Prepared in cooperation with the Indianapolis Department of Public Works, Engineering Division

Biological Assessment and Streambed-Sediment Chemistry of Streams in the Indianapolis Metropolitan Area, Indiana, 2003–2008

Scientific Investigations Report 2012–5096

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

Cover. Stream Ecosystem. (Painting by Rick Hill, Kentucky Department of Fish and Wildlife Resources.)

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KEN SALAZAR, Secretary

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

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

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

°F=(1.8×°C)+32

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

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

Concentrations of chemical constituents in bed sediments are given either in grams per kilogram (g/kg) or micrograms per kilogram (µg/kg).

Concentrations of dissolved oxygen in water are given as milligrams per liter (mg/L).

Abbreviations and initialisms used in this report:

CSO	Combined-sewer overflow
CSS	Combined-sewer system
DPW	Department of Public Works (Indianapolis)
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera Index
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
NAWQA	National Water-Quality Assessment Program
NWQL	National Water Quality Laboratory
Ohio EPA	Ohio Environmental Protection Agency
PCB	Polychlorinated biphenyls
PEL	Probable effect level
SVOC	Semivolatile organic compounds
TEL	Threshold effect level
USGS	U.S. Geological Survey
WWTF	Wastewater-treatment facility

Biological Assessment and Streambed-Sediment Chemistry of Streams in the Indianapolis Metropolitan Area, Indiana, 2003–2008

By David C. Voelker

Abstract

During 2003–2008, the U.S. Geological Survey sampled 13 sites in the Indianapolis metropolitan area in Indiana for benthic invertebrates, fish communities, and streambed-sediment chemistry. Data from seven White River sites and six tributary sites complement surface-water chemistry data collected by the Indianapolis Department of Public Works. The information is being used to assess changes in water quality in conjunction with the City's programs to reduce combined sewer overflows and other point and nonpoint sources of pollution in the Indianapolis area.

During the study, 233 benthic-invertebrate taxa were identified from which the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index, the Hilsenhoff Biotic Index (HBI), and the Invertebrate Community Index (ICI) were calculated. EPT index scores ranged from 2 to 16 on the White River and from 2 to 17 on the tributaries. EPT index scores indicate that these pollution-intolerant taxa are more prevalent upstream from and away from the combined-sewer areas of Indianapolis. HBI scores from sites on the White River ranged from 4.67 (good) to 9.55 (very poor), whereas on the tributaries, scores ranged from 4.21 (very good) to 8.14 (poor). Lower HBI scores suggest that less organic pollution was present and, like the EPT scores, indicate better conditions where combined-sewer overflows (CSOs) are not present. Similarly, ICI scores indicated better conditions upstream from the CSO outfalls on the White River. White River scores ranged from 12 to 46, where higher ICI scores indicate better conditions in the benthic-invertebrate community. ICI scores at the tributary sites ranged from 12 to 52, with the highest scores on streams without CSOs.

Fish-community data collected during 2006 and 2008 identified 65 taxa (51 on the White River and 53 on tributaries). The Centrarchidae (sunfishes) were the predominant fishes collected on the White River, while the Cyprinidae (carps and minnows) were predominant on the tributaries. Index of Biotic Integrity (IBI) scores ranged from 20 to 52 on the White River and from 26 to 52 on the tributaries. White River scores all improved from 2006 to 2008.

Streambed sediments were collected at the study sites in 2005 and 2007. The number of chlorinated pesticides detected in those samples increased in 2007, with *trans*-nonachlor, *cis*-chlordane, dieldrin, *trans*-chlordane, and PCBs being most frequently detected. Three organophosphate insecticides were detected. More than 30 semivolatile organic compounds (SVOCs) were detected at more than half the sites sampled. Sites below CSO outfalls had higher concentrations of SVOCs, whereas sites not near CSOs had lower concentrations.

Historical biological data consistently indicated that the Nora site—upstream from CSO influence—showed the least impairment among the White River sites. The data also indicated that the Morris and Harding sites—closest to the CSOs—showed the poorest biological conditions on the White River. The Buck Creek site, followed by the Williams Creek site, scored best among the tributaries, whereas the most urban sites—Fall Creek, Pleasant Run, and Pogues Run—scored the poorest.

Historical numbers of pollution-tolerant and pollution-intolerant organisms in the White River reflect changes at the wastewater treatment facilities in 1983 to tertiary treatment, including ozonation, and in 1994 to chlorination. The advent of ozone treatment of the effluents had a positive effect on the benthic-invertebrate communities downstream from the wastewater treatment facilities. The benthic-invertebrate communities at the upstream site exhibited minor yearly variations until a chemical spill in 1999 had a dramatic impact on the biological communities in the river, including the killing of thousands of fish.

Historical IBI data collection began in 1999 and show that fairly stable fish communities are present in the study area. Like the benthic-invertebrate data, the IBI scores reflect more pollution-tolerant fish communities near the CSO-affected sites. Only the Waverly site on the White River and the Pogues Run site appear to have slightly decreased IBI scores with time, whereas the remaining sites showed only minor year to year variations.

Introduction

Purpose and Scope

This report describes the abundance and diversity of benthic-invertebrate and fish communities and analyses of streambed-sediment chemistry at 13 sites in and around Marion County, Indiana (fig. 1), with emphasis on biotic and streambed-sediment data collected from 2003 through 2008. The data are used to describe the effects that combined-sewer overflows (CSOs) have on receiving streams through differences in biological communities in the CSO-served areas. Benthic invertebrates were collected twice yearly from 2003 through 2008, fish communities were sampled once during 2006 and 2008, and streambed sediments were sampled and chemically analyzed during 2005 and 2007. Methods of study are described and the data are presented in tables and graphs.

This report uses the biological and sediment data to evaluate the location of impaired biological communities relative to areas that receive effluent from CSOs, wastewater treatment facilities, or urbanized areas. The report evaluates biological data by use of biotic indexes to assess the biological condition of the aquatic environment. Benthic-invertebrate communities were assessed with the Ephemeroptera, Plecoptera, and Trichoptera (EPT) index, a modified Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987), and the Invertebrate Community Index (ICI) (Ohio Environmental Protection Agency, 1987). Fish communities were assessed with an Index of Biotic Integrity (IBI). These biological indexes are described, and the results of the analyses are presented. The results indicate how biotic conditions have changed with time. Streambed-sediment chemistry data also are presented. Long-term variations in the data are discussed and referenced to historical data collected during previous cooperative studies from 1981 through 2001 between the U.S. Geological Survey (USGS) and the Indianapolis Department of Public Works (DPW).

Background

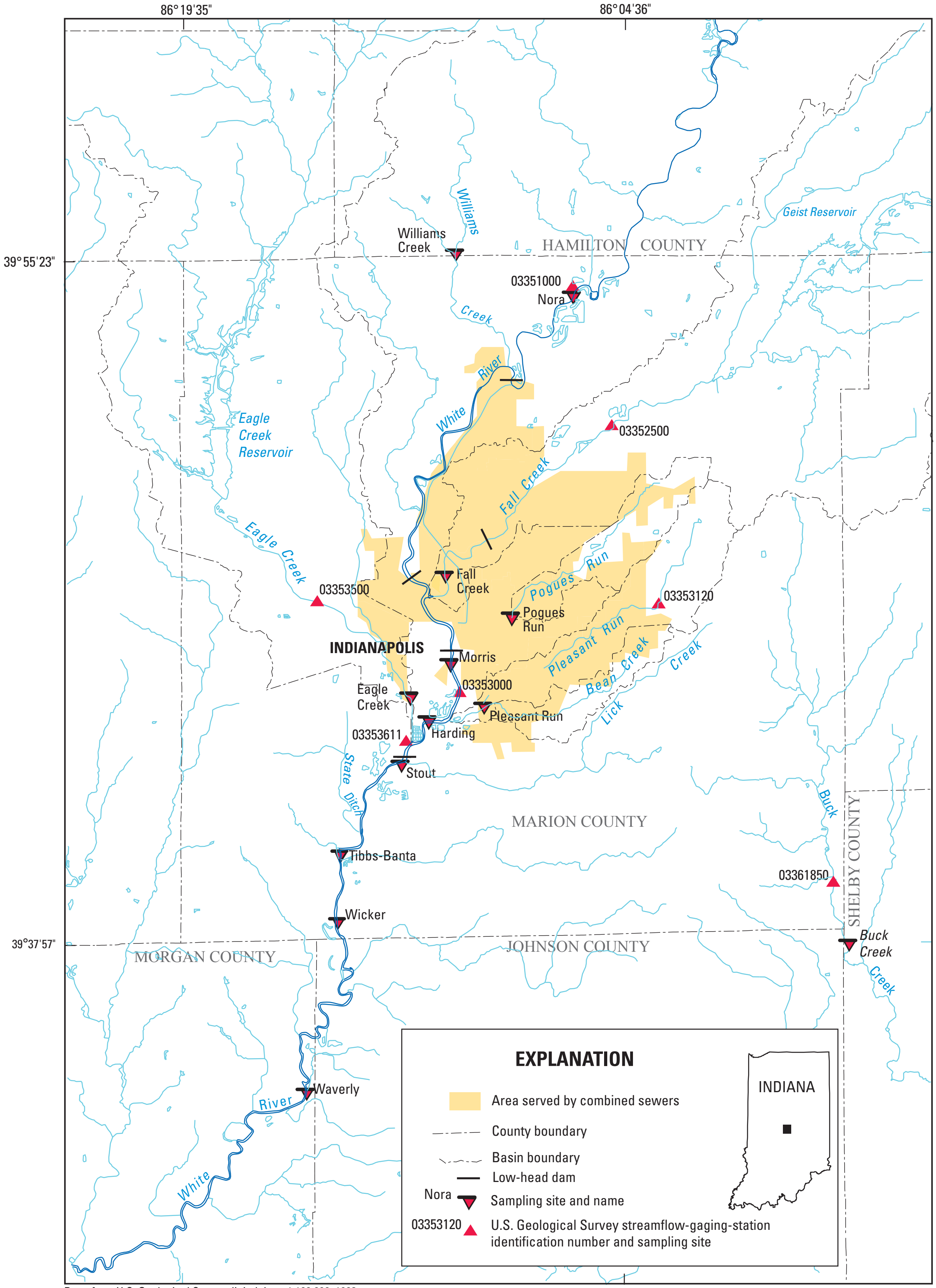
The DPW manages the combined-sewer system (CSS) and is responsible for implementing control strategies to mediate the effects of CSOs on water quality of receiving streams in and around Marion County, including the City of Indianapolis. A CSS is designed, constructed, and operated to carry both sanitary sewage and stormwater runoff in the same system. Diversion structures within the CSS route sanitary sewage to the wastewater-treatment facility (WWTF) during dry weather. During wet weather, the CSS often discharges directly to surface water via CSO outfalls (State of Indiana, 1996).

