0	49
Shredder (percent)	shp_i	6	0	83
Most abundant three taxa (percent)	dom3p_i	58	28	90
Margalef diversity index	margdv_i	7.1	3.7	13.4
Simpson diversity index	simpdv_i	.86	.34	.95
Shannon diversity index	shandv_i	1	.4	1.4
Tolerance value, based on richness	tolrch_i	5.5	4.8	6.6
Tolerance value, based on abundance	tolabd_i	5.3	4.1	8.5
Fish				
Revised Illinois Index of Biotic Integrity	revIBI	33	6	57
Native fish species (number)	NFSH01	13	2	31
Native sucker species (Catosmidae) (number)	NSUC02	1	0	7
Native sunfish species (Centrarchidae) (number)	NSUN03	3	0	7
Native intolerant species (number)	INTOL04	1	0	7
Native minnow species (Cyprinidae) (number)	NIMN05	6	1	12
Native benthic invertivore species (number)	NBINV06	2	0	11
Specialist benthic invertivores (percent)	SIB07	6	0	52
Generalist feeders (percent)	GEN08	72	21	100
Obligate coarse-mineral-substrate spawner and not tolerant (percent)	LITOT09	13	0	71
Tolerant species (percent)	PRTOL10	38	5	99

Table 3. Watershed land-cover categories and ranges of other urban indicators for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01.

[km^2, square kilometers; >, greater than]

Watershed urban land-cover category	Code	Number of sites	Watershed urban land cover (percent)	Road density (km^2/km^2)	Estimated impervious cover (percent)	Population density (people/km^2)
Low	LO	17	0–10	0.008–0 .029	0–3	5–311
Middle-low	ML	8	>10–25	.025–.040	2–7	204–646
Middle-high	MH	9	>25–50	.031–.044	5–11	311–881
High	HI	11	>50–100	.043–.081	17–41	510–1,689

Table 4. Variables with significant (p <0.05) Spearman rank correlation coefficients with variables and urban indicators for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definition of variable abbreviations.

[Correlation coefficients in bold have p-values < 0.001; na, not applicable; -, not significant, p-value > 0.05; <, less than; >, greater than]

	Correlation coefficient				
Abbreviation	Watershed urban land cover	Road density	Estimated impervious cover	Population density	Watershed agricultural land cover
			Urban Indicator		
ROADDEN	**0.97**	na	**0.96**	**0.99**	**-0.91**
IMPERV	**.99**	**0.96**	na	**.96**	**-.91**
POPDEN00	**.95**	**.99**	**.96**	na	**-.86**
AGRICUL	**-.94**	**-.91**	**-.91**	**-.86**	na
INDUSLU	**.95**	**.90**	**.97**	**.89**	**-.87**
POPDEN90	**.97**	**.98**	**.96**	**.99**	**-.88**
POPDENCH	-.31	-	-.30	-	.36
POPDEN80	**.96**	**.97**	**.96**	**.97**	**-.89**
HOUSE	**.97**	**.98**	**.97**	**.98**	**-.89**
			Landscape Characteristics		
DRAIN	-.39	-.42	-.39	-.37	.47
WATLOPER	.33	-	.32	-	-.30
WATMOPER	-.34	-	-.33	-	.31
CSTLE	-.39	-.41	-.38	-.36	.47
WATCLAY	**.58**	**.52**	**.55**	**.51**	**-.55**
BUFBEDRO	-	.30	-	.30	-
WATBEDRO	-	.30	-	.31	-
BUFMOPER	-.32	-	-.30	-	.31
BUFFOWE	-	-	-	-	-.44
			Geomorphology and Hydrology		
SINUOS	-	-	-	-	.37
AREABFDA	**.59**	**.56**	**.59**	**.53**	**-.56**
BFLOWDA	.46	.44	.46	.42	-.40
FLOWXS	-	-	-	-	.30
FLOWVAR2	.32	.30	-	.30	-.31
			Reach-Scale Habitat		
WDRAT	-	-	-	-	.30
WDRATCO	-.33	-.34	-.33	-.33	.31
CHANSHCO	-.35	-.33	-.35	-.31	.35
BWDRATRU	-.33	-.32	-.34	-.31	.39
BWDRAT	-.33	-.33	-.34	-.31	.40
RIPCLOCO	-.31	-.33	-.35	-.32	-
ASPCO	-.29	-.34	-	-	-
			Water Chemistry		
PHOTOT_W	**.56**	.46	**.53**	.47	**-.53**
NITRAT_W	-.37	-.40	-.36	-.37	.47
NITTKN_W	.46	.38	.43	.38	**-.52**

Table 4. Variables with significant (p <0.05) Spearman rank correlation coefficients with variables and urban indicators for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definition of variable abbreviations—continued.

[Correlation coefficients in bold have p-values < 0.001; na, not applicable; -, not significant, p-value > 0.05; <, less than; >, greater than]

Abbreviation	Correlation coefficient: Watershed urban land cover	Road density	Estimated impervious cover	Population density	Watershed agricultural land cover
			Water Chemistry (cont.)		
NA_W	**0.87**	**0.80**	**0.86**	**0.80**	**-0.86**
CL_W	**.82**	**.76**	**.81**	**.75**	**-.80**
K_W	**.78**	**.70**	**.75**	**.70**	**-.78**
CA_W	**-.55**	**-.61**	**-.53**	**-.57**	**.56**
MG_W	**-.67**	**-.66**	**-.66**	**-.64**	**.62**
COND_W	.31	-	.32	-	-.30
F_W	**.48**	.40	**.49**	.42	-.47
SI_W	-.40	-.45	-.42	-.45	.31
SO4_W	.33	.32	.35	.35	-
FE_W	.37	.33	.33	-	**-.52**
WWTPDET	**.61**	**.54**	**.61**	**.49**	**-.63**
			Trace Elements in Streambed Sediment		
PB_S	**.87**	**.86**	**.86**	**.84**	**-.80**
ZN_S	**.81**	**.76**	**.81**	**.77**	**-.73**
CU_S	**.76**	**.73**	**.77**	**.74**	**-.72**
CD_S	**.64**	**.62**	**.64**	**.60**	**-.61**
NI_S	**.57**	**.53**	**.59**	**.57**	**-.49**
HG_S	**.58**	**.54**	**.56**	**.52**	**-.58**
CR_S	**.55**	**.50**	**.56**	**.54**	**-.48**
AS_S	.46	.46	.45	.47	-.41
METSUM_S	**.76**	**.72**	**.76**	**.72**	**-.72**
			Algae and Chlorophyll		
pollut_d	-.39	-.32	-.35	-.35	.34
psens_d	-.30	-	-	-	-
ptoler_d	.34	-	.34	.31	-.30
aalltx_a	-.30	-	-	-	.34
gild1_d	-	-	-	-	-.29
gild4_d	-.40	-.46	-.37	-.42	.41
gild9_d	-	-	-	-	.32
chlphy_a	.40	.37	.37	.41	-.37
phephy_a	.31	.30	-	.34	-.34
			Macroinvertebrates		
taxa_i	**-.68**	**-.62**	**-.68**	**-.60**	**.66**
ept_i	**-.72**	**-.64**	**-.72**	**-.63**	**.75**
ephem_i	**-.65**	**-.59**	**-.64**	**-.56**	**.74**
trich_i	**-.59**	**-.51**	**-.60**	**-.51**	**.53**
dipt_i	-.37	-.38	-.38	-.40	-

Table 4. Variables with significant (p <0.05) Spearman rank correlation coefficients with variables and urban indicators for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definition of variable abbreviations—continued.

