Prepared in cooperation with the City of Independence, Missouri Water Pollution Control Department

Assessment of Macroinvertebrate Communities in Adjacent Urban Stream Basins, Kansas City, Missouri, Metropolitan Area, 2007 through 2011

Scientific Investigations Report 2012–5284

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

Front cover. Little Blue River near Lake City, Missouri. Photograph by Heather M. Krempa, U.S. Geological Survey.

Assessment of Macroinvertebrate Communities in Adjacent Urban Stream Basins, Kansas City, Missouri, Metropolitan Area, 2007 through 2011

By Eric D. Christensen and Heather M. Krempa

Prepared in cooperation with the City of Independence,
Missouri Water Pollution Control Department

Scientific Investigations Report 2012–5284

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2013

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Christensen, E.D., and Krempa, H.M., 2013, Assessment of macroinvertebrate communities in adjacent urban stream basins, Kansas City, Missouri, metropolitan area, 2007 through 2011: U.S. Geological Survey Scientific Investigation Report 2012–5284, 45 p. and tables.

Contents

Figures

Tables

Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	35.311	cubic foot (ft^3)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

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

$$°F=(1.8\times°C)+32$$

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

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

ALS	aquatic-life status
ANOSIM	analysis of similarity
B-IBI	Benthic Index of Biotic Integrity
COLEOPR	Coleoptera richness
CSO	combined sewer overflow
CUII	common urban intensity index
CWA	Clean Water Act
CWQM	continuous water-quality monitor
E. coli	*Escherichia coliform* bacteria
EPA	Environmental Protection Agency
EPEMRp	percent Ephemeroptera richness
EPHEMR	Ephemeroptera richness
EPp	percent Ephemeroptera plus Plecoptera abundance
EPT	Ephemeroptera plus Plecoptera plus Trichoptera
EPTR	EPT richness
EPTRp	percent EPT richness
FBS	fully biologically supporting
IDAS	invertebrate data analysis system
ISOPR	Isopoda richness
KDHE	Kansas Department of Health and Environment
Landsat	land remote sensing satellite program
LRL	laboratory reporting level
MBI	Macroinvertebrate Biotic Index
MDS	multidimensional scaling
MMI	multimetric index
MODNR	Missouri Department of Natural Resources
MSCI	Missouri Stream Condition Index
NAT_TOL	national tolerance listing
NBS	nonbiologically supporting
NONINSRp	percent noninsect richness
NPDES	National Pollutant Discharge Elimination System
NWQL	National Water Quality Laboratory
OLIGOp	percent Oligochaeta abundance
OLIGORp	percent Oligochaeta richness

PBS	partially biologically supporting
PLECOR	Plecoptera richness
PLECORp	percent Plecoptera richness
RICH	total taxa richness
RICHTOL	average of taxa tolerance
RTH	richest-targeted habitat
SCI	Stream Condition Index
SHANDIV	Shannon Diversity Index
sp.	species
SUII	simple urban intensity index
USGS	United States Geological Survey
WWTP	wastewater-treatment plant

Acknowledgments

The authors express appreciation to Dick Champion and Dorris Bender, Independence, Missouri Water Pollution Control Department for their support throughout this study.

The authors also thank Suzanne Femmer, U.S. Geological Survey, for sharing her expertise in organizing and processing macroinvertebrate data.

Assessment of Macroinvertebrate Communities in Adjacent Urban Stream Basins, Kansas City, Missouri, Metropolitan Area, 2007 through 2011

By Eric D. Christensen and Heather M. Krempa

Abstract

Macroinvertebrates were collected as part of two separate urban water-quality studies from adjacent basins, the Blue River Basin (Kansas City, Missouri), the Little Blue River and Rock Creek Basins (Independence, Missouri), and their tributaries. Consistent collection and processing procedures between the studies allowed for statistical comparisons. Seven Blue River Basin sites, nine Little Blue River Basin sites, including Rock Creek, and two rural sites representative of Missouri ecological drainage units and the area's ecoregions were used in the analysis. Different factors or levels of urban intensity may affect the basins and macroinvertebrate community metrics differently, even though both basins are substantially developed above their downstream streamgages (Blue River, 65 percent; Little Blue River, 52 percent). The Blue River has no flood control reservoirs and receives wastewater effluent and stormflow from a combined sewer system. The Little Blue River has flood control reservoirs, receives no wastewater effluent, and has a separate stormwater sewer system. Analysis of macroinvertebrate community structure with pollution-tolerance metrics and water-quality parameters indicated differences between the Blue River Basin and the Little Blue River Basin.

A four-metric score (total taxa richness, Ephemeroptera plus Plecoptera plus Trichoptera taxa richness, Macroinvertebrate Biotic Index, and Shannon Diversity Index) for richest-targeted habitat was used to calculate a Stream Condition Index (SCI) in order to evaluate the aquatic-life status of the streams. About 80 percent of all samples combined were determined to be less than fully biologically supporting, and about 11 percent of spring samples were fully biologically supporting. No sites within the Blue River Basin had a fully supporting score. The aquatic-life status scores for the Little Blue River and its tributaries were higher (indicating more optimal conditions) than for the Blue River and its tributaries. Fall samples scored higher than spring samples. However, fall samples were collected at the Little Blue River Basin and rural sites only. The Little Blue River sites scored higher for fall samples than spring samples; about 39 percent fully biologically supporting and 61 percent partially biologically supporting; more similar to the rural comparison sites, 40 percent fully biologically supporting and 60 percent partially biologically supporting.

The SCI was compared to other multimetric indices with more or other component metrics to determine if the SCI effectively described differences among sites. Environmental variables (streamflow, water quality, land use, impervious cover, and population density) were used in statistical analyses to evaluate relations to macroinvertebrate metrics. Multimetric indices (MMIs) were modeled using step regression with a simple urban intensity index (SUII) based on percentage of impervious cover, population density, and forest cover in a 30-meter stream-buffer zone, and two were selected for further analysis. Three other multimetric indices composed of metrics common to local and national studies show results similar to the two modeled MMIs. A common Benthic Index of Biotic Integrity (R^2 equals 0.71) developed for a national study had the highest correlation with urban intensity as measured with the SUII, followed by a modeled 6-metric index (R^2 equals 0.61). The other MMIs and the SCI explained less than a half of the variability in macroinvertebrate communities in relation to the SUII.

Wastewater-treatment plant discharges during base flow, which elevated specific conductance and nutrient concentrations, combined sewer overflows, and nonpoint sources likely contributed to water-quality impairment and lower aquatic-life status at the Blue River Basin sites. Releases from upstream reservoirs to the Little Blue River likely decreased specific conductance, suspended-sediment, and dissolved constituent concentrations and may have benefitted water quality and aquatic life of main-stem sites. Chloride concentrations in base-flow samples, attributable to winter road salt application, had the highest correlation with the SUII (Spearman's ρ equals 0.87), were negatively correlated with the SCI (Spearman's ρ equals -0.53) and several pollution sensitive Ephemeroptera plus Plecoptera plus Trichoptera abundance and percent richness metrics, and were positively correlated with pollution tolerant Oligochaeta abundance and percent richness metrics. Study results show that the easily calculated SUII and the

selected modeled multimetric indices are effective for comparing urban basins and for evaluation of water quality in the Kansas City metropolitan area.

Introduction

The Blue River and Little Blue River flow north-northeast to the Missouri River and drain about a half of the Kansas City metropolitan area in Jackson County, Missouri (fig. 1). Kansas City and Independence, Mo., in efforts to comply with requirements of the Clean Water Act (CWA) and subsequent legislation, have been issued permits from the Missouri Department of Natural Resources (MODNR) under the National Pollutant Discharge Elimination System (NPDES) to monitor and control pollutant discharges to streams from their respective storm-sewer systems. The Blue River and Little Blue River have been listed by the MODNR as impaired for the protection of aquatic life, whole-body contact recreation (swimming), and secondary-contact recreation (fishing and boating), under section 303(d) of the CWA. The Little Blue River listing currently (2012) is pending United States Environmental Protection Agency (EPA) approval. Bacteria from urban point and nonpoint sources are a listed pollutant for both streams. Indian Creek, a tributary of the Blue River (fig. 1), also has been listed for urban point and nonpoint source bacteria and chloride pollutants. Missouri's 303(d) listings can be accessed at *http://www.dnr.mo.gov/env/wpp/waterquality/303d.htm*.

In support of NPDES permit requirements and to better understand processes affecting water quality and aquatic life, the U.S. Geological Survey (USGS) in cooperation with the City of Independence, Missouri Pollution Control Department initiated this ongoing study (2012) to characterize water-quality and ecological conditions of urban streams and the Little Blue River in Independence, Mo. An objective of this study was to assess Independence streams relative to other local streams. Comparable macroinvertebrate data collected for the Independence study and previous USGS studies conducted in Kansas City, Mo., during 1998 through 2010 also were used for this study to address this objective.

Macroinvertebrates are invertebrates (organisms that lack a backbone) that are large enough to be seen with the unaided eye. Aquatic macroinvertebrates include insects in their larval or nymph forms, aquatic worms, mussels, snails, and crayfish. A macroinvertebrate community is the sum of all the macroinvertebrates found in a defined ecological system (for example a stream) or habitat (riffle or pool) and may be constrained temporally (season) and geographically. Biological assessment data, including macroinvertebrate community data, are important for determining whether a stream or other waterbody is meeting its designated aquatic life uses and can validate whether existing water-quality criteria are adequately protecting those aquatic life uses. Macroinvertebrate community data are useful because community analysis provides evidence for present and past water quality in streams (U.S. Environmental Protection Agency, 2002). Results of macroinvertebrate community analysis from this study will assist Independence, as well as other area municipalities, in assessing the biological integrity of their urban streams, provide methods for detection of water-quality impairment that may not be apparent with traditional water-quality monitoring methods, and supply information for the development and refinement of best management practices to address NPDES permit requirements.

Purpose and Scope

This report presents the results from an analysis of macroinvertebrate communities in urban streams in the Kansas City, Mo., metropolitan area south of the Missouri River, primarily within the Independence and Kansas City, Mo., city boundaries (fig. 1). Macroinvertebrate community data collected from adjacent basins, the Blue River Basin (Kansas City, Mo.), the Little Blue River and Rock Creek Basins (Independence, Mo.), and their tributaries during 2007 through 2011 were used to compute various macroinvertebrate community metrics. Macroinvertebrate community structure, community metrics, multimetric indices (MMIs) and their relation to environmental variables including habitat scores, urban intensity, hydrologic variables, physical parameters, and water-quality variables were used to evaluate individual sites, differences among sites and river basins, and the aquatic-life status (ALS) of streams. Combinations of commonly used macroinvertebrate metrics included in multimetric scoring schemes were evaluated for their relation to a simple urban intensity index (SUII). This report presents multiple ways for determining the aquatic-life status of streams from which local officials may assess the current and future effects of urbanization and implementation of best management practices on stream ecologic condition.

Description of Study Area

Data from 18 macroinvertebrate sampling sites were selected and analyzed from urban basins in the Kansas City, Mo., metropolitan area and adjacent counties (fig. 1, table 1). Seven sites were located in the Blue River Basin, including five sites on the main-stem Blue River and one site each on Indian Creek and Brush Creek, tributaries to the Blue River. Eight sites were located in the Little Blue River Basin, including three sites on the main-stem Little Blue River and five sites located on tributaries to the Little Blue River (Adair Creek, East Fork Little Blue River, Crackerneck Creek, Spring Branch Creek, and Burr Oak Creek). Rock Creek, located almost entirely within Independence city boundaries between the Blue River and Little Blue River Basins, was included in analyses with the Little Blue River sites. Two rural sites that are relatively free from development, located outside the Kansas City metropolitan area in adjacent Ray and Cass Counties, were selected for comparison (fig. 1).

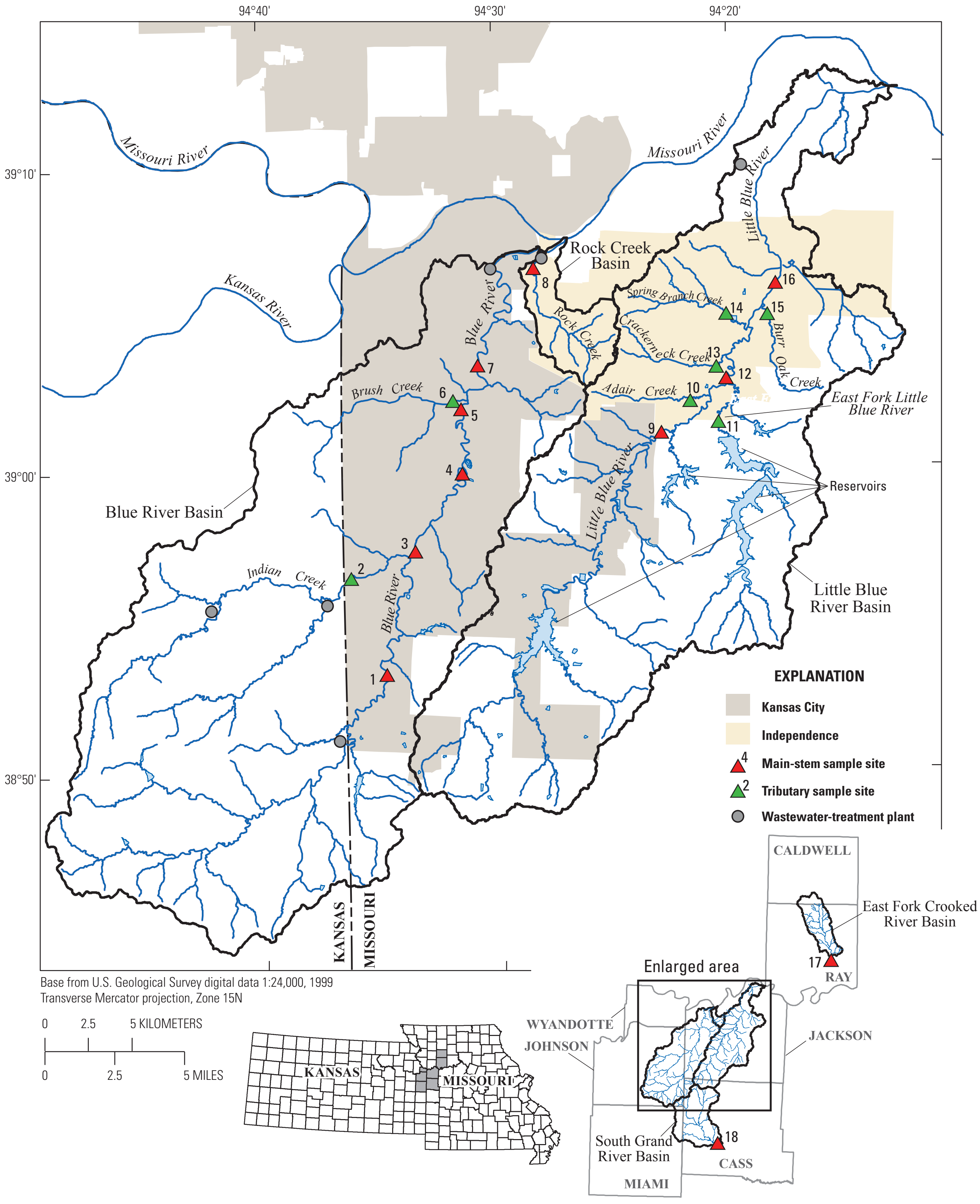

Figure 1. The Blue River, Little Blue River, and Rock Creek Basins, sampling sites, and political boundaries for Kansas City and Independence, Missouri.

Table 1. Locations of macroinvertebrate sampling sites in Kansas City and Independence, Missouri, and Cass and Ray Counties, Missouri, and type of hydrologic, water-quality, and ecologic data collected, March 2007 through March 2011.

[ID, identification number; mi², square mile; km², square kilometer; SUII, simple urban intensity index; QC, continuous discharge; PCP, precipitation; BQW, base-flow water quality; SQW, stormflow water quality; CWQ, continuous water quality; IQW, benthic macroinvertebrates; HAB, habitat assessment; DWS, dry-weather screening; BBU, Upstream Blue River; °, degrees; ′, minutes; ″, seconds; X, sampled; --, no data; BBT, Blue River tributaries; BBM, Middle Blue River; BBD, Downstream Blue River; RCK, Rock Creek; LBM, Middle Little Blue River; LBT, Little Blue River tributaries; LBD, Downstream Little Blue River; RUR, Rural stream]

Site number (fig. 1)	Station name or watershed	Station ID	Stream category[1]	Stream order	Latitude	Longitude	Drainage area[2], (mi²)	Drainage area[2], (km²)	Population density[3] (km²)	Percent impervious surface[4]	Percent forest buffer	SUII	Q_C	PCP	BQW	SQW	CWQ	IQW[5]	HAB	DWS
	Kansas City, Missouri Sites																			
1	Blue River at Blue Ridge Boulevard Extension, Kansas City, Mo.	06893150	BBU	5	38°53′24″	94°40′31″	93.2	241	220	8.0	26.4	27.1	X	X	X	X	X	4	X	--
2	Indian Creek at 103rd Street, Kansas City, Mo.	06893400	BBT	4	38°56′31″	94°36′16″	65.0	168	1,184	33.9	12.5	80.2	X	X	X	X	--	4	X	--
3	Blue River near Kansas City, Mo.	06893500	BBM	5	38°57′26″	94°33′31″	184	477	641	19.0	23.4	47.7	X	--	X	X	X	4	X	--
4	Blue River near Gregory Boulevard, Kansas City, Mo.	06893520	BBM	5	38°59′58″	94°31′39″	204	529	652	19.5	23.7	48.3	--	--	X	--	--	2	X	--
5	Blue River at Blue Parkway, Kansas City, Mo.	06893552	BBM	5	39°02′06″	94°31′36″	213	551	641	19.5	24.5	47.5	--	--	X	X	--	2	--	--
6	Brush Creek at Elmwood Avenue, Kansas City, Mo.	06893564	BBT	4	39°02′11″	94°31′52″	29.9	77.5	1,581	37.4	0.6	100.0	--	--	X	--	--	4	X	--
7	Blue River at Stadium Drive, Kansas City, Mo.	06893578	BBD	5	39°03′30″	94°30′42″	255	660	758	22.1	22.9	53.4	X	X	X	X	--	4	X	--
	Independence, Missouri sites																			
8	Rock Creek at Kentucky Road in Independence, Mo.	06893620	RCK	3	39°06′43″	94°28′20″	9.4	24.4	1,119	29.4	9.7	76.7	X	X	X	X	--	7	X	X
9	Little Blue River at Lee′s Summit Road in Independence, Mo.[6]	06893820	LBM	4	39°01′02″	94°23′14″	98.6	255	519	14.0	38.8	29.8	X	X	X	X	X	2	X	X
10	Adair Creek at Independence, Mo.[7]	06893830	LBT	3	39°02′16″	94°21′48″	5.2	13.4	1,027	36.6	22.7	72.1	X	X	X	X	X	2	X	X
11	East Fork Little Blue River near Blue Springs, Mo.[8]	06893890	LBT	4	39°01′32″	94°20′37″	34.4	89.0	483	14.8	25.6	39.2	X	X	X	X	X	2	X	X
12	Little Blue River at 39th St. in Independence, Mo.[9]	06893910	LBM	5	39°02′50″	94°20′15″	155	401	539	15.5	31.2	37.0	X	X	X	X	X	6	X	X
13	Crackerneck Creek at Selsa Rd. in Independence, Mo.[10]	06893940	LBT	3	39°03′22″	94°20′41″	5.0	12.8	957	29.6	21.0	65.5	X	X	X	X	--	4	X	X
14	Spring Branch Creek at 78 Highway in Independence, Mo.[11]	06893970	LBT	3	39°05′18″	94°20′36″	9.1	23.4	904	20.0	35.4	45.7	X	X	X	X	X	7	X	X
15	Burr Oak Creek in Independence, Mo.	06893990	LBT	3	39°05′10″	94°18′32″	8.1	20.9	343	11.1	47.3	17.6	--	--	X	X	--	2	X	X
16	Little Blue River near Lake City, Mo.	06894000	LBD	5	39°06′02″	94°18′01″	186	481	550	15.6	31.1	37.4	X	X	X	X	X	7	X	X

Table 1. Locations of macroinvertebrate sampling sites in Kansas City and Independence, Missouri, and Cass and Ray Counties, Missouri, and type of hydrologic, water-quality, and ecologic data collected, March 2007 through March 2011.—Continued

[ID, identification number; mi², square mile; km², square kilometer; SUII, simple urban intensity index; QC, continuous discharge; PCP, precipitation; BQW, base-flow water quality; SQW, stormflow water quality; CWQ, continuous water quality; IQW, benthic macroinvertebrates; HAB, habitat assessment; DWS, dry-weather screening; BBU, Upstream Blue River; °, degrees; ′, minutes; ″, seconds; X, sampled; --, no data; BBT, Blue River tributaries; BBM, Middle Blue River; BBD, Downstream Blue River; RCK, Rock Creek; LBM, Middle Little Blue River; LBT, Little Blue River tributaries; LBD, Downstream Little Blue River; RUR, Rural stream]

Site number (fig. 1)	Station name or watershed	Station ID	Stream category[1]	Stream order	Latitude	Longitude	Drainage area[2], (mi²)	Drainage area[2], (km²)	Population density[3] (km²)	Percent impervious surface[4]	Percent forest buffer	SUII	Q_c	PCP	BQW	SQW	CWQ	IQW[5]	HAB	DWS
								Reference sites												
17	East Fork Crooked River near Richmond, Mo. (Ray County)	06895090	RUR	5	39°22′22″	94°54′32″	93.3	242	6	0.5	43.7	3.5	--	--	--	--	--	4	X	--
18	South Grand River below Freeman, Mo. (Cass County)	06921582	RUR	5	38°35′20″	94°26′30″	150	389	69	3.6	28.8	18.2	--	--	X	X	--	8	X	--

[1]Stream categories used in data analysis.

[2]Calculated using 2006 data. Areas may vary from previously published values.

[3]Calculated using 2010 census data (U.S. Census Bureau, 2010a, 2010b).

[4]Calculated using 2006 data (U.S. Geological Survey, 2010).

[5]Number of macroinvertebrate samples collected at site from 2007 to 2011.

[6]Station established October 2009.

[7]Station established October 2008.

[8]Station re-established December 2009.

[9]Station discontinued October 2009.

[10]Station discontinued October 2008.

[11]Gage moved downstream to Missouri State Highway 78 bridge on August 15, 2007, because of sedimentation at the site on Holke Road.

The Blue River Basin encompasses 725 square kilometers (km^2) and includes about one-half of the Kansas City metropolitan area south of the Missouri River (fig.1; Wilkison and others, 2006). Parts of the Blue River Basin receive discharges from wastewater-treatment plants (WWTPs) to streams and combined sewer overflows (CSOs; Wilkison and others, 2006). These discharges, in combination with other permitted point and nonpoint sources and extensive flood mitigation efforts, affect hydrology, water quality, and in-stream ecology (Wilkison and others, 2009; Graham and others, 2010). The Blue River Basin is mostly developed above its downstream streamgage (65 percent; fig. 2) with crops (23 percent) and some forest (9 percent; U.S. Geological Survey, 2010). The Blue River is located in the Central Irregular Plains ecoregion (Omernik, 1987), which can be further divided into the Wooded Osage Plains, Osage Cuestas, Rolling Loess Prairies, and Missouri Alluvial Plain (Omernik, 1987; Chapman and others, 2001; Nigh and Schroeder, 2002).

The Little Blue River Basin encompasses 580 km^2 and is located on the eastern side of the Kansas City metropolitan area (fig. 1). Municipalities within the basin use separate storm-sewer systems (Christensen and others, 2010). A WWTP located within the Little Blue River Basin (fig. 1) discharges to the Missouri River; however, currently (2012) no WWTPs discharge directly to streams in the basin. The basin is mostly developed above its downstream streamgage (52 percent; fig. 2) with some forest (16 percent) and crops (26 percent; U.S. Geological Survey, 2010).

The Rock Creek Basin is located almost entirely within Independence city boundaries between the Blue River Basin and Little Blue River Basin and flows directly to the Missouri River. A WWTP discharges effluent near Rock Creek's mouth (fig. 1). The basin is mostly developed above its streamgage (92 percent; fig. 2) with little forest (5 percent). Three divisions of the Central Irregular Plains ecoregion are represented within the Little Blue River and Rock Creek Basins: Wooded Osage Plains, Rolling Loess Prairies, and Missouri Alluvial Plain (Omernik, 1987; Chapman and others, 2001; Nigh and Schroeder, 2002). The two rural sites, located outside the Kansas City metropolitan area in Ray County and Cass County, Missouri (fig. 1) are representative of the Central Irregular Plains ecoregion and are largely undeveloped with less than 20 percent developed land use above their streamgages (fig. 2) and less than 5 percent impervious cover (table 1).