The U.S. Environmental Protection Agency (EPA) (1999), in its guidance document for monitoring and modeling of CSOs, states that baseline conditions of the receiving water need to be defined. The DPW has an ongoing program to collect and analyze surface-water samples within Marion County; however, if chemical analysis of samples is used as the sole method to determine water quality, substantial effects on the biological communities such as habitat degradation, siltation, and flow alterations can be missed. Therefore, the DPW proposed using biological indicators to monitor the overall health of the White River and its tributaries (City of Indianapolis, 2000).

Evaluation of stream biota is one way to determine cumulative effects of CSOs on water quality because the aquatic organisms are affected by long-term exposure to a variety of environmental stressors, including CSO and WWTF effluent; however, because biological indicators reflect the overall effects from all pollution sources entering the receiving waters, it would be difficult to attribute existing biological conditions directly to the CSOs alone. The EPA (1999) also suggested that investigators should (1) limit the use of biotic indexes as general indicators of environmental effects and (2) limit comparisons within a study to those sites where sampling and sample-analysis methods have been consistent over time.

Receiving waters in the study area for CSO and WWTF effluent include the White River, Pogues Run, Pleasant Run, Eagle Creek, and Fall Creek (fig. 1). Williams Creek and Buck Creek are tributaries of the White River that do not have CSO inputs but can be subject to input from septic systems or sanitary-sewer failures. Because there is little, if any, upstream input from the Indianapolis sewer system, sites at Nora (on the White River) and on Williams and Buck Creeks are considered for the purposes of this study to be the control sites (unaffected by CSOs) for comparing data within the study area.

To achieve the objectives of the Clean Water Act (U.S. Environmental Protection Agency, 2002), comprehensive information about the ecological integrity of aquatic environments is needed. Biotic integrity is described by Karr and Dudley (1981) as the ability to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of a region. Biotic integrity may be the most critical assessment of the water quality of streams because stream biota are subject to a full range of environmental influences (chemical, physical, and biological). Many stream biota complete most or all of their life cycles in the water, thereby serving as continuous monitors of environmental quality. Biological criteria can indicate water-quality impairments, provide data in support of regulatory controls that address water-quality problems, and assess improvements in water quality from regulatory efforts. Biological criteria complement water-quality programs that focus on direct measures of water chemistry and physical properties of the aquatic environment.



Base from U.S. Geological Survey digital data, 1:100,000, 1983.
Albers equal area projection. Standard parallels 29°30' and 45°30', central meridian -86°.
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

0 5 10 MILES
0 5 10 KILOMETERS

Figure 1. Location of the study area and site locations on the White River and tributaries in the Indianapolis metropolitan area.

Benthic-invertebrate and fish-community assessments are used as measures of biotic integrity in streams and rivers. Benthic invertebrates have limited mobility and can be used as indicators of the long-term effects of water quality in streams. Benthic invertebrates can be found in all but the most severely polluted habitats. Fish communities, although much more mobile than benthic invertebrates, can also represent water-quality conditions in a stream. Fish communities are sensitive to a wide variety of environmental factors such as habitat degradation, siltation, pesticides, nutrients (primarily nitrogen and phosphorus), and alterations in streamflow. Absence of fish from a stream may be due to natural or human-induced causes, such as dams or shallow riffles that obstruct fish passage along a stream reach. Diversity among fish communities can be affected by colonization rates, the presence of suitable habitat, extinction rates, competition, predation, physical disturbances, pollution, and other factors (Crowder, 1990).

Streambed-sediment chemistry was investigated to complement the biological data collected by the USGS and streamwater-chemisty data being collected by the DPW Office of Environmental Services. Streambed-sediment sampling helped determine which chemical constituents were attached to the sediments of the Indianapolis metropolitan area and thereby helped explain differences in the biological communities at each site. Streambed sediments strongly affect biological communities because metals and organic chemicals can bind with benthic organic matter, which is a major food source for some stream invertebrates (Benke and Wallace, 1997). Mortality of aquatic invertebrates can be high in urban streams and can indicate possible toxicity associated with streambed-sediment contact or ingestion of toxins associated with the sediments (Pratt and others, 1981; Medeiros and others, 1983). Rochfort and others (2000) indicate that runoff from urban areas, including municipal wastewater discharge, produces increased contaminant loads to streams that often cause a decline in the numbers of taxa (richness) of biological communities in urban streams. Chemical effects of urbanization are variable and depend on the type of urbanization, presence of WWTF effluents and/or CSOs, and the extent of stormwater drainage (Paul and Meyer, 2001). Urbanization is second only to agriculture as a major cause of stream impairment (Paul and Meyer, 2001).

Data collected for this project complement (1) data collected by prior cooperative studies between the DPW and USGS and (2) monthly chemical monitoring of surface waters by the DPW. In the early 1980s, the USGS, in cooperation with the DPW, began a study to assess changes in the benthic-invertebrate communities in the White River in response to changes and upgrades in Indianapolis WWTFs (Crawford and others, 1992). In the 1990s, a second study was begun to assess biological communities and streambed-sediment chemistry in the White River and selected tributaries relative to CSO issues that the City was assessing (Renn, 1998; Voelker and Renn, 2000). A third study during 1999–2001 included benthic-invertebrate and fish communities (Voelker, 2004). During 2003 and 2004, collection of benthic-invertebrate samples resumed. In 2005, there was renewed interest in continued monitoring, and a 4-year cooperative study ensued. Although the biological condition of the studied streams cannot be attributed solely to effects from CSOs, it does reflect the overall effect from all sources entering the receiving waters.

Description of Study Area

Indianapolis is the capital of Indiana and largest city in the State. The city is incorporated with Marion County, and covers approximately 402 square miles (mi^2). Approximately 41 mi^2 are served by a CSO system (fig. 1). In 2007, this system had approximately 130 CSOs that discharged into the White River directly or into several of its tributaries. The rest of the sewer system in Indianapolis consists of separate sanitary and storm sewers and covers slightly more than 200 mi^2. The remaining areas of Indianapolis not served by CSOs or other sewers use private septic systems, but most of these areas are gradually being converted to sanitary sewers (City of Indianapolis, 2007).

The study area is in the Central climate division in Indiana, which is characterized by hot, humid summers and cold, wet winters (Newman, 1966). Physiographically, the study area is within the Eastern Corn Belt Plains ecoregion (Woods and others, 1998). Crop production, primarily corn and soybeans, is the predominant land use outside of the urban areas of Indianapolis (Simon and Dufour, 1997).

The total drainage area of the White River is 5,372 mi^2 at the confluence with the East Fork White River. At the most downstream site sampled (Waverly) the drainage area is 2,026 mi^2. The drainage area at the most upstream site sampled (Nora) is 1,219 mi^2 (Hoggatt, 1975) (table 1). In addition to the CSOs, large inputs to the White River are discharges from the Belmont and Southport WWTFs in the southern reaches of the study area and the Carmel WWTF approximately 3 river miles upstream from the Nora site. The Belmont WWTF has a capacity of 120 million gallons per day (Mgal/d), with peak flows up to 300 Mgal/d. The Southport facility can handle 125 Mgal/d, with peak flows to 180 Mgal/d. Together, the two Indianapolis WWTFs treat more than 70 billion gallons of wastewater each year (City of Indianapolis, 2007).

Annual mean discharges at the 10 streamflow-gaging stations in the study area (table 2) were mostly higher than the mean discharge for the period of record. Annual mean discharges at the four White River sites ranged from 102 to 178 percent of the mean discharge for the period of record at those sites. Similarly, at four of the tributary sites, annual mean discharges ranged from 90 to 169 percent of the mean discharge for the period of record.

Two of the tributary streamflow-gaging stations operated for only 1 year during the study period. Four of the eight streamflow-gaging stations have been in operation for periods that ranged from 16 to 78 years; those stations had the highest annual mean discharges recorded at those sites in either 2007 or 2008.