[Correlation coefficients in bold have p-values < 0.001; na, not applicable; -, not significant, p-value > 0.05; <, less than; >, greater than]

Abbreviation	Correlation coefficient				
	Watershed urban land cover	Road density	Estimated impervious cover	Population density	Watershed agricultural land cover
Macroinvertebrates (cont.)					
ephemp_i	**-0.54**	**-0.48**	**-0.53**	-0.45	**0.64**
coleop_i	-	-	-	-	.30
tanyp_i	-.37	-.33	-.38	-.35	-
nninsp_i	.42	.44	.43	.42	-.38
oligop_i	.34	.35	.35	.37	-.35
nchdip_i	-.30	-.29	-.32	-.33	-
nchnip_i	.45	.47	.45	.43	-.42
mlcrp_i	.35	.40	.35	.37	-.31
tnychr_i	-.33	-	-.34	-	-
scrp_i	-.35	-	-.32	-	.40
dom3p_i	**.57**	**.49**	**.56**	**.49**	**-.56**
margdv_i	**-.61**	**-.56**	**-.61**	**-.54**	**.61**
simpdv_i	**-.56**	**-.48**	**-.56**	**-.48**	**.54**
shandv_i	**-.60**	**-.53**	**-.60**	**-.52**	**.58**
tolrch_i	**.66**	**.58**	**.63**	**.57**	**-.68**
tolabd_i	**.50**	.45	.47	.41	**-.54**
Fish					
revIBI	**-.81**	**-.77**	**-.80**	**-.74**	**.80**
NFSH01	**-.70**	**-.70**	**-.71**	**-.66**	**.72**
NSUC02	**-.50**	-.45	**-.49**	-.42	**.54**
INTOL04	**-.75**	**-.71**	**-.74**	**-.68**	**.75**
NIMN05	**-.66**	**-.66**	**-.66**	**-.61**	**.68**
NBINV06	**-.75**	**-.75**	**-.73**	**-.72**	**.75**
SIB07	**-.58**	**-.53**	**-.55**	**-.49**	**.61**
GEN08	.44	.42	.42	.39	**-.52**
LITOT09	**-.63**	**-.59**	**-.65**	**-.58**	**.59**
PRTOL10	**.57**	**.53**	**.59**	**.53**	**-.54**

Table 5. Reach-scale habitat characteristics with significant ($p < 0.05$) Spearman rank correlation coefficients with low-flow water-surface slope (SLOPELO) for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definition of abbreviations.

[Correlation coefficients in bold have p-values < 0.001; <, less than]

Abbreviation	Correlation Coefficient
ROUGH	**0.74**
RIFFLE	**.71**
DEPCO	**.65**
SUBST	**.62**
WDRATCO	**.50**
GRAVEL	**.49**
BWDRATCO	.47
SUBSTMOD	.47
BWDRUCO	.46
RBPHABIN	.37
ASPCO	.32
WIHABIN	.32
CHANSHCO	.31
RIPCLO	.30
HABCOVER	-.32
WOODDEBR	-.32
WETSURAR	-.38
BKFSURAR	-.41
DEPMAX	-.50
WETVOL	**-.51**
RUN	**-.52**
BKFXSAR	**-.53**
DEPAVG	**-.55**
FINES	**-.55**
EMBED	**-.56**
WETXSAR	**-.56**

Table 6. Number of total detections of each wastewater compound and percent detections in each watershed urban land-cover category for 44 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01.

[**Watershed urban land-cover category**: LO, Low; ML, Middle-low; MH, Middle-high; HI, High; N,N-diethyl-meta-toluamide (DEET) was detected at every site and is not listed; sample was lost for Flag Creek; n, number of samples; PAH, Polycyclic Aromatic Hydrocarbon]

Analyte name	Category	Number of detections	Percent detections			
			Watershed urban land-cover category			
		All sites	LO	ML	MH	HI
		n=44	n=17	n=8	n=9	n=10
Octylphenol, diethoxylate	Detergent	31	59	50	89	90
Naphthalene	PAH	30	47	50	100	90
Diazinon	Insecticide	26	24	38	100	100
Tris(2-chloroethyl) phosphate	Flame retardant	26	47	25	78	90
Fluoranthene	PAH	24	18	25	100	100
Phthalic anhdride	Plasticizer	24	35	38	78	80
Pyrene	PAH	22	18	13	100	90
Triclosan	Disinfectant	20	24	50	67	60
ethanol, 2-butoxy, phosphate	Plasticizer	18	29	25	56	60
Bisphenol A	PAH	14	24	25	44	40
5-Methyl-1H-benzotriazole	Antioxidant	14	12	25	33	70
bis(2-ethylhexyl) pthalate	Plasticizer	10	24	13	22	30
Caffeine	Pharmaceutical	10	12	0	44	40
2, 6-di-*tert*-para-benzoquinone	Antioxidant	9	18	13	44	10
Cotinine	Pharmaceutical	9	6	0	33	50
Nonylphenol, monoethoxyate (total)	Detergent	8	12	0	22	40
Benzo[a]pyrene	PAH	6	6	0	22	30
para-Cresol	PAH	6	12	0	33	10
Nonylphenol, diethoxylate (total)	Detergent	4	6	0	0	30
Carbaryl	Herbicide	4	6	0	22	10
Diethlyphthalate	Plasticizer	4	12	13	0	10
1, 4-diclorobenzene	PAH	3	6	0	0	20
bis(2-ethylhexyl) adipate	Plasticizer	3	6	0	11	10
Phenanthrene	PAH	3	0	0	0	30
Phenol	Disinfectant	3	12	0	11	0
Chlorpyrifos	Insecticide	3	6	0	0	20
para-Nonylphenol (total)	Detergent	2	0	0	11	10
3-*tert*-Butyl-4-hydroxytoluene (BHT)	Antioxidant	2	6	0	11	0
3-beta-Coprostanol	Sterol	2	6	0	0	10
Anthracene	PAH	1	0	0	0	10
Tetrachloroethylene	PAH	1	6	0	0	0
Triphenyl phosphate	Plasticizer	1	6	0	0	0
17 beta-estradiol	Hormone	1	0	0	0	10
Cholesterol	Sterol	1	6	0	0	0

Table 6. Number of total detections of each wastewater compound and percent detections in each watershed urban land-cover category for 44 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01—continued.

[**Watershed urban land-cover category**: LO, Low; ML, Middle-low; MH, Middle-high; HI, High; N,N-diethyl-meta-toluamide (DEET) was detected at every site and is not listed; sample was lost for Flag Creek; n, number of samples; PAH, Polycyclic Aromatic Hydrocarbon]

		Number of detections	Percent detections			
			Watershed urban land-cover category			
		All sites	LO	ML	MH	HI
Analyte name	Category	n=44	n=17	n=8	n=9	n=10
Codeine	Pharmaceutical	1	6	0	0	0
Acetophenone	PAH	0	0	0	0	0
Octylphenol, monoethoxylate	Detergent	0	0	0	0	0
cis-chlordane	Pesticide	0	0	0	0	0
Dieldren	Pesticide	0	0	0	0	0
Lindane	Pesticide	0	0	0	0	0
Methyl parathion	Pesticide	0	0	0	0	0
2, 6-*ditert*-butylphenol	Antioxidant	0	0	0	0	0
3-*tert*-Butyl-4-hydroxyanisole (BHA)	Antioxidant	0	0	0	0	0
beta-Stigmastanol	Sterol	0	0	0	0	0

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000.