Previous Investigations

Water-quality studies for the upper Blue River in Johnson County, Kansas (Lee and others, 2005; Rasmussen and others, 2008, 2009; Graham and others, 2010), and the lower Blue River and its tributaries in Kansas City, Mo. (Wilkison and others, 2002, 2005, 2006, 2009), included macroinvertebrate sampling and data analysis. Poulton and others (2007) conducted an assessment of biological conditions using macroinvertebrate data and metrics for the Blue River Basin in Missouri and Kansas during 2003 and 2004. A comprehensive water-quality study was conducted for the Little Blue River and its tributaries within Independence, Missouri, from 2005 through 2008 (Christensen and others, 2010) that included a preliminary assessment of macroinvertebrate samples collected in 2007 and 2008.

Bioassessments conducted in the Blue River Basin (Wilkison and others, 2006, 2009; Poulton and others, 2007; Rasmussen and others, 2009; Graham and others, 2010) have indicated that stream health is negatively correlated to several urbanization factors including developed land use, impervious cover, and wastewater effluent discharges. Previous studies indicated that the Blue Ridge sampling site (site 1; table 1, fig.1), the furthest upstream Blue River site in this study, typically had less optimal macroinvertebrate metric scores than other sites in the upper Blue River Basin that were also above wastewater effluent discharges (fig. 1). However, more optimal metric scores found in these studies in increasingly developed reaches further downstream from WWTP discharges indicated that although the WWTPs may affect stream biota, effluent effects decreased with distance from the point of discharge (Poulton and others, 2007; Graham and others, 2010). None of the sites included in these studies consistently met the Kansas Department of Health and Environment (KDHE) fully supporting criteria for ALS. Similarly, Christensen and others (2010) identified no sites for the Little Blue River within Independence city boundaries that met the MODNR criteria for fully supporting ALS. One of the rural comparison sites, South Grand River below Freeman (site 18, table 1, fig. 1), scored only partially biologically supporting on the MODNR scale for five macroinvertebrate samples collected during previous studies from 2002 to 2007 (Poulton and others, 2007; Wilkison and others, 2006, 2009).

Tate and others (2005) examined the effects of urbanization on aquatic biota as part of the USGS National Water-Quality Assessment (NAWQA) program and presented a Common Urban Intensity Index (CUII). Five variables were included in the CUII: percent basin developed land use, percent basin forest plus shrub land, percent stream buffer developed, percent stream buffer forest plus shrub land, and basin road density. The CUII provided a consistent measure of urban intensity among three urban study areas. The CUII was used as a starting point for determining a simple urban intensity index for this study.

The term "urban intensity" has been selected in this report to represent many descriptors for urbanization. These descriptors include environmental perturbation, environmental disturbance, urbanization, urban gradient, and other similar terminology used with small distinctions or interchangeably in previous studies cited and in the literature for macroinvertebrate studies in urban streams. Urban intensity as used in this study should be interpreted broadly with the terminology used in the references cited.

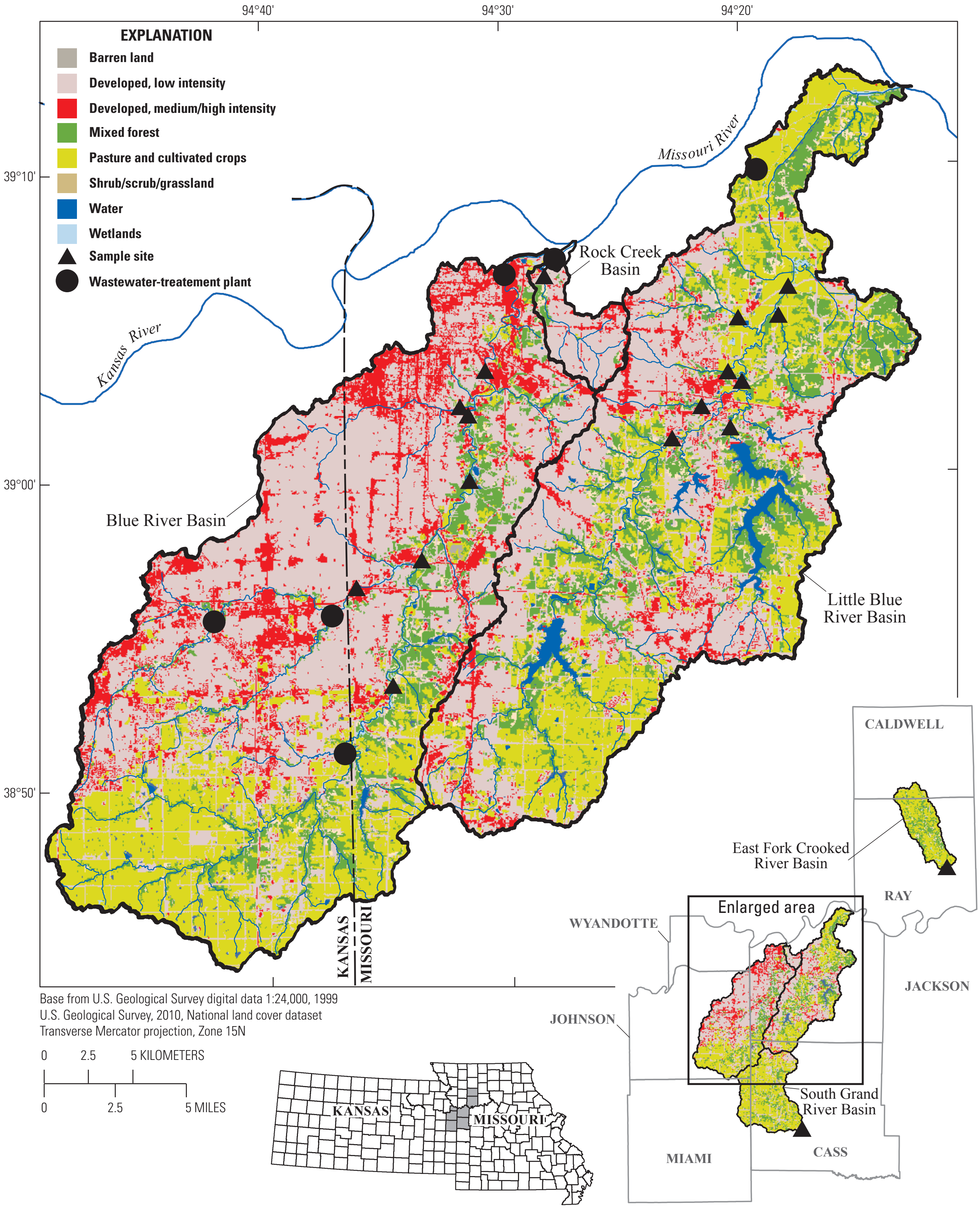

Figure 2. Land use in the Blue River, Little Blue River, and Rock Creek Basins.

Methods

Eighteen macroinvertebrate sampling sites in the Kansas City metropolitan area were selected based on data availability and comparability. Sites were included from adjacent river basins from two studies, one in Kansas City (Wilkison and others, 2009) and the other in Independence (Christensen and others, 2010). Macroinvertebrate data collection for the Kansas City study ended in April 2010. The Independence study currently (2012) is ongoing. Collection and processing of macroinvertebrate samples for these studies were performed by USGS personnel using consistent methods. Study sites are located in Jackson County, Missouri, within the Kansas City and Independence city boundaries except for the two rural sites, which are located in Ray and Cass Counties (table 1, fig. 1).

Data Collection

Hydrologic, water-quality, macroinvertebrate, and habitat data collected for the Kansas City and Independence water-quality studies were compiled and reviewed for this report. Brief summaries of the data collection procedures are presented below. Additional discussion of the procedures and types of samples collected can be found in Wilkison and others (2009) and Christensen and others (2010). Hydrologic and water-quality data can be accessed at *http://nwis.waterdata.usgs.gov/nwis/nwis*.

Hydrology

Streamflow (discharge) was determined at the time of sample collection or from established stage-discharge relations at the sites that had streamgages using standard USGS procedures (U.S. Geological Survey, 2004, 2007; Oberg and others, 2005; Mueller and Wagner, 2009: Sauer and Turnipseed, 2010; Turnipseed and Sauer, 2010). Continuous discharge was measured and recorded at 12 sites (table 1) for all or part of the period covered in this report. Precipitation data were collected at 11 of the 12 sites using unheated tipping-bucket rain gages.

Water Quality

Water-quality samples were analyzed for nutrients, metals, wastewater-indicator compounds, bacteria, and suspended sediment and were collected as grab, depth- and width-integrated, or automatic samples depending on stream and streamflow conditions. Automatic samplers equipped with peristaltic pumps and Teflon tubing were programmed to collect flow-weighted composite samples when a predetermined stage threshold was exceeded during stormflow events. Details of the USGS water-quality sample collection procedures can be accessed at *http://pubs.water.usgs.gov/twri9A*. Continuous water-quality monitors (CWQMs) were installed at two Blue River Basin and six Little Blue River Basin sites for all or part of March 2007 through March 2011 (table 1). CWQM data (temperature, pH, specific conductance, dissolved oxygen, and turbidity) were corrected as needed based on knowledge of conditions at the individual stream sites, manufacturer's specifications, and USGS methods presented by Wagner and others (2006) before being finalized. Historical and real-time CWQM data can be accessed at *http://nwis.waterdata.usgs.gov/nwis/sw*.

Macroinvertebrates

The macroinvertebrate sampling protocol was based on procedures described by Barbour and others (1999) and Sarver (2003a) for the collection of qualitative samples. The richest-targeted habitat (RTH) method (Barbour and others, 1999) was used where riffle/run habitats are targeted. Samples collected from this habitat type are likely representative of the stream reach (Barbour and others, 1999; Cuffney and others, 2010). For each sample, six collections were made from various riffle locations to incorporate a variety of substrate size, stream velocity, and water depth, and processed and composited in the field according to Sarver (2003a). The composite sample was brought back to the laboratory for further processing and placed in a lighted white processing tray for visibility with enough water to cover the bottom of the tray. A total of 600 individuals (or amount enumerated in 1 hour) was collected from the composite sample. Counting focused on maximizing sample biodiversity based on visually identified morphological differences of individuals selected during collection. Finished samples were preserved with 90-percent ethanol until analysis.

Habitat Assessments

Stream habitat assessments were performed at each sampling site to relate physical characteristics to biological variables. Ten physical-habitat characteristics (epifaunal substrate, embeddedness, velocity-depth regime, sediment deposition, channel flow status, channel alteration, riffle quality, bank stability, vegetative protection, and riparian vegetation) were measured and assigned a standardized score on a scale of 0 to 20 according to procedures described in Sarver (2003b). The scores were then summed to provide an overall assessment of stream physical-habitat quality.

Sample Analysis

Water-quality samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, using established USGS procedures (Garbarino and Struzeski, 1998; Fishman and Friedman, 1989; Fishman, 1993; Patton and Truitt, 1992; Patton and Truitt, 2000). Total coliform and *Escherichia coliform* (*E. coli)* bacteria were analyzed at the USGS Missouri Water Science Center—Kansas City laboratory using a semi-automated quantification method

(IDEXX, 2009). Suspended-sediment concentration samples were analyzed at the USGS sediment laboratory in Rolla, Mo., according to methods presented in Guy (1969). Preserved macroinvertebrate samples were sent to the USGS NWQL for enumeration and taxonomic identification according to USGS protocols (Moulton and others, 2000, 2002).

Quality Assurance and Quality Control

Quality-assurance procedures ensure data precision and accuracy. Quality-control samples test sample collection and analysis procedures (U.S. Geological Survey, variously dated). About 10 percent of water-quality samples collected in the studies presented in this report were quality-control samples and included replicate and blank samples. Generally, the field and laboratory quality control and assurance data (data not presented) indicate that sample collection and processing procedures were not a source of bias. Quality assurance data are on file at the Missouri Water Science Center—Kansas City office and available upon request. More detailed information on field and laboratory quality-assurance and quality-control procedures used in collection of data used in this report are presented in Wilkison and others (2009) and Christensen and others (2010).

Fifty-four quality-assurance samples, including analyses for nutrients, chloride, bacteria, and suspended-sediment concentration, were collected from April 2008 through February 2011 at 16 study sites excluding the two rural comparison sites (table 1). The quality-assurance samples included seven procedure blanks (field and laboratory) collected to monitor for environmental and cross contamination and 47 replicate environmental samples to monitor for analytical precision. Nutrient concentrations in the seven blank samples were less than the laboratory reporting level (LRL) with the following qualifications: total ammonia plus organic nitrogen detected in one sample [estimated 0.05 milligram per liter (mg/L), LRL 0.10 mg/L] and ammonia detected in one sample (estimated 0.017 mg/L, LRL 0.020 mg/L). The LRL is the lowest measured concentration that may be reported reliably with the risk of a false negative of less than one percent. Values less than the LDL, but greater than the long term method detection level, are reported as estimated (Childress and others, 1999). All chloride concentrations in blank samples were less than the LRL. Most constituent concentrations in the replicate environmental samples were comparable and within laboratory analytical error. Seven laboratory equipment blanks for bacteria reported no *E. coli* densities, but two blanks reported total coliform densities of 3 most probable number per 100 milliliters. The potential for sample bias was minimal.

Macroinvertebrate sample collection and enumeration are expensive, labor intensive, and time consuming. The MODNR determined that collection of an additional macroinvertebrate sample from a different reach of the same stream improved impairment detection by only 9.3 percent (Rabeni and others, 1997). Collection of duplicate samples was identified to the same impairment category 95 percent of the time (Sarver and others, 2002). Given collection, identification, and enumeration constraints, duplicates for macroinvertebrate samples were not collected. A taxon-based approach to quality control and assurance was used at the USGS NWQL (Grotheer and others, 2000; Moulton and others, 2000, 2002). Quality-assurance measures included repeat identification of new specimens by a different taxonomist and random reviews for a minimum of 10 percent of all identifications. Taxonomic keys and specimens are maintained at the USGS NWQL in Lakewood, Colo. Additional information on quality-control and quality-assurance procedures for data presented in this report can be found in Wilkison and others (2009) and Christensen and others (2010) and for the USGS NWQL at *http://nwql.usgs.gov/Public/quality.shtml*.

Since widespread adoption of rapid-bioassessement protocols using biologic indices for the assessment of water quality introduced by Karr (1981), Hilsenhoff (1988), and Plafkin and others (1989), methods for macroinvertebrate sample collection and data analysis remain highly variable (Hannaford and Resh, 1995; Barbour and others, 1999; Cuffney and others, 2010). Factors that affect data comparability include sample collection and processing, sampling effort, equipment, habitats sampled, sampling personnel, timing and frequency of sampling (year and season), sample sorting and enumeration, taxonomic accuracy and resolution, and selection and location of calibration sites (Cao and Hawkins, 2011). Data for sites and samples for this study were selected from studies (Christensen and others, 2010; Wilkison, 2009) conducted using consistent methods in order to maximize comparability of these factors.

The accuracy and comparability of biotic indices and other tolerance-based metrics rely on the assigned tolerance values. Tolerance values from published sources generally are used, including Hilsenhoff (1977, 1988), Huggins and Moffet (1988), Lenat (1993), Bode and others (2002), and Klemm and others (2002). State and national listings may vary because some tolerance values are regionally adjusted to better represent local tolerance. Tolerance values are less accurate when applied to streams outside of the geographic area from which the tolerance values were established (Blocksam and Winters, 2006). Missouri’s taxa tolerance listing uses values that are representative and applicable to the study area and continues to be refined (Sarver, 2005). Therefore, tolerance values from the Missouri taxa listings (Sarver, 2005) were used, or if unavailable, assigned from established regional tolerance values (Cuffney and Brightbill, 2011). Greater than 97 percent of identified taxa in samples were assigned tolerance values.

Environmental Variables

Percent land use (2006) and forest canopy (2001) for upstream basin areas were calculated from 1:24,000 digital raster data (U.S. Geological Survey, 2010; Missouri Spatial Data Information Service, 2011). Percent impervious cover for the upstream basin area for each site was calculated from corrected 2006 30-meter (m) resolution Landsat data (Nowak and Greenfield, 2010; U.S. Geological Survey, 2010; Xian and Homer, 2010). Population densities for individual basins were calculated from 2010 census tract data (U.S. Census Bureau, 2010a, 2010b). Land use, forest canopy, impervious cover, and population density variables also were determined for a 30-m buffer area around hydrologic features of the upstream basin area for each site. The SUII for each basin was computed on a scale of low to high (0 to 100) from the average of the similarly scaled impervious cover, population density, and buffer forest cover.

Data Analysis

Sample sites were divided into nine stream categories (table 1) for analysis based on location (upstream, middle, or downstream) and stream size (main stem or tributary); upstream Blue River (BBU; site 1), middle Blue River (BBM; sites 3, 4, and 5), downstream Blue River (BBD; site 7), Blue River tributaries (BBT; sites 2 and 6), middle Little Blue River (LBM; sites 9 and 12), downstream Little Blue River (LBD; site 16), Little Blue River tributaries (LBT; sites 10, 11, 13, 14, and 15), Rock Creek (RCK; site 8), and rural (RUR; sites 17 and 18).

Water-quality and macroinvertebrate data (table 1; Wilkison and others, 2009; Christensen and others, 2010) were analyzed for water-quality and environmental factors that characterize, or commonly affect, the ecologic condition of streams including nutrient, chloride, and sediment concentrations, land use, and habitat assessments. The Kruskal-Wallis rank sum test (Kruskal and Wallis, 1952) was used to screen for differences among water-quality and environmental factors for samples, sites, and stream categories. If the Kruskal-Wallis test indicated the likelihood of significant [*p*-value (*p*) less than or equal to 0.10] differences among samples, sites, or categories, a multiple comparison test on the ranked data using the Tukey method (Tukey, 1953) was used to identify the significant (*p* less than or equal to 0.05) differences (Helsel and Hirsch, 2002).

Correlations among factors were assessed using Spearman's correlation coefficient (ρ). Spring and fall samples were analyzed separately. All data from Blue River site 4 (samples collected in 2009 and 2010) and site 5 (samples collected in 2007 and 2008; fig. 1) were combined for statistical analyses to maintain consistency as were data from Independence sites 9 and 12 (table 1; fig. 1). The Rock Creek Basin, located almost entirely within Independence city boundaries, was included with the Little Blue River Basin sites for all sample and group comparisons. The software program TIBCO Spotfire S+ version 8.1 (The Information Bus Company Software Inc., 2008) was used unless otherwise noted for all statistical analyses in this study.

Water Quality

Two of the Blue River and six of the Little Blue River sites had streamgages to measure stream stage and CWQMs to measure physical parameters for all or part of the study duration (table 1). Parameters calculated for those sites include 90-day average and median discharge, peak discharge, and 90-day average and maximum specific conductance. Sufficient data were collected at four Blue River and eight Little Blue River sites to calculate average base-flow concentrations for nutrients, chloride, and suspended sediment, and densities for *E. coli* and total coliform bacteria.

Physical parameters (temperature, pH, specific conductance, dissolved oxygen, and turbidity) were recorded at the time of macroinvertebrate sampling at all sites. Additional water-quality data were collected at selected sites (table 1). The number and timing of samples varied among sites because water-quality samples and physical-property measurements were collected at four of seven Blue River sites and all of the Little Blue River sites except Burr Oak Creek prior to, but independent of, the collection of macroinvertebrate samples. Measured and calculated physical properties and selected streamflow and water-quality parameters for macroinvertebrate samples are presented in table 2 (in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*).

Macroinvertebrates

The Invertebrate Data Analysis System (IDAS) version 5.0 was used for processing data and calculating taxa richness, abundance, and diversity metrics for macroinvertebrate samples (Cuffney and Brightbill, 2011). Generally, taxa were identified by the NWQL to genus or species. However, some taxa were identified to a higher taxonomic level, typically family. Ambiguous taxa were resolved by removing the parent or merging the children with the parent. If the abundance of the ambiguous parent was higher than the sum of the children's abundances, the children were deleted and their abundances were added to the parent. If the sum of the ambiguous children's abundances was higher, the children were retained and the parent was deleted (Cuffney and Brightbill, 2011). This method of resolving ambiguities is conservative and may result in reduced sample richness and abundance but retains sensitivity of the data to differences in urban intensity (Cuffney and others, 2007).

Because of their proximity, urban character, and potential macroinvertebrate populations, data from the Blue River and Little Blue River Basins (sites 1–16; table 1) were combined for the purpose of resolving taxonomic ambiguities. Rural comparison streams (sites 17–18; table 1) were processed together but separately from the urban sites. About 22 percent of sample taxonomic levels, abundances, and tolerance values were assigned because of ambiguous taxonomy.

A total of 154 macroinvertebrate community metrics were calculated using IDAS (Cuffney and Brightbill, 2011), including metrics based on taxa richness, abundance, tolerance, and functional feeding group. Tolerance values for taxa that were used to calculate the Macroinvertebrate Biotic Index (MBI) were assigned from the Missouri taxa listings (Sarver, 2005) or, if unavailable, assigned from established regional tolerance values (Cuffney and Brightbill, 2011). Taxa were defined as intolerant if the tolerance value was less than or equal to 4, moderately tolerant if values were greater than 4 and less than 7, and tolerant if values were greater than or equal to 7. Taxa functional feeding group classifications were assigned as stated in procedures by Sarver (2005) and include shredders, collector/gatherers, collector/filterers, scrapers, macrophyte piercers, predators, herbivores, parasites, and unknown (Merritt and Cummins, 1996). Functional feeding groups are used to describe the balance of feeding strategies (Barbour and others, 1999) and available organic matter size and type (Vannote and others, 1980). For example, shredders utilize coarse particulate organic matter, collector/filterers filter from fine particulate organic matter, and scrapers are adapted to utilize attached algae. All metrics were calculated separately for urban and rural sites and for spring and fall seasons.

For manageability during analysis, the number of metrics was reduced by selection based on: the four metrics included in the Missouri stream biological assessment procedure (Sarver, 2003a); metrics used for assessing local area streams in previous studies (Poulton and others, 2007; Rasmussen and others, 2009; Wilkison and others, 2009; Graham and others, 2010); metrics found to be responsive in urban-intensity studies (Cuffney and others, 2005); metrics determined to have some correlation with the SUII (|ρ| greater than or equal to 0.15); and elimination of metrics with high colinearity (|ρ| greater than or equal to 0.95). The number of metrics was reduced to 23 metrics to calculate MMIs. Abbreviations for macroinvertebrate metrics used in this report, definitions, and correlation coefficients to the SUII are presented in table 3.

Four metrics are used by the MODNR (Sarver, 2003a) in the calculation of the Missouri Stream Condition Index (MSCI): total taxa richness (RICH), Ephemeroptera plus Plecoptera plus Trichoptera (EPT) richness (EPTR), Shannon Diversity Index (SHANDIV), and the MBI (table 3). These metrics were used to calculate the ALS for samples from a stream's richest-targeted habitat, which was usually riffle habitat. The MSCI is calculated from samples collected from multiple habitats within a stream reach. This study's stream condition index is noted simply as SCI because of this difference in calculation of the MSCI and the SCI. Other lesser differences in the calculation of individual metrics are noted below. Differences are not substantial and the MSCI and SCI are considered equivalent. RICH is the total number of distinct taxa present in a sample. EPTR is the total richness of Ephemeroptera, Plecoptera, and Trichoptera taxa in a sample. SHANDIV is a measure of taxa diversity in a community that takes into consideration taxa richness and evenness of the relative abundance of community (Shannon and Weaver, 1949). IDAS calculates the SHANDIV using base 10 logarithms. The SHANDIV was converted to base *e* in order to be comparable with the MSCI. The MBI is a measure of the overall pollution tolerance of a macroinvertebrate community expressed on a scale of 0 to 10 with less tolerant individuals having a smaller tolerance value and more tolerant individuals having a larger tolerance value (Sarver, 2003a) and is comparable to the Hilsenhoff Biotic Index (Hilsenhoff, 1977, 1988). Tolerance values for taxa used to calculate the MBI were assigned from Missouri taxa listings (Sarver, 2005) or assigned from established regional tolerance values. MODNR uses only the Missouri taxa listings when calculating the MSCI.

Breakpoints for scoring the ALS of streams are determined and updated frequently by MODNR. Breakpoints for the ALS of individual habitats, including riffle habitat, were obtained from the MODNR for reference streams in the Central Irregular Plains ecoregion (Omernik, 1987) and Missouri tributaries between the Blue and Lamine Rivers ecological drainage unit (Sarver and others, 2002) that includes the study area. Reference site samples were collected between April 1998 and September 2008 (David Michaelson, Missouri Department of Natural Resources, written commun., 2011).

Measures of urban intensity for the basins and a 30-m stream buffer zone were included in a proportional index to measure urban intensity (the SUII; table 1). Percent impervious cover, population density, and forest cover in a 30-m stream-buffer zone were included in the SUII because they were easily calculated from available data sources and were highly correlated (|ρ| greater than or equal to 0.7) with total taxa richness and Ephemera-Plecoptera-Trichoptera taxa richness, which are two macroinvertebrate metrics sensitive to pollution (Barbour and others, 1999; Cuffney and others, 2005, 2010).