Table 1. Sites sampled for benthic invertebrates, fish communities, and streambed-sediment chemistry in the Indianapolis metropolitan area, 2003–2008.

[USGS, U.S. Geological Survey; ddmmss, degrees minutes seconds; Ind., Indiana; nr, near; mi, miles; DS, downstream]

Station name	USGS station number	Latitude (ddmmss)	Longitude (ddmmss)	River mile	Drainage area (square miles)	Year first sampled		
						Benthics	Fish	Bed sediment
White River (boat sites)								
White River near **Nora**[1], Ind.	03351000	395435	−860620	247.9	1,219	1981	1999	1994
White River at **Morris** Street, Indianapolis, Ind.	394505086103001	394515	−861026	230.3	1,635	1994	1999	1994
White River at **Harding** Street, Indianapolis, Ind.	03353193	394505	−861030	227.9	1,660	1994	1999	1994
White River below **Stout** Generating Station, Indianapolis, Ind.	394234086120900	394234	−861209	226.2	1,898	1981	1999	1995
White River at **Tibbs**/Banta Landfill near Southport, Ind.	394019086134601	394019	−861346	222.5	1,920	1994	2005	1994
White River at **Wicker** Road near Southport, Ind.	393827086141701	393827	−861417	220.2	1,947	1994	1999	1994
White River at **Waverly**, Ind.	03353660	393402	−861518	211.0	2,026	1981	1999	1994
Tributaries: Wadeable sites								
Eagle Creek at Raymond Street, Indianapolis, Ind.	394613086114700	394411	−861148	1.2	209	1994	1999	1994
Fall Creek at 16th Street, Indianapolis, Ind.	03352875	394720	−861040	1.3	317	1994	1999	1994
Pleasant Run nr South Meridian Street, Indianapolis, Ind.	394358086092100	394358	−860921	1.2	20.8	1994	1999	1994
Pogues Run at Vermont Street, Indianapolis, Ind.	03352990	394617	−860825	2.5	8.87	1994	1999	1994
Tributaries: Headwater sites								
Buck Creek 1.2 mi DS Maze Road near Brookfield, Ind.	393749086030501	393749	−855656	1.9	81.9	1999	2000	2005
Williams Creek at 96th Street, Indianapolis, Ind.	03351072	395537	−861020	4.8	17	1994	1999	1994

[1] Short name used throughout text to identify sites is in **bold** type.

Table 2. Discharge at U.S. Geological Survey streamflow-gaging stations in the study area, 2003–2008.

[WY, water year; ft³/s; cubic foot per second; --, not applicable]

Station name and number	River-mile location	WY 2003	WY 2004	WY 2005	WY 2006	WY 2007	WY 2008	Mean discharge for the period of record	
		Percent normal flow for period of record							
		Annual mean discharge						Period of record	Mean discharge (ft^3/s)
White River near Nora, 03351000	247.9	152	126	148	122	173	161	78 years	
		1,809	1,497	1,763	1,455	2,064*	1,918	1930–2008	1,191
White River at Indianapolis, 03353000	229.2	148	131	153	128	178	172	77 years	
		2,241	1,979	2,316	1,947	2,697	2,613	1931–2008	1,514
White River at Stout Generating Station, 03353611	226.3	117	102	115	107	139	132	16 years	
		2,539	2,205	2,504	2,320	3,006*	2,873	1992–2008	2,171
White River at Centerton, 03354000	199.3	136	118	131	116	154	156	60 years	
		3,615	3,138	3,479	3,086	4,087	4,133*	1948–2008	2,654
Buck Creek at Acton, 03361850	4.1	111	90	122	111	141	149	40 years	
		107	86.5	118	107	136	144	1968–2008	96.4
Eagle Creek at Indianapolis, 03353500	7.1	149	110	118	125	169	153	69 years	
		241	178	191	202	274	248	1939–2008	162
Fall Creek at Millersville, 03352500	9.2	148	135	147	134	160	167	78 years	
		450	411	446	407	485	509	1930–2008	304
Pogues Run at Indianapolis, 03352988	9.74	--	--	--	--	--	100	1 year	
		--	--	--	--	--	9.95*	2007–2008	9.95
Pleasant Run at Arlington Ave. at Indianapolis, 03353120	7.9	118	147	142	133	145	153	48 years	
		10.3	12.8	12.3	11.6	12.6	13.3*	1960–2008	8.69
Williams Creek at 96th St., 03351072	5.13	--	--	--	--	--	100	1 year	
		--	--	--	--	--	36.0*	2007–2008	36.0

* Highest annual mean discharge for the period of record.

Methods of Investigation

Thirteen sites were sampled in the study area, seven of which were on the White River and six on tributaries to the White River (table 1). Most sites were selected to coincide with sites used by the Indianapolis Department of Public Works for monthly water-quality sampling. In addition, several sites were selected to maintain continuity of data collection from previous studies and allow for historical comparison of data. During 2003 and 2004, only benthic-invertebrate data were collected. In 2005 and 2007, benthic invertebrates and bed sediments were sampled, whereas in 2006 and 2008, benthic invertebrates and fish communities were assessed.

Voelker (2004) described sampling locations and conditions for 12 of the sites used in the previous study. Seven are along the White River as it travels through Marion County and into Morgan County (fig. 1). Nora, the most upstream site, is the only site upstream from the CSO-served areas and upstream from the Indianapolis WWTFs. The Stout site is just downstream from a low-head dam on the river and downstream from the Belmont WWTF. Beginning in 2004, an additional site was added to obtain more information on the biology of the White River downstream from the CSO area and just upstream from the Southport WWTF. This site is referred to as the “Tibbs” or “Tibbs-Banta” site in this report, and it is adjacent to and directly north of the Southport WWTF.

The Tibbs site is at river mile 222.5 and has a drainage area of 1,920 mi^2. Benthic invertebrates were collected at the upstream end of an extensive gravel bar. Fish were collected along a 500-meter (m) reach that extended from a riffle at the upstream end of the gravel bar and comprised riffles, runs, and one or two deeper pools.

Six sites were on tributaries in and around Marion County (fig. 1). Two of those sites (Buck Creek and Williams Creek) are outside the CSO-served area. The remaining four tributary sites all receive input from CSOs, although the number and volume of such overflows varies by drainage basin (Voelker, 2004). Pleasant Run has the most CSOs (49), followed by Fall Creek (27), Pogues Run (24), and Eagle Creek (5). Pogues Run is the only site with periods of no flow. In 2004, a wetland was completed in the headwaters of Pogues Run to help mediate the effects of CSOs.

Benthic Invertebrates

Benthic invertebrates are used to assess biological integrity because they occupy all stream habitats and have a wide range of feeding preferences. They are also good indicators of overall stream quality because they respond to environmental stresses and are not very mobile. Benthic invertebrates occupy intermediate levels of the aquatic food chain and are a major food source for fish and other aquatic life. They are an excellent indicator of biological integrity in aquatic environments because much is known about their life cycles and tolerance to environmental stresses (Koryak and Stafford, 2002; Ohio Environmental Protection Agency, 1989; Reece and Richardson, 2000).

Benthic invertebrates were collected twice a year during periods of relatively stable low streamflow. Samples were collected in the spring (May through June) and again in the late summer/early fall (September through October). Higher than normal discharges on occasion resulted in delayed sampling so that benthic-invertebrate samples could be collected during periods of relatively steady-state low flow. Three individual samples were collected from habitats where the greatest diversity and abundance of invertebrates was expected. Such habitats are usually riffle sections; however, those sections were not available at all sites, so the next best available habitat was sampled. Benthic invertebrates were collected at each site by using a Surber sampler with a 0.0929-square-meter sample grid and a collection-net mesh opening of 210 micrometers (µm). Sampling followed the guidelines set forth in Britton and Greeson (1988) and described in Voelker (2004).

Benthic invertebrates were preserved and sent to a laboratory (Pennington and Associates, Cookeville, Tennessee) where they were identified to the lowest possible taxonomy—generally genus and species. For this study, ambiguous taxa were those that could not be identified to species, and these were counted as a distinct taxon only if there were no reported individuals from the next highest taxonomic level. Possible reasons for the inability to classify an organism to species may be that the organism was damaged in the sampling process or that the life stage could not be classified to a lower taxon. The laboratory also calculated the number of organisms in the sample, the number of taxa, and HBI for each set of three samples. The results of the three individual samples were combined to determine the EPT Index, HBI, and ICI scores for each sampling round at each site. The HBI was calculated from pollution-tolerance values assigned to benthic-invertebrate taxa, using the number of individuals in each family and a tolerance value for that family, summing the products, and dividing that sum by the total number of arthropods in the sample. Scores can range from 0 to 10, and they increase with presumed organic contamination. The ICI was developed to provide a descriptive statistic that could be used to compare sites within a study area (Ohio Environmental Protection Agency, 1987). The ICI consists of 10 structural and functional community metrics that describe the benthic-invertebrate community sampled. The metrics include total number of taxa present; number of mayfly (Ephemeroptera), caddisfly (Trichoptera), and Dipteran taxa present; percent mayfly (Ephemeroptera), caddisfly (Trichoptera), Tribe Tanytarsini midge composition, other Dipteran and non-insect composition, and tolerant organisms; and total number of EPT taxa.