Phylum (Algae Group) Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Chrysophyta (Diatoms)				
Achnanthes affinis Grunow	ACaffini	14	0.36	6.65
Achnanthes amoena Hustedt	ACamoena	2	.03	.75
Achnanthes deflexa Reimer	ACdeflex	1	.00	.18
Achnanthes delicatula (Kützing) Grunow	ACdelica	12	.17	1.66
Achnanthes exigua Grunow	ACexigua	2	.05	1.93
Achnanthes exigua var. *elliptica* Hustedt	ACexiell	1	.00	.17
Achnanthes exilis Kützing	ACexilis	5	.11	4.01
Achnanthes hungarica (Grunow) Grunow	AChungar	2	.01	.30
Achnanthes lanceolata (Brébisson in Kützing) Grunow	AClanceo	38	1.37	6.13
Achnanthes lanceolata subsp. rostrata (Øestrup) Lange-Bertalot	AClanros	1	.00	.18
Achnanthes lanceolata var. *dubia* Grunow	AClandub	9	.07	.69
Achnanthes marginulata Grunow	ACmargin	2	.01	.23
Achnanthes minutissima Kützing	ACminuti	23	.69	17.41
Achnanthes minutissima var. *saprophila* Kobayasi & Mayama	ACminsap	1	.00	.21
Achnanthes pinnata Hustedt	ACpinnat	19	.27	2.82
Achnanthes ploenensis Hustedt	ACploene	1	.04	1.86
Achnanthes rupestoides Hohn	ACrupest	1	.00	.18
Achnanthes sp. 1	ACsp1	3	.02	.42
Achnanthes sublaevis Hustedt	ACsublae	1	.01	.41
Amphora inariensis Krammer	AMinarie	9	.13	1.78
Amphora libyca Ehrenberg	Amlibyca	6	.05	.86
Amphora montana Krasske	AMmontan	4	.04	.73
Amphora ovalis (Kützing) Kützing	Amovalis	5	.07	.88
Amphora pediculus (Kützing) Grunow	AMpedicu	45	11.32	34.73
Amphora veneta Kützing	AMveneta	1	.01	.33
Anomoeoneis vitrea (Grunow) Ross	ANvitrea	1	.00	.21
Aulacoseira alpigena (Grunow) Krammer	AUalpige	2	.01	.26
Aulacoseira ambigua (Grunow) Simonsen	AUambig	1	.01	.63
Aulacoseira granulata (Ehrenberg) Simonsen	AUgranlt	4	.02	.23
Aulacoseira muzzanensis (Meister) Krammer	AUmuzzan	4	.05	1.32
Caloneis amphisbaena (Bory) Cleve	CAamphis	1	.01	.33
Caloneis bacillum (Grunow) Cleve	CAbacill	16	.17	1.79
Cocconeis neothumensis Krammer	CCneothu	2	.03	1.10
Cocconeis pediculus Ehrenberg	CCpedcls	27	.73	9.43
Cocconeis placentula Ehrenberg	CCplacen	38	.81	4.03
Cocconeis placentula var. *euglypta* (Ehrenberg) Cleve	CCplaeug	39	.73	3.82
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	CCplalin	41	.89	4.33
Cyclotella atomus Hustedt	CYatomus	8	.28	4.77

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Cyclotella bodanica Grunow	CYbodani	2	0.01	0.31
Cyclotella bodanica var. *affinis* (Grunow) Cleve-Euler	Cybodaff	1	.00	.19
Cyclotella comensis Grunow *et* Van Heurck	CYcomens	1	.01	.33
Cyclotella meneghiniana Kützing	CYmenegh	27	.92	11.20
Cyclotella michiganiana Skvortzow	CYmichig	1	.00	.21
Cyclotella nana Hustedt	CYnana	1	.01	.26
Cyclotella ocellata Pantosek	CYocella	5	.04	.66
Cyclotella pseudostelligera Hustedt	CYpsdste	4	.05	1.05
Cyclotella stelligera (Cleve *et* Grunow) Van Heurck	CYstelli	2	.01	.33
Cymatopleura solea var. *apiculata* (Smith) Ralfs	CTsolapc	2	.01	.21
Cymbella affinis Kützing	CMaffins	2	.02	.64
Cymbella caespitosa Brun	CMcaespi	2	.01	.28
Cymbella cuspidata Kützing	CMcuspid	1	.01	.43
Cymbella mesiana Cholnoky	CMmesian	1	.00	.22
Cymbella microcephala Grunow	CMmicroc	1	.00	.18
Diatoma mesodon (Ehrenberg) Kützing	DAmesodo	1	.00	.13
Diatoma tenuis Agardh	DAtenuis	1	.03	1.32
Diatoma vulgare Bory	DAvulgar	2	.05	2.18
Diploneis parma Cleve	DPparma	5	.07	1.34
Diploneis peterseni Hustedt	DPpeters	1	.01	.39
Encyonema minutum (Hilse in Rabenhorst) Mann	ECminutu	8	.12	1.41
Encyonema prostrata (Berk.) Mann	ECprostr	2	.03	.76
Eunotia formica Ehrenberg	EUformic	1	.01	.26
Eunotia soleirolii (Kützing) Rabenhorst	EUsoleir	1	.01	.28
Eunotia sudetica Müller	EUsudeti	1	.01	.60
Fallacia pygmaea (Kützing) Stickle & Mann	FApygmae	3	.02	.42
Fragilaria capucina var. *mesolepta* Rabenhorst	FRcapmes	2	.19	8.15
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	FRcaprum	2	.01	.33
Fragilaria constricta Ehrenberg	FRctastr	1	.01	.26
Fragilaria crotonensis Kitton	FRcroton	1	.02	1.07
Fragilaria pinnata Ehrenberg	FRpinnat	2	.02	.53
Fragilaria vaucheriae (Kützing) Peterson	FRvauche	9	.10	1.22
Frustulia vulgaris (Thwaites) DeT.	FSvulgar	1	.01	.63
Gomphonema affine Kützing	GOaffine	1	.01	.28
Gomphonema affine var. *insigne* (Greg.) Andrews	GOaffins	1	.00	.21
Gomphonema angustatum (Kützing) Rabenhorst	GOangstt	9	.08	1.24
Gomphonema clavatum Ehrenberg	GMclvtm	2	.01	.33
Gomphonema gibba Wallace	GOgibba	1	.01	.26
Gomphonema gracile Ehrenberg emend. V. H.	GOgracil	1	.01	.25

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Gomphonema kobayasii Kociolek & Kingston	GOkobaya	27	0.69	7.14
Gomphonema minutum (C.A. Agardh) C.A. Agardh	GOminut	23	.30	1.66
Gomphonema olivaceum (Lyngb.) Kützing	GOolivcm	12	.08	.52
Gomphonema parvulum (Kützing) Kützing	GOparvul	26	.36	2.09
Gyrosigma acuminatum (Kützing) Rabenhorst	GYacumin	5	.03	.58
Gyrosigma attenuatum (Kützing) Rabenhorst	GYattenu	1	.01	.44
Gyrosigma scalproides (Rabenhorst) Cleve	GYscalpd	6	.04	.42
Hantzschia amphioxys (Ehrenberg) Grunow	HAamphio	2	.01	.42
Karayevia Clevei Grunow *in* Cleve et Grunow	KVclevei	4	.03	.66
Luticola goeppertiana (Bleisch in Rabenhorst) Mann	LUgoeppe	3	.03	.57
Luticola mutica (Kutzing) Mann	LUmutica	2	.02	.84
Melosira varians Agardh	MEvarian	23	.71	7.62
Navicula atomus (Kützing) Grunow	NAatomus	2	.02	.66
Navicula atomus var. *permitis* (Hustedt) Lange-Bertalot	NAatoper	10	.23	4.60
Navicula bicephala Hustedt	NAbiceph	1	.00	.17
Navicula canalis Patr.	NAcanals	2	.01	.17
Navicula capitata Ehrenberg	NAcapita	9	.08	1.02
Navicula capitata var. *lueneburgensis* (Grunow) Patr.	NAcaplun	1	.01	.31
Navicula capitatoradiata Germain	NAcaprad	16	.33	4.85
Navicula cari Ehrenberg	NAcari	3	.07	2.98
Navicula circumtexta Meist. ex Hustedt	NAcircum	1	.00	.21
Navicula confervacea (Kützing) Grunow	NAconfer	3	.02	.28
Navicula contenta Grunow *ex* V. H.	NAconten	1	.00	.21
Navicula cryptocephala Kützing	NAcrypto	11	.12	.99
Navicula cryptotenella L.B. in Krammer & L.-B.	NAcryten	41	3.46	18.67
Navicula decussis Øestrup	NAdecuss	1	.00	.21
Navicula erifuga Lange-Bertalot	NAerifga	15	.47	7.47
Navicula gastrum (Ehrenberg) Kützing	NAgastru	1	.01	.29
Navicula germainii Wallace	NAgermii	16	.19	1.31
Navicula gregaria Donk.	NAgregar	32	2.11	15.54
Navicula ingenua Hustedt	NAingnua	15	.47	4.03
Navicula integra (Smith) Ralfs	NAintgra	1	.00	.17
Navicula lenzii Hustedt *in* A.S.	NAlenzii	2	.02	.88
Navicula microcephala Grunow	NAmicroc	1	.01	.33
Navicula minima Grunow	NAminima	43	7.54	27.68
Navicula molestiformis Hustedt	NAmolest	5	.17	4.77
Navicula monoculata var. *omissa* (Hustedt) Lange-Bertalot	NAmnomis	2	.01	.33
Navicula phyllepta Kützing	NAphylpt	2	.05	1.67
Navicula pseudoventralis Hustedt	NApseven	8	.16	1.75