Ordinary least squares subset regression (Miller, 1990) with Mallows' C_p statistic as the stopping criterion was used to determine 27 MMIs with 2 to 10 metrics that characterize stream condition in relation to the SUII. The C_p statistic estimates the mean-squared-prediction error and weighs colinearity of factors so C_p does not continue to increase or decrease with the addition of variables to the model as do other common statistics used for model evaluation such as the standard error, coefficient of determination (R^2), or the predicted residual sum of squares (PRESS). Thus, the C_p statistic provides a criterion to prevent over fitting of the model (Mallows, 1973). Sample and site scores for the SUII and MMIs were calculated from proportionally scaled values ranging from 0 to 100 to equalize metric weight when calculating MMIs (Kreis, 1988).

Multidimensional scaling (MDS) of richness, relative abundance, tolerance, and trophic level data using PRIMER statistical program software (Clarke, 1993; Clarke and Gorley, 2006) was used to evaluate sample and macroinvertebrate community similarities. On graphs showing MDS results, similar data points are located near each other and those that are more dissimilar are located farther apart. Macroinvertebrate taxa relative abundances were calculated by dividing

Table 3. Macroinvertebrate metric abbreviations, definitions, and Spearman's correlation coefficients with the simple urban intensity index (SUII).

[Moderately correlated (|ρ| greater than or equal to 0.45) values in **bold**; *, highly correlated (|ρ| greater than or equal to 0.65) values; ≤, less than or equal to; ≥, greater than or equal to]

Metric	Definition	Correlation coefficient
RICH	Total taxa richness	**-0.61**
EPTR	EPT (Ephemeroptera, Plecoptera, Trichoptera) richness	**-0.63**
EPT/CHR	Ratio of EPT to Chironomidae taxa richness	**-0.59**
EPHEMR	Ephemeroptera richness	**-0.61**
PLECOR	Plecoptera richness	**-0.63**
TRICHR	Trichoptera richness	-0.23
ODONOR	Odonata richness	-0.14
COLEOPR	Coleoptera richness	**-0.61**
DIPR	Diptera richness	-0.34
CHR	Chironomidae richness	-0.28
ORTHOR	Orthocladinae richness	**-0.48**
ORTHO/CHR	Ratio of Orthocladinae to Chironomidae taxa richness	**-0.47**
TANYR	Tanytarsini richness	-0.06
TANY/CHR	Ratio of Tantarsini to Chironomidae taxa richness	0.02
NCHDIPR	Non-Chironomidae diptera richness	-0.40
NONINSR	Non-insect richness	-0.03
ODIPNIR	Other diptera plus non-insect richness	-0.22
MOLCRUR	Mollusca plus Crustacea richness	-0.28
AMPHIR	Amphipoda richness	-0.35
ISOPR	Isopoda richness	0.19
OLIGOR	Oligochaeta richness	0.23
EPTRp	Percent EPT richness	**-0.57**
EPEMRp	Percent Ephemeroptera richness	**-0.65***
PLECORp	Percent Plecoptera richness	**-0.63**
TRICHRp	Percent Trichoptera richness	0.02
NONINSRp	Percent non-insect richness	**0.48**
ODIPNIRp	Percent other diptera plus non-insect richness	0.41
OLIGORp	Percent Oligochaeta richness	**0.57**
PLECO	Plecoptera abundance	**-0.62**
COLEOP	Coleoptera abundance	-0.34
EPTp	Percent EPT abundance	-0.44
EPEMp	Percent Ephemeroptera abundace	**-0.53**
PLECOp	Percent Plecoptera abundance	**-0.62**
EPp	Percent Ephemeroptera plus Plecoptera abundance	**-0.63**
TRICHp	Percent Trichoptera abundance	-0.17
COLEOPp	Percent Coleoptera abundance	-0.29
DIPp	Percent Diptera abundance	-0.18
CHp	Percent Chironomidae abundance	-0.18
TANYp	Percent Tanytarsini abundance	0.11
ODIPNIp	Percent other diptera plus non-insect abundance	0.39
CORBICp	Percent Corbicula abundance	-0.24

Table 3. Macroinvertebrate metric abbreviations, definitions, and Spearman's correlation coefficients with the simple urban intensity index (SUII).—Continued

[Moderately correlated (|ρ| greater than 0.45) values in **bold**; *, highly correlated (|ρ| greater than 0.65) values; ≤, less than or equal to; ≥, greater than or equal to]

Metric	Definition	Correlation coefficient
OLIGOp	Percent Oligochaeta abundance	0.27
RICHTOL	Average of taxa tolerance	**0.55**
INTOLR	Intolerant taxa richness (tolerance value ≤ 4.0)	**-0.62**
MBI (ABUNDTOL)	Abundance-weighted average taxa tolerance	0.24
INTOLp	Percent intolerant taxa abundance (tolerance value ≤ 4.0)	-0.25
TOLp	Percent tolerant taxa abundance(tolerance value ≥ 7.0))	0.31
FCR	Filtering-collector richness	-0.16
SCR	Scraper richness	**-0.57**
PRp	Percent predator abundance	0.34
OMp	Percent omnivore abundance	-0.35
GCp	Percent Gqatherer-collector abundance	0.06
FCp	Percent filtering collector abundance	0.08
SCp	Percent scraper abundance	-0.37
SHp	Percent shredder abundance	**-0.45**
SC.FCp	Ratio of scraper to filtering-collector abundance	-0.44
SHANDIV	Shannon diversity index	-0.23
DOM1	Percent most abundant taxa	-0.00
DOM2	Percent two most abundant taxa	0.03
DOM5	Percent five most abundant taxa	0.20

taxa abundance by total sample abundance. The abundance data were square-root transformed with Bray-Curtis resemblance matrix calculations (Bray and Curtis, 1957; Clarke and Warwick, 2001). Two-dimensional MDS plots of macroinvertebrate taxa and tolerance metrics, functional feeding groups, water quality, and physical characteristics of the basin were created to visually analyze data similarities and dissimilarities.

Analysis of similarities (ANOSIM) in PRIMER statistical program software was used to determine dissimilarities among basin categories based on species relative abundances using the Bray-Curtis measure of similarity. ANOSIM is a multivariate analysis that calculates differences between groups of community samples using randomization methods on a resemblance matrix (Clarke, 1993; Clarke and Gorley, 2006). Results are presented as the R statistic (Clarke, 1993), based on the difference of mean ranks between groups and within groups, and significance levels (p-values). R values are scaled from -1 to 1. Pair-wise analyses were statistically significant if p was less than or equal to 0.05. BEST analysis was performed to determine the top 10 species driving the community pattern among categories. BEST is a procedure in PRIMER, which examines the value of the selection criteria for all possible combinations of predictor variables (Clarke and Gorley, 2006).

MDS plots of spring sample macroinvertebrate community structure based on richness, relative abundance, tolerance, and functional feeding groups were visually analyzed and compared to basin categories, the SUII of sites, and environmental variables. Basin categories were visually delineated with different colored ellipses to assist in interpretation of the plots. Samples that were not included within the ellipses were dissimilar from other samples in their basin category and were not as similar as other samples included within the ellipses. Samples that are shown further apart have higher dissimilarity than samples that are close together.

Assessment of Macroinvertebrate Communities

A total of 165 macroinvertebrate taxa were identified in samples collected during spring (March 2007 through March 2011) and fall (September 2008 through October 2010) at 18 study sites. Of these taxa, 79 were at the Blue River Basin sites, 134 were at the Little Blue River and Rock Creek Basin sites, and 95 were at the rural comparison sites. Fall samples were not collected at the Blue River Basin sites. Ten taxa were unique to Blue River Basin sites, 43 to the Little Blue River and Rock Creek Basin sites, and 21 to the rural sites. Eight taxa were common to all sites, and 51 taxa were unique to an individual site (table 4, in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*). Counts generally were small for taxa unique to basins or sites. A taxa summary list is presented in table 5 (in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*).

Pair-wise comparison of sites indicated significant differences (Kruskal-Wallis rank test; *p* less than or equal to 0.10; table 6) for SCI metrics between the upstream Blue River and Blue River tributaries categories. Middle and downstream Blue River categories also were significantly different than the middle and downstream Little Blue River sites. The Blue River tributaries category, with higher SUII scores (table 1), receives effluent from two WWTPs and was significantly different from all other categories except the middle and downstream Blue River categories located downstream from the tributaries confluence with the Blue River (fig. 1). The rural category was significantly different from the middle, downstream, and tributary Blue River categories.

The upstream Blue River category is the only Blue River category that was not significantly different from the rural category based on the 4-metric index and its component metrics. This likely is because of lower effects from WWTP effluent on stream health. The WWTP located upstream from site 1 in Kansas that discharges directly to the Blue River (fig. 1) underwent upgrades prior to this study including biological nutrient removal resulting in lower total nitrogen concentrations in the Blue River downstream from the plant (Graham and others, 2010). The upstream Blue River site is located above the confluence of the Blue River and Indian Creek with two other WWTPs (fig. 1). Significant differences among the Blue River categories (excluding the upstream category) and the rural category indicate that urban-intensity effects, including those from WWTP effluent, on macroinvertebrate communities are not as apparent at the upstream Blue River site. This indicates that the upstream Blue River macroinvertebrate community is more similar to the Little Blue River and rural comparison site communities than the macroinvertebrate communities for other Blue River categories. There were no significant differences among the Little Blue River, the upstream Blue River, Rock Creek, and rural sites.

Macroinvertebrate Community Structure

Degraded stream health has been related to low biodiversity of macroinvertebrate communities. Macroinvertebrate community composition generally is less tolerant upstream with a more tolerant community composition downstream (Barbour and others, 1996; Klein, 1979; Paul and Meyers, 2001; Walsh and others, 2005). As more tributaries enter a river, the potential exists downstream for the release of more toxins and pollutants into the river from point and nonpoint sources. As upstream basin size increases, the area from which nonpoint source pollutants can enter the river also increases. This often leads to a community structure dominated by tolerant taxa including Chironomidae (nonbiting midges; Paul and Meyers, 2001; Seager and Abrahams, 1990; Wright and others 1995) and Oligochaeta (aquatic worms). Chironomidae taxa relative abundances indicated low variability among basins. All three basin categories had about 40 percent chironomid relative abundances for spring samples (table 7). However, the Blue River Basin had a relative abundance of Oligochaeta taxa (about19 percent) more than two or three times higher than the percentage identified for the Little Blue River Basin (5 percent) and the rural comparison sites (about 9 percent; table 7). These data indicate the effect of differences in habitat among sites, lower urban-intensity effects at Little Blue River sites, or a combination of both factors.

A total of 142 taxa and about 20,500 individuals in 54 samples were identified from samples collected during the spring season (table 7). The Blue River Basin and the rural comparison sites had similar total taxa richness (79 and 77 taxa). The Little Blue River Basin sites had the greatest total taxa richness (107 taxa). The majority (116 taxa) of identified taxa were insects (class Insecta). The lowest insect

Table 6. Stream categories with significant differences (Kruskal-Wallis rank test, *p* less than or equal to 0.10) in 4-metric index or individual component metric (total taxa richness, Ephemeroptera-Plecoptera-Trichoptera taxa richness, Macroinvertebrate Biotic Index, and Shannon Diversity Index) scores.

[X, significant difference (*p* less than or equal to 0.10)]

Stream category (table 1)	BBU	BBM	BBD	BBT	LBM	LBD	LBT	RCK	RUR
Blue River—upstream (BBU)									
Blue River—middle (BBM)									
Blue River—downstream (BBD)									
Blue River—tributaries (BBT)	X								
LittleBlue River—middle (LBM)		X	X	X					
Little Blue River—downstream (LBD)		X	X	X					
Little Blue River—tributaries (LBT)				X					
Rock Creek (RCK)				X					
Rural streams (RUR)		X	X	X					

Table 7. Taxa richness, total abundance, and relative abundance summary of spring data for the Blue River Basin, Rock Creek and Little Blue River Basins, and rural comparison sites for sites sampled March 2007 through March 2011.

[Tolerances for taxa were assigned from the Missouri taxa listings (Sarver, 2005), or if unavailable assigned established regional values (Cuffney and Brightbill, 2011); EPT, Ephemeroptera plus Plecoptera plus Trichoptera]

	Blue River Basin	Rock Creek and Little Blue River Basin	Rural basins	Total
Number of samples	24	23	7	54
Total Taxa				
Richness	79	107	77	142
Total abundance	7,734	9,875	2,855	20,500
Relative abundance[1]	37.7	48.2	13.9	100
Oligochaeta Taxa				
Richness	4	3	3	4
Total abundance	1,486	491	266	2,243
Relative abundance[1]	19.2	5.0	9.3	10.9
Insecta Taxa				
Richness	60	88	61	116
Total abundance	4,690	8,530	2,346	15,566
Relative abundance[1]	60.6	86.4	82.2	75.9
EPT Taxa				
Richness	15	22	19	30
Total abundance	621	2,691	791	4,103
Relative abundance[1]	8.0	27.3	27.7	20.0
Chironomidae Taxa				
Richness	29	43	28	51
Total abundance	2,841	4,213	1,246	8,300
Relative abundance[1]	36.7	42.7	43.6	40.5
Intolerant Taxa[2]				
Richness	8	18	13	27
Total abundance	507	487	215	1,209
Relative abundance[1]	6.6	4.9	7.5	5.9
Highly Intolerant Taxa[3]				
Richness	3	1	3	6
Total abundance	9	1	54	64
Relative abundance[1]	0.1	0.001	1.9	0.31

[1]Relative abundance equals abundance divided by total taxa abundance times 100.

[2]Tolerance value less than or equal to 4.0.

[3]Tolerance value less than or equal to 2.0.

relative abundance was at the Blue River Basin sites (about 61 percent). The Little Blue River Basin sites and the rural basin sites had over 80 percent insect abundance (table 7). Larger percent insect abundance indicates better water-quality conditions.

High taxa richness and abundance of intolerant taxa can indicate low urban intensity and healthier streams (Barbour and others, 1999; Kerans and Karr, 1994; Lenat and Crawford, 1994; Roy and others, 2003). The Blue River Basin sites had the lowest richness of intolerant taxa (8 taxa) and the Little Blue River sites had the highest intolerant taxa richness (18 taxa; table 7). The rural comparison sites had the highest intolerant taxa relative abundance (about 8 percent). Although the Little Blue River sites had higher intolerant taxa richness, it also had lower relative abundance of intolerant taxa (about 5 percent) than the Blue River Basin (about 7 percent) and rural comparison sites (about 8 percent). This indicates that there are likely additional factors affecting the ability of these streams to support an intolerant community than the urban-intensity factors considered for this study.

The rural comparison sites had the highest percentage of highly intolerant taxa (about 2 percent; table 7). Both the Blue River and Little Blue River basin sites had low abundances of highly intolerant taxa (less than 0.2 percent). Macroinvertebrate tolerance values and functional feeding group classifications are presented in table 8 (in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*).

The insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively referred to as EPT taxa, have been described as containing pollution intolerant taxa (Barbour and others, 1992, 1996; Carlisle and Clements, 1999; Kerans and Karr, 1994; Lydy and others, 2000; Paul and Meyers, 2001). High abundances of these orders may be an indicator of healthy stream conditions (Barbour and others, 1999; Karr, 1999; Kenney and others, 2009; Paul and Meyers, 2001). The Blue River Basin had the lowest relative abundance of EPT taxa (8 percent; table 7). The Little Blue River Basin sites (about 27 percent) were more similar to the rural comparison sites (about 28 percent) than the Blue River Basin sites with more than one-fourth of the identified taxa at the Little Blue River Basin sites and rural comparison sites being EPT taxa (table 7).

Ephemeroptera were the most abundant EPT order in spring samples although the average tolerance values for the 10 mayfly taxa identified in spring samples was 5.5, in the moderately tolerant range. The upstream Blue River site (site 1) had lower abundances for most mayfly taxa with a lower urban intensity (SUII 27.1) than the middle Little Blue River sites (SUII 29.8 and 37.0; sites 9 and 12, table 1). Urban intensity, as measured with the SUII, increased downstream for the Blue River and the Little Blue River. The Blue River increase was greater (table 1). Ephemeroptera richness and abundance decreased in the downstream direction in the Blue River (figs. 3*A*, *B*). In contrast, mayfly taxa richness and abundance remained similar for most years in the middle and downstream Little Blue River sites (figs. 3*C*, *D*).

Plecoptera are intolerant to degraded stream conditions (DeWalt and others, 2005; Kenney, 2009). Plecoptera taxa are poorly represented in urban streams likely because of their sensitivity to pollution (Paul and Meyer, 2001). The Blue River Basin and the Little Blue River Basin had one taxa of stonefly, *Allocapnia* sp. This taxon had only a few individuals identified in samples (less than 0.20 percent abundance). The tolerance value of 2.8 for *Allocapnia* sp. (table 8) is within the intolerant range and may represent a pollution-tolerance

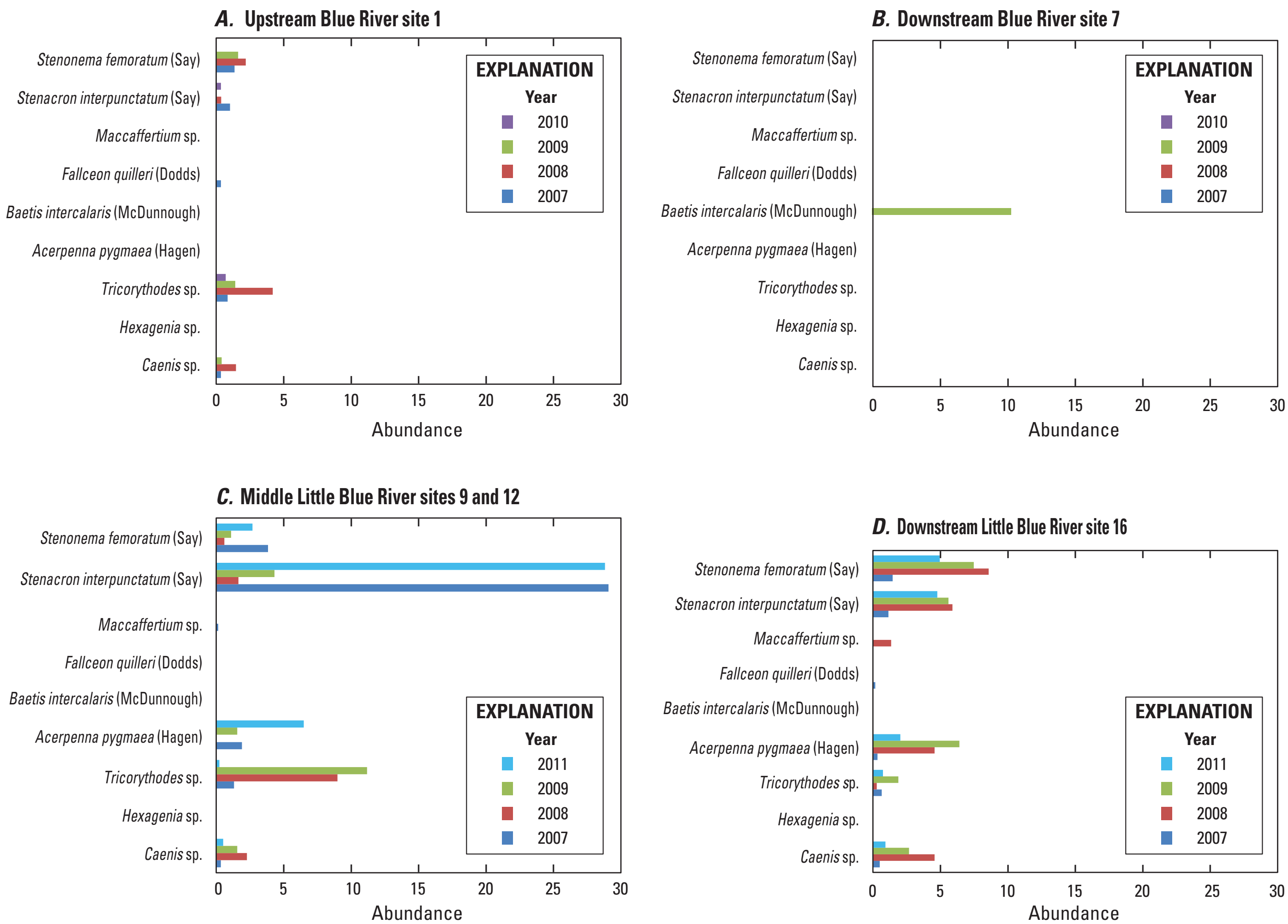

Figure 3. Ephemeroptera taxa abundances by site and year at upstream and downstream Blue River (*A* and *B*) and middle and downstream Little Blue River (*C* and *D*) sites.

threshold for stonefly taxa in area streams. Kansas City metropolitan urban streams may lack conditions that allow these highly intolerant taxa to establish. The rural comparison sites had a stonefly taxa richness of five taxa (*Allocapnia* sp., *Zealeuctra* sp., *Perlesta* sp., *Isoperla* sp., *and Hydroperla* sp.), comprising about 6 percent total richness, with tolerance values ranging from 0.0 to 2.8 (table 8).

Figure 4 is a MDS plot showing percent taxa abundance and similarities and dissimilarities among basin categories. A green line surrounds samples from the Blue River tributaries (table 1; sites 2 and 6). A shaded green ellipse includes the Blue River main-stem samples (table 1; sites 1, 3–5, and 7), except one sample from site 1. The Little Blue River main-stem samples (table 1; sites 9, 12, and 16) are included within a blue shaded ellipse. The Little Blue River tributary samples (table 1; sites 10, 11, and 13–15) are surrounded by a blue line, with the exception of one sample from site 14. The blue shaded ellipse is relatively small showing less variation in sample percent taxa abundance among the Little Blue River main-stem samples than other stream categories. However, there are fewer Little Blue River main-stem samples than Blue River main-stem samples and the sample sites are closer to each other (fig. 1). A red elongated ellipse shows the rural comparison site samples (table 1; sites 17 and 18), with the exception of one rural comparison sample. Generally, there were clear groupings of samples within basin categories showing less dissimilarity of percent taxa abundance within basin categories than among samples from different basin categories. Overlapping categories were mostly Blue River upstream site 1, main-stem Little Blue River, and rural comparison site 18 samples. Blue River tributary samples were dissimilar from the Blue River main-stem samples and did not overlap with Little Blue River samples or rural comparison samples. ANOSIM results indicated that basin category was the most significant indicator for dissimilarities in percent taxa abundance (R equals 0.55; fig. 4). Pair-wise analyses were statistically significant if the *p*-value (*p*) is less than or equal to 0.05. Pair-wise ANOSIM analysis indicated a significant difference among all basin categories.