Fish

Fish communities were sampled because, although they are more mobile than benthic invertebrates, they typically remain in a particular stream reach for their entire life cycle. Similar to benthic invertebrates, fish also are sensitive to water-quality conditions, with limited options to escape stressors in their environment. Because of these factors, fish-community data also are a reliable indicator of long-term water-quality conditions in a stream.

Fish communities were sampled during the summer in 2006 and 2008 in accordance with guidelines established by the USGS National Water-Quality Assessment (NAWQA) Program (Meador and others, 1993) and the Indiana Water Science Center quality-assurance plan for fish taxonomic data (Brian Caskey, U.S. Geological Survey, written commun., 2011). On the White River, stream reaches of 500 m were sampled, and on the tributaries, reaches were 150 m in length. The sampled stream-reach lengths were set as close to these distances as possible, and samples were collected as much as was practical between riffle cross sections, because riffles serve as natural barriers to fish migration out of a given reach. Fish were collected by using pulsed direct-current electrofishing techniques. Specially designed electrofishing boats were used at nonwadeable sites (all White River sites), and backpack or tote-barge mounted equipment was used at wadeable stream sites (all tributaries). Two passes were made through each site to sample the fish community. After each pass was completed, the collected fish were identified to species, measured, and weighed, and any external anomalies were identified and recorded. Voucher specimens were collected to provide a reference for fish taxonomic classifications made by this study. Voucher specimens either were collected photographically or were physically preserved in a 10-percent formalin solution and returned to the USGS laboratory. Taxonomic nomenclature followed that established by Nelson and others (2004).

Fish data were analyzed by using the Indiana Index of Biotic Integrity (IBI) developed by Simon and Dufour (1997) for sites in the Eastern Cornbelt Plains Ecoregion. The 12 metrics used in the IBI are described by Simon and Dufour (1997) specifically for use in Indiana. These metrics are based on those developed by the State of Ohio (Ohio Environmental Protection Agency, 1989). The IBI combines measures of fish-community structure, function, and health, and scores are assigned to the sampled fish community relative to a reference fish community.

Streambed-Sediment Chemistry

Streambed sediments were collected in accordance with guidelines set forth by Shelton and Capel (1994) and Radtke (2005). Samples were collected during low streamflow conditions in the summers of 2005 and 2007. Polypropylene scoops were used to collect the topmost layer of wetted fine sediments. These were placed into a glass jar for transport back to the USGS laboratory in Indianapolis for processing. In the Indianapolis laboratory, these samples were split and sieved into two components: a 63-µm fraction for analyzing trace elements, and a 2-millimeter fraction for analyzing organic constituents. The samples were then shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for analysis.

Sediment-quality guidelines were developed in Canada (Canadian Council of Ministers of the Environment, 1995) and were further supported by MacDonald and others (2000). Two assessment values—the threshold effect level (TEL) and the probable effect level (PEL)— are presented in this text for 19 compounds detected in the study area.

Condition of Benthic-Invertebrate Communities

During this study, 233 distinct benthic-invertebrate taxa were identified. A summary list of those taxa is presented in table 3 (at back of report). A complete list of all benthic-invertebrate data for each sample is presented in appendix 1.

Species richness (number of taxa) at the sites ranged from 17 to 60 distinct benthic-invertebrate taxa identified during a single sampling event. Median diversity among all the samples collected at sites along the White River generally decreased downstream, with the upstream sites Nora (41 taxa) and Morris (43 taxa) having the highest number of taxa and Waverly having the lowest (28 taxa) (fig. 2). On the tributaries, Buck Creek (one of the CSO control sites) had the highest median diversity (52 taxa), and Pleasant Run had the lowest (32 taxa). Williams Creek (the other CSO control site) had moderate numbers of taxa (38), an indication that other stressors are affecting this stream.

Dipterans were the dominant taxa found at all sites. Although generally pollution tolerant, the Dipterans also tend to have the greatest range of pollution tolerance among benthic invertebrates (Ohio Environmental Protection Agency, 1989). Among the White River sites, Dipterans composed from about 21 to 63 percent of the samples; at the tributary sites, they composed from 42 to 86 percent of the samples. Although the Diptera were the predominant taxa present, other taxa from the class Insecta often made up a considerable portion of the sample. Those taxa were usually from the primarily pollution-intolerant orders of Ephemeroptera and Tricoptera. Only at the Harding site on the White River were the pollution-tolerant Ostracoda crustaceans at times the overwhelmingly dominant taxa.

The highest (Tibbs, at 22,060/m^2) and lowest (Wicker, at 8,154/m^2) median density of benthic-invertebrate organisms were found on the White River (fig. 3). Of the tributary sites, Fall Creek had the highest density at 19,081/m^2, and Pogues Run had the lowest density at 9,109/m^2.

Benthic-Invertebrate Indexes

Three benthic-invertebrate indexes were calculated to describe the benthic-invertebrate composition at sites. These include the Ephemeroptera, Plecoptera, Trichoptera (EPT) Index, Hilsenhoff Biotic Index (HBI), and the Invertebrate Community Index (ICI).

Ephemeroptera, Plecoptera, Trichoptera (EPT) Index

The EPT index for each site was calculated from the sum of the number of taxa in the Ephemeroptera, Plecoptera, and Trichoptera orders. These pollution-intolerant groups reflect improved water-quality conditions as the number of taxa increases.

During the 2003–2008 study period, the EPT scores on the White River ranged from 16 at Nora (November 2003, May 2005, and October 2006) to 2 at Harding (November 2003) and Wicker (May 2004 and May 2005) (table 4). The median scores at the White River sites ranged from 5 to 8 at sites downstream from the CSO influence. The median score was 13 at Nora—the only site on the White River that was upstream from CSOs (fig. 4).

On the tributaries, EPT scores ranged from lows of 2 at Eagle Creek (June 2008), Fall Creek (May 2004), and Pogues Run (May 2005) to 17 at Buck Creek (September 2007) (table 4). The median scores at these sites ranged from 6 at Fall Creek, Pleasant Run, and Pogues Run to 13 at Buck Creek (fig. 4).

The EPT scores indicate that the greatest numbers of these pollution-intolerant organisms are found upstream from, or away from, the combined-sewer areas. Sites directly affected by CSOs or that are in the more urbanized areas have less diversity among these taxa.

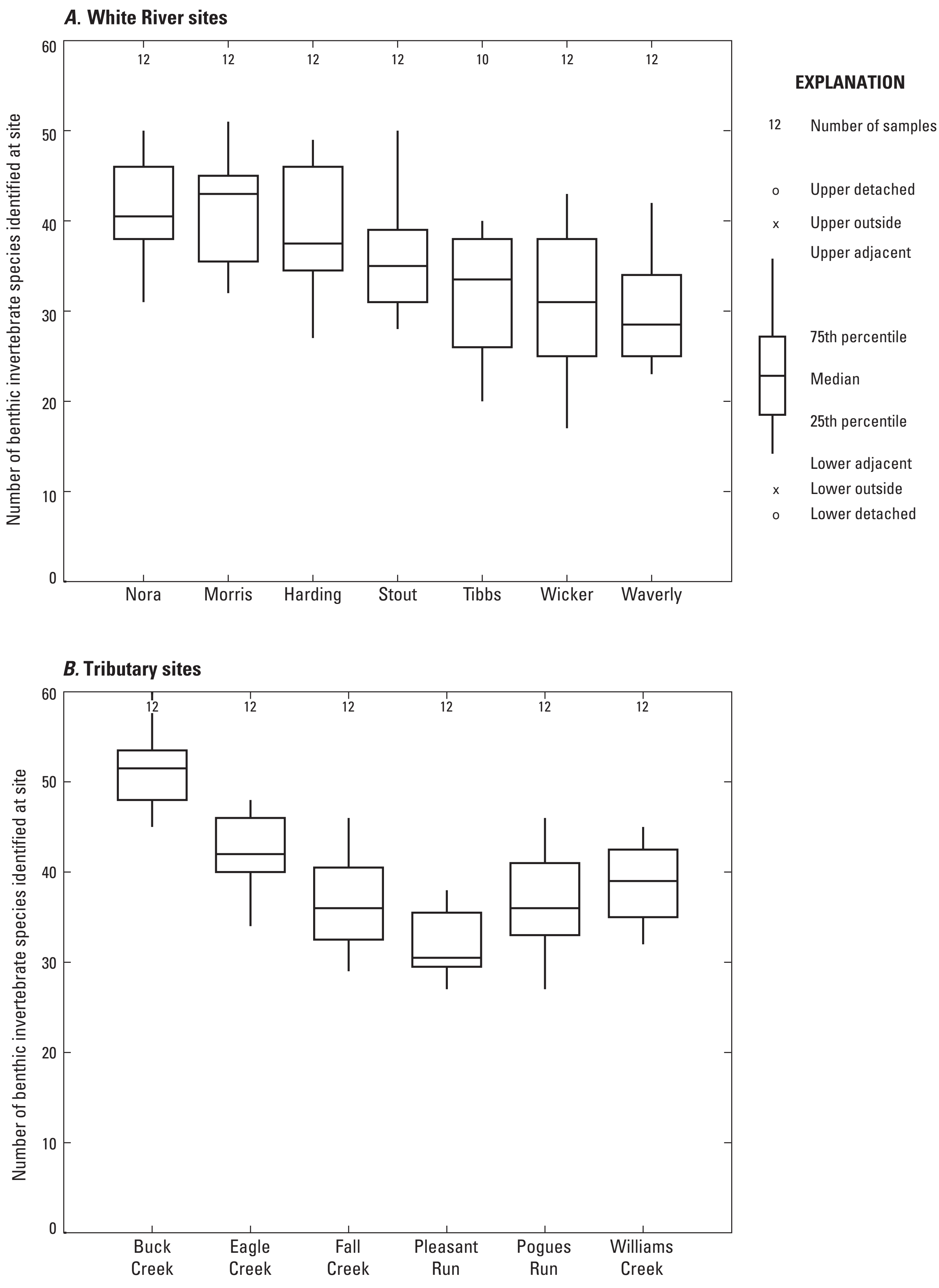


Figure 2. Diversity of the benthic-invertebrate population, 2003–2008. *A*, Sites on the White River. *B*, Tributary sites.