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Navicula radiosa Kützing	NAradios	2	0.01	0.44
Navicula recens Lange-Bertalot	NArecens	30	2.55	25.00
Navicula reichardtiana Lange-Bertalot	NAreichd	14	.28	3.54
Navicula rhynchocephala Kützing	NArhynch	1	.01	.28
Navicula salinarum Grunow	NAsalinm	4	.09	2.01
Navicula seminulum Grunow	NAsemlum	26	.70	5.38
Navicula sp. 0	NAkmnq0B	1	.01	.30
Navicula sp. 1	NA1	1	.02	.74
Navicula subhamulata Grunow	NAsubham	2	.02	.55
Navicula sublucidula Hustedt	NAlucdla	2	.08	3.26
Navicula subminuscula Mang.	NAsubmin	20	.73	9.26
Navicula symmetrica Patr.	NAsymtrc	8	.10	1.20
Navicula tantula Hustedt	NAtantul	26	.37	1.87
Navicula tenelloides Hustedt	NAtenell	5	.02	.31
Navicula tenera Hustedt	NAtenera	5	.04	.84
Navicula tripunctata (Müller) Bory	NAtripun	34	1.04	7.92
Navicula trivialis Lange-Bertalot	NAtrivia	18	.27	2.89
Navicula veneta Kützing	NAveneta	32	.91	5.95
Navicula viridula (Kützing) Kützing emend. V. H.	NAvirdla	1	.01	.24
Navicula viridula var. *linearis* Hustedt	NAvirlin	1	.00	.22
Navicula viridula var. *rostellata* (Kützing) Cleve	NAvirros	11	.08	.98
Neidium bisulcatum (Lagerst.) Cleve	NEbisulc	1	.01	.26
Nitzschia acicularis (Kützing) Smith	NIacicul	8	.09	1.11
Nitzschia aequorea Hustedt	Niaeqrea	1	.01	.28
Nitzschia agnita Hustedt	NIagnita	3	.01	.33
Nitzschia ambigua Mang.	NIambigu	1	.01	.26
Nitzschia amphibia Grunow	NIamphib	32	.46	4.01
Nitzschia calida Grunow in Cleve et Grunow	Nicalid	6	.05	.60
Nitzschia capitellata Hustedt	NIcapite	3	.01	.33
Nitzschia clausii Hantz.	NIclausi	3	.04	1.00
Nitzschia constricta (Kützing) Ralfs	NIconstr	16	.16	1.67
Nitzschia debilis Arnott	NIdebili	1	.01	.33
Nitzschia desertorum Hustedt	NAdesert	2	.02	.57
Nitzschia dissipata (Kützing) Grunow	NIdissip	30	1.69	10.52
Nitzschia dissipata var. *media* (Hantz.) Grunow	NIdismed	2	.02	.48
Nitzschia dubia W. Sm.	NIdubia	2	.02	.53
Nitzschia filiformis var. *conferta* (Reich.) Lange-Betralot	NLfilcon	1	.01	.26
Nitzschia frustulum (Kützing) Grunow	NIfrustu	41	6.77	38.20

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Nitzschia gracilis Hantz. ex Rabenhorst	NIgracil	4	0.03	0.53
Nitzschia hungarica Grunow	NIhungrc	7	.05	.62
Nitzschia inconspicua Grunow	NIincons	6	.15	3.33
Nitzschia intermedia Hantz. ex Cleve et Grunow	NIinterm	1	.01	.29
Nitzschia levidensis (Smith) Grunow in V.H.	NIlevdns	1	.01	.26
Nitzschia levidensis var. *salinarum* Grunow	NIlevsal	2	.01	.33
Nitzschia levidensis var. *victoriae* Grunow	NIlevvic	10	.07	.62
Nitzschia liebethruthii Rabenhorst	NIliebrt	1	.01	.23
Nitzschia linearis (Agardh ex Smith) Smith	NIlinear	4	.02	.26
Nitzschia microcephala Grunow	NImicroc	1	.00	.14
Nitzschia palea (Kützing) Smith	NIpalea	22	.70	8.16
Nitzschia palea var. *debilis* (Kützing) Grunow	NIpaldeb	17	.41	3.32
Nitzschia perminuta (Grunow) Peragallo	NIpermin	2	.02	.62
Nitzschia recta Hantz. ex Rabenhorst	NIrecta	2	.02	.65
Nitzschia reversa Smith	NIrevers	2	.02	.62
Nitzschia sociabilis Hustedt	NIsociab	9	.09	1.00
Nitzschia solita Hustedt	NIsolita	3	.02	.28
Nitzschia sp. 1	NI1	1	.00	.11
Nitzschia sublinearis Hustedt	NIsublin	1	.00	.17
Nitzschia supralitorea Lange-Bertalot	NIsupral	8	.09	1.71
Nitzschia thermaloides Hustedt	NIthermd	1	.01	.33
Nitzschia tropica Hustedt	NItropic	6	.04	.73
Nitzschia valdecostata Lange-Bertalot & Simon.	NIvaldec	1	.01	.33
Nitzschia valdestriata Aleem & Hustedt	NIvaldes	1	.00	.12
Pleurosira laevis (Ehrenberg) Compere	PRlaevis	3	.12	3.33
Pseudostaurosira brevistriata (Grunow in V.H.) Williams & Round	PDbrevis	2	.05	1.50
Reimeria sinuata (Greg.) Kociolek & Stoermer	REsinuta	30	.41	2.33
Rhoicosphenia curvata (Kützing) Grunow ex Rabenhorst	ROcurvat	44	5.41	28.29
Rhopalodia musculus (Kützing) Müller	Rpmuscul	1	.02	.74
Sellaphora pupula (Kützing) Meresckowsky	SFpupula	9	.05	.51
Simonsenia delognei (Grunow) Lange-Bertalot	SIdelog	14	.31	4.85
Skeletonema potamos (Weber) Hasle	SKpotamo	2	.10	4.28
Stauroneis obtusa Lagerst.	SSobtusa	1	.00	.18
Stauroneis smithii var. *incisa* Pantosek	SSsmiinc	1	.01	.33
Staurosira construens (Ehrenberg) Williams & Round	SRconstr	1	.01	.64
Staurosira construens var. *venter*	SRconven	3	.02	.35
Staurosirella lapponica (Grunow In V.H.) Williams & Round	SAlappon	2	.02	.88
Stephanodiscus dubius (Fricke) Hustedt	STdubius	5	.06	1.06