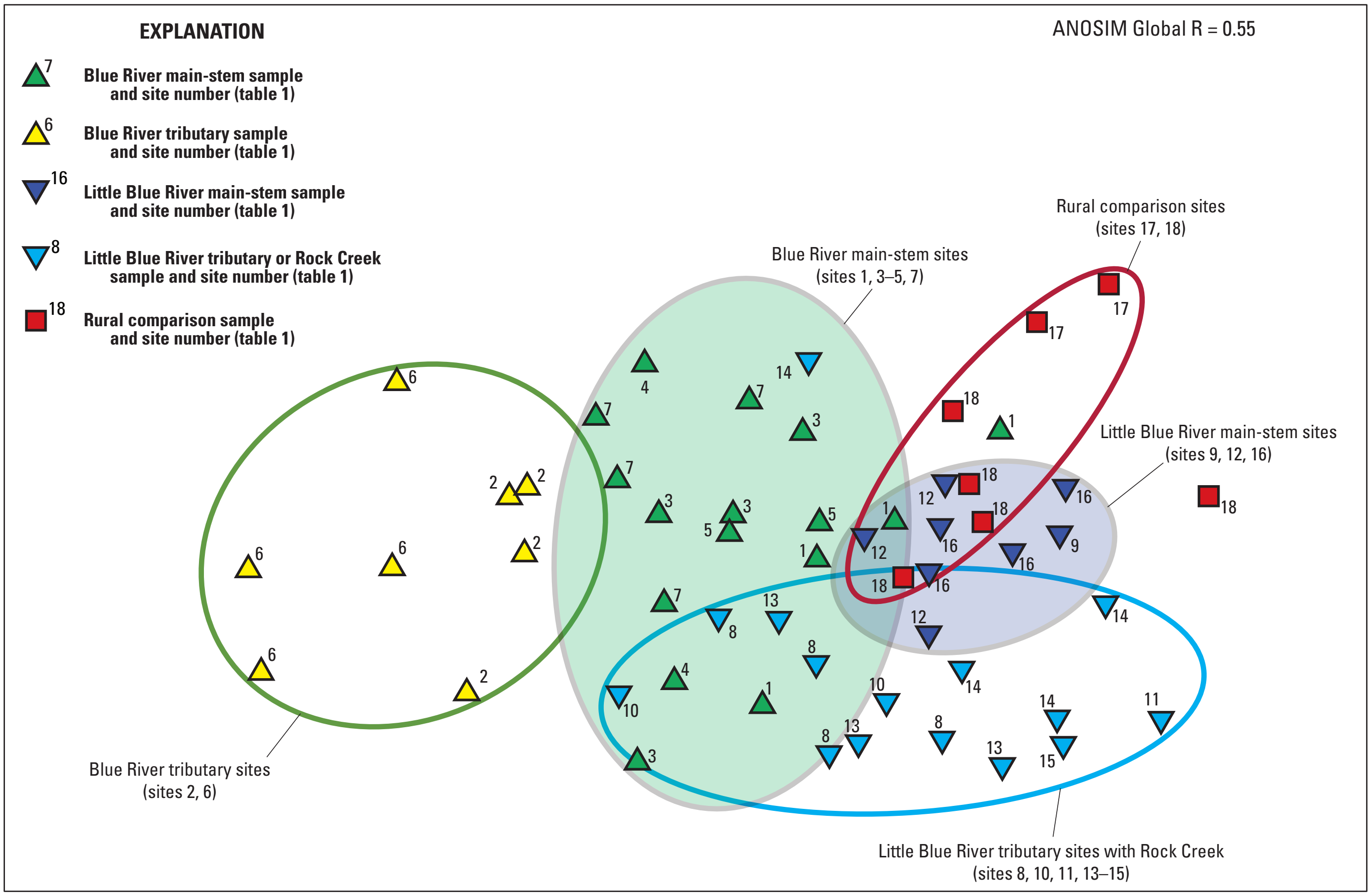

Figure 4. Multidimensional scaling plot of percent taxa abundance as grouped by basin category. [The analysis of similiarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

BEST analysis was performed in PRIMER (Clarke, 1993; Clarke and Gorley, 2006) to determine the taxa from all identified taxa “best explaining” dissimilarities among basins based on percent taxa abundance. Six of the 10 macroinvertebrate taxa that had the largest effect on dissimilarities in percent taxa abundance were in the family Chironomidae (table 9). Chironomidae are common in urban streams, lakes, and ponds. Some larval chironomids are commonly called bloodworms because of their red coloring. Bloodworms generally live in bottom sediments and feed on suspended organic material in water and sediments. Many taxa are pollution tolerant (table 8) and can tolerate nutrient-rich low-oxygen environments (Armitage and others, 1995). The remaining four taxa that had the most dissimilarity effect on percent taxa abundance consisted of one mayfly (*Caenis* sp.), one caddisfly (*Cheumatopsyche* sp.), and two noninsect taxa (table 9). The two non-insect taxa were *Corbicula* sp., an invasive Asiatic clam, and a freshwater leech (family Erpobdellidae). All “best-explaining” taxa had moderate or tolerant pollution-tolerance values with the exception of one midge taxa (*Eukiefferella* sp., tolerance value equals 4.0). Six functional feeding groups are represented in the “best-explaining” taxa; two filterer-collectors (*Corbicula* sp. and *Cheumatopsyche* sp.), one predator (Erpobdellidae), two collector-gatherers (*Caenis* sp. and *Eukiefferiella* sp.), three shredders (*Dicrotendipes* sp., *Cricotopus/Orthocladius* sp., and *Cricotopus* sp.), one omnivore (*Cricotopus bicinctus* group), and one scraper (*Hydrobaenus* sp.). The most abundant taxon identified at all sites was *Cricotopus/Orthocladius* sp. (table 10, in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*). This taxon has been described as tolerant (Coffman and Ferrington, 1996), but the tolerance value used in this study (6.5) was within the moderately tolerant class.

Figure 5 shows dissimilarities in macroinvertebrate community structure (percent taxa abundance) with quartiles of the SUII. The first quartile represents sites and samples with lower values of the SUII, and the fourth quartile represents sites and samples with higher values. Ellipses created based on basin category (from fig. 4) were retained in this plot to allow visual relation of basin categories and SUII scores. Samples within basin categories with similar macroinvertebrate communities based on percent taxa abundance mostly had similar SUII scores. Rural comparison sites 17 and 18 that were selected for their low urban intensity (table 1) were in the first quartile of the SUII, Little Blue River main-stem samples were all in the second quartile of the SUII, and the Blue River tributary samples were all in the fourth quartile of the SUII. The Blue River

Table 9. Ten macroinvertbrate taxa having highest effect on community structure with taxa tolerance classes.

[sp., species]

Class	Order	Family	Taxa identification (table 5)	Tolerance (table 8)	Tolerance class[1]	Blue River Basin[2] (percent)	Little Blue River Basin[2] (percent)	Rural basins[2] (percent)
Bivalvia	Basommatophora	Corbiculidae	*Corbicula* sp.	6.3	Moderate	79.2	51.2	50.0
Hirudnea	Arhynchobdellae	Erpobdellidae	Erpobdellidae	7.8	Tolerant	100.0	80.5	100.0
Insecta	Ephemeroptera	Caenidae	*Caenis* sp.	7.6	Tolerant	16.7	53.7	75.0
Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	6.6	Moderate	87.5	97.6	91.7
Insecta	Diptera	Chironomidae	*Dicrotendipes* sp.	7.9	Tolerant	100.0	48.8	25.0
Insecta	Diptera	Chironomidae	*Cricotopus/Orthocladius* sp.	6.5	Moderate	75.0	73.2	58.3
Insecta	Diptera	Chironomidae	*Cricotopus* sp.	6.5	Moderate	0.0	26.8	33.3
Insecta	Diptera	Chironomidae	*Cricotopus bicinctus* group	8.7	Tolerant	91.7	34.1	0.0
Insecta	Diptera	Chironomidae	*Eukiefferiella* sp.	4.0	Intolerant	54.2	26.8	58.3
Insecta	Diptera	Chironomidae	*Hydrobaenus* sp.	9.6	Tolerant	33.3	48.8	58.3

[1]Moderate, greater than 4.0 and less than 7.0; Tolerant, greater than or equal to 7.0; Intolerant, less than or equal to 4.0.

[2]Percentage of samples within a basin category with taxon identified.

main-stem samples were in the second or third quartile of the SUII, and the Little Blue River tributary samples were mostly in the second or third quartile of the SUII, with one sample (site 15) in the first quartile. The only samples in the fourth quartile of the SUII that overlap with other basin categories were samples from Rock Creek (site 8, included with Little Blue River tributary samples). These samples plot among samples in the second and third quartile of the SUII, indicating that the community structure of these samples are less dissimilar from samples within the second and third quartile than with other samples in the fourth quartile. These samples were also the only samples in the fourth quartile of the SUII that are not Blue River tributary samples.

MDS plots of community structure (percent taxa abundance) and quartiles of sample specific conductance (fig. 6) and base-flow chloride concentration (fig. 7; table 2) showed similar results as the SUII plots. Samples within basin categories (from fig. 4) with similar macroinvertebrate communities based on percent taxa abundance mostly had similar specific conductance and chloride concentrations. By visually comparing specific conductance and chloride concentration quartiles with ellipses drawn to represent basin categories, most samples in the first and second quartile of specific conductance and chloride concentration were samples that are in the rural comparison or Little Blue River main-stem category. Blue River main-stem samples and Little Blue River tributary samples included samples from all quartiles, and Blue River tributary samples were all in the fourth quartile. Pair-wise ANOSIM results of specific conductance and chloride concentration indicated there was no significant difference between the first and second quartile category (p equals 0.12 and p equals 0.10) and second and third quartile category (p equals 0.56 and p equals 0.30). Significant differences between the fourth quartile category of specific conductance and chloride concentration and all other quartiles and between the first and third quartile of specific conductance were determined.

When sample percent taxa abundances were compared with quartiles of selected nutrient parameters (total nitrogen, nitrite plus nitrate, and total phosphorus concentrations), similar groupings were apparent. Rural comparison and Little Blue River main-stem sites generally had samples in the lower nutrient concentration quartiles and Blue River main-stem and Blue River tributary sites had samples in the higher nutrient concentration quartiles (fig. 8).

The MDS plot of the MBI grouped by basin category (fig. 9) showed greater overlap of basin categories than in the previously presented MDS plot of percent taxa abundance, indicating less dissimilarity of MBI values among samples from different basin categories than for percent taxa abundance. This also is indicated by results of ANOSIM (R equals 0.14, fig. 9). The Little Blue River tributary samples were scattered among samples from the Blue River and Little Blue River main-stem sites. The Blue River and the Little Blue River main-stem samples generally were separated with a few Blue River main-stem samples plotting among Little Blue River main-stem samples, including Blue River upstream

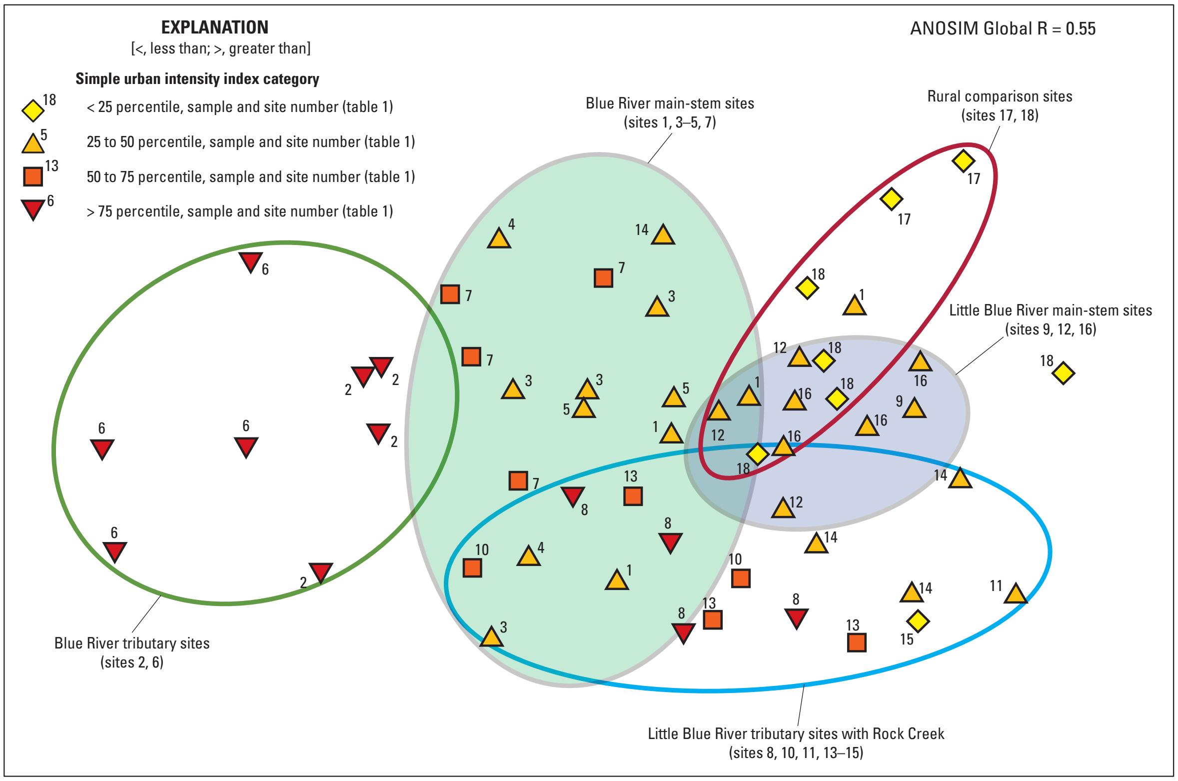

Figure 5. Multidimensional scaling plot of percent taxa abundance and quartiles of the simple urban intensity index. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups and is scaled from -1 to 1, where 0 indicates completely random grouping.]

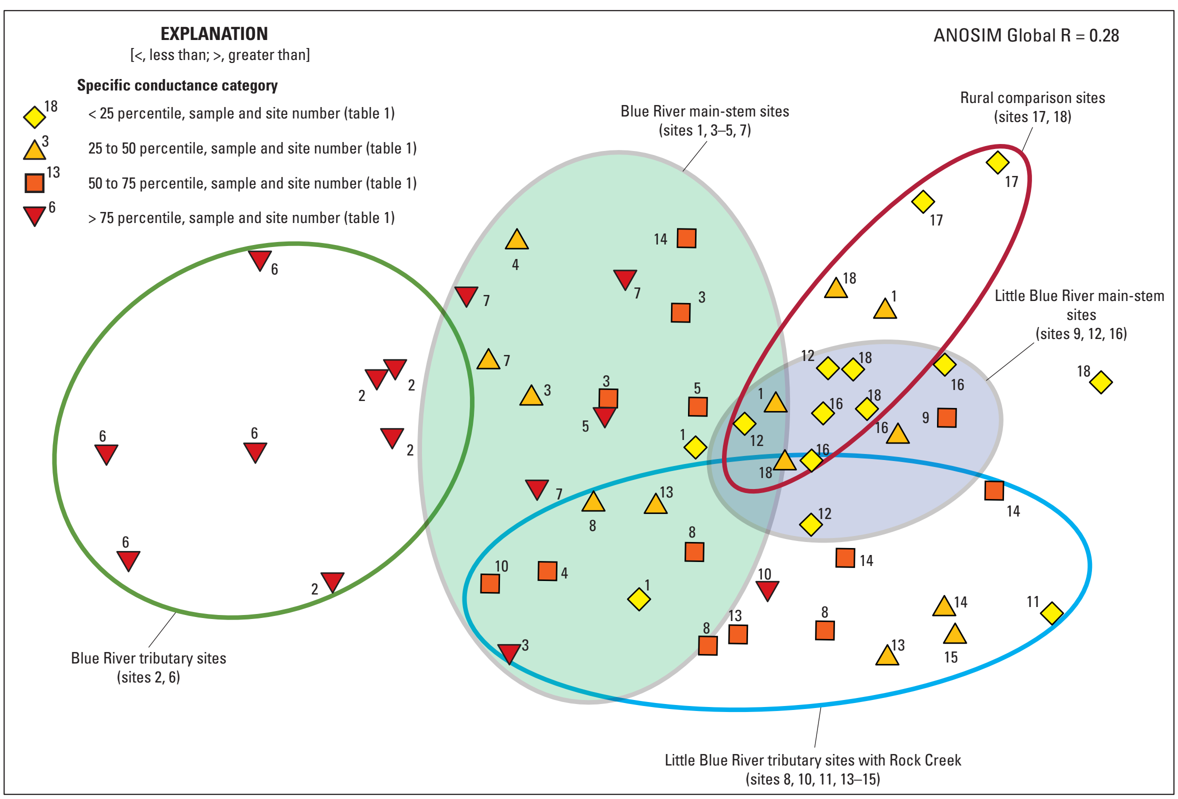

Figure 6. Multidimensional scaling plot of percent taxa abundance and quartiles of sample specific conductance. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

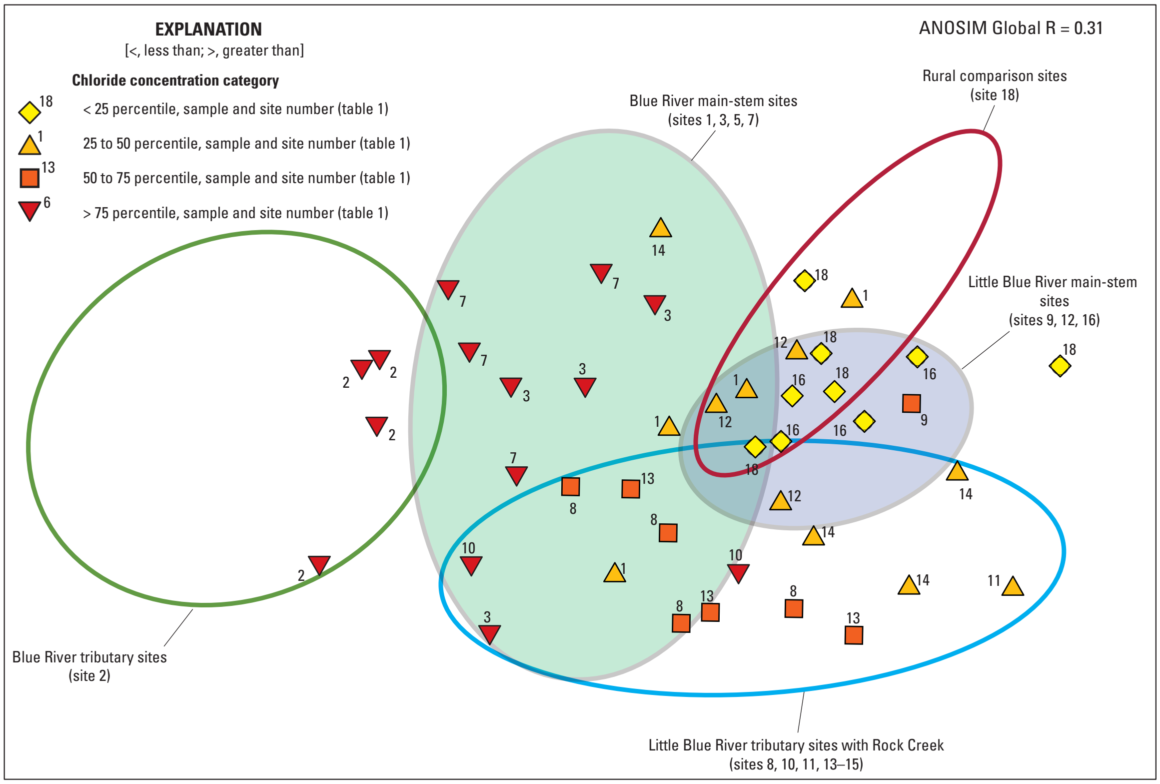

Figure 7. Multidimensional scaling plot of percent taxa abundance and quartiles of base-flow chloride concentration. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

samples and one sample from site 5. Two Blue River tributary samples one from site 2 and one from site 6 were not included in the green shaded ellipse encompassing the Blue River tributary samples, indicating dissimilarity to other samples from this category. Pair-wise ANOSIM analysis showed similar results. The Little Blue River tributary category was not statistically different than the Little Blue River main-stem category (*p* equals 0.55) or the main-stem Blue River category (*p* equals 0.52). Pair-wise statistical differences were determined between all other stream categories.

Plots of the MBI (plots not shown) with categories of nutrient parameters (total phosphorus, total nitrogen, and nitrite plus nitrate concentrations; table 2) showed similar groupings. Samples with nutrient concentrations in the higher quartiles generally were Blue River Basin samples, and most samples with nutrient concentrations in the lower quartiles generally were rural comparison site samples and Little Blue River Basin samples.

The MDS plot of functional feeding group categories showed separation of basin categories (fig. 10) as might be expected because basin categories were based on size and position (upstream, middle, downstream, and tributary), which can affect types and availability of food resources (Vannote and others, 1980). Ellipses show respective basin categories. Upstream Blue River samples (site 1) were not included in the green shaded ellipse containing the other Blue River samples and three Little Blue River tributary samples were not included within the ellipse for that basin category indicating dissimilarity. Blue River Basin samples generally were shown separate from Little Blue River Basin samples with the exception of upstream Blue River site 1 samples. ANOSIM results indicated dissimilarity among basin groups (R equals 0.44, fig. 10), and pair-wise analysis indicated significant difference among all basin categories.

Differences in functional feeding groups among stream categories could simply be attributed to differences in stream size. A transition from shredders, which utilize coarse particulate organic matter, to filterers, which utilize fine and ultra-fine particulate organic matter, should occur as stream order increases downstream (Vannote and others, 1980). However, this progression assumes relatively undisturbed conditions. For the urban streams included in this study, relations between functional feeding groups and stream order is not so clear. For example, functional feeding groups for third order stream sites

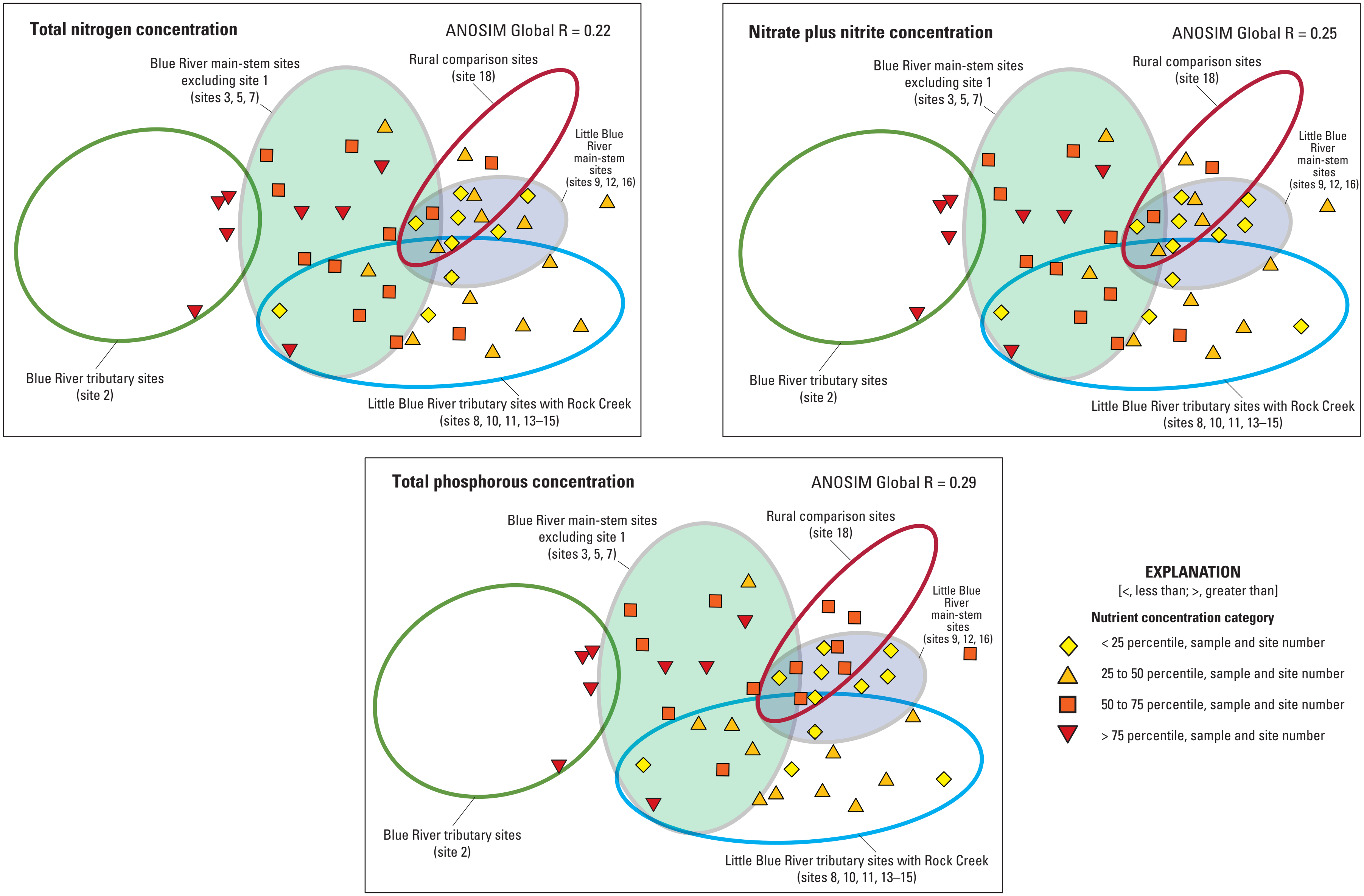

Figure 8. Multidimensional scaling plot of percent taxa abundance and quartiles of base-flow total nitrogen, nitrite plus nitrate, and total phosphorous concentration. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