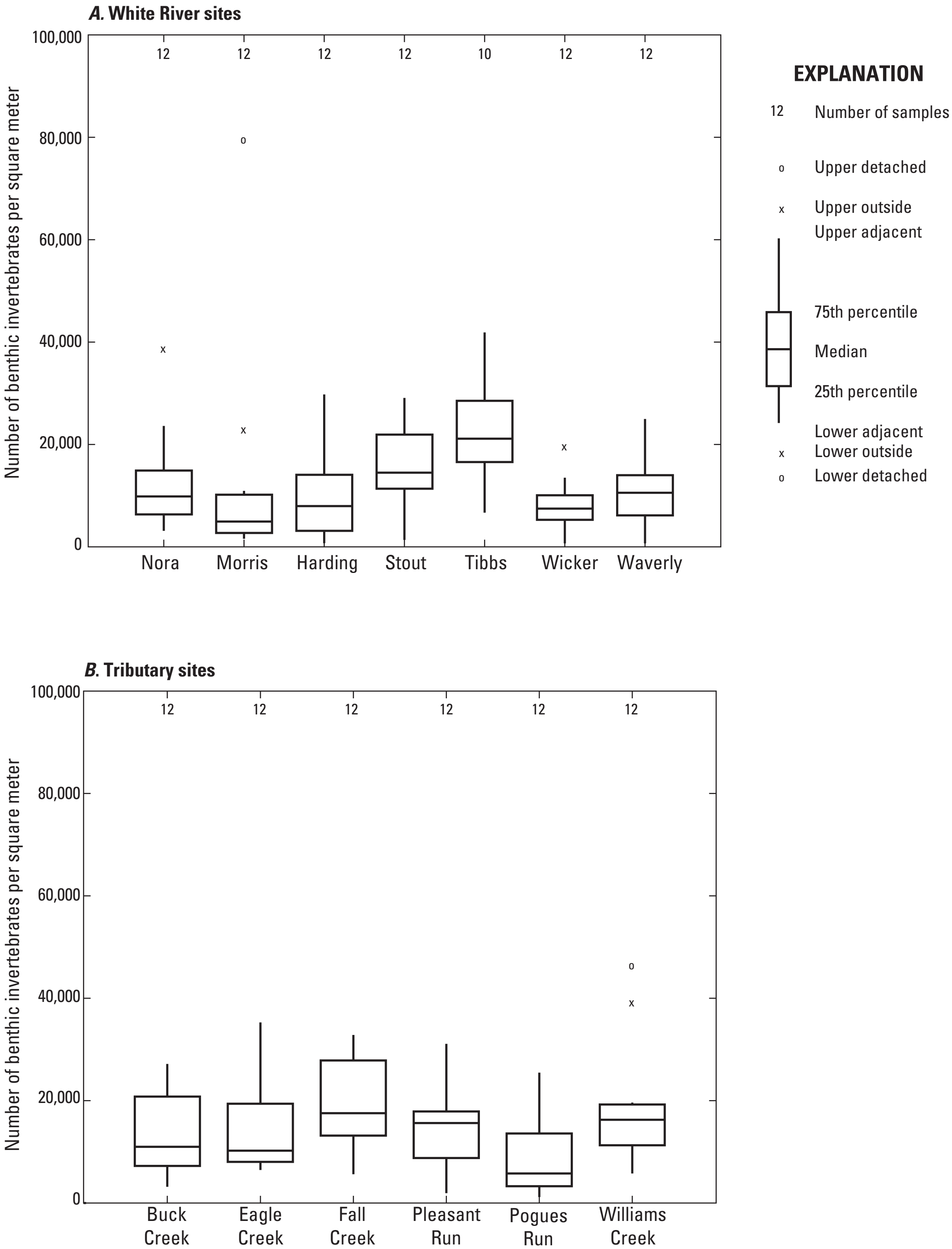


Figure 3. Density of benthic invertebrates, 2003–2008. *A*, Sites on the White River. *B*, Tributary sites.

Table 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores at all sites in the Indianapolis metropolitan area, 1981–2008.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck Creek	Eagle Creek	Fall Creek	Pleasant Run	Pogues Run	Williams Creek
Data from Crawford and others, 1992													
1981	14	--	--	2	--	--	1	--	--	--	--	--	--
1982	11	--	--	1	--	--	0	--	--	--	--	--	--
1983	6	--	--	3	--	--	6	--	--	--	--	--	--
1984	5	--	--	2	--	--	8	--	--	--	--	--	--
1985	9	--	--	4	--	--	3	--	--	--	--	--	--
1986	13	--	--	8	--	--	8	--	--	--	--	--	--
1987	10	--	--	5	--	--	7	--	--	--	--	--	--
Data from Voelker and Renn, 2000													
May 1994	7	5	3	--	5	2	2	--	7	1	0	0	9
September 1994	6	0	0	--	4	6	6	--	4	3	3	1	4
July 1995	6	0	1	3	4	2	3	--	5	3	2	0	4
September 1995	7	3	3	5	5	4	4	--	5	4	4	2	--
July 1996	7	7	6	8	--	--	--	--	6		2	3	5
September 1996	6	4	4	6	5	4	4	--	5	3	5	3	5
Data from Voelker, 2004													
May 1999	12	2	3	4	--	4	6	--	8	4	2	0	7
September 1999	13	5	2	5	--	9	8	15	7	6	7	--	7
May 2000	13	1	0	4	--	2	4	10	8	4	2	1	8
September 2000	10	6	4	6	--	7	6	16	11	6	5	6	12
May 2001	15	4	1	6	--	5	6	16	8	5	3	3	10
September 2001	12	5	5	8	--	6	6	16	10	6	5	4	9
Data from this study													
June 2003	12	7	4	6	--	3	4	15	11	5	5	3	7
November 2003	16	8	2	12	--	4	7	14	8	6	4	8	8
May 2004	9	5	4	5	7	2	6	12	6	2	4	5	7
September 2004	11	5	3	8	6	5	5	13	11	4	6	6	8
May 2005	16	5	7	6	6	2	3	10	9	4	6	2	4
September 2005	14	6	5	7	7	7	8	14	11	7	7	8	6
June 2006	15	6	6	9	12	6	12	7	11	9	4	6	8
October 2006	16	6	5	12	11	9	9	15	6	6	7	5	6
May 2007	13	8	5	8	10	4	5	11	7	4	4	4	8
September 2007	10	4	5	7	9	9	11	17	12	7	10	6	10
June 2008	13	6	4	13	7	6	6	9	2	5	6	6	7
September 2008	9	5	6	10	12	6	6	8	10	8	8	9	9
Median values													
2003–2008	13	6	5	8	8	5.5	6	12.5	9.5	5.5	6	6	7.5
1994–2008	12	5	4	7	7	5	6	14	8	5	5	4	7