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) / Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Stephanodiscus hantzschii Grunow	SThantzs	2	0.02	0.66
Stephanodiscus minutus H. L. Sm.	STminut	1	.02	.97
Stephanodiscus parvus Stoerm. & Håkansson	STparvus	1	.00	.21
Stephanodiscus tenuis Hustedt	STtenuis	2	.01	.33
Surirella angusta Kützing	SUangust	3	.04	1.34
Surirella bifrons Ehrenberg	SUbifron	1	.01	.52
Surirella brebissonii Krammer & Lange-Bertalot	SUbreb	2	.03	1.00
Surirella brebissonii var. *kuetzingii* Kramm. & Lange-Bertalot	SUbrekut	2	.07	2.84
Surirella minuta Brébisson	Suminuta	10	.20	1.96
Surirella ovata var. *salina* Smith	SUovasal	2	.01	.24
Surirella splendida (Ehrenberg) Kützing	SUsplen	1	.00	.17
Surirella subsalsa Smith	SUsubsal	1	.01	.33
Synedra acus Kützing	SYacus	3	.01	.26
Synedra parasitica (Smith) Hustedt	SYparasi	3	.02	.33
Synedra parasitica var. *subconstricta* (Grunow) Hustedt	SYparsub	1	.00	.21
Synedra pulchella Ralfs ex Kützing	SYpulche	3	.04	1.24
Synedra tabulata (Agardh) Kützing	SYtabula	4	.04	.84
Synedra tenera Smith	SYtenera	2	.01	.43
Synedra ulna (Nitz.) Ehrenberg	SYulna	3	.05	1.11
Thalassiosira pseudonana Hasle & Heimdal	THpsnana	7	.09	1.64
Thalassiosira weissflogii (Grunow) Fryxell & Hasle	THweiss	3	.01	.28
Chrysophyta (Yellow-Green Algae)				
Dinobryon divergens Imhof	DNDIVERG	3	.04	.64
Ophiocytium cochleare (Eichwald) Braun	OPCOCHLE	1	.02	1.11
Cyanophyta (Blue-Green Algae)				
Amphithrix janthina (Mont.) Born. and Flah.	AMJANTHI	10	3.65	32.98
Aphanocapsa grevillei Rabenhorst	APGREVIL	1	.28	12.48
Chamaesiphon incrustans Grunow	CSINCRUS	2	.13	5.18
Chroococcus limneticus Lemmermann	CHLIMNET	7	1.71	25.27
Chroococcus limneticus var. *distans* G.M. Sm.	CHLIMDIS	1	.22	9.90
Chroococcus limneticus var. *subsalsus* Lemmermann	CHLIMSUB	1	.18	8.30
Chroococcus minor (Kützing) Nägeli	CHMINOR	2	.14	3.23
Chroococcus pallidus Nägeli	CHPALLID	1	.09	4.04
Dactylococcopsis rhaphidioides Hansg.	DCRHAPID	1	.01	.47
Gomphosphaeria aponina Kützing	GOAPONIN	4	1.30	23.53
Lyngbya hieronymusii Lemm.	LYHIERON	2	.36	9.84
Lyngbya major Meneghini	LYMAJOR	2	.56	21.83
Lyngbya sp. 1	LY1	5	1.11	21.54
Merismopedia tenuissima Lemmermann	MMTENUIS	2	.33	10.43
Microcystis aeruginosa Kützing	MIAERUGI	3	1.70	50.34

Table 7. Algal species, taxon, code, number of sites found, mean abundance and maximum abundance of algae collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000—continued.

Phylum (Algae Group) / Scientific Name	Code	Number of Sites	Mean Abundance (percent)	Maximum Abundance (percent)
Oscillatoria amoena (Kützing) Gom.	OSAMOENA	3	0.45	10.53
Oscillatoria formosa Bory	OSFORMOS	1	.14	6.08
Oscillatoria granulata Gardner	OSGRANUL	11	2.92	23.33
Oscillatoria limosa (Dillw.) Agardh	OSLIMOSA	4	.37	8.06
Oscillatoria minnesotensis Tilden	OSMINNES	2	.62	20.69
Oscillatoria princeps Vauch.	OSPRINCE	2	.82	34.06
Oscillatoria prolifica (Grev.) Gom.	OSPROLIF	2	.36	9.02
Oscillatoria sp. 1	OSEJNQ0B	9	1.22	30.54
Oscillatoria tenuis C.A. Agardh	OSTENUIS	4	.43	6.61
Chlorophyta (Green Algae)				
Actinastrum hantzschii var. *fluviatile* Schröd.	ACTHNSTB	1	.02	1.11
Ankistrodesmus falcatus (Corda) Ralfs	ANFALCAT	1	.01	.24
Cladophora glomerata (L.) Kützing	CFGLOMER	1	.06	2.61
Cladophora sp.	CFSP	4	.07	1.47
Closterium moniliferum Ehrenberg	CUMONILI	3	.02	.50
Coelastrum microporum Nägeli	COMICROP	2	.23	6.14
Cosmarium circulare Reinsch	COCIRCUL	2	.02	.50
Cosmarium granatum Brébisson ex Ralfs	COGRANUL	2	.01	.27
Crucigenia rectangularis (A. Braun) Gay	CRRECTAN	1	.13	6.02
Crucigenia sp.	CRsp	1	.10	4.43
Kirchneriella obesa (W. West) Schmidle	KIOBESA	2	.07	1.89
Scenedesmus acuminatus (Lagerh.) Chodat	SCACUMIN	4	.17	3.87
Scenedesmus arcuatus Lemmermann	SCARCUAT	1	.02	.70
Scenedesmus ecornis (Ralfs) Chodat	SCECORNI	4	.08	1.28
Scenedesmus opoliensis Richt.	SCOPOLIE	1	.02	1.04
Scenedesmus quadricauda (Turpin) Brébisson	SCQUADRI	5	.16	3.60
Scenedesmus spinosus Chodat	SCSPINOS	6	.14	1.52
Staurastrum tetracerum Ralfs	SMTETRAC	1	.00	.22
Stigeoclonium lubricum (Dillw.) Kützing	SGLUBRIC	3	.60	15.16
Pyrrhophyta (Dinoflagellates)				
Glenodinium pulvisculus (Ehrenberg) Stein	GLPULVIS	1	.01	.38
Euglenophyta (Euglenoids)				
Euglena proxima Dangeard	EUPROXIM	1	.01	.29
Phacus orbicularis Huebner	PHORBICU	1	.00	.19
Phacus pseudoswirenkoi Prescott	PHPSEUDO	1	.01	.28
Rhodophyta (Red Algae)				
Unknown Rhodophyte Florideophycidae (chantransia)	XRHchant	32	14.64	39.21

Table 8. Spearman rank correlations for algal and macroinvertebrate variables with urban land cover, for two sampling substrates, for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definition of variable abbreviations.

[Correlation coefficients in bold have p-values < 0.001; n, number of samples; -, not significant, p-value > 0.05; <, less than; >, greater than]

	Correlation coefficient		
Abbreviation	All sites n=45	Cobble n=34	Snag n=14
Algae and periphyton chlorophyll			
pollut_d	-0.39	-0.40	-
psens_d	-.30	-	-
ptoler_d	.34	-	-
aalltx_a	-.30	-.49	-
gild3_d	-	-	0.58
gild4_d	-.40	-.48	-
phephy_a	.31	-	-
Macroinvertebrates			
taxa_i	**-.68**	**-.82**	-
ept_i	**-.72**	**-.80**	-
ephem_i	**-.65**	**-.68**	-
trich_i	**-.59**	**-.68**	-
dipt_i	-.37	-.48	-
ephemp_i	**-.54**	**-.59**	-
coleop_i	-	-	-.60
tanyp_i	-.37	-.44	-
nninsp_i	.42	**.62**	-
oligop_i	.34	.46	-
nchdip_i	-.30	-.37	-
nchnip_i	.45	**.62**	-
mlcrp_i	.35	.53	-
tnychr_i	-.33	-.36	-
scrp_i	-.35	-.46	-
dom3p_i	**.57**	**.68**	-
margdv_i	**-.61**	**-.73**	-
simpdv_i	**-.56**	**-.68**	-
shandv_i	**-.60**	**-.72**	-
tolrch_i	**.66**	**.74**	-
tolabd_i	**.50**	**.58**	-

Table 9. Gradient length and eigenvalues for algae, macroinvertebrate, and fish detrended correspondence analysis for 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01.