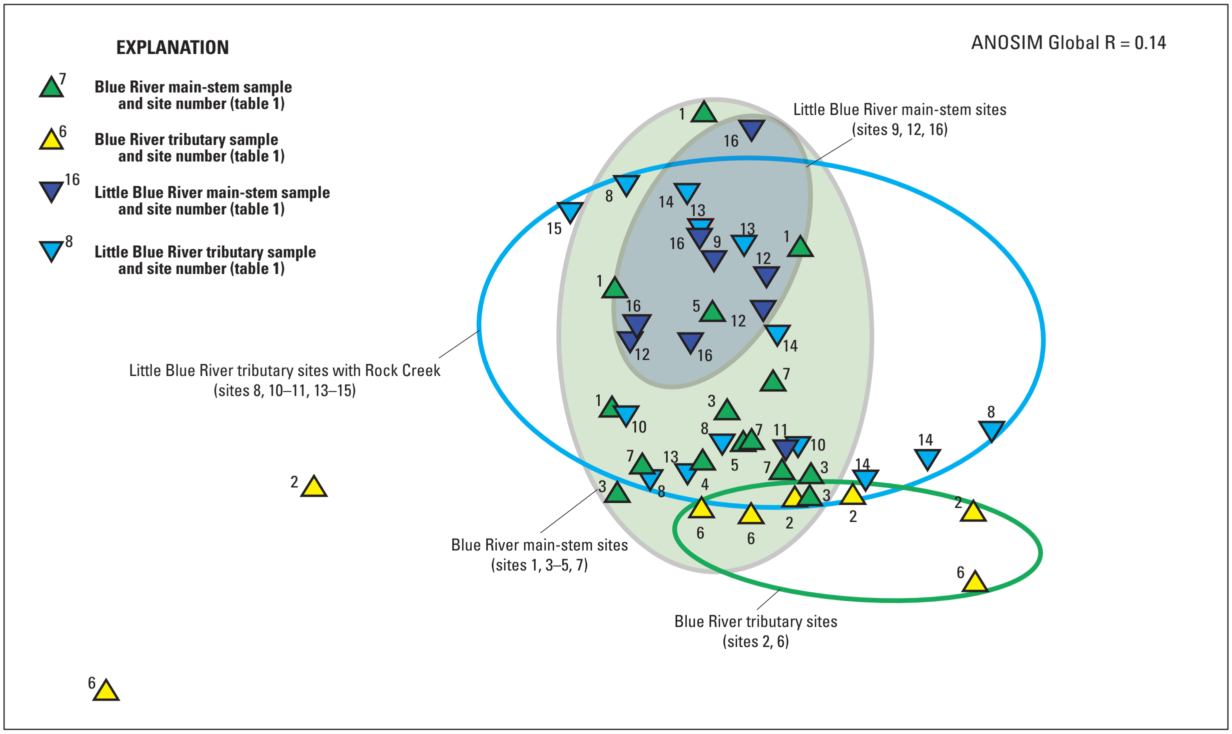

Figure 9. Multidimensional scaling plot of the Macroinvertebrate Biotic Index and basin category. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

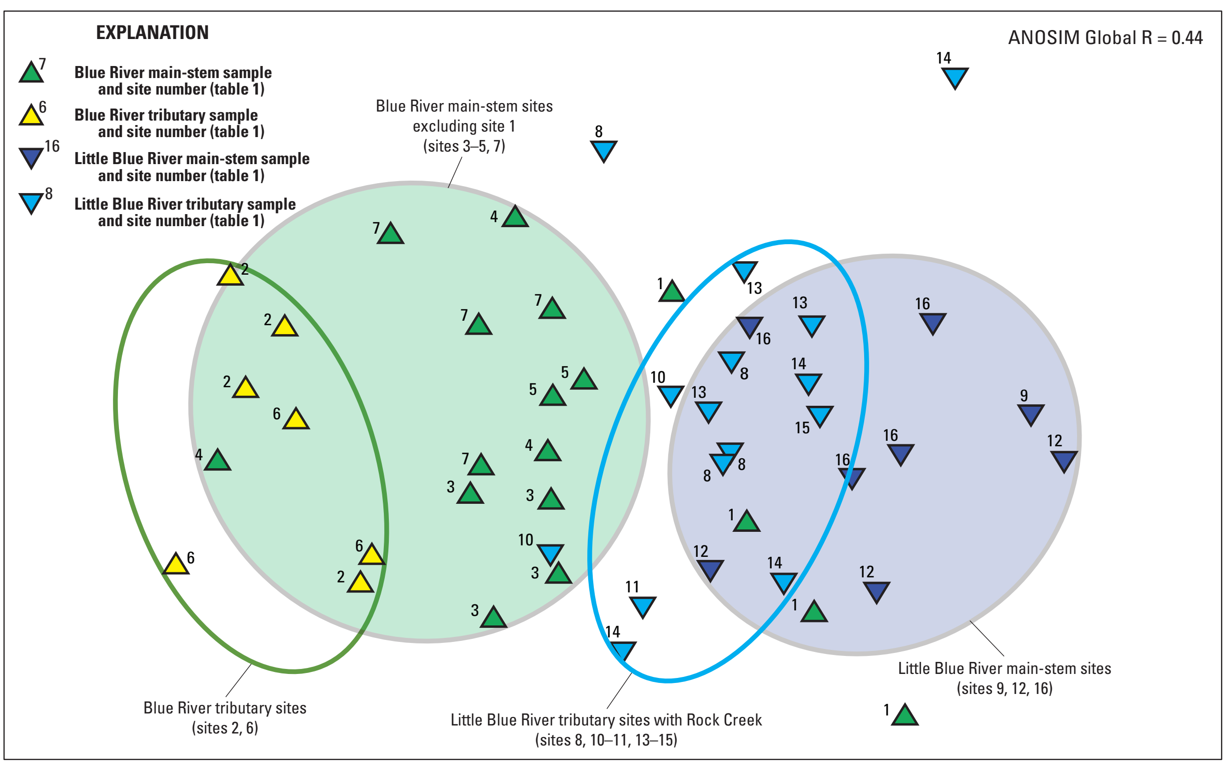

Figure 10. Multidimensional scaling plot of functional feeding group abundance and basin category. [The analysis of similarity (ANOSIM) Global R statistic is based on the difference of mean ranks between groups and within groups, and is scaled from -1 to 1, where 0 indicates completely random grouping.]

included in the Little Blue River tributary category (sites 10, 13–15, table 1) were not determined to be statistically different than the fourth and fifth order Little Blue River main-stem sites (sites 9, 12, and 16, table 1). Also, fourth order Blue River tributary sites (sites 2 and 6, table 1) had the lowest percent abundance of shredders included among dominant taxa for all sites (table 10), including the higher order Blue River main-stem sites (sites 1, 3–5, and 7, table 1; fifth order). This indicates that urban intensity, not just stream size, likely was affecting differences in functional feeding group abundances among stream categories. When functional feeding groups were compared with quartiles of selected nutrient parameters (total nitrogen, nitrite plus nitrate, and total phosphorus concentrations; table 2) similar groupings were observed (plots not shown), and higher nutrient concentrations generally were from Blue River Basin samples and samples in the first and second quartiles generally were Little Blue River Basin samples.

MDS plots based on taxa abundance, taxa tolerance, and functional feeding groups all showed similar results with Blue River tributary sites having high dissimilarity to other basin categories. ANOSIM results generally indicated high dissimilarity among basin categories compared to within basin sample dissimilarity. Pair-wise analysis indicated that the Blue River tributary sample category is statistically different than all other categories with respect to taxa abundance, taxa tolerance, and functional feeding groups. MDS plots show site 1 Blue River main-stem samples had higher dissimilarity than other samples within this category, based on sample plot location. Upstream Blue River site 1 is the only Blue River main-stem site that is above the confluence of Indian Creek, which receives effluent from two WWTPs. Basin categories that were not statistically different based on the MBI were the Little Blue River tributary category with the Blue River and Little Blue River main-stem categories (p equals 0.52 and p equals 0.55). All other basin categories were statistically different in taxa abundance, taxa tolerance, and functional feeding groups indicating dissimilarities of macroinvertebrate communities.

Community Metrics

Twenty-three metrics commonly used in local and national studies or selected from statistical analysis were used to calculate MMIs. Values for selected metrics from spring and fall samples and calculated MMIs are presented in table 11 (in the Excel spreadsheet at *http://pubs.usgs.gov/sir/2012/5284*). Numeric scores for individual metrics were assigned and then summed to calculate the SCI. If a site scored 100 to 80 percent of reference stream criteria, it was considered fully biologically supporting and scored 5 points; if a site scored 70 to 50 percent of reference stream criteria, it was considered partially biologically supporting and scored 3 points; and if a site scored 40 to 20 percent of reference stream criteria, it was classified as nonbiologically supporting and scored 1 point (Sarver and others, 2003a). ALS for sites and samples were determined by calculating SCIs (table 12). The ALS breakpoints for riffle habitat, based on the distribution of a metric's range of values for reference streams, are presented in table 13. Four metrics composing the SCI (total taxa richness, EPT taxa richness, Macroinvertebrate Biotic Index, and Shannon Diversity Index) and metric scores for samples are discussed below.

Total taxa richness (RICH), the total number of distinct taxa in a sample, ranged from 12 to 39 for spring samples at all sites and from 18 to 35 for fall samples from the Little Blue River Basin and rural comparison sites. Generally, RICH increases with improved water quality and habitat diversity (Barbour and others, 1999; Sarver, 2003a). Lower RICH values for spring samples were mostly for the middle, downstream, and Blue River tributary sites and higher values from the Little Blue River Basin and rural comparison sites. About 7 percent of spring RICH scores were fully biologically supporting, 74 percent were partially biologically supporting, and 19 percent were nonbiologically supporting (table 12). All nonbiologically supporting scores were for the middle, downstream, and Blue River tributary sites. All 23 fall samples scored at least partially biologically supporting.

Because EPT insect orders generally are considered to be pollution intolerant, EPT richness (EPTR) is expected to decrease with increasing urban intensity (Barbour and others, 1999; Sarver, 2003a). EPTR ranged from 0 to 12 for spring samples and from 3 to 12 for fall samples (table 11). Seven percent of EPTR scores for spring samples were fully biologically supporting, 43 percent were partially biologically supporting, and 50 percent were nonbiologically supporting of aquatic life. About 70 percent of nonbiologically supporting scores for EPTR were from the Blue River Basin and the majority of the remainder was from the Little Blue River tributaries. Seven samples for the Blue River Basin had one EPT taxon. Brush Creek site 6 had no EPT taxa in 3 of 4 years. For fall samples, about 22 percent scored fully biologically supporting, 69 percent partially biologically supporting, and 9 percent nonbiologically supporting for the Little Blue River Basin and rural comparison sites. Two of three samples for downstream Little Blue River site 16 and rural site 18 had fully biologically supporting fall scores.

The MBI is a measure of the overall pollution tolerance of a macroinvertebrate community expressed on a scale of 0 to 10 (Sarver, 2003a). Higher values represent higher tolerance to pollution and other environmental stresses and are expected to increase with urban intensity (Hilsenhoff, 1988; Sarver, 2003a). Tolerance values used for calculating the MBI and other tolerance metrics are presented in table 8. MBI values were all moderately tolerant to tolerant and ranged from 5.45 to 7.96 for spring samples and from 5.04 to 7.90 for fall samples (table 11). MBI values were variable among years at individual sites but generally were higher for the middle, downstream, and Blue River tributary sites. Brush Creek (site 6) had the lowest MBI score for spring samples of 5.45 in 2009, although in other years this site had MBIs of more than 7.0. The low MBI was the result of the high unique

Table 12. Macroinvertebrate metrics used in the Stream Condition Index, percent tolerance, percent dominant taxa, and aquatic-life status for samples, March 2007 through March 2011.

[RICH, total taxa richness; EPTR, Ephemeroptera-Plecoptera-Trichoptera taxa richness; MBI, Macroinvertebrate Biotic Index; SHANDIV, Shannon Diversity Index; SCI, Stream Condition Index; ALS, aquatic-life support status; PBS, partially biologically supporting; NBS, nonbiologically supporting; FBS, fully biologically supporting]

Site number (table 1, fig. 1)	Year	RICH	EPTR	MBI	SHANDIV (log *e*)	Percent tolerant taxa[1]	Percent intolerant taxa[2]	Percent dominant taxa[3]	RICH score	EPTR score	SHANDIV score	MBI score	SCI[4]	ALS rating[5]
Spring samples														
1	2007	32	8	5.68	2.06	39.3	10.7	81.3	3	3	3	3	12	PBS
	2008	33	6	6.33	2.20	45.2	9.7	79.1	3	3	3	3	12	PBS
	2009	32	6	5.75	2.52	40.7	11.1	69.9	3	3	5	3	14	PBS
	2010	31	6	6.09	2.50	38.5	11.5	67.0	3	3	5	3	14	PBS
2	2007	13	1	7.35	1.79	44.4	0.0	91.4	1	1	3	3	8	NBS
	2008	14	2	7.37	1.70	33.3	0.0	94.6	1	1	3	3	8	NBS
	2009	13	1	7.19	1.91	40.0	10.0	84.1	1	1	3	3	8	NBS
	2010	16	2	5.56	1.85	38.5	7.7	83.2	1	1	3	3	8	NBS
3	2007	21	4	7.18	2.37	52.9	5.9	75.3	3	1	5	3	12	PBS
	2008	16	3	6.76	2.03	46.2	15.4	83.6	1	1	3	3	8	NBS
	2009	23	3	6.89	2.08	47.4	10.5	74.3	3	1	3	3	10	PBS
	2010	19	1	6.46	2.43	33.3	26.7	69.0	3	1	5	3	12	PBS
4	2009	27	4	6.88	2.13	50.0	4.5	79.7	3	1	3	3	10	PBS
	2010	25	3	6.57	2.22	36.8	5.3	74.6	3	1	3	3	10	PBS
5	2007	21	3	7.12	2.36	55.6	5.6	71.4	3	1	5	3	12	PBS
	2008	21	5	6.10	2.09	47.1	5.9	79.8	3	3	3	3	12	PBS
6	2007	16	0	7.17	2.12	75.0	8.3	77.0	1	1	3	3	8	NBS
	2008	14	0	7.70	2.21	83.3	0.0	77.0	1	1	3	3	8	NBS
	2009	12	0	5.45	1.68	77.8	11.1	91.2	1	1	3	5	10	PBS
	2010	16	1	7.36	1.58	58.3	8.3	89.0	1	1	3	3	8	NBS
7	2007	17	1	7.96	1.89	57.1	0.0	84.0	1	1	3	1	6	NBS
	2008	19	1	7.35	2.12	56.3	6.3	77.3	3	1	3	3	10	PBS
	2009	24	3	5.99	2.26	57.9	0.0	73.8	3	1	3	3	10	PBS
	2010	22	1	6.71	2.44	47.1	11.8	68.6	3	1	5	3	12	PBS
8	2007	27	5	6.49	2.34	50.0	8.3	74.8	3	3	5	3	14	PBS
	2008	26	4	6.56	2.39	43.5	8.7	69.1	3	1	5	3	12	PBS
	2009	30	7	6.62	2.79	50.0	7.7	57.2	3	3	5	3	14	PBS
	2011	27	6	5.83	2.55	34.8	21.7	64.2	3	3	5	3	14	PBS

Table 12. Macroinvertebrate metrics used in the Stream Condition Index, percent tolerance, percent dominant taxa, and aquatic-life status for samples, March 2007 through March 2011.—Continued

[RICH, total taxa richness; EPTR, Ephemeroptera-Plecoptera-Trichoptera taxa richness; MBI, Macroinvertebrate Biotic Index; SHANDIV, Shannon Diversity Index; SCI, Stream Condition Index; ALS, aquatic-life support status; PBS, partially biologically supporting; NBS, nonbiologically supporting; FBS, fully biologically supporting]

Site number (table 1, fig. 1)	Year	RICH	EPTR	MBI	SHANDIV (log *e*)	Percent tolerant taxa[1]	Percent intolerant taxa[2]	Percent dominant taxa[3]	RICH score	EPTR score	SHANDIV score	MBI score	SCI[4]	ALS rating[5]
Spring samples—Continued														
9	2011	35	10	6.10	2.57	38.7	22.6	66.2	3	5	5	3	16	FBS
10	2009	31	5	6.92	2.72	65.4	3.8	60.5	3	3	5	3	14	PBS
	2011	28	2	5.98	2.48	56.0	8.0	68.2	3	1	5	3	12	PBS
11	2011	36	4	6.98	2.68	59.4	12.5	64.1	3	1	5	3	12	PBS
12	2007	32	5	6.31	2.33	50.0	7.1	71.4	3	3	5	3	14	PBS
	2008	35	7	6.30	2.41	51.5	6.1	67.2	3	3	5	3	14	PBS
	2009	39	7	6.30	2.63	37.1	8.6	65.2	5	3	5	3	16	FBS
13	2007	30	5	6.67	2.64	51.9	3.7	60.6	3	3	5	3	14	PBS
	2008	30	4	5.99	2.35	40.7	7.4	76.9	3	1	5	3	12	PBS
	2011	30	4	6.39	2.46	38.5	11.5	69.9	3	1	5	3	12	PBS
14	2007	26	4	7.30	2.35	69.6	4.3	72.8	3	1	5	3	12	PBS
	2008	28	4	6.85	2.30	50.0	3.8	74.9	3	1	5	3	12	PBS
	2009	32	7	6.20	2.70	48.1	14.8	60.2	3	3	5	3	14	PBS
	2011	27	5	5.90	2.38	50.0	12.5	74.5	3	3	5	3	14	PBS
15	2011	38	9	5.97	2.48	39.4	24.2	71.3	5	3	5	3	16	FBS
16	2007	34	10	6.19	2.16	40.0	16.7	78.7	3	5	3	3	14	PBS
	2008	32	9	5.89	2.55	48.3	17.2	63.8	3	3	5	3	14	PBS
	2009	29	9	5.80	2.68	37.5	20.8	60.6	3	3	5	3	14	PBS
	2011	34	8	5.80	2.24	43.3	16.7	72.9	3	3	3	3	12	PBS
17	2007	32	4	6.55	2.26	50.0	7.1	79.9	3	1	3	3	10	PBS
	2008	39	9	7.29	2.60	41.7	16.7	69.6	5	3	5	3	16	FBS
18	2007	33	8	6.25	2.21	34.5	20.7	71.8	3	3	3	3	12	PBS
	2008	25	8	6.43	2.07	37.5	20.8	76.6	3	3	3	3	12	PBS
	2009	38	12	5.88	2.96	31.4	25.7	50.0	5	5	5	3	18	FBS
	2010	28	11	6.76	2.66	34.6	26.9	61.9	3	5	5	3	16	FBS
	2011	30	8	6.28	2.60	38.5	11.5	70.4	3	3	5	3	14	PBS

Table 12. Macroinvertebrate metrics used in the Stream Condition Index, percent tolerance, percent dominant taxa, and aquatic-life status for samples, March 2007 through March 2011.—Continued

[RICH, total taxa richness; EPTR, Ephemeroptera-Plecoptera-Trichoptera taxa richness; MBI, Macroinvertebrate Biotic Index; SHANDIV, Shannon Diversity Index; SCI, Stream Condition Index; ALS, aquatic-life support status; PBS, partially biologically supporting; NBS, nonbiologically supporting; FBS, fully biologically supporting]

Site number (table 1, fig. 1)	Year	RICH	EPTR	MBI	SHANDIV (log *e*)	Percent tolerant taxa[1]	Percent intolerant taxa[2]	Percent dominant taxa[3]	RICH score	EPTR score	SHANDIV score	MBI score	SCI[4]	ALS rating[5]
							Fall samples							
8	2008	26	6	6.34	2.52	45.8	8.3	61.2	3	3	5	5	16	FBS
	2009	28	7	6.01	2.51	32.0	8.0	66.9	3	3	5	5	16	FBS
	2010	24	6	6.28	2.41	27.3	9.1	68.3	3	3	5	5	16	FBS
9	2010	31	10	5.75	1.80	33.3	10.0	72.0	3	5	5	5	18	FBS
10	2009	23	3	5.69	2.44	72.7	4.5	82.7	3	1	5	5	12	PBS
	2010	29	5	6.02	2.47	37.0	7.4	72.1	3	3	5	5	16	FBS
11	2010	28	6	7.64	2.20	52.0	8.0	68.8	3	3	3	3	14	PBS
12	2008	23	8	5.93	2.02	31.8	13.6	77.6	3	3	5	5	14	PBS
	2009	21	9	5.04	2.02	26.3	15.8	77.7	3	3	5	5	14	PBS
	2010	27	9	5.58	2.63	30.8	15.4	81.7	3	3	5	5	14	PBS
13	2008	25	5	6.56	2.44	52.2	0.0	62.7	3	3	3	5	14	PBS
14	2008	29	7	6.69	2.15	40.7	7.4	67.0	3	3	3	5	14	PBS
	2009	24	5	6.97	2.39	50.0	4.5	76.9	3	3	3	5	12	PBS
	2010	29	8	6.27	1.89	44.4	7.4	72.5	3	3	5	5	14	PBS
15	2010	22	6	6.68	1.72	40.0	15.0	89.5	3	3	3	5	12	PBS
16	2008	27	10	6.18	1.98	33.3	16.7	81.2	3	5	5	5	16	FBS
	2009	18	7	5.67	2.65	18.8	12.5	81.5	3	3	5	5	14	PBS
	2010	35	11	5.90	1.80	35.3	17.6	62.5	3	5	5	5	18	FBS
17	2008	15	4	7.90	2.13	67.6	7.5	82.0	3	1	3	3	10	PBS
	2009	24	5	6.76	2.19	18.7	3.9	79.6	3	3	3	5	12	PBS
18	2008	30	11	6.21	2.02	16.8	20.7	77.2	3	5	5	5	16	FBS
	2009	33	12	6.04	1.76	9.1	24.2	80.6	3	5	5	5	16	FBS
	2010	21	7	6.03	2.50	6.6	15.0	87.8	3	3	5	5	14	PBS

[1]Percent sample abundance with tolerance value greater than or equal to 7.

[2]Percent sample abundance with tolerance value less than or equal to 4.

[3]Percent total abundance consisting of the five most abundant taxa in a sample.

[4]SCI is RICH score plus EPTR score plus SHANDIV score plus MBI score.

[5]Samples with a SCI of 8 or lower have an aquatic-life support status (ALS) of NBS, 10 to 14, PBS, and 16 or higher, FBS.

Table 13. Criteria for aquatic-life support categories for riffle habitats for the Missouri tributaries between the Blue and Lamine ecological drainage unit.

[RICH, total taxa richness; EPTR, Ephemeroptera-Plecoptera-Trichoptera taxa richness; MBI, Macroinvertebrate Biotic Index; SHANDIV, Shannon Diversity Index; SCI, Stream Condition Index; FBS, fully biologically supporting; >, greater than; <, less than; PBS, partially biologically supporting; ≥, greater than or equal to; ≤, less than or equal to; NBS, nonbiologically supporting]

Riffle aquatic-life support category	RICH		EPTR		MBI		SHANDIV		SCI
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	
FBS	>36	>37	>9	>9	<5.5	<6.5	>2.27	>2.39	16–20
PBS	≥18–≤36	≥19–≤37	≥5–≤9	≥5–≤9	≥5.5–≤7.7	≥6.5–≤8.3	≥1.13–≤2.27	≥1.19–≤2.39	10–14
NBS	<18	<19	<5	<5	>7.7	>8.3	<1.13	<1.19	4–8

abundance of the Class Turbellaria (flatworms, tolerance value 4.0; table 10). A study to revise tolerance values based on response to measured multiple stressors increased the tolerance value for Turbellaria from 4.0 to 6.8 (Bressler and others, 2006). MBI scores for spring samples were about 2 percent fully biologically supporting, 96 percent partially biologically supporting, and 2 percent nonbiologically supporting. Fall samples indicated MBI scores that were about 91 percent fully biologically supporting and 9 percent nonbiologically supporting. The MBI showed the lowest variation in site scores and ability to identify differences among sites of the four metrics composing the SCI.

The Shannon Diversity Index (SHANDIV) takes into consideration both taxa richness and the evenness of the relative abundance of the taxa in the community. SHANDIV is expected to decrease with increasing urban intensity (Barbour and others, 1999; Sarver, 2003a). Spring scores ranged from 1.58 to 2.96 and fall scores from 1.72 to 2.65 (table 11). Based on SHANDIV, about 57 percent of spring samples were fully biologically supporting and 43 percent partially biologically supporting. About 91 percent of the SHANDIV scores for the Little Blue River Basin were fully biologically supporting compared to 25 percent for the Blue River Basin sites and about 57 percent for rural sites. Nonbiologically supporting sites were not identified so the full range of ALS was not determined. Fall SHANDIV scores for the Little Blue River and rural sites were about 70 percent fully biologically supporting and 30 percent partially biologically supporting.

Multimetric Indices

MMIs were modeled using ordinary least squares subset regression to characterize macroinvertebrate communities in relation to the SUII. MMIs were calculated with 2 to 10 component metrics (table 14). MMIs measured taxa richness, composition and abundance, pollution tolerance, and functional feeding groups (Karr and Kerans, 1992; Klemm and others, 2002). Measures of taxa richness likely provide the best indications of urbanization effects (Cuffney and others 2005, 2010). Fourteen metrics selected for inclusion in the MMIs were richness measures and two were abundance measures (table 14).

The calculated best 6-metric and best 10-metric MMIs were selected for further comparison to three other MMIs (table 15)—a four-metric index with components that are used to calculate the MSCI (Sarver, 2003a), a modified 10-metric index used in previous studies in Johnson County, Kans., and Kansas City, Mo. (Poulton and others, 2007; Rasmussen and others, 2009; Graham and others, 2010; Wilkison and others, 2009), and an 8-metric benthic index of biotic integrity (B–IBI) (Cuffney and others, 2005).