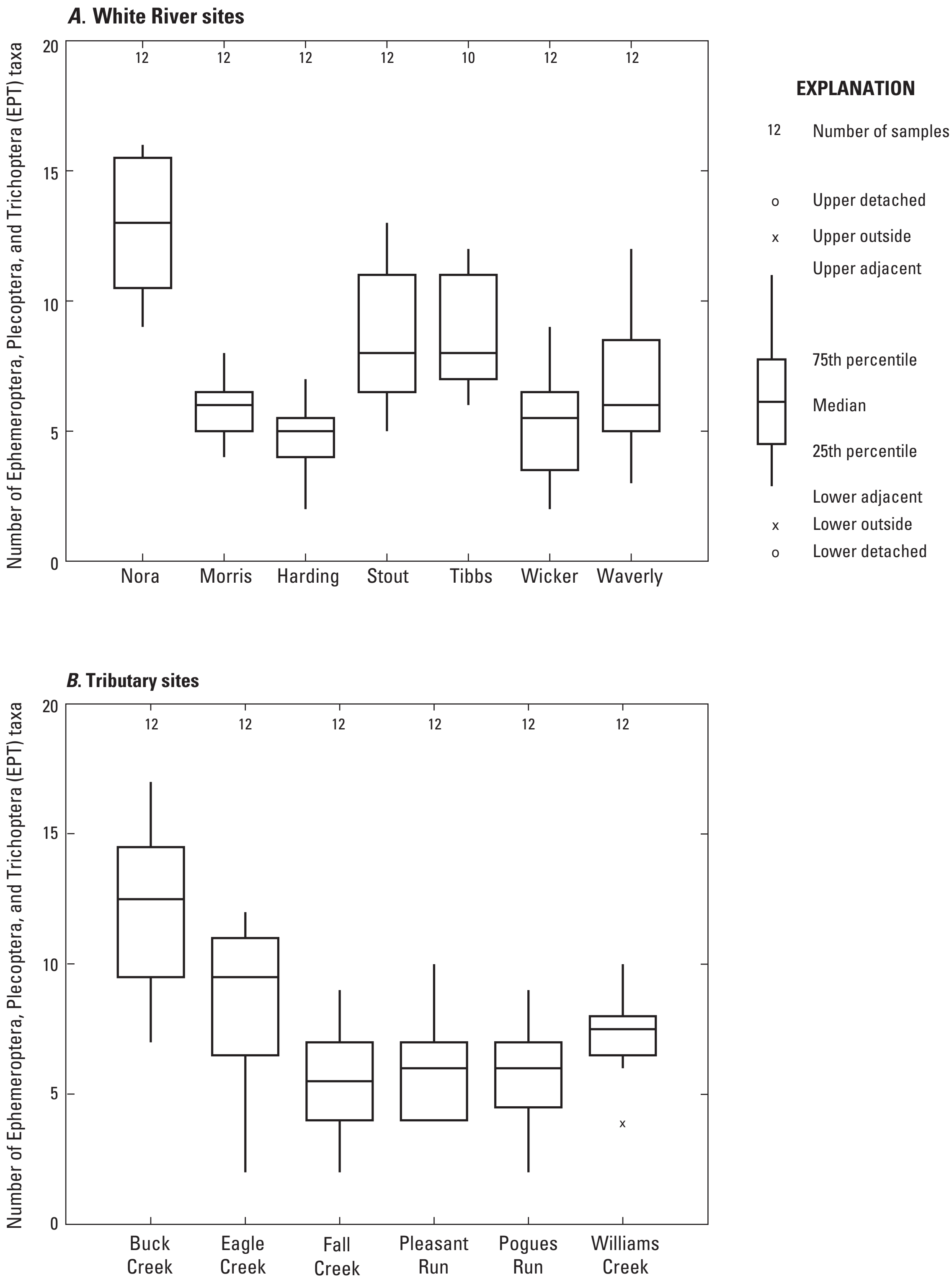


Figure 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores, 2003–2008. *A*, Sites on the White River. *B*, Tributary sites.

Hilsenhoff Biotic Index (HBI)

The HBI was developed to assess organic pollution through its effect on benthic-invertebrate populations. HBI scores for individual sampling events were lowest (4.67, good) at Nora in June 2006 and highest (9.55, very poor) at Morris in September 2008 for sites on the White River (table 5). Median HBI scores for all samples from sites on the White River ranged from 5.78 (fair) at Nora to 8.00 (poor) at Harding (fig. 5). Median scores at the Nora, Wicker, and Waverly sites all rated “good,” indicating some organic pollution present. The HBI scores at the Stout and Tibbs sites rated “fair,” indicating fairly significant organic pollution. The median scores for the Morris and Harding sites both rated “fairly poor” indicating significant organic pollution at those sites.

On the tributaries, HBI scores ranged from a low of 4.21 (very good) at Buck Creek (November 2003) to a high of 8.14 (poor) at Pogues Run (May 2004) (table 5). Median scores ranged from 5.84 (fair) at Williams Creek to 7.1 (fairly poor) at Fall Creek during the study period (fig. 5). All other tributary sites also rated “fair,” indicating fairly significant organic pollution at those sites.

Invertebrate Community Index (ICI)

The ICI was developed to use 10 structural and functional metrics to describe the benthic-invertebrate communities. The ICI was developed to compare sites within a study area and is used to identify streams that are biologically impaired. The higher the ICI score, the less impaired the water-quality conditions at that site.

The ICI scores on the White River ranged from a high of 46 at Nora (June 2008) to 12 at Harding (November 2003) and Wicker (May 2004) during the study period (table 6). The median scores at the White River sites ranged from 35 at Nora to 22 at both Harding and Wicker. As is evident from figure 6, ICI scores were lowest at the Morris, Harding, Wicker, and Waverly sites, which are all downstream from the CSO area. The Stout and Wicker sites have higher ICI scores than the other sites downstream from the CSO area, but none of these sites score as high as the Nora site upstream from the CSO influence.

For sites on the tributary streams, ICI scores ranged from 54 at Buck Creek (September 2004) to 12 at Fall Creek (May 2004) during the study period (table 6). The median scores during the study ranged from 38 (Buck Creek) to 26 (Fall Creek and Pleasant Run) (fig. 6). The remaining sites had median scores from 33 to 35. All of these tributary scores were higher than for most sites on the White River, with the exception of Fall Creek and Pleasant Run.

These ICI scores also indicate that the best conditions in support of pollution-intolerant benthic-invertebrate communities are at the Nora, Buck Creek, and Williams Creek sites. On the White River, data support the thesis that the most impaired communities are at sites downstream from CSOs and in highly urbanized areas.

Condition of Fish Communities

During the course of this study, 65 taxa (including 1 hybrid) were collected (tables 7 and 8, at back of report). On the White River, 51 fish species (1 hybrid) were collected (table 7), whereas on the tributaries, 53 fish species were collected (table 8). A complete list of all fish data for each sample is presented in appendix 2.

On the White River, the number of species identified ranged from 16 at Waverly in 2008 to 27 at Stout in 2008 (table 7). The total number of fish collected at each site ranged from 176 at Harding in 2006 to 710 at Morris in 2008. The Centrarchidae (sunfishes) were 20 percent and the Catostomidae (suckers and buffalo) 12 percent of all fish collected at the White River sites. On the tributaries, the number of species collected ranged from 8 at Pogues Run in 2006 to 34 at Buck Creek in 2008 (table 8). The total number of fish collected ranged from 424 at Eagle Creek in 2006 to 2,345 at Pleasant Run in 2008. Cyprinidae (carps and minnows) made up 30 percent and Centrarchidae made up 12 percent of all fish collected among all the tributary sites in 2006 and 2008.

During the 2008 sampling, sand shiners (*Notropis stramineus*) and central stonerollers (*Campostoma anomalum*) dominated the fish communities at several sites: 369 sand shiners were collected at the Tibbs site, representing 60 percent of that sample’s population; 714 central stonerollers, or 30 percent of the sample population, were among the Pleasant Run sample. The most dominant species by number identified on the White River were sand shiners (14 percent), longear sunfish (*Lepomis megalotis*) (9 percent), bluegill (*Lepomis macrochirus*) (6 percent), spotfin shiners (*Cyprinella spiloptera*) (5 percent), and northern hog suckers (*Hypentelium nigricans*) and central stonerollers (4 percent each). Dominant species at the tributary sites were central stonerollers (17 percent), longear sunfish and bluegill (5 percent each), and creek chubs (*Semotilus atromaculatus*) and sand shiners (4 percent each).

Fish anomalies were identified and recorded while field personnel processed the length and weights of the fish collected. Most anomalies were recorded during the 2006 sampling (table 9). The number of anomalies ranged from zero at Pogues Run to 24 at Stout. During 2008, fish anomalies ranged from a zero at five sites to 13 anomalies at the Nora site. Eroded fins were most often recorded, followed by lesions and ulcers. Fish with leeches and blindness in at least one eye were also more numerous in 2006 than in 2008.

Table 5. Hilsenhoff Biotic Index (HBI) scores at all sites in the Indianapolis metropolitan area, 1981–2008.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck Creek	Eagle Creek	Fall Creek	Pleasant Run	Pogues Run	Williams Creek
Data from Crawford and others, 1992													
1981	5.33	--	--	7.19	--	--	7.35	--	--	--	--	--	--
1982	5.99	--	--	8.41	--	--	9.88	--	--	--	--	--	--
1983	6.69	--	--	7.77	--	--	6.12	--	--	--	--	--	--
1984	5.86	--	--	6.12	--	--	5.21	--	--	--	--	--	--
1985	6.18	--	--	6.88	--	--	5.92	--	--	--	--	--	--
1986	5.03	--	--	5.62	--	--	5.34	--	--	--	--	--	--
1987	5.69	--	--	5.06	--	--	5.3	--	--	--	--	--	--
Data from Voelker and Renn, 2000													
May 1994	5.4	5.9	5.9	--	5.9	6	6	--	6	5.9	6	6.4	5.4
September 1994	5.2	7.96	6.4	--	4.9	5.8	5.2	--	6.8	6.7	6.4	7.8	5.3
July 1995	4.4	7.4	6.8	5.4	5.6	6.3	5.4	--	6.6	6.7	7.1	7	5
September 1995	4.7	6.9	7	4.7	5.5	6.8	4.8	--	6.7	6.6	6.5	6.4	--
July 1996	5.2	9	8.4	6.1	--	--	--	--	6.1		6.2	6.1	5.6
September 1996	4.8	9.2	9.4	6.4	5.7	6.3	4.9	--	6.2	4.9	6.5	6.6	5.2
Data from Voelker, 2004													
May 1999	6.28	7.74	7.82	7.4	--	8.41	7.41	--	7.19	6.45	7.87	7.96	6.47
September 1999	6.08	9.5	9.59	7.01	--	5.56	5.9	5.2	6.92	6.63	7.28	--	6.35
May 2000	6.8	6.98	7.8	7.43	--	7.79	7.29	6.97	6.6	7.59	7.91	7.75	6.19
September 2000	5.62	8.85	9.09	6.53	--	7.79	7.29	5.78	5.78	6.37	6.71	6.55	5.38
May 2001	6.09	7.93	8.04	7.1	--	7.41	7.17	2.86	6.88	7.25	7.24	7.89	6.33
September 2001	4.95	8.2	8.8	5.73	--	5.56	5.63	5.36	5.5	5.69	7.34	6.94	5.46
Data from this study													
June 2003	6.36	7.76	9.04	7.25	--	8.12	7.51	5.93	6.91	7.32	6.51	6.88	5.95
November 2003	5.79	6.84	8.55	6.23	--	6.45	6.03	4.21	6.59	6.41	6.27	6.94	5.28
May 2004	6.21	7.74	7.02	7.68	6.57	7.37	7.18	5.84	6.78	7.74	7.35	8.14	6.04
September 2004	5.92	7.17	6.66	6.18	5.85	6.67	5.97	5.59	5.64	7.19	6.4	6.42	5.44
May 2005	6.73	7.16	8.49	6.81	7.2	7.77	7.48	6.72	6.18	7.05	7.08	7.05	5.9
September 2005	4.85	8.34	9.13	6.48	5.59	5.47	5.37	5.26	5.6	7.76	6.32	5.8	5.42
June 2006	4.67	7.59	7.1	5.53	5.92	5.37	5.67	6.05	5.61	7.14	6.8	6.55	5.78
October 2006	5.71	6.83	8	5.65	5.57	5.65	5.79	6	5.45	6.39	6.8	6.13	6.07
May 2007	6.12	7.87	8.62	6.59	7.79	8.19	7.19	6.88	6.83	8	6.88	6.03	6.65
September 2007	5.38	9.11	7.18	6.38	5.53	5.45	5.19	5.26	5.33	6.56	6.14	6.33	5.05
June 2008	5.77	7.44	6.87	5.75	6.09	6.08	6.65	5.84	5.62	5.83	4.59	5.63	5.99
September 2008	5.77	9.55	9.11	6.98	6.07	7.4	6.38	5.99	6.68	6.07	5.78	6.14	5.36
Median values													
2003–2008	5.78	7.67	8.25	6.43	6.00	6.56	6.21	5.89	5.91	7.10	6.46	6.38	5.84
1994–2008	5.77	7.75	8.02	6.48	5.85	6.45	5.99	5.84	6.40	6.63	6.61	6.55	5.60