Statistic	Algae	Macroinvertebrate	Fish
Length of gradient	2.77	2.10	3.00
Axis 1 eigenvalue	.29	.23	.30
Axis 2 eigenvalue	.23	.15	.20
Axis 3 eigenvalue	.20	.10	.10
Axis 4 eigenvalue	.16	.07	.08

Table 10a. Spearman Rank correlations of environmental variables with algae DCA axes for samples collected in 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definitions of abbreviations.

[Correlation coefficients in bold have p-values < 0.001; -, not significant, p-value > 0.05; <, less than; >, greater than]

Abbreviation	DCA Axis 1	DCA Axis 2
	Algae	
MG_W	**0.56**	-
WATMOPER	.43	-
BUFMOPER	.40	-
CA_W	.39	0.45
ASPCO	.31	-
WDRATCO	.31	-
WATOUT	.30	-
NITRAT_W	-	.37
DEPCO	-	.31
POPDEN90	**-.74**	-.37
HOUSE	**-.74**	-.33
URBANLU	**-.73**	-.37
POPDEN80	**-.73**	-.34
ROADDEN	**-.73**	-.41
POPDEN00	**-.72**	-.37
K_W	**-.72**	-.29
IMPERV	**-.72**	-.37
NA_W	**-.69**	-
PB_S	**-.69**	-.31
WATCLAY	**-.66**	-
ZN_S	**-.65**	-
INDUSLU	**-.64**	-
CL_W	**-.64**	-
PHOTOT_W	**-.63**	-
CU_S	**-.61**	-
F_W	**-.55**	-
CR_S	**-.55**	-
NI_S	**-.53**	-
CD_S	**-.52**	-.32
NITTKN_W	**-.51**	-.31
AS_S	-.47	-
WATLOPER	-.42	-
FLOWVAR2	-.39	-
HG_S	-.37	-.35
AREABFDA	-.34	-
MN_W	-.31	-

Table 10b. Spearman Rank correlations of environmental variables with macroinvertebrate DCA axes for samples collected in 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000–01. See table 2 for definitions of abbreviations.

[Correlation coefficients in bold have p-values < 0.001; -, not significant, p-value > 0.05; <, less than; >, greater than]

Abbreviation	DCA Axis 1	DCA Axis 2
	Macroinvertebrates	
MG_W	**0.71**	-
WATMOPER	**.58**	-
CA_W	**.57**	-
BUFMOPER	**.54**	-
CSTLE	**.52**	-
DRAIN	**.52**	-
WATOUT	**.51**	0.34
MG_W	**.71**	-
BUFCOARS	.46	.32
POPDENC2	.34	-
WDRAT	.34	-
BWDRAT	.33	-
POPDENCH	.32	-
BWDRATRU	.31	-
GRAVEL	.31	-
DEPCO	.31	-
TRANSIN	.30	**.49**
RELIEF	-	**.50**
WATSLOP1	-	.43
LATITU	-	.36
WATSLOP2	-	.33
SLOPEBF	-	.32
DEGDAY	-	.31
SLOPELO	-	.31
WETSURAR	-	-.31
FLOW	-	-.35
BKFSURAR	-	-.37
AREABF	-	-.37
BKFXSAR	-	-.37
PB_S	**-.76**	-
WATCLAY	**-.76**	-.31
CR_S	**-.72**	-.38
CU_S	**-.69**	-
URBANLU	**-.69**	-
NI_S	**-.69**	-.33
POPDEN80	**-.69**	-
IMPERV	**-.68**	-
INDUSLU	**-.68**	-
ZN_S	**-.68**	-
AREABFDA	**-0.67**	-
ROADDEN	**-.66**	-
METSUM_S	**-.65**	-
POPDEN90	**-.64**	-
HOUSE	**-.64**	-
POPDEN00	**-.63**	-
K_W	**-.62**	-
NA_W	**-.57**	-
AS_S	**-.54**	-
WATLOPER	**-.54**	-
F_W	**-.52**	-
PHOTOT_W	**-.48**	-
FLOWVAR2	**-.48**	-
BFLOWDA	-.48	-
CL_W	-.47	-
CD_S	-.41	-
NITTKN_W	-.41	-
HG_S	-.32	-
MN_W	-.32	-
HABCOVER	-.31	-
FE_W	-.31	-

Table 10c. Spearman Rank correlations of environmental variables with fish DCA axes for samples collected in 45 stream sites in northeastern Illinois and southeastern Wisconsin, 1995–2001. See table 2 for definitions of abbreviations.

[Correlation coefficients in bold have p-values < 0.001; -, not significant, p-value > 0.05; <, less than; >, greater than]

Abbreviation	DCA Axis 1	DCA Axis 2
	Fish	
POWERBF	**0.61**	-
ROUGH	**.59**	-
COMPETBF	**.57**	-
SLOPESE	**.54**	-0.35
SUBST	**.51**	-
SLOPELO	.43	-.32
GRAVEL	.42	-
SLOPEBF	.40	-.34
WDRATCO	.40	-
DEPCO	.39	-
RIFFLE	.37	-
NITRAT_W	.35	-
MG_W	.35	.31
SUBSTMOD	.34	-
SINUOS	.34	-
WDRAT	.33	.35
BFLOW	.33	-
MANNBF	.30	-
ASPCO	.30	-
DRAIN	-	**.70**
CSTLE	-	**.69**
BWDRAT	-	**.57**
WETSURAR	-	**.56**
BKFSURAR	-	**.55**
FLOWXS	-	**.50**
BWDRATRU	-	**.49**
AREABF	-	.47
CANOPY	-	.46
WETVOL	-	.43
RIPCLOCO	-	.42
CHANSH	-	.42
WETXSAR	-	.41
FLOW	-	.36
BKFXSAR	-	.35
FLOWSTAB	-	.33
NA_W	**-.57**	-
URBANLU	**-.56**	-.30
NITTKN_W	**-.56**	-
INDUSLU	**-.55**	-.31
PHOTOT_W	**-0.55**	-
IMPERV	**-.55**	-0.31
K_W	**-.54**	-.31
POPDEN80	**-.52**	-.33
HOUSE	**-.52**	-.30
CL_W	**-.52**	-
METSUM_S	**-.51**	-
ROADDEN	**-.51**	-.30
POPDEN90	**-.49**	-.32
POPDEN00	**-.49**	-
CR_S	-.48	-
ZN_S	-.47	-
FE_W	-.47	-.33
HG_S	-.46	-
PB_S	-.45	-
CD_S	-.38	-
NI_S	-.38	-
FLOWVAR2	-.36	-
LATITU	-.35	-
EMBED	-.33	-
WATCLAY	-.33	-.33
HABCOVER	-.32	-
DEPAVG	-.32	-
BUFFOWE	-.31	-.38
DEPMAX	-.30	-
COND_W	-.30	-
CANOPYCO	-	**-.61**
BFLOWDA	-	-.42
AREABFDA	-	-.41
RIPCLO	-	-.39
FLOWVAR1	-	-.33
AS_S	-	-.30

Table 11. Canonical correlation coefficients of environmental variables with the first four partial canonical correspondence analysis axes for the algal, macroinvertebrate and fish communities in 45 stream sites in northeastern Illinois and southeastern Wisconsin, 1995–2001. See table 2 for definitions of abbreviations.