The best 6-metric and best 10-metric indices were selected based on the summary statistics for the regression (table 14). The best 6-metric index was selected based on the stopping criteria using Mallows' C_p. Because 10 dependent variables were the maximum considered, the best 10-metric index was selected based on the downward trend of the PRESS statistic (Allen, 1974), standard error, and increasing adjusted R^2. However, statistical methods alone are not sufficient for model selection. Additional consideration for model selection was given to including component metrics from four metric categories; richness, abundance, tolerance, and trophic measures. The metrics selected include measures of tolerant and intolerant taxa and measures that both increase and decrease with urban intensity (table 16).

The ALS for sites based on the calculated SCI is presented in table 12. A SCI score of 4 through 8 indicates a non-supporting ALS, a score of 10 through 14 indicates a partially supporting ALS, and a score of 16 through 20 indicates a fully supporting ALS. Previous studies in the Kansas City metropolitan area (Poulton and others, 2007; Rasmussen and others, 2009; Wilkison and others, 2009; Graham and others, 2010) concluded that urban streams are likely incapable of fully supporting aquatic life. No sites within the Blue River Basin had a fully supporting score in this study. The Little Blue River Basin sites 9, 12, and 15 and the rural sites 17 and 18 had fully supporting scores for spring samples. About 80 percent of all samples combined were less than fully biologically supporting, and only about 11 percent of spring samples were fully biologically supporting. The aquatic-life status for the Little Blue River and its tributaries was more supporting of aquatic life than for the Blue River and its tributaries.

Table 14. Multimetric indices determined by step regression with a simple urban intensity index.

[Metric definitions are listed in table 3; stderr, standard error; adj R^2, adjusted coefficient of determination; Cp, Mallows; Cp, PRESS; predicted residual sum of squares]

Model metrics	stderr	adj R^2	Cp	PRESS
EPTR + COLEOPR	15.6	60.5	1.0	14,001
EPEMRp + COLEOPR + ORTHOR	14.8	64.4	-2.7	12,956
EPEMRp + COLEOPR + ORTHOR + NCHDIPR	14.3	66.7	-4.3	12,493
COLEOPR + DIPR + EPT/CHR + OLIGOp + RICHTOL	13.9	68.5	-5.2	12,286
PLECOR + COLEOPR + DIPR + OLIGOp + RICHTOL + SCR	13.5	70.2	-5.9	11,601
PLECOR + COLEOPR + DIPR + NCHDIPR + OLIGOp + RICHTOL + SCR	13.5	70.5	-5.0	11,627
RICH + EPEMR + EPp + COLEOPR + NCHDIPR + OLIGOp + RICHTOL + SCR	13.3	71.3	-4.5	11,601
EPTR + EPTRp + PLECOR + COLEOPR + DIPR + OLIGOp + OLIGORp + RICHTOL + SCR	13.0	72.4	-4.4	11,392
EPTR + EPTRp + PLECOR + COLEOPR + DIPR + NCHDIPR + OLIGOp + OLIGORp + RICHTOL + SCR	12.9	73.1	-3.8	11,385

Average SCI aquatic-life status categories for sites with three or more spring samples (table 12) are shown in figure 11 and are arranged by stream category (tributary-stream sites and main-stem stream sites) and decreasing SUII (table 1). Three years were the minimum number of years considered to characterize site ALS. Average Blue River Basin tributaries (sites 2 and 6) had nonbiologically supporting SCI scores. Average Rock Creek and Little Blue River tributaries (sites 8, 13, 14) had partially biologically supporting SCI scores. Blue River tributary sites scored significantly lower than the Little Blue River tributary sites. The Blue River main-stem sites, with the exception of upstream site 1 (table 1, fig. 1) also scored significantly lower than the Little Blue River sites and rural site 18 (table 1, fig. 1). All main-stem sites scored as partially biologically supporting.

Although most samples indicated sites as partially biologically supporting, some Little Blue River Basin fall samples were fully supportive. Fall samples were collected only at the Little Blue River Basin and rural sites in 2008 and 2010. The Rock Creek Basin site 8 and Little Blue River Basin site16 had average fully supporting ALS (fig. 12). Some effects of urban intensity may be reduced within the Little Blue River Basin likely because of upstream reservoirs (fig. 1). Water from reservoirs has lower specific conductance than area streams, particularly during base flow, and reservoirs trap suspended sediment during stormflow. On the other hand, Blue River Basin sites consistently had lower SCI scores than the Little Blue River Basin and rural sites.

SCI scores decreased for sites with urban intensity as was found in other local studies (Poulton and others, 2007; Rasmussen and others, 2009; Wilkison and others, 2009; Graham and others, 2010). However, urban intensity in this study was calculated using the SUII. Factors included in the SUII were selected based on their correlation to RICH and EPTR; two of the SCI's component metrics (table 16). An EPA evaluation of methods (Blocksam and Winters, 2006) found that using RICH and EPTR, with the assumption of EPT taxa intolerance to pollution, to define urban intensity and explain stream impairment, if not circular reasoning, to be at least biased. Therefore, the SCI was compared to five MMIs (table 15), four containing all or some of the metrics in the SCI, and one with none of the SCI metrics (table 16) to test for this bias.

EPTR was included in four of the MMIs. Three metrics, Plecoptera richness (PLECOR), Coleopotera (beetle) richness (COLEOPR), and percent Oligochaeta (aquatic worms) taxa (OLIGOp) were common to three MMIs. Six metrics, RICH, Diptera taxa richness (DIPR), tolerant taxa richness (RICHTOL), MBI, SHANDIV, and scraper richness (SCR), were common to two MMIs (table 16). No individual metric was common to all MMIs. Spearman's correlation coefficients among the five MMIs ranged from 0.70 to 0.90 when compared to the SCI scores for spring samples (table 17). The modified 10-metric MMI, based on component metrics from local area studies, had the highest correlation (ρ equals 0.90) to the SCI and the best 6-metric MMI had the lowest correlation (ρ equals 0.70).

Table 15. Proportionally scaled values for a simple urban intensity index (SUII), component values, and average spring multimetric index (MMI) scores by site.

[Metric definitions are listed in table 3; IMPERV, impervious cover; POPD, population density; FORBUF, forest buffer; SUII, simple urban intensity index; B-IBI, benthic index of biotic integrity]

Site number (table 1, fig. 1)	IMPERV	POPD	FORBUF	SUII	4-Metric index[1]	10-Metric index[2]	B-IBI index[3]	Best 10-metric index[4]	Best 6-metric index[5]
Site 1	21.19	14.50	45.48	27.06	65.69	49.82	41.67	57.18	55.68
Site 2	90.70	75.05	74.82	80.19	20.83	17.68	9.48	23.00	20.95
Site 3	50.63	40.91	51.69	47.75	36.58	28.58	18.46	32.90	31.98
Sites 4–5	52.08	41.63	51.05	48.25	43.11	30.30	17.29	33.95	30.15
Site 6	100.00	100.00	100.00	100.00	19.77	16.86	5.31	13.20	14.90
Site 7	59.08	48.28	52.81	53.39	32.00	21.38	13.99	24.05	23.55
Site 8	78.49	70.95	80.79	76.74	58.96	49.20	23.94	44.40	39.85
Sites 9–12	40.16	34.24	31.21	35.20	70.29	52.09	30.72	55.55	52.13
Site 13	78.92	60.78	56.77	65.49	58.45	41.90	22.12	45.00	42.53
Site 14	53.32	57.43	26.25	45.66	55.24	44.91	30.65	48.83	46.50
Site 16	41.52	35.20	35.39	37.37	73.04	56.21	39.17	61.33	55.90
Site 18	9.31	4.96	40.35	18.21	62.95	53.18	54.19	66.78	61.18

[1]Metrics used to calculate the index; RICH, EPTR, MBI, SHANDIV.

[2]Metrics used to calculate the index; RICH, EPTR, EPTp, EPp, TANYp, OLIGOp, MBI, INTOLp, SHANDIV, SCp.

[3]Metrics used to calculate the index; EPTR, PLECOR, COLEOPR, PLECO, COLEOP, COLEOPp, PLECORp, NONINSRp.

[4]Metrics used to calculate the index; EPTR, PLECOR, COLEOPR, DIPR,NCHDIPR, EPTRp, OLIGOp, OLIGORp, RICHTOL, SCR.

[5]Metrics used to calculate the index; PLECOR, COLEOPR, DIPR, OLIGOp, RICHTOL, SCR.

Table 16. Metrics included in the Stream Condition Index (SCI) and selected multimetric indices (MMI) and predicted direction of response to increasing urban intensity.

[Metric definitions are listed in table 3; SCI, Stream Condition Index; B-IBI, benthic index of biotic integrity; X, index component metric]

Metric category	Metric	Expected response to urban intensity[1]	SCI	4-Metric index	10-Metric index	B-IBI index	Best 10-metric index	Best 6-metric index
Richness	RICH	Decrease	X	X	X			
	EPTR	Decrease	X	X	X	X	X	
	PLECOR	Decrease				X	X	X
	COLEOPR	Decrease				X	X	X
	DIPR	Decrease					X	X
	NCHDIPR	Decrease					X	
Composition	PLECO	Decrease				X		
	COLEOP	Decrease				X		
	EPTp	Decrease			X			
	EPTRp	Decrease					X	
	EPp	Decrease			X			
	COLEOPp	Decrease				X		
	TANYp	Decrease			X			
	OLIGOp	Increase			X		X	X
	PLECORp	Decrease				X		
	NONINSRp	Increase				X		
	OLIGORp	Increase					X	
Tolerance	RICHTOL	Increase					X	X
	MBI	Increase	X	X	X			
	INTOLp	Decrease			X			
Diversity	SHANDIV	Decrease	X	X	X			
Trophic	SCR	Decrease					X	X
	SCp	Decrease			X			

[1]Barbour and others, 1996; Barbour and others, 1999; DeShon, 1995; Kerans and Karr, 1994.

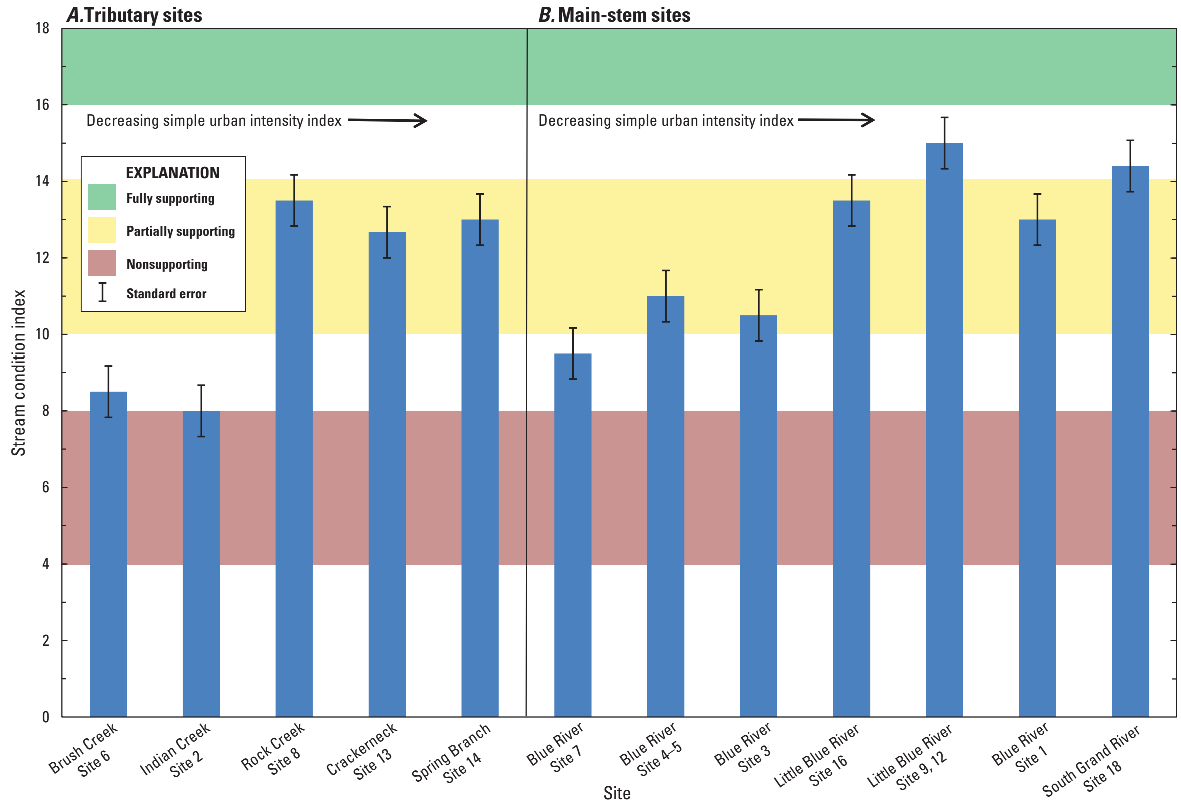

Figure 11. Average Stream Condition Index for richest-targeted habitat spring macroinvertebrate samples by site for *A*, tributary sites and *B*, main-stem sites.

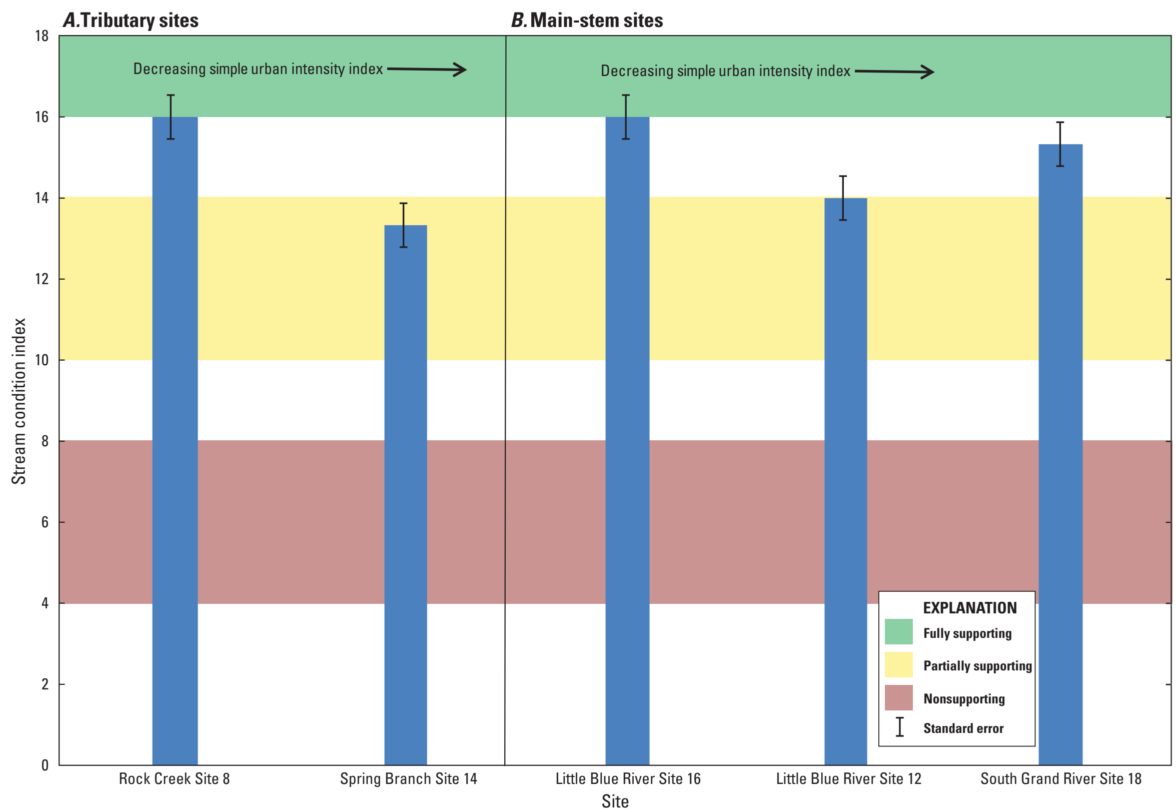

Figure 12. Average Stream Condition Index for richest-targeted habitat for fall macroinvertebrate samples by site for *A*, tributary sites and *B*, main-stem sites.

Table 17. Correlation coefficients for multimetric indices and the Stream Condition Index for spring samples.

[ρ, rho; B-IBI, benthic index of biotic integrity]

Multimetric index name	Stream Condition Index (Spearman's ρ)
4-metric index	0.87
10-metric index	0.90
B-IBI index	0.78
Best-10 metric index	0.81
Best-6 metric index	0.70

Figures 13*A* and *B* show the average MMIs for sites with three or more years of spring samples arranged by decreasing SUII. Although MMI scores for individual samples had high variability (table 11), sites with lower SUIIs generally had higher MMIs (table 15). All the MMIs place the Blue River and Blue River tributary site samples (with the exception of the upstream site 1) in the bottom half of possible MMI scores. The two Blue River tributary sites (sites 2 and 6) had nonsupporting ALS average SCI scores (table 12) with all MMIs in the lowest quartile of possible scores (table 15). No sites with at least three spring samples had average fully supporting SCI scores. The combined middle Little Blue River sites 9 and 12 and rural site 18 had the highest average spring SCIs, and one or more years with a fully supporting SCI score (table 12) were calculated to be in the third quartile of possible scores by four and five MMIs (table 15).

Fall sample trends are less apparent. Figure 14 shows the MMI scores for the Little Blue River Basin, Rock Creek, and rural comparison sites with at least three fall samples. Generally, fall samples had lower scores than spring samples, but the SCI had more samples that were fully biologically supporting (39 percent) than spring samples (20 percent; table 12). Fall MMI scores were similar to spring sample scores. The B–IBI had the lowest average scores, and the 4-metric index had the highest average scores. Individual MMIs for stream categories mostly scored sites within one standard error; therefore, MMI scores could not be related to the SUII.

The two modeled MMIs, the best 6- and best 10-metric indices, and three other MMIs composed of metrics common to local and national studies for fall samples show similar results among each other. The B–IBI that included EPTR as a metric had the highest correlation with urban intensity as measured with the SUII (R^2 equals 0.71) followed by the best 6-metric index (R^2 equals 0.61). The other MMIs and the SCI explained less than half of the variability in macroinvertebrate communities in relation to urban intensity.

Responses of macroinvertebrate communities to urban intensity and among basins were apparent in MDS plots, community analysis, and MMIs. RICH was substantially higher (table 4) for the Little Blue River and rural comparison sites than for the Blue River sites except upstream Blue River site 1 as well as most other richness measures used in the calculation of MMIs (table 11). One metric, percent Ephemeroptera taxa richness (EPEMRp) was highly correlated with the SUII (|ρ| greater than or equal to 0.65; table 3). However, measures of urban intensity used to calculate the SUII were selected because of a high correlation (|ρ| greater than or equal to 0.7) with two macroinvertebrate metrics sensitive to pollution; one of which includes a measure of Ephemeroptera taxa richness (EPTR).

Twenty metrics used in MMIs were moderately correlated (|ρ| greater than or equal to 0.45 and less than 0.65; table 3) including richness metrics (RICH, EPTR, PLECOR, and COLEOPR), percent richness metrics, percent EPT taxa richness (EPTRp), percent Plecoptera taxa richness (PLECORp), percent noninsect taxa richness (NONINSRp), and percent Oligochaeta taxa richness (OLIGORp); and a richness tolerance measure (RICHTOL).

Relations among Metrics and Environmental Variables

The 23 metrics used to calculate MMIs and the SCI were compared to selected environmental variables including habitat scores, hydrologic variables, physical parameters, and water-quality variables (table 18). Not all environmental variables were collected at all sites (table 1). Metrics were considered to be moderately correlated when Spearman's |ρ| is greater than or equal to 0.45 and strongly correlated when |ρ| is greater than or equal to 0.65. Sixteen metrics were moderately or strongly correlated with at least one environmental variable (table 18). No metrics were at least moderately correlated with habitat assessment scores, hydrologic (discharge) variables, temperature, or pH (table 2). However, previous area studies have found correlations. Rasmussen and others (2009) found a significant correlation between habitat score and several metrics, including RICH and EPTR, and some hydrologic variables in Johnson County, Kans., streams and the upstream Blue River and its tributaries in Kansas (fig. 1). Wilkison and others (2009) found that, although habitat assessment scores were not robust indicators for macroinvertebrate community metrics for Blue River Basin sites, they were marginally significant.

Sample specific conductance (|ρ| equals 0.66), average base-flow specific conductance (|ρ| equals 0.71), and average base-flow chloride concentration (|ρ| equals 0.87) were highly correlated with the SUII (table 19). Daily discharge for the sampling date (|ρ| equals -0.50), average base-flow ammonium concentration (|ρ| equals 0.64), and average base-flow total dissolved solids concentration (|ρ| equals 0.53) were moderately correlated. Seven environmental variables were moderately correlated to the SCI, including specific conductance measures and average base-flow nutrient and chloride concentrations.

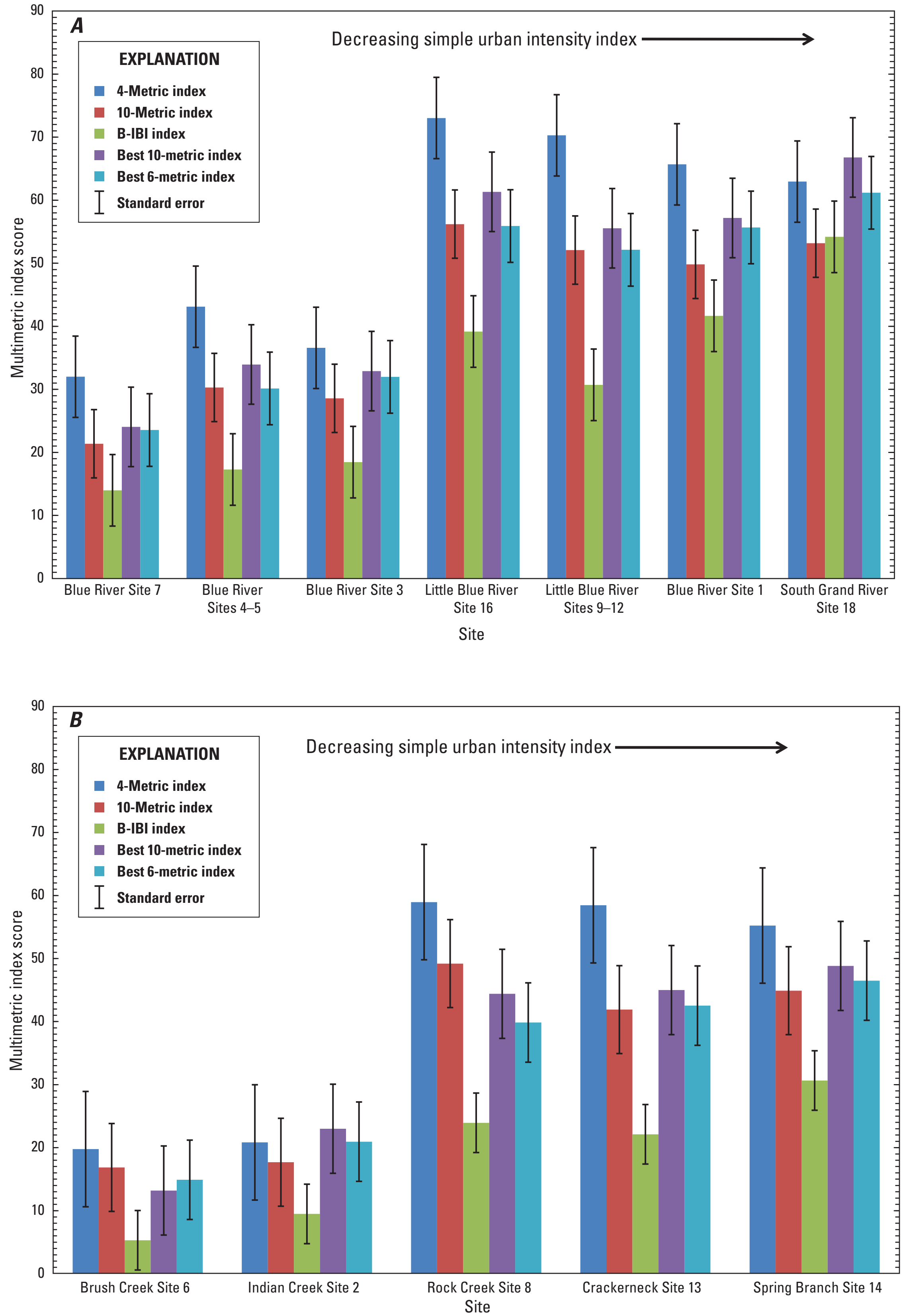

Figure 13. Average spring multimetric indices for sites sampled in 3 or more years for *A*, the Blue River, Little Blue River, and South Grand River, and *B*, Blue River tributaries, Little Blue River tributaries, and Rock Creek.