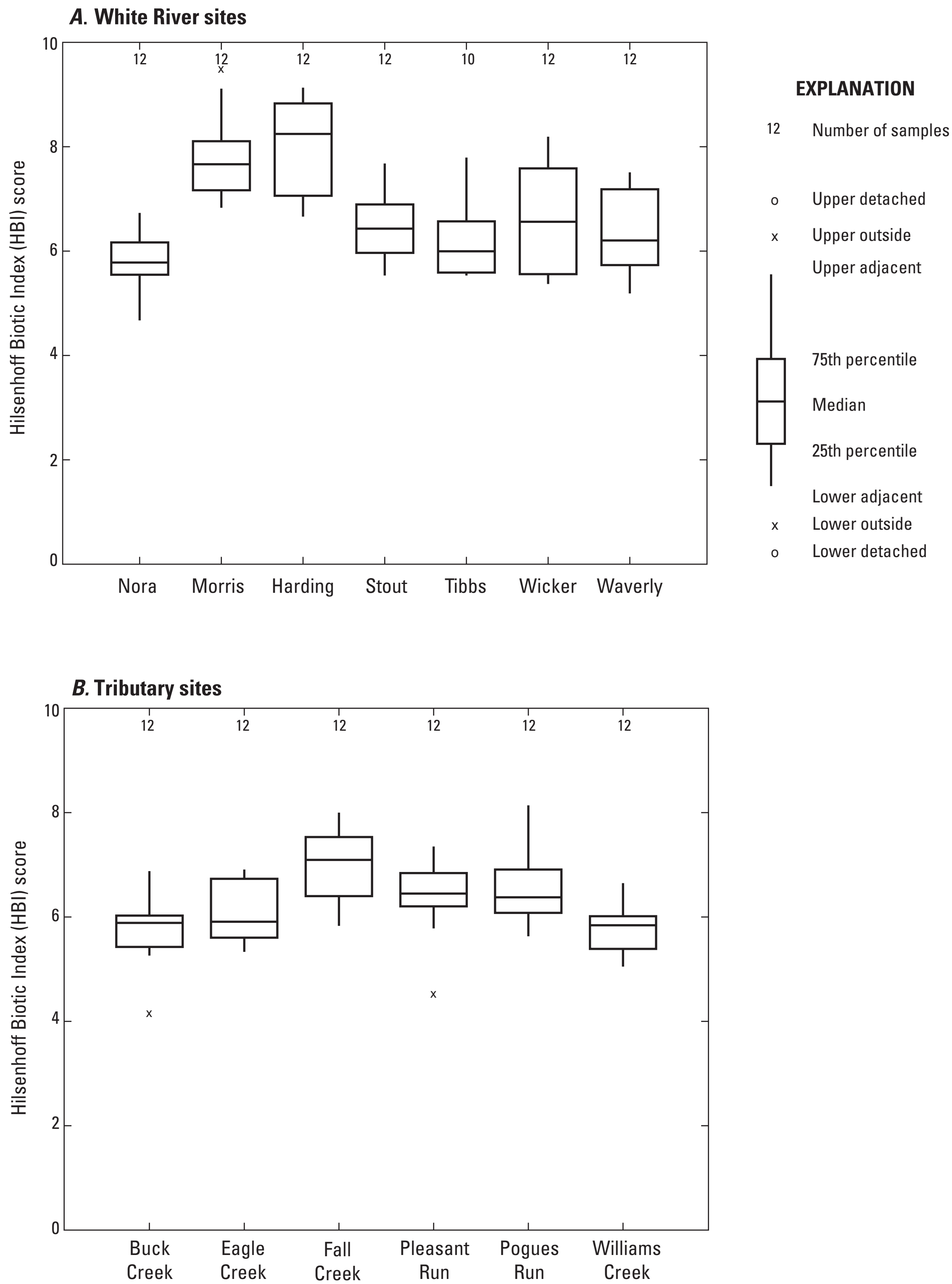


Figure 5. Hilsenhoff Biotic Index (HBI) scores, 2003–2008. *A*, Sites on the White River. *B*, Tributary sites.

Table 6. Invertebrate Community Index (ICI) scores at all sites in the Indianapolis metropolitan area, 1999–2008.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck Creek	Eagle Creek	Fall Creek	Pleasant Run	Pogues Run	Williams Creek
Data from Voelker, 2004													
May 1999	36	16	16	12	--	14	20		26	18	12	4	34
September 1999	38	22	12	26	--	30	30	48	22	22	30	--	36
May 2000	36	14	8	18	--	14	18	30	26	16	10	12	32
September 2000	32	28	20	26	--	24	30	50	34	28	32	36	46
May 2001	32	22	16	22	--	22	22	48	26	20	22	20	36
September 2001	32	22	26	30	--	26	32	50	38	30	30	32	42
Data from this study													
June 2003	34	24	16	24	--	16	18	36	34	26	24	22	40
November 2003	42	26	12	32	--	16	24	42	34	30	26	42	46
May 2004	28	20	20	26	26	12	22	46	30	12	20	26	34
September 2004	32	22	16	30	28	26	24	54	38	20	24	34	32
May 2005	36	22	24	24	20	14	16	34	32	20	24	18	30
September 2005	36	24	22	32	34	26	26	44	42	26	32	38	34
June 2006	42	22	26	36	32	22	30	34	34	30	24	32	44
October 2006	42	22	22	42	36	34	32	40	28	24	30	38	28
May 2007	34	28	22	28	32	34	22	20	30	20	26	34	38
September 2007	28	18	26	28	26	34	34	30	40	30	40	34	42
June 2008	46	30	20	36	24	32	24	26	20	20	26	32	32
September 2008	34	26	30	30	34	46	24	22	32	34	46	46	40
Median values													
2003–2008	35	23	22	30	30	26	24	35	33	25	26	34	36
1994–2008	35	22	21	29	30	26	24	41	32	23	26	34	36