[Correlation coefficients in bold have t-values greater than 2, indicating a significant relation to the axis]

Abbreviation	Axis 1	Axis 2	Axis 3	Axis 4
		Algae		
AS_S	**0.52**	**-1.00**	-0.10	0.03
BUFFOWE	**.39**	-.14	**-.27**	-.07
CANOPY	.08	-.07	**-.39**	**.46**
EROSION	**-.28**	**-.15**	.05	**-.30**
HABCOVER	.07	.10	.07	**-.66**
NITRAT_W	**.50**	**-.46**	**-.66**	**-.91**
PHOTOT_W	.25	.13	**.27**	**.54**
SLOPELO	**-.45**	**-.27**	**-.35**	.06
SUBSTCO	**.46**	-.04	**-.27**	**.32**
URBANLU	**.42**	**.24**	**-.48**	.08
WATCLAY	-.16	**.30**	**.60**	-.11
WATSLOP2	-.10	**.53**	**-.56**	**-.72**
WDRAT	**-.21**	**-.49**	**.19**	.03
WIHABIN	**-.21**	-.09	**.25**	**.28**
WWTPDET	-.18	-.14	.13	**-.38**
		Macroinvertebrates		
DRAIN	**.22**	**-.80**	.09	.39
DEGDAY	-.02	**.44**	.17	**.76**
TRANSIN	**.35**	.15	-.14	**.65**
WATCLAY	**-.36**	**-.43**	-.16	**1.46**
URBANLU	**-.36**	.30	**.72**	-.41
chlper_a	**.34**	.12	**1.01**	**.55**
		Fish		
DRAIN	-.06	**.97**	**-.69**	.13
DEGDAY	**.92**	.08	**1.41**	.03
WATCLAY	**.93**	-.25	.30	**1.53**
URBANLU	**.42**	.10	**-.40**	**-.52**
FINES	**.41**	.10	-.13	**.42**
NITTKN_W	-.28	.22	.00	**-.78**
chlper_a	.15	.06	**.90**	**.59**

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis.

Phylum / Class / Order / Suborder / Family / Subfamily / Tribe	Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
Platyhelminthes					
Turbellaria					
	Turbellaria	Turbella	39	2.3	14.1
Nematoda					
	Nematoda	Nematoda	12	.4	3.3
Mollusca					
Gastropoda					
Mesogastropoda					
Pleuroceridae					
	Elimia	Elimia	7	.3	7.5
Basommatophora					
Ancylidae					
	Ferrissia	Ferrissi	21	.6	8.7
Physidae					
Physinae					
	Physella	Physella	6	.1	4.6
Bivalvia					
Veneroida					
Corbiculidae					
	Corbicula	Corbicul	5	.3	5.1
Sphaeriidae					
Pisidiinae					
	Pisidium	Pisidium	21	2.4	52.1
Sphaeriinae					
	Musculium	Musculiu	12	.7	14.6
	Sphaerium	Sphaeriu	16	.3	2.5
Annelida					
Oligochaeta					
Tubificida					
Tubificina					
Naididae					
	Naididae	Naididae	14	.5	4.6

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis—continued.

Phylum / Class / Order / Suborder / Family / Subfamily / Tribe	Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
Tubificidae					
	Tubificidae	Tubifici	39	9.8	79.7
Enchytraeida					
Enchytraeidae					
	Enchytraeidae	Enchytra	13	.2	1.7
Hirudinea					
Rhynchobdellae					
Glossiphoniidae					
	Helobdella	Helobdel	8	.1	.8
Arhynchobdellae					
Erpobdellidae					
	Erpobdellidae	Erpobdel	18	.3	3.4
Arthropoda					
Arachnida					
	Arachnida	Arachnid	35	2.0	10.3
Malacostraca					
Decapoda					
Pleocyemata					
Cambaridae					
Cambarinae					
	Orconectes	Orconect	21	.0	.3
Isopoda					
Asellota					
Asellidae					
	Caecidotea	Caecidot	34	6.6	72.4
Amphipoda					
Gammaridea					
Gammaridae					
	Gammarus	Gammarus	8	.3	8.6
Hyalellidae					
	Hyalella	Hyalella	5	.6	24.8
Insecta					
Collembola					

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis—continued.

Phylum	Class	Order	Suborder	Family	Subfamily	Tribe	Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
							Collembola	Collembo	4	0.0	0.4
		Ephemeroptera									
			Furcatergalia								
				Caenidae							
							Caenis	Caenis	9	.7	26.0
				Leptohyphidae							
							Tricorythodes	Tricoryt	15	1.5	25.7
			Pisciforma								
				Baetidae							
							Baetis	Baetis	38	7.3	48.1
			Setisura								
				Heptageniidae							
							Leucrocuta	Leucrocu	13	.6	7.9
							Stenacron	Stenacro	30	.7	4.3
							Stenonema	Stenonem	9	.1	2.3
				Isonychiidae							
							Isonychia	Isonychi	13	.4	6.2
		Odonata									
			Zygoptera								
				Calopterygidae							
							Hetaerina	Hetaerin	3	.0	.3
				Coenagrionidae							
							Argia	Argia	7	.1	.7
		Plecoptera									
							Plecoptera	Plecopte	4	.0	1.0
		Megaloptera									
				Sialidae							
							Sialis	Sialis	6	.1	2.5
		Trichoptera									
			Spicipalpia								
				Hydroptilidae							
					Hydroptilinae						
							Hydroptila	Hydropti	32	1.8	12.9

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis—continued.

Phylum / Class / Order / Suborder / Family / Subfamily / Tribe / Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
Annulipalpia				
Philopotamidae				
Chimarrinae				
Chimarra	Chimarra	12	0.7	9.1
Hydropsychidae				
Hydropsychinae				
Ceratopsyche	Ceratops	23	2.5	21.0
Cheumatopsyche	Cheumato	41	10.2	33.5
Hydropsyche	Hydropsy	37	6.6	38.4
Integripalpia				
Limnephilidae				
Limnephilinae				
Pycnopsyche	Pycnopsy	5	.0	.7
Leptoceridae				
Leptocerinae				
Oecetis	Oecetis	8	.1	.6
Helicopsychidae				
Helicopsyche	Helicops	10	.3	3.9
Lepidoptera				
Pyralidae				
Nymphulinae				
Argyactini				
Petrophila	Petrophi	9	.1	1.7
Coleoptera				
Polyphaga				
Elmidae				
Dubiraphia	Dubiraph	18	.4	3.5
Macronychus	Macronyc	7	.7	9.5
Optioservus	Optioser	14	.6	5.7
Stenelmis	Stenelmi	37	10.6	38.4
Coleoptera				
Polyphaga				
Psephenidae				

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis—continued.

Phylum / Class / Order / Suborder / Family / Subfamily / Tribe / Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
Ectopria	Ectopria	5	0.0	0.7
Psephenus	Psephenu	5	.2	3.2
Diptera				
Nematocera				
Chironomidae				
Chironominae				
Chironomini				
Cryptochironomus	Cryptoch	13	.1	1.1
Dicrotendipes	Dicroten	16	.4	4.1
Glyptotendipes	Glyptote	7	.2	2.1
Microtendipes	Microten	22	1.1	13.0
Phaenopsectra	Phaenops	6	.2	5.0
Polypedilum	Polypedi	44	8.0	83.6
Stenochironomus	Stenochi	12	.3	3.0
Chironomidae				
Chironominae				
Tanytarsini				
Cladotanytarsus	Cladotan	6	.3	7.0
Paratanytarsus	Paratany	18	.6	8.4
Rheotanytarsus	Rheotany	25	1.1	12.4
Tanytarsus	Tanytars	15	.4	4.2
Orthocladiinae				
Brillia	Brillia	5	.1	1.2
Corynoneura	Corynone	3	.0	.4
Cricotopus	Cricotop	34	4.0	40.3
Eukiefferiella	Eukieffe	6	.1	2.2
Nanocladius	Nanoclad	10	.1	2.2
Parakiefferiella	Parakief	4	.1	3.0
Parametriocnemus	Parametr	6	.5	16.8
Rheocricotopus	Rheocric	13	.4	4.3
Thienemanniella	Thienema	16	.6	7.5
Tvetenia	Tvetenia	14	1.4	26.9
Tanypodinae				

Table 12. Macroinvertebrate genera, taxon, codes, number of sites found, mean abundance, and maximum abundance of macroinvertebrates collected from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 2000. Taxa reduced to genus level for multivariate analysis—continued.