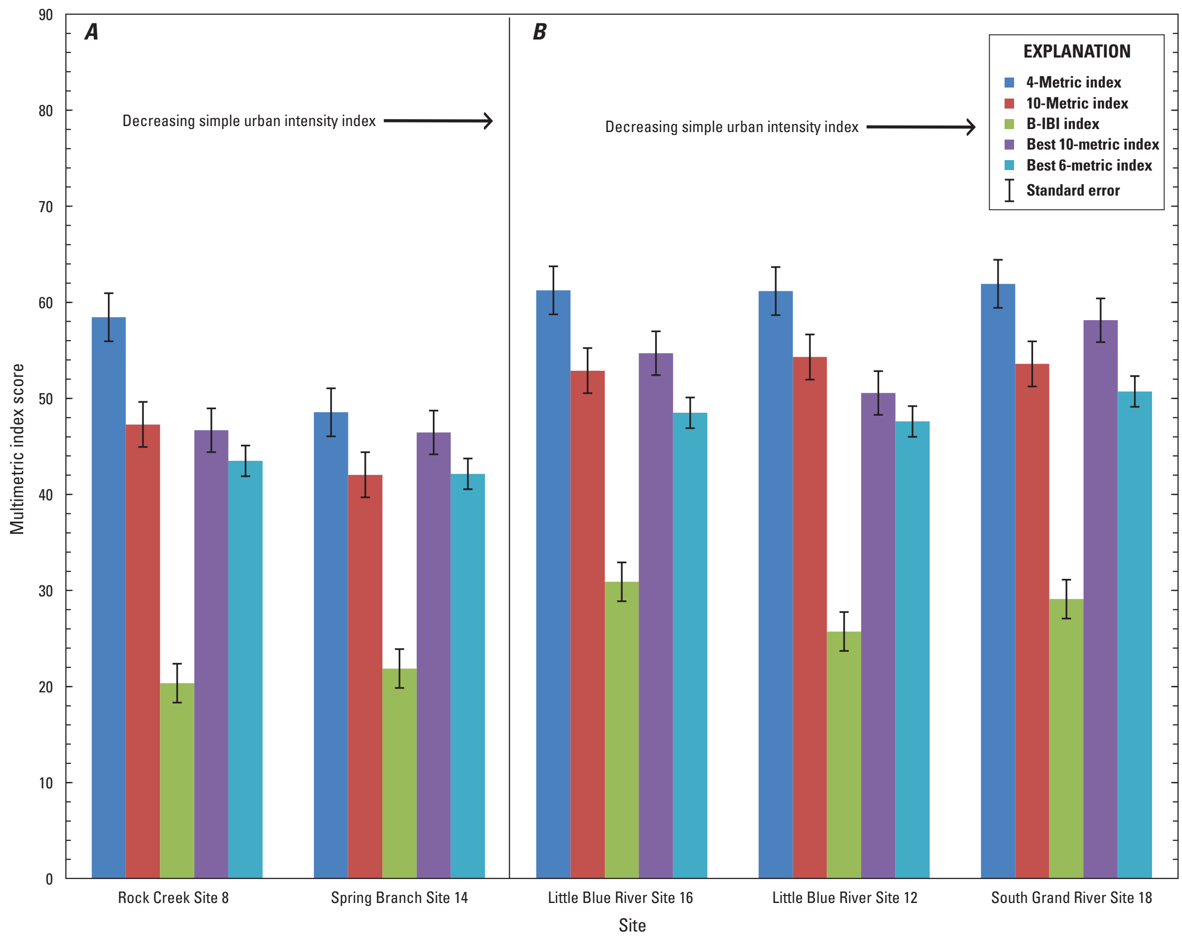

Figure 14. Average fall multimeltric indices for sites sampled in 3 or more years, 2007 through 2011, for *A*, Rock Creek and Spring Branch Creek, and *B*, the Little Blue River and South Grand River.

Higher specific conductance and chloride concentration were negatively correlated with metrics that decrease with increasing urban intensity (tables 16 and 18). For example, specific conductance measured at the time of sample collection was consistently higher for developed tributary sites (table 2; sites 2, 6, 10, 13, and 14) and for upstream main-stem sites (table 2; sites 1, 9, and 12) compared to sites further downstream in the same basin. Specific conductance at the time of macroinvertebrate sampling and the average and maximum values calculated for the preceding 90 days were moderately or highly negatively correlated with six metrics. Metrics including EPT taxa showed the highest correlations, with EPTR and EPp having high negative correlation. Measured chloride concentrations in base-flow samples were at least moderately correlated with 10 metrics. Negative correlation with metrics that included EPT taxa and Coleoptera (beetles) were most evident with EPTR and EPTRp. Oligochaeta percent abundance (OLIGOp) and percent richness (OLIGORp) metrics were positively correlated with chloride concentration. High chloride values in tributary streams, especially peak concentrations during winter months from road salt application, may be toxic to aquatic life (Wilkison and others, 2009; Christensen and others, 2010). Higher relative abundances of Oligochaeta and lower relative abundances or absence of EPT taxa may be attributed to the higher tolerance of Oligochaeta taxa (Megadrile, Enychytraeidae, Tubificidae, Naididae; table 8) and burrowing habits that may protect them from contact with intermittent or short-duration toxic chloride levels in stream water.

Higher nutrient values were negatively correlated with metrics that decrease with increasing urban intensity (tables 16 and 18). Seven metrics were moderately correlated with average base-flow nutrient concentrations. Dissolved bioavailable nutrients (ammonium and nitrite plus nitrate) were negatively correlated with richness metrics (RICH, EPTR, EPTRp, and COLEOPR) and a functional feeding group metric (SCR). Ammonium concentration also was correlated with the MBI. Higher nutrient concentrations during base flow in the middle Blue River (sites 3, 4, and 5 table 2, fig.1) and the Blue River tributary streams receiving WWTP discharges and CSOs (sites 2 and 6; table 2, fig. 1) likely have contributed to lower RICH and higher average MBI values (Wilkison and others, 2009; Graham and others; 2010). However, conditions for the Blue River Basin sites may currently (2012) be changing (2012).

Table 18. Correlation coefficients for selected macroinvertebrate metrics and environmental variables.

[Metric definitions are listed in table 3; Moderately correlated (|ρ| greater than or equal to 0.45) values in **bold**; *, highly correlated (|ρ| greater than or equal to 0.65) values; SC, specific conductance; NH4, ammonium; NO_2 +NO_3, nitrite plus nitrate; P, phosphorous; total P, total phosphorous; TDS, total dissolved solids]

Metric	Habitat score	Sample discharge	Sample daily discharge	Sample temperature	Sample SC	Sample pH	90-day average discharge[1]	90-day median discharge[1]	90-day peak discharge[1]	90-day average SC[1]	90-day maximum SC[1]	Base-flow average SC[2]	Base-flow average total nitrogen[2]	Base-flow average NH_4[2]	Base-flow average $NO_2 + NO_3$[2]	Base-flow average total P[2]	Base-flow average total P[2]	Base-flow average chloride[2]	Base-flow average suspended sediment[2]	Base-flow average TDS[2]
RICH	-0.16	-0.19	0.02	-0.28	-0.43	-0.06	-0.18	-0.16	-0.12	0.02	0.11	**-0.47**	**-0.46**	**-0.56**	**-0.47**	-0.41	-0.42	**-0.54**	0.25	-0.28
EPTR	-0.08	-0.20	0.03	0.17	**-0.65***	-0.05	0.05	0.01	0.12	**-0.50**	-0.41	**-0.58**	**-0.46**	**-0.61**	**-0.47**	-0.34	-0.36	**-0.80***	0.21	**-0.49**
EPTRp	-0.05	-0.22	-0.05	0.27	**-0.61**	-0.09	0.05	0.01	0.12	**-0.58**	**-0.55**	**-0.48**	-0.38	**-0.50**	-0.38	-0.27	-0.29	**-0.71***	0.20	-0.42
PLECOR	0.15	0.13	0.36	-0.29	-0.21	0.11	0.20	0.20	0.28	0.12	0.20	-0.34	-0.13	-0.28	-0.12	-0.06	-0.07	-0.42	-0.17	-0.26
PLECO	0.14	0.13	0.36	-0.29	-0.21	0.09	0.20	0.19	0.28	0.13	0.19	-0.34	-0.13	-0.27	-0.13	-0.07	-0.08	-0.42	-0.18	-0.26
PLECORp	0.15	0.13	0.36	-0.29	-0.22	0.10	0.21	0.21	0.28	0.12	0.19	-0.33	-0.13	-0.27	-0.12	-0.06	-0.07	-0.42	-0.17	-0.25
EPp	-0.07	-0.21	-0.04	0.31	**-0.68***	-0.10	0.09	0.03	0.14	**-0.66***	**-0.62**	**-0.58**	**-0.47**	**-0.53**	**-0.47**	-0.35	-0.36	**-0.79***	0.18	**-0.52**
EPTp	-0.19	-0.19	-0.12	0.30	**-0.48**	-0.14	0.04	0.03	0.08	**-0.53**	**-0.47**	-0.36	-0.35	-0.32	-0.36	-0.28	-0.30	**-0.59**	0.27	-0.28
COLEOPR	0.00	0.18	0.22	-0.07	-0.44	0.16	0.13	0.17	0.07	0.18	0.23	-0.42	-0.33	**-0.56**	-0.32	-0.18	-0.16	**-0.45**	0.11	-0.21
COLEOP	-0.00	-0.37	-0.27	0.04	-0.23	0.03	-0.23	-0.23	-0.14	0.11	0.16	-0.01	-0.15	-0.42	-0.15	-0.13	-0.16	-0.30	**0.56**	0.35
COLEOPp	0.08	-0.37	-0.34	0.13	-0.06	0.05	-0.29	-0.27	-0.22	0.30	0.30	0.14	-0.05	-0.33	-0.04	-0.02	-0.05	-0.19	**0.61**	**0.52**
DIPR	-0.09	-0.29	-0.04	**-0.54**	0.12	-0.14	-0.37	-0.32	-0.27	**0.59**	**0.57**	0.05	-0.12	-0.14	-0.12	-0.18	-0.17	0.01	0.37	0.25
TANYp	-0.15	-0.43	-0.22	-0.14	0.02	-0.22	-0.41	-0.37	-0.37	0.18	0.19	-0.02	-0.14	-0.08	-0.14	-0.25	-0.22	0.08	0.33	0.13
NCHDIPR	-0.04	-0.18	-0.10	-0.24	-0.03	0.04	-0.12	-0.11	-0.04	0.25	0.29	0.03	-0.11	-0.16	-0.11	-0.11	-0.14	-0.25	0.31	0.25
NONINSRp	-0.05	0.12	-0.09	0.35	0.19	0.08	0.12	0.11	-0.01	-0.40	-0.43	0.23	0.19	0.34	0.18	0.12	0.10	0.40	-0.26	-0.01
OLIGOp	0.19	0.30	0.35	-0.09	0.44	0.23	0.38	0.33	0.38	0.40	0.35	0.20	0.39	0.42	0.40	0.34	0.37	**0.45**	**-0.47**	-0.02
OLIGORp	0.02	0.38	0.12	0.22	0.37	0.08	0.28	0.23	0.22	0.03	-0.10	0.34	0.29	0.43	0.29	0.20	0.21	**0.62**	-0.35	0.17
RICHTOL	-0.25	-0.03	-0.23	-0.25	0.42	-0.13	-0.24	-0.23	-0.30	0.34	0.28	0.36	0.07	0.32	0.07	-0.05	-0.04	**0.53**	0.09	0.40
MBI	0.23	0.11	-0.02	-0.17	**0.45**	0.13	-0.01	0.04	-0.02	0.39	0.32	0.34	0.33	**0.53**	0.32	0.30	0.30	0.30	-0.13	0.24
INTOLp	0.04	0.31	0.32	-0.13	-0.32	-0.08	0.08	0.10	0.01	-0.17	-0.12	-0.32	-0.17	-0.35	-0.17	-0.09	-0.10	-0.34	-0.10	-0.28
SHANDIV	-0.20	-0.18	-0.17	-0.21	-0.07	-0.25	-0.34	-0.29	-0.30	0.17	0.23	-0.08	-0.22	-0.14	-0.23	-0.30	-0.30	-0.11	0.38	0.10
SCR	-0.05	-0.05	0.10	-0.29	-0.36	-0.04	-0.16	-0.12	-0.08	0.26	0.29	**-0.45**	-0.37	**-0.61**	-0.38	-0.26	-0.27	**-0.53**	0.21	-0.24
SCp	0.09	-0.35	-0.23	-0.09	-0.05	0.03	-0.35	-0.26	-0.28	0.42	0.45	0.09	-0.02	-0.30	-0.01	-0.00	-0.03	-0.28	**0.65**	0.45

[1]Value for measurements made during the 90 days preceding macroinvertebrate sample collection.

[2]Average value in base-flow samples collected June 2006 to June 2011. Number of samples ranged from one to five at each site.

Table 19. Correlation coefficients for selected environmental variables with the simple urban intensity index (SUII) and the Stream Condition Index (SCI).

[ρ, rho; SUII, simple urban intensity index; SCI, Stream Condition Index; Moderately correlated |ρ| greater than or equal to 0.45 values in **bold**; *, highly correlated (|ρ|)]

Environmental variable	Spearman's ρ	
	SUII	SCI
Habitat score	-0.30	-0.30
Sample discharge	-0.29	-0.28
Sample temperature	-0.08	0.27
Sample specific conductance	**0.66***	**-0.50**
Sample pH	-0.26	-0.24
90-day average discharge	-0.43	-0.18
90-day median discharge	-0.42	-0.22
90-day peak discharge	-0.39	-0.14
Daily sample discharge	**-0.50**	-0.25
90-day specific conductance	0.43	**-0.50**
90-day maximum specific conductance	0.32	-0.36
Base-flow specific conductance	**0.71***	-0.38
Base-flow total nitrogen	0.34	**-0.47**
Base-flow ammonium	**0.64**	**-0.54**
Base-flow nitrite plus nitrate	0.35	**-0.49**
Base-flow dissolved phosphorous	0.08	-0.43
Base-flow total phosphorous	0.11	**-0.46**
Base-flow chloride	**0.87***	**-0.53**
Base-flow suspended sediment	0.20	0.39
Base-flow total dissolved solids	**0.53**	-0.22

Efforts have been initiated to reduce nutrient concentrations in streams in the Blue River Basin by Johnson County, Kans., improvements to WWTPs (Graham and others, 2010) and Kansas City, Mo., stormwater and sewer (CSO) projects (U.S. Environmental Protection Agency, 2010).

The six selected MMIs in this study were better than the SCI at characterizing urban intensity effects on water-quality conditions of streams and macroinvertebrate communities. All the MMIs had significant (*p* less than or equal to 0.05) differences among the Blue River tributary sites (sites 2 and 6; table 11) and all other basin categories except the Blue River sites (sites 3–5, and 7; fig. 1) that receive WWTP effluent. Metrics based on EPT and Coleoptera taxa that were positively correlated with the SUII (table 3) are better represented using MMIs, rather than the SCI, for urban streams in the Kansas City metropolitan area. The common B-IBI (R^2 equals 0.71) and the best 6-metric index (R^2 equals 0.61) explained more than half of the variability among sites and were best at determining differences in macroinvertebrate communities among sites.

Differences between the Blue River Basin and Little Blue River Basin macroinvertebrate community metrics were identified. Blue River Basin sites affected by WWTP discharges, CSOs, and other urban intensity factors had higher specific conductance and nutrient concentrations that likely contribute to water-quality impairment and lower ALS (Wilkison and others, 2009; Graham and others, 2010). Regulated low-flow releases from upstream reservoirs in the Little Blue River Basin, with lower specific conductance values, suspended sediment, and dissolved constituent concentrations, have an overall benefit to base-flow water quality and may raise the ALS of streams (Christensen and others, 2010). Average base-flow chloride concentrations had the highest correlation with the SUII (ρ equals 0.87; table 19), and were negatively correlated with SCI scores (ρ equals -0.53; table 19) and pollution sensitive EPT taxa metrics (ρ equals -0.42 to -0.80; table 18), and were positively correlated with pollution tolerant Oligochaeta taxa metrics (ρ equals 0.45 to 0.62; table 18). Higher average impervious cover, a component of the SUII, for most Blue River Basin sites (table 1) likely contributes to higher chloride concentrations as a result of increased runoff from winter road salt applications. Study results show that the easily calculated SUII and the selected modeled multimetric indices are effective for comparing urban basins and for evaluation of water quality in the Kansas City metropolitan area.

Summary

This report examined macroinvertebrate communities from the Blue River, Little Blue River, and Rock Creek Basins, which are adjacent urban basins largely located in Kansas City and Independence, Missouri, and two rural comparison sites. Macroinvertebrate community structure, community metrics, multimetric indices (MMI) and their relation to environmental variables were used to determine aquatic-life status (ALS) of streams and to evaluate sites and river basins. Combinations of commonly used macroinvertebrate bioassessment metrics were related to a simple urban intensity index (SUII) consisting of three variables; forest cover in a 30-meter stream-buffer zone, percent impervious cover, and population density. Hydrologic, water-quality, macroinvertebrate, and habitat data collected for two water-quality studies in the Kansas City metropolitan area were analyzed to evaluate individual sites, differences among sites and river basins, and stream ALS. MMIs with 2 to 10 metrics were related to the SUII to characterize stream condition using a proportional scaling approach. Nonmetric multidimensional scaling (MDS) and analysis of similarity (ANOSIM) were used to analyze the relative dissimilarities of biologic conditions among sites.

Initial screening using macroinvertebrate four-metric scores, individual component metrics, and pair-wise comparison showed differences among the Blue River, Little Blue River, their tributaries, and rural stream categories. The Blue River middle and downstream categories were significantly

different (*p* less than or equal to 0.05) than the middle and downstream Little Blue River categories. The Blue River tributary category was significantly different (*p* less than or equal to 0.05) from all other categories except the middle and downstream Blue River categories. The rural comparison category was significantly different (*p* less than or equal to 0.05) from the Blue River middle, downstream, and tributary categories.

The Blue River Basin sites had the lowest richness of intolerant taxa and the Little Blue River sites had the highest. The rural comparison sites had the highest relative abundance of highly intolerant taxa. Both the Blue River Basin sites and the Little Blue River Basin sites had low abundances of highly intolerant taxa. Although the Little Blue River sites had higher intolerant taxa richness, it also had lower relative abundance of intolerant taxa than the Blue River Basin and rural comparison sites. This indicates there are likely additional factors affecting the ability of these streams to support an intolerant community than the urban-intensity factors considered for this study.

The Blue River Basin had the lowest relative abundance of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. More than 25 percent of the identified taxa at the Little Blue River Basin sites and the rural comparison sites were EPT taxa. Ephemeroptera were the most abundant EPT order in spring samples although the average tolerance values for the 10 mayfly taxa identified in spring samples were in the moderately tolerant range. Plecoptera taxa were poorly represented in these streams likely because of their pollution sensitivity.

Multidimensional scaling (MDS) plots of spring sample macroinvertebrate community structure based on richness, relative abundance, tolerance, and functional feeding groups showed differences among the Blue River, Little Blue River, tributary, and rural stream categories, the SUII of sites, and environmental variables. ANOSIM was used to compare basin categories. BEST analysis was performed to determine the species "best explaining" dissimilarities among basins.

Generally, there were clear groupings of samples within basin categories showing less dissimilarity within basin categories than among samples from different basin categories. ANOSIM results indicated that basin category was the most substantial indicator for dissimilarities in percent taxa abundance among basin categories (R equals 0.55). Pair-wise ANOSIM analysis indicated a significant difference among all basin categories based on percent taxa abundance.

BEST analysis was performed in PRIMER to determine the species "best explaining" dissimilarities among basins based on percent taxa abundance. Six of the macroinvertebrate taxa that had the largest effect on driving dissimilarities in percent taxa abundance were in the family Chironomidae. The four remaining taxa consisted of one mayfly, one caddisfly, and two noninsect taxa. Six functional feeding groups are represented in the "best-explaining" taxa; two filterer-collectors, one predator, two collector-gatherers, three shredders, one omnivore, and one scraper. The most common taxon identified at all sites among the "best explaining" taxa was a chironomid and moderately tolerant shredder, *Cricotopus/Orthocladius* sp.

MDS plots based on taxa abundance, taxa tolerance, and functional feeding groups were similar, with Blue River tributary sites having high dissimilarity to other basin categories. ANOSIM results generally indicated a high dissimilarity among basin categories compared to within basin sample dissimilarity. Pair-wise analysis indicated the Blue River tributary category was statistically different than all other categories when comparing taxa abundance, taxa tolerance, and functional feeding groups. Blue River main-stem samples that had higher dissimilarity than other samples within this category were from the upstream site. This site was the only Blue River main-stem site above the outfalls from two wastewater treatment plants on Indian Creek. Basin categories that were not statistically different based on MBI were the Little Blue River tributary category with the Blue River and Little Blue River main-stem categories. All other basin categories were statistically different in taxa abundance, taxa tolerance, and functional feeding groups indicating dissimilarities in macroinvertebrate communities.

Previous studies in the Kansas City metropolitan area have determined that urban streams likely are incapable of fully supporting aquatic life. For this study there were no sites within the Blue River Basin having a fully supporting score. About 80 percent of all samples combined were less than fully biologically supporting, and only about 11 percent of spring samples were fully biologically supporting. The aquatic-life status for the Little Blue River and its tributaries were more supportive than for the Blue River and its tributaries. Three Little Blue River Basin sites and the rural comparison sites had fully supporting Stream Condition Index (SCI) scores for spring samples, and no site with more than one sample had an average fully supporting score. Fall samples, collected only for the Little Blue River Basin and rural sites, had four Little Blue River Basin sites and one rural site with fully supporting ALS scores in one or more years. Three Little Blue River sites had fully supporting average fall ALS scores.

Several best MMIs were determined to characterize macroinvertebrate communities in relation to the SUII and three other MMIs from previous studies. The calculated best 6- and best 10-metric MMIs were selected for further comparison to the three other MMIs. Although MMI scores of spring samples for individual sites were variable, sites with lower SUIIs generally had higher MMIs. All five MMIs place the two Blue River tributary sites with nonsupporting aquatic-life status average SCI scores in the lowest quartile of possible scores. The combined middle Little Blue River sites 9 and 12 and rural site 18 had the highest average spring SCIs, and one or more years with a fully supporting SCI score were calculated to be in the third quartile of possible scores by four and five MMIs. Results were less clear for fall samples. Generally, fall samples had lower scores than spring samples, but the SCI had more samples that were fully biologically supporting than spring samples.

The two calculated MMIs and the three MMIs composed of metrics common to local and national studies had similar results. The common benthic index of biotic integrity (R^2 equals 0.71) and the best 6-metric index (R^2 equals 0.61) were best at determining differences in macroinvertebrate communities among sites. The other MMIs and the SCI explained less than half of the variability in macroinvertebrate communities in relation to urban intensity.

Twenty-three metrics were compared to selected environmental variables. Not all variables were correlated with the metrics. Specific conductance at the time of macroinvertebrate sampling and the average and maximum values calculated for the preceding 90 days were moderately or highly negatively correlated with six metrics. Chloride concentrations in base-flow samples showed at least moderate correlation with 10 metrics. High chloride values in tributary streams in the study area, especially peak concentrations during winter months, may be toxic to aquatic life. Seven metrics were moderately correlated with average base-flow nutrient concentrations. Higher nutrient concentrations during base flow for the middle Blue River sites and the Blue River tributary streams receiving wastewater discharges and combined sewer overflows likely contributed to lower taxa richness and higher average abundance tolerance. Chloride concentrations during base flow that were attributable to winter road salt applications had the highest correlation with the SUII (ρ equals 0.87) and were negatively correlated with SCI scores (ρ equals -0.53) and pollution sensitive EPT taxa metrics and positively correlated with pollution tolerant Oligochaeta taxa metrics.

Differences between the Blue River Basin and Little Blue River Basin macroinvertebrate community metrics were identified. Blue River Basin sites affected by WWTP discharges, combined sewer overflow, and other urban intensity factors had higher specific conductance and nutrient concentrations that likely contribute to water-quality impairment and lower ALS. Differences between the Blue River Basin and Little Blue River Basin macroinvertebrate community metrics were identified. Upstream reservoirs in the Little Blue River Basin reduced specific conductance, suspended sediment, and dissolved constituent concentrations with regulated releases, which may have had an overall benefit to water quality and raised the ALS of streams. Study results show that the easily calculated SUII and the selected modeled multimetric indices are effective for comparing urban basins and for evaluation of water quality in the Kansas City metropolitan area.

References Cited

Allen, D.M., 1974, The relationship between variable selection and data augmentation and a method for prediction: Technometrics, v. 16, no. 1, p. 125–127.

Armitage, P.D., Cranston, P.S., and Pinder, L.C.V., 1995, The Chironomidae—Biology and ecology of non-biting midges: London, Chapman & Hall, p. 572.

Barbour, M.T., Plafkin, J.L., Bradley, B.P., Graves, C.G., and Wisseman, R.W., 1992, Evaluation of EPA’s rapid bioassessement benthic metrics—Metric redundancy and variability among reference stream sites: Environmental Toxicology and Chemistry, v. 11, p. 437–449.