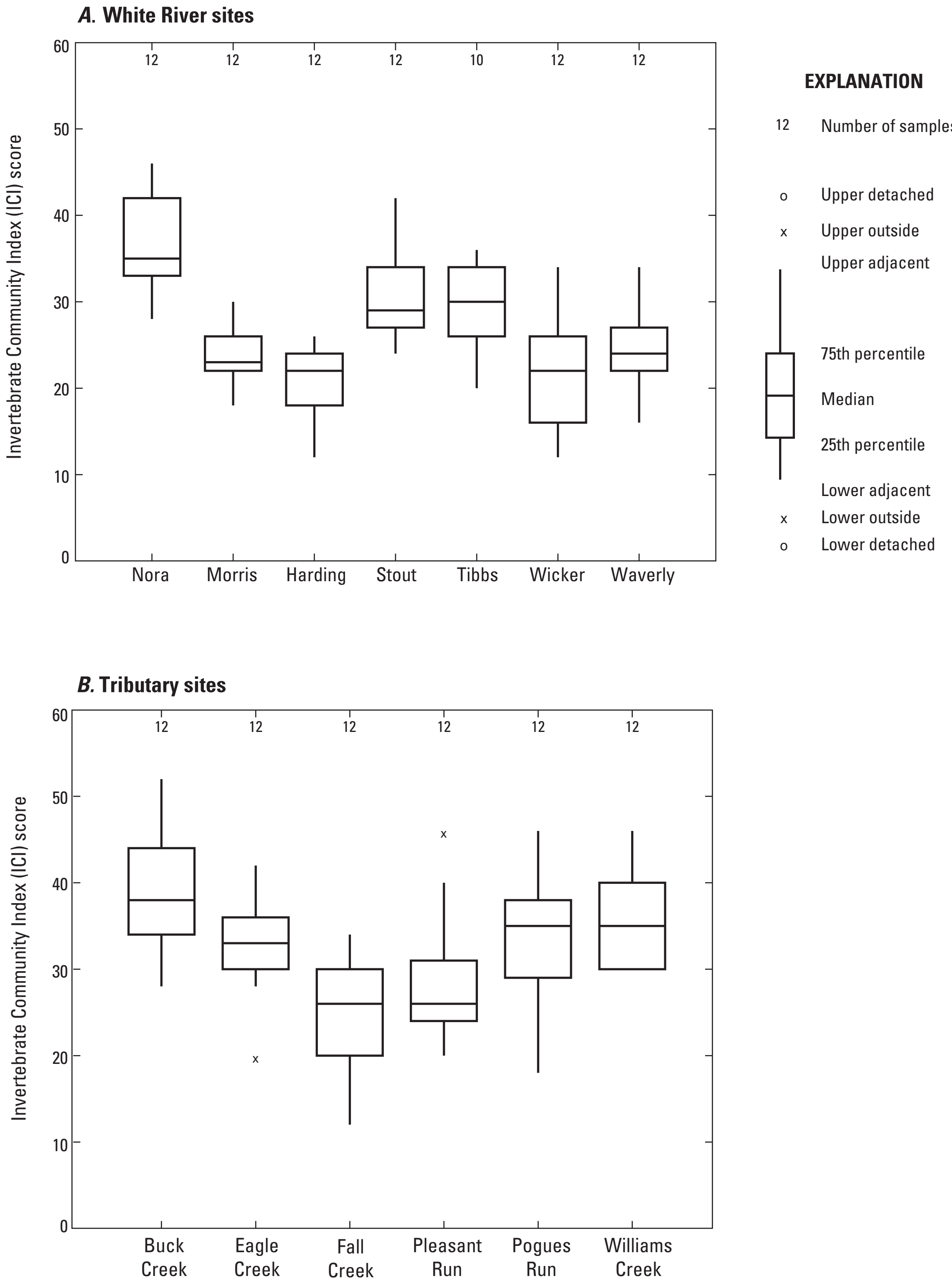


Figure 6. Invertebrate Community Index (ICI) scores, 2003–2008. *A*, Sites on the White River. *B*, Tributary sites.

Table 9. Fish anomalies observed at all sites in the Indianapolis metropolitan area during 2006 and 2008.

Sampling site	Deformi-ties	Eroded fins	Lesions and ulcers	Tumors	Anchor worms	Black spot	Leeches	Fungus	White spot	Blind	Para-sites	Popeye	Total
2006													
Nora	1	1	2	0	0	0	0	0	0	0	0	0	4
Morris	1	2	0	0	0	0	0	0	0	1	0	0	4
Harding	1	0	0	1	0	0	0	0	0	1	0	0	3
Stout	0	6	6	0	0	0	9	0	0	3	0	0	24
Tibbs	0	5	1	0	0	0	0	0	0	1	0	0	7
Wicker	0	1	0	0	0	0	0	0	0	0	0	0	1
Waverly	0	3	2	0	0	0	0	0	0	1	0	0	6
Buck Creek	0	1	1	0	0	0	1	0	0	0	0	0	3
Eagle Creek	0	1	0	0	0	0	0	0	0	0	0	0	1
Fall Creek	0	0	0	0	0	0	0	0	0	0	0	1	1
Pleasant Run	0	1	3	0	0	0	0	0	0	0	0	0	4
Pogues Run	0	0	0	0	0	0	0	0	0	0	0	0	0
Williams Creek	0	1	0	0	0	0	0	0	0	0	0	0	1
Total	3	22	15	1	0	0	10	0	0	7	0	1	59
2008													
Nora	0	3	5	0	0	0	3	0	0	1	1	0	13
Morris	0	0	1	0	0	0	0	0	0	0	0	0	1
Harding	0	4	1	0	0	0	0	0	0	1	0	0	6
Stout	0	1	0	0	0	0	0	0	0	0	0	1	2
Tibbs	0	0	0	0	0	0	0	0	0	0	0	1	1
Wicker	0	0	1	0	0	0	0	0	0	0	0	0	1
Waverly	0	1	0	0	0	1	0	0	0	0	0	0	2
Buck Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Eagle Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Fall Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleasant Run	0	0	0	0	0	1	0	0	0	0	0	0	1
Pogues Run	0	0	0	0	0	0	0	0	0	0	0	0	0
Williams Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	9	8	0	0	2	3	0	0	2	1	2	27

Index of Biotic Integrity (IBI)

The IBI incorporates various metrics relating to species richness, composition, presence/absence of indicator species, trophic and reproductive functions, and overall abundance and/or individual conditions. Scores for each metric are combined; the higher the resultant score, the more robust the fish community.

IBI scores in the White River ranged from 20 (very poor) at Harding to 44 (fair) at Wicker during 2006 and from 34 (poor) at Waverly to 52 (good) at Morris during 2008 (table 10). White River IBIs at individual sites increased from 2006 to 2008, indicating that the condition of the fish community had improved (fig. 7).

Tributary IBI scores ranged from 26 (very poor) at Pogues Run to 52 (good) at Buck Creek and Pleasant Run during 2006 (table 10). During 2008, IBI scores ranged from 26 (very poor) at Pogues Run to 52 (good) at Williams Creek. There was no consistent pattern in IBI scores between the two sampling periods at the tributary sites (fig. 7). IBI scores at Buck Creek and Fall Creek decreased slightly, those at Pogues Run remained the same, and those at Eagle Creek and Williams Creek increased.

Streambed-Sediment Chemistry

Streambed-sediment samples were collected during extended low-flow periods in early August 2005 and late July 2007; data are presented in appendix 3. Physical water-quality parameters (table 3–1) were measured at each site, and the sediments were analyzed for carbon species (table 3–2), chlorinated pesticides (table 3–3), organophosphate pesticides (table 3–4), trace metals (table 3–5), and semivolatile organic compounds (SVOCs) (table 3–6).

Sediment-quality guidelines for the protection of aquatic life, along with the number of sites at which those guidelines were exceeded, are listed in table 11. The TEL is a concentration below which effects on aquatic life occur rarely, and the PEL is a concentration above which effects on aquatic life occur frequently.

Figure 8 shows the number of sites at which selected chlorinated pesticides were detected. This includes the number of sites where the compound was determined to be present; however, a concentration may have been too low to be quantifiable. Among the most frequently detected chlorinated pesticides were *trans*-nonachlor, *cis*-chlordane, dieldrin, *trans*-chlordane, and PCBs. Of the 33 chlorinated pesticides analyzed for, 9 were detected in 2005 and 12 were detected in 2007.

Only three organophosphate pesticides were detected in the streambed-sediment samples (fig. 9). Chlorpyrifos, a broad-spectrum organophosphate insecticide originally used to kill mosquitoes, was detected at eight sites in 2005. Diazinon, an insecticide used to control cockroaches, silverfish, ants, and fleas in residential, non-food buildings, was detected at four sites during 2005. Ethoprophos, a soil insecticide and nematocide, was detected at three sites and only during the 2007 sampling.

Numerous SVOCs were detected in the streambed sediments collected in both 2005 and 2007 (figs. 10 and 11). Similar results for the two sampling periods showed that more than 30 of these compounds were detected at more than half of the sites sampled. Of the 69 SVOCs analyzed for, 35 were quantified in 2005 along with an addition 6 that were detected but not quantified; in 2007, 30 were quantified and an additional 13 were detected but not quantifiable. In general, the Buck Creek site had the lowest number of detectable SVOCs, as well as the lowest concentrations of these compounds in the streambed sediments (table 3–6). The Harding site on the White River had the highest concentrations of these compounds among all the sites in the study area.

SVOCs detected at every site during both sample periods include nitrobenzene-d5, 2-fluorobiphenyl, fluoranthene, phenanthrene, pyrene, and terphenyl-d14. Most of these compounds are produced by the combustion of hydrocarbon fuels and organic materials (Verschueren, 1983). Several are also characteristic of coal-tar-based parking lot sealcoat (Mahler and Van Metre, 2011), commonly found in metropolitan areas.

Table 10. Index of Biotic Integrity (IBI) scores at all sites in the Indianapolis metropolitan area, 2006 and 2008.

Sampling site	2006 IBI score	Habitat status	2008 IBI score	Habitat status
White River sites				
Nora	38	Poor to fair	46	Fair to good
Morris	32	Poor	52	Good
Harding	20	Very poor	36	Poor to fair
Stout	42	Fair	46	Fair to good
Tibbs	40	Fair	42	Fair
Wicker	44	Fair	46	Fair to good
Waverly	30	Poor	34	Poor
Tributary sites				
Buck Creek	52	Good	50	Good
Eagle Creek	40	Fair	44	Fair
Fall Creek	52	Good	50	Good
Pleasant Run	40	Fair	44	Fair
Pogues Run	26	Very poor to poor	26	Very poor to poor
Williams Creek	44	Fair	52	Good