Phylum / Class / Order / Suborder / Family / Subfamily / Tribe / Taxon	Code	Number of sites	Mean abundance (percent)	Maximum abundance (percent)
Natarsiini				
Natarsia	Natarsia	5	0.1	1.0
Pentaneurini				
Ablabesmyia	Ablabesm	42	1.6	7.9
Simuliidae				
Simulium	Simulium	33	3.3	22.4
Tipulidae				
Tipulinae				
Tipula	Tipula	7	.0	.8
Limoniinae				
Antocha	Antocha	9	.2	2.6

Table 13. Fish species, taxon codes, number of fish collected, and number of sites from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 1995–2001.

Order	Family	Genus species	Common name	Code	Number of fish collected	Number of sites
Petromyzontiformes						
	Petromyzontidae					
		Lampetra appendix	American brook lamprey	Lamp app	10	1
Amiiformes						
	Amiidae					
		Amia calva	bowfin	Amia cal	2	1
Clupeiformes						
	Clupeidae					
		Dorosoma cepedianum	gizzard shad	Doro cep	7	3
Cypriniformes						
	Cyprinidae					
		Campostoma anomalum	central stoneroller	Camp ano	1,114	25
		Campostoma oligolepis	largescale stoneroller	Camp oli	95	5
		Carassius auratus	goldfish	Cara aur	1	1
		Cyprinella spiloptera	spotfin shiner	Cypr car	686	21
		Cyprinus carpio	common carp	Cypr spi	159	21
		Ericymba buccata	silverjaw minnow	Eric buc	2	1
		Luxilus chrysocephalus	striped shiner	Luxi chr	345	8
		Luxilus cornutus	common shiner	Luxi cor	2,333	17
		Lythrurus umbratilis	redfin shiner	Lyth umb	148	5
		Nocomis biguttatus	hornyhead chub	Noco big	837	24
		Notemigonus crysoleucas	golden shiner	Note cry	33	5
		Notropis atherinoides	emerald shiner	Notr ath	1	1
		Notropis dorsalis	bigmouth shiner	Notr dor	321	9
		Notropis hudsonius	spottail shiner	Notr hud	5	4
		Notropis ludibundus	sand shiner	Notr lud	1,231	20
		Notropis rubellus	rosyface shiner	Notr rub	63	5
		Phenacobius mirabilis	suckermouth minnow	Phen mir	36	4
		Phoxinus erythrogaster	southern redbelly dace	Phox ery	1	1
		Pimephales notatus	bluntnose minnow	Pime not	2,096	36
		Pimephales promelas	fathead minnow	Pime pro	40	13
		Rhinichthys atratulus	blacknose dace	Rhin atr	49	5
		Semotilus atromaculatus	creek chub	Semo atr	637	31
	Catostomidae					
		Carpiodes cyprinus	quillback	Carp cyp	36	3
		Carpiodes velifer	highfin carpsucker	Carp vel	5	2
		Catostomus commersoni	white sucker	Cato com	814	35
		Hypentelium nigricans	northern hogsucker	Hype nig	159	10
		Minytrema melanops	spotted sucker	Miny mel	1	1

Table 13. Fish species, taxon codes, number of fish collected, and number of sites from from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 1995–2001—continued.

Order	Family	Genus species	Common name	Code	Number of fish collected	Number of sites
		Moxostoma duquesnei	black redhorse	Moxo duq	160	2
		Moxostoma erythrurum	golden redhorse	Moxo ery	184	10
		Moxostoma macrolepidotum	shorthead redhorse	Moxo mac	32	4
		Moxostoma valenciennesi	greater redhorse	Moxo val	1	1
	Cobitidae					
		Misgurnus anguillicaudatus	oriental weatherfish	Misg ang	1	1
Siluriformes						
	Ictaluridae					
		Ameiurus melas	black bullhead	Amei mel	152	9
		Ameiurus natalis	yellow bullhead	Amei nat	190	25
		Ictalurus punctatus	channel catfish	Icta pun	43	10
		Noturus exilis	slender madtom	Notu exi	40	1
		Noturus flavus	stonecat	Notu fla	74	8
		Noturus gyrinus	tadpole madtom	Notu gyr	3	3
		Noturus nocturnus	freckled madtom	Notu noc	1	1
		Pylodictis olivaris	flathead catfish	Pylo oli	1	1
Salmoniformes						
	Esocidae					
		Esox americanus	grass pickerel	Esox ame	22	5
		Esox hybrid	Esox hybrid	Esox hyb	1	1
		Esox lucius	northern pike	Esox luc	5	2
	Umbridae					
		Umbra limi	central mudminnow	Umbr lim	46	7
Atheriniformes						
	Atherinidae					
		Labidesthes sicculus	brook silverside	Labi sic	1	1
Cyprinodontiformes						
	Fundulidae					
		Fundulus notatus	blackstripe topminnow	Fund not	128	9
Cyprinodontiformes						
	Poeciliidae					
		Gambusia affinis	western mosquitofish	Gamb aff	23	1
Gasterosteiformes						
	Gasterosteidae					
		Culaea inconstans	brook stickleback	Cula inc	1	1
Scorpaeniformes						
	Cottidae					
		Cottus bairdi	mottled sculpin	Cott bai	11	3

Table 13. Fish species, taxon codes, number of fish collected, and number of sites from from 45 stream sites in northeastern Illinois and southeastern Wisconsin, 1995–2001—continued.

Order	Family	Genus species	Common name	Code	Number of fish collected	Number of sites
Perciformes						
	Centrarchidae					
		Ambloplites rupestris	rock bass	Ambl rup	48	9
		Lepomis cyanellus	green sunfish	Lepo cya	999	39
		Lepomis gibbosus	pumpkinseed	Lepo gib	18	4
		Lepomis gulosus	warmouth	Lepo gul	1	1
		Lepomis humilis	orangespotted sunfish	Lepo hum	26	4
		Lepomis hybrid	Lepomis hybrid	Lepo hyb	11	9
		Lepomis macrochirus	bluegill	Lepo mac	358	27
		Lepomis megalotis	longear sunfish	Lepo meg	66	2
		Micropterus dolomieu	smallmouth bass	Micr dol	84	14
		Micropterus salmoides	largemouth bass	Micr sal	169	26
		Pomoxis nigromaculatus	black crappie	Pomo nig	15	5
	Percidae					
		Etheostoma caeruleum	rainbow darter	Ethe cae	14	1
		Etheostoma chlorosomum	bluntnose darter	Ethe chl	49	3
		Etheostoma flabellare	fantail darter	Ethe fla	235	11
		Etheostoma nigrum	johnny darter	Ethe nig	508	30
		Etheostoma spectabile	orangethroat darter	Ethe spe	96	8
		Etheostoma zonale	banded darter	Ethe zon	109	8
		Perca flavescens	yellow perch	Perc fla	2	1
		Percina caprodes	logperch	Perc cap	58	3
		Percina maculata	blackside darter	Perc mac	102	9

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Harris and others—**Physical, Chemical, and Biological Responses to Urbanization in the Fox and Des Plaines River Basins of Northeastern Illinois and Southeastern Wisconsin**—Scientific Investigations Report 2005-5218