Barbour, M.T., Gerritsen, J., Griffith, G.E., Frydenborg, R., McCarron, E., White, J.S., and Bastian, M.L., 1996, A framework for biological criteria for Florida streams using benthic macroinvertebrates: Journal of the North American Benthological Society, v. 15, no. 2, p. 185–211.

Barbour, M.T., Gerritsen, J., Snyder, B.D., and Stribling, J.B., 1999, Rapid bioassessment protocols for use in streams and wadeable rivers—Periphyton, benthic Macroinvertebrates and fish (2d ed.): Washington, D.C., U.S. Environmental Protection Agency EPA 841–B–99–002, Office of Water.

Blocksom, K.A., and Winters, L., 2006, The evaluation of methods for creating defensible, repeatable, objective and accurate tolerance values for aquatic taxa: Cincinnati, Ohio, U.S. Environmental Protection Agency, Office of Research and Development, National Exposure Research Laboratory, p. 52.

Bode, R.W., Novak, M.A., Abele, L.E., Heitzman, D.L., and Smith, A.J., 2002, Quality assurance work plan for biological stream monitoring in New York State: Albany, New York, NYS Department of Environmental Conservation, 122 p.

Bray, J.R., and Curtis, J.T., 1957, An ordination of upland forest communities of southern Wisconsin: Ecological Monographs, v. 27, no. 4, p. 325–394.

Bressler, D.W., Stribling, J.A., Paul, M.J., and Hicks, M.B., 2006, Stressor tolerance values for benthic macroinvertebrates in Mississippi: Hydrobiologia, v. 573, p. 155–172.

Cao, Y., and Hawkins, C.P., 2011, The comparability of bioassessments—A review of conceptual and methodological issues: Journal of the North American Benthological Society, v. 30, no. 3, p. 680–701.

Carlisle, D.M., and Clements, W.H., 1999, Sensitivity and variability of metrics used in biological assessments of running waters: Environmental Toxicology and Chemistry, v. 18, no. 2, p. 285–291.

Chapman, S.S., Omernik, J.M., Freeouf, J.A., Huggins, D.G., McCauley, J.R., Freeman, C.C., Steinauer, G., Angelo, R.T., and Schlepp, R.L., 2001, Ecoregions of Iowa and Missouri (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,950,000), accessed October 2008 at *http://www.epa.gov/wed/pages/ecoregions/moia_eco.htm*.

Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p., accessed November 2012 at *http://water.usgs.gov/owq/OFR_99-193/ofr99_193.pdf*.

Christensen, E.D., Harris, T.E., and Neisen, S.L., 2010, Water quality and ecological condition of urban streams in Independence, Missouri, June 2005 through December 2008: U.S. Geological Survey Scientific Investigations Report 2010–5074, 113 p.

Clarke, K.R., 1993, Non-parametric multivariate analyses of changes in community structure: Australian Journal of Ecology, v. 18, p. 117–143.

Clarke, K.R., and Gorley, R.N., 2006, PRIMER v6—User Manual/Tutorial: Plymouth, United Kingdom, PRIMER_E Ltd., 192 p.

Clarke, K.R., and Warwick, R.M., 2001, Changes in marine communities—An approach to statistical analysis and interpretation: Plymouth, United Kingdom, PRIMER_E Ltd., 174 p.

Coffman, W.P., and Ferrington,L.C., Jr., 1996. Chironomidae, *in* Merrit, R.W., and Cummins, K.W., eds., An introduction to the aquatic insects of North America (3d ed.): Dubuque, Iowa, Kendall/Hunt Publishing Co., p. 635–754.

Cuffney, T.F., Bilger, M.D., and Haigler, A.M., 2007, Ambiguous taxa—Effects on the characterization and interpretation of invertebrate assemblages: Journal of the North American Benthological Society , v. 26, no. 2, p. 286–307.

Cuffney, T.F., and Brightbill, R.A., 2011, User's manual for the National Water-Quality Assessment Program Invertebrate Data Analysis System (IDAS) software, version 5: U.S. Geological Survey Techniques and Methods 7–C4, 126 p. (available only online at *http://pubs.usgs.gov/tm/7c4/*).

Cuffney, T.F., Brightbill, R.A., May, J.T., and Waite, I.R., 2010, Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas: Ecological Applications, v. 20, p. 1384–1401.

Cuffney, T.F., Zappia, H., Giddings, E.M.P., and Coles, J.F., 2005, Effects of urbanization on benthic macroinvertebrate assemblages in contrasting environmental settings: Boston, Massachusetts; Birmingham, Alabama; and Salt Lake City, Utah: *in* Brown, L.R., Gray, R.H, Hughes, R.M., and Meador, M.R., eds., Effects of urbanization on stream ecosystems: Bethesda, Maryland, American Fisheries Society, Symposium 47, p. 361–407.

DeWalt, R.E., Favret, C., Webb, D.W., Favret, D., and Webb, D.W., 2005, Just how imperiled are aquatic insects? A case study of stoneflies (Plecoptera) in Illinois: Annals of the Entomological Society of America, v. 98, no. 6, p. 941–950.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, p. 545, accessed January 2005 at *http://water.usgs.gov/pubs/twri/twri5-a1/*.

Garbarino, J.R., and Struzeski, T.M., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of elements in whole-water digests using inductively coupled plasma- optical emission spectrometry and inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 98–165, 101 p.

Graham, J.L., Stone, M.L., Rasmussen, T.J., and Poulton, B.C., 2010, Effects of wastewater effluent discharge and treatment facility upgrades on environmental and biological conditions of the upper Blue River, Johnson County, Kansas, and Jackson County, Missouri, January 2003 through March 2009: U.S. Geological Survey Scientific Investigations Report 2010–5248, 85 p.

Grotheer, S.A., Moulton, S.R., Carter, J.L., Cuffney, T.F., and Short, T.M., 2000, Quality-control of benthic macroinvertebrate identifications—A taxon-based approach, *in* North American Benthological Society Annual Meeting, Keystone Colorado, 2000, Abstracts: accessed July 2009 at *http://www.benthos.org/meeting/nabs2000/nabstracts2000.cfm/id/233*.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1, 58 p.

Hannaford, M.J. and Resh, V.H., 1995, Variability in macroinvertebrate rapid-bioassessment and habitat assessments in a northern California stream: Journal of the North American Benthological Society, v. 14, no. 3, p. 430–439.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources—Studies in environmental science 49: New York, Elsevier Science Publishing Company, 522 p.

Hilsenhoff, W.L., 1977, Use of arthropods to evaluate water quality of streams: Technical Bulletin, Wisconsin Department of Natural Resources, no. 100, p. 15.

Hilsenhoff, W.L., 1988, Rapid field assessment of organic pollution with a family-level biotic index: Journal of the North American Benthological Society, v. 7, p. 65–68.

Huggins, D.G., and Moffett, M.F., 1988, Proposed biotic and habitat indices for use in Kansas streams: Lawrence, Kansas, Kansas Biological Survey Report No. 35, p. 128.

IDEXX Laboratories, Inc., 2009, IDEXX Quanti-Tray, accessed July 2012 at *http://www.idexx.com/pubwebresources/pdf/en_us/water/0602030.pdf*.

Karr, J.R. ,1981, Assessment of biotic integrity using fish communities: Fisheries v. 6, p. 21–27.

Karr, J.R., 1999. Defining and measuring river health: Freshwater Biology, v. 41, p. 221–234.

Karr, J.R. and Kerans, B.L.. 1992, Components of biological integrity—Their definition and use in development of an invertebrate IBI *in* Simon, T.P. and Davis, W.S.,eds.:, Environmental Indicators— Measurement and assessment endpoints: Chicago, Illinois, U.S. Environmental Protection Agency, p. 1–16.

Kenney, M.A., Sutton-Grier, A.E., Smith, R.F., and Gresens, S.E., 2009, Benthic macroinvertebrates as indicators of water quality—The intersection of science and policy: Terrestrial Arthropod Reviews, v. 2, p. 99–128.

Kerans, B.L., and Karr, J.R., 1994, A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley: Ecological Applications, v. 4, p. 768–785.

Klein, R.D., 1979, Urbanization and stream quality impairment: Water Resource Bulletin, v. 15, p. 948–963.

Klemm, D.J., Blocksom, K.A., Thoeny, W.T., Fulk, F.A., Herlihy, A.T., Kaufmann, P.R., and Cormier, S.M., 2002, Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the Mid-Atalantic Highlands Region: Environmental Monitoring and Assessment, v. 78, p. 169–212.

Kreis, R.G., Jr., 1988, Integrated study of exposure and biological effects of in-place sediment pollutants in the Detroit River, Michigan—An upper Great Lakes connecting channel: U.S. Environmental Protection Agency, final report to the EPA Office of Research and Development, EPA ERL—Duluth, Minnesota, and EPA LLRS—Grosse Ile, Michigan, 153 p.

Kruskall, W.H., and Wallis, W.A., 1952, Use of ranks in one-criterion variance analysis: Journal of the American Statistical Association, v. 47, no. 260, p. 583–621.

Lee, C.J., Mau, D.P., and Rasmussen, T.J., 2005, Effects of nonpoint and selected point contamination sources on stream-water quality and relation to land use in Johnson County, northeastern Kansas, October 2002 through June 2004: U.S. Geological Survey, Scientific Investigations Report 05–5144, 104 p.

Lenat, D.R., 1993, A biotic index for the southeastern United States—Derivation and list of tolerance values, with criteria for assigning water quality ratings: Journal of the North American Benthological Society, v. 12, no. 3, p. 279–290.

Lenat, D.R., and Crawford, J.K., 1994, Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams: Hydrobiologia, v. 294, p. 185–199.

Lydy, M.J., Crawford, C.G., and Frey, J.W., 2000, A comparison of selected diversity, similarity and biotic indices for detecting changes in benthic-invertebrate community structure and stream quality: Archives of Environmental Contamination and Toxicology, v. 39, p. 469–479.

Mallows, C.L., 1973, Some comments on C_p: Technometrics, v. 15, no. 4, p. 661–675.

Merritt, R. W., and Cummins, K.W., eds., 1996, An introduction to the aquatic insects of North America (revised 3rd ed.): Dubuque, Iowa, Kendall and Hunt Publishing Co., 862 p.

Miller, A.J.,1990, Monographs on statistics & applied probability 40—Subset selection in regression: London, England, New York, N.Y., Chapman and Hall.

Missouri Spatial Data Information Service, 2011, accessed November 2012 at *http://msdis.missouri.edu/data/themelist.html*.

Moulton, S.R. II, Carter, J.L., Grotheer, S.A., Cuffney, T.S., and Short, T.M., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Processing, taxonomy, and quality control of benthic macroinvertabrates samples: U.S. Geological Survey Open-File Report 00–212, 49 p.

Moulton, S.R. II, Kennen, J.G., Goldstein, R.M., and Hambrook, J.A., 2002, Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 02–150, 75 p.

Mueller, D.S., and Wagner, C.R., 2009, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A–22, 72 p., accessed July 2012 at *http://pubs.water.usgs.gov/tm3a22.*

Nigh, T.A., and Schroeder, W.A., 2002, Atlas of Missouri ecoregions: Missouri Department of Conservation, 212 p.

Nowak, D.J., and Greenfield, E.J., 2010, Evaluating the National Land Cover Database tree canopy and impervious-cover estimates across the conterminous United States—A comparison with photo-interpreted estimates: Environmental Management, v. 46, p. 378–390.

Oberg, K.A., Morlock, S.E., and Caldwell, W.S., 2005, Quality-assurance plan for discharge measurements using acoustic Doppler profilers: U.S. Geological Survey Scientific Investigations Report 2005–5183, 35 p.

Omernik, J.M., 1987. Ecoregions of the conterminous United States: Association of American Geographers, v. 77, p. 118–125.

Patton, C.J., and Truitt, E.P., 1992, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of total phosphorus by a Kjeldahl digestion method and an automated colorimetric finish that includes dialysis: U.S. Geological Survey Open-File Report 92–146, 39 p.

Patton, C.J., and Truitt, E.P., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of ammonium plus organic nitrogen by a Kjeldahl digestion method and an automated photometric finish that includes digest cleanup by gas diffusion: U.S. Geological Survey Open-File Report 00–170, 31 p.

Paul, M.J., and Meyers, J.L., 2001, Streams in the urban landscape: Annual Review of Ecology and Systematics, v. 32, p. 333–365.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Goss, S.K., and Hughes, R.M., 1989, Rapid bioassessment protocols for use in streams and rivers—Benthic macroinvertebrates and fish: EPA/444/ 4–89/001, U.S. Environmental Protection Agency, Washington, D.C.

Poulton, B.C., Rassmussen, T.J., and Lee, C.J, 2007, Assessment of biological conditions at selected stream sites in Johnson County, Kansas, and Cass and Jackson Counties, Missouri, 2003 and 2004: U.S. Geological Survey Scientific Investigations Report 2007–5108, 68 p.

Rabeni, C.F., Sarver, R.J., Wang, N.,Wallace, G.S., Wieland, M., and Petersen, J.T., 1997, Development of regionally based biological criteria for streams of Missouri: Unpublished report to the Missouri Department of Natural Resources from the U.S. Geological Survey, 270 p.

Rasmussen, T.J., Lee, C.J., and Ziegler, A.C., 2008, Estimation of constituent concentrations, loads, and yields in streams of Johnson County, northeast Kansas, using continuous water-quality monitoring and regression models, October 2002 through December 2006: U.S. Geological Survey Scientific Investigations Report 2008–5014, 103 p.

Rasmussen, T.J., Poulton, B.C., and Graham, J.L., 2009, Quality of streams in Johnson County, Kansas, and relations to environmental variables, 2003–07: U.S. Geological Survey Scientific Investigations Report 2009–5235, 84 p. with appendices.

Roy, A.H., Rosemond, A.D., Paul, M.J., Leigh, D.S., and Wallace, J.B., 2003, Stream macroinvertebrate response to catchment urbanisation (Georgia, U.S.A.): Freshwater Biology, v. 48, p. 329–346.

Sarver, R.J., 2003a, Semi-quantitative macroinvertebrate stream bioassessment: Jefferson City, Missouri, Missouri Department of Natural Resources, Air and Lands Protection Division, Environmental Services Program 24 p., accessed July 2009 at *http://www.cpcb.ku.edu/datalibrary/assets/library/techdocs/Semiquant2003Aug.pdf*.

Sarver, R.J., 2003b, Stream habitat assessment: Jefferson City, Missouri, Missouri Department of Natural Resources, Air and Lands Protection Division, Environmental Services Program, 40 p., accessed February 2008 at *http://www.cpcb.ku.edu/datalibrary/assets/library/techdocs/Streamhab2003Aug.pdf*.

Sarver, R.J., 2005, Taxonomic levels for macroinvertebrate identifications: Jefferson City, Missouri, Missouri Department of Natural Resources, Air and Lands Protection Division, Environmental Services Program, 30 p., accessed July 2009 at *http://www.cpcb.ku.edu/datalibrary/assets/library/techdocs/Taxlevels2005May.pdf*.

Sarver, R.J., Harlan, Stuart, Rabeni, Charles, and Sowa, S.P., 2002, Biological criteria for wadeble/perennial streams of Missouri: Jefferson City, Missouri, Missouri Department of Natural Resources, Air and Lands Protection Division, Environmental Services Program, 47 p., accessed July 2009 at *http://www.dnr.mo.gov/env/esp/docs/BiologicalCriteriaforWadeableStreamsofMissouri.pdf.*

Sauer, V.B., and Turnipseed, D.P., 2010, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A7, 45 p., accessed August 2012 at *http://pubs.usgs.gov/tm/tm3-a7/*.

Seager, J., and Abrahams, R.G., 1990, The impact of storm sewage discharges on the ecology of a small urban river: Water Science and Technology, v. 22, p. 169–171.

Shannon, C.E., and Weaver, W.W., 1949, The mathematical theory of communication: Urbana, Illinois, University of Illinois Press, 125 p.

Tate, C.M., Cuffney, T.F., McMahon, G., Giddings, E.M.P., Coles, J.F., and Zappia, H., 2005, Use of an urban intensity index to assess urban effects on streams in three contrasting environmental settings, *in* Brown, L.R., Gray, R.H., Hughes, R.M., and Meador, M.R., eds., Effects of urbanization on stream ecosystems: Bethesda, Maryland, American Fisheries Society, Symposium 47, p. 291–315.

The Information Bus Company Software Inc., 2008, TIBCO Spotfire S+ 8.1 for Windows User's Guide, 572 p.

Tukey, J.W., 1953, The problem of multiple comparisons,*in* Braun, H.I, 1994, The collected works of John W. Tukey; Multiple comparisons 1948–1983 (v. VIII): New York, N.Y., Chapman & Hall, 396 p.

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p., accessed August 2012 at *http://pubs.usgs.gov/tm/tm3-a8/*.

U.S. Census Bureau, 2010a, American FactFinder: accessed February 2012 at *http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml*.

U.S. Census Bureau, 2010b, 2010 Tiger/Line® Shapefiles: Census Tracts: accessed February 2012 at *http://www.census.gov/cgi-bin/geo/shapefiles2010/layers.cgi*.

U.S. Environmental Protection Agency, 2002, Using biological data as indicators of water quality: accessed September 2012 at *http://www.epa.gov/owow/monitoring/calm/calm_ch5.pdf*.

U.S. Environmental Protection Agency, 2010, Kansas City, Missouri Clean Water Act Settlement: accessed July 2012 at *http://epa.gov/compliance/resources/cases/civil/cwa/kansascity.html*.

U.S. Geological Survey, 2004, Policy on the use of the FlowTracker for discharge measurements: Office of Surface Water Technical Memorandum 2004.04, p. 6: accessed February 2009 at *http://hydroacoustics.usgs.gov/memos*.

U.S. Geological Survey, 2007, SonTek/YSI FlowTracker firmware version 3.10 and software version 2.11 upgrades and additional policy on the use of FlowTrackers for discharge measurements: Office of Surface Water Technical Memorandum 2007.01, p. 12, accessed February 2009 at *http://hydroacoustics.usgs.gov/memos*.

U.S. Geological Survey, 2010, The USGS Land Cover Institute (LCI), USGS land cover, accessed September 2011 at *http://landcover.usgs.gov/usgslandcover.php*.

U.S. Geological Survey, [variously dated], National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapters A1–A9: accessed April 2008 at *http://pubs.water.usgs.gov/twri9A*.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., and Cushing, C.E., 1980, The river continuum concept: Canadian Journal of Fisheries and Aquatic Sciences, v. 37, p. 130–137.

Wagner, R.J., Boulger R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, tecord vomputation, and fata reporting: U.S. Geological Survey Techniques and Methods1–D3, 51 p.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., and Morgan, R.P., II, 2005, The urban stream syndrome: current knowledge and the search for a cure: Journal of the North American Benthological Society, v. 24, no. 3, p. 706–723.

Wilkison, D.H., Armstrong, D.J., and Blevins, D.W., 2002, Effects of wastewater and combined sewer overflows on water quality in the Blue River Basin, Kansas City, Missouri and Kansas, July 1998–October 2000: U.S. Geological Survey Water-Resources Investigations Report 02–4107, 62 p.

Wilkison, D.H., Armstrong, D.J, Brown, R.E., Poulton, B.C., Cahill, J.D., and Zaugg, S.D., 2005, Water quality and biologic data for the Blue River Basin, Kansas City metropolitan area, Missouri and Kansas, October 2000 to October 2004: U.S. Geological Survey Data Series Report 127, p. 158, [cd rom; *http://pubs.usgs.gov/ds/2005/127/*.

Wilkison, D.H., Armstrong, D.A., and Hampton, S.A., 2009, Water-quality and ecological trends and patterns in the Blue River Basin, Kansas City metropolitan area, Missouri and Kansas, 1998 to 2007: U.S. Geological Survey Scientific Investigations Report 2009–5169, 211p.

Wilkison, D.H., Armstrong, D.J., Norman, R.D., Poulton, B.C., Furlong, E.T., and Zaugg, S.D., 2006, Water quality in the Blue River Basin, Kansas City metropolitan area, Missouri and Kansas, July 1998 to October 2004: U.S. Geological Survey Scientific Investigations Report 2006–5147, 170 p.

Wright, I.A., Chessman, B.C., Fairweather, P.G., and Benson L.J., 1995, Measuring the impact of sewage effluent on the macroinvertebrate community of an upland stream–The effect of different levels of taxonomic resolution and quantification: Australian Journal of Ecology, v. 20, p. 142–149.

Xian, G., and Homer C., 2010, Updating the 2001 National Land Cover Database impervious surface products to 2006 using Landsat imagery change detection methods: Remote Sensing of Environment, v. 114, p. 1676–1686.

Glossary

abundance The number of organisms collected or identified in a sample.

ambiguous child A taxon that occurs at a lower taxonomic level in a group.

ambiguous taxon A taxon for which data are reported at more than one taxonomic level.

ambiguous parent A taxon within a group of ambiguous taxa that is identified at a higher taxonomic level than other taxa in the group.

community metric A calculated numerical value that summarizes some aspect or characteristic of a macroinvertebrate community.

diversity How the abundance of a sample is variably distributed among the taxa in a sample.

dominant taxa The most abundant taxon in a sample.

functional feeding group Classification of taxa that have similar physical adaptations or behavior for food acquisition.

macroinvertebrate Animals that do not have backbones, such as worms, crustaceans and insects, that are visible to the unaided eye.

macroinvertebrate community The listing of macroinvertebrate taxa and their relative abundances found in a designated stream reach or sample.

relative abundance The percentage composition in a sample of a particular taxon.

richest-targeted habitat The habitat in a stream reach, usually riffle habitat, with the theoretically richest macroinvertebrate community.

similarity A measure of how alike two or more samples are based on taxa composition and abundance.

taxa The plural of taxon.

taxa richness The number of taxa in a sample.

taxon A group of related organisms that are sufficiently distinct that can be placed in a definite category of the taxonomic hierarchy and designated with a unique name.

taxonomic hierarchy The ordering of taxa into groups based on morphological similarity. The hierarchal order from most general to most specific similarity is: phylum, class, order, suborder, family, subfamily, tribe, genus, and species.

tolerance A numerical value assigned to a taxon from low (intolerant) to high (tolerant) to indicate a taxon's tolerance to pollution and environmental stress.

Tables

Table 2. Measured and calculated habitat scores and selected physical properties, streamflow, and water-quality parameters for macroinvertebrate samples. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Table 4. Macroinvertebrate community richness by major taxonomic group and site with summaries by basin category for combined spring and fall samples, 2007 through 2011. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Table 5. List of macroinvertebrate taxa identified in samples collected at sites in Kansas City and Independence, Missouri, and selected sites in Cass and Ray Counties, Missouri, March 2007 through March 2011. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Table 8. Tolerance values and functional feeding groups for taxa identified at study sites, March 2007 through March 2011. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Table 10. Five most dominant taxa and functional feeding groups collected at macroinvertebrate sampling sites, March 2007 through March 2011. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Table 11. Selected macroinvertebrate metric values and multimetric indices for spring and fall samples, March 2007 through March 2011. The Excel file may be downloaded from *http://pubs.usgs.gov/sir/2012/5284/downloads/tables.xlsx*.

Publishing support provided by:
Rolla and Lafayette Publishing Service Centers

For more information concerning this publication, contact:
Director, USGS Missouri Water Science Center
1400 Independence Road
Rolla, MO 65401
(573) 308–3667

Or visit the Missouri Water Science Center Web site at:
http://mo.water.usgs.gov

Back cover. Top, left to right—South Grand River below Freeman, Missouri. Photograph by Heather M. Krempa, U.S. Geological Survey. U.S. Geological Survey personnel preparing to collect macroinvertebrate samples, Rock Creek at Kentucky Road in Independence, Missouri. Photograph by Sophia A. Mingoia, U.S. Geological Survey. U.S. Geological Survey personnel collecting macroinvertebrate samples, Rock Creek at Kentucky Road in Independence, Missouri. Photograph by Sophia A. Mingoia, U.S. Geological Survey.

Middle, left to right—Macroinvertebrate sampling net and kick sample. Photograph by Heather M. Krempa, U.S. Geological Survey. Macroinvertebrate sampling net and kick sample. Photograph by Heather M. Krempa, U.S. Geological Survey. Crayfish (*Orconectes* sp.). Photograph by Sophia A. Mingoia, U.S. Geological Survey.

Bottom, left to right— Dobsonfly (*Corydalus cornutus*). Photograph by Heather M. Krempa, U.S. Geological Survey. Mayfly (*Baetisca* sp.) under a microscope. Photograph by Scott A. Grotheer, National Water Quality Laboratory. U.S. Geological Survey personnel identifying macroinvertebrates at the National Water Quality Laboratory in Lakewood, Colorado. Photograph by Scott A. Grotheer, National Water Quality Laboratory.

USGS

Christensen and Krempa—**Assessment of Macroinvertebrate Communities in Adjacent Urban Stream Basins, Kansas City, Missouri, 2007 through 2011**—SIR 2012–5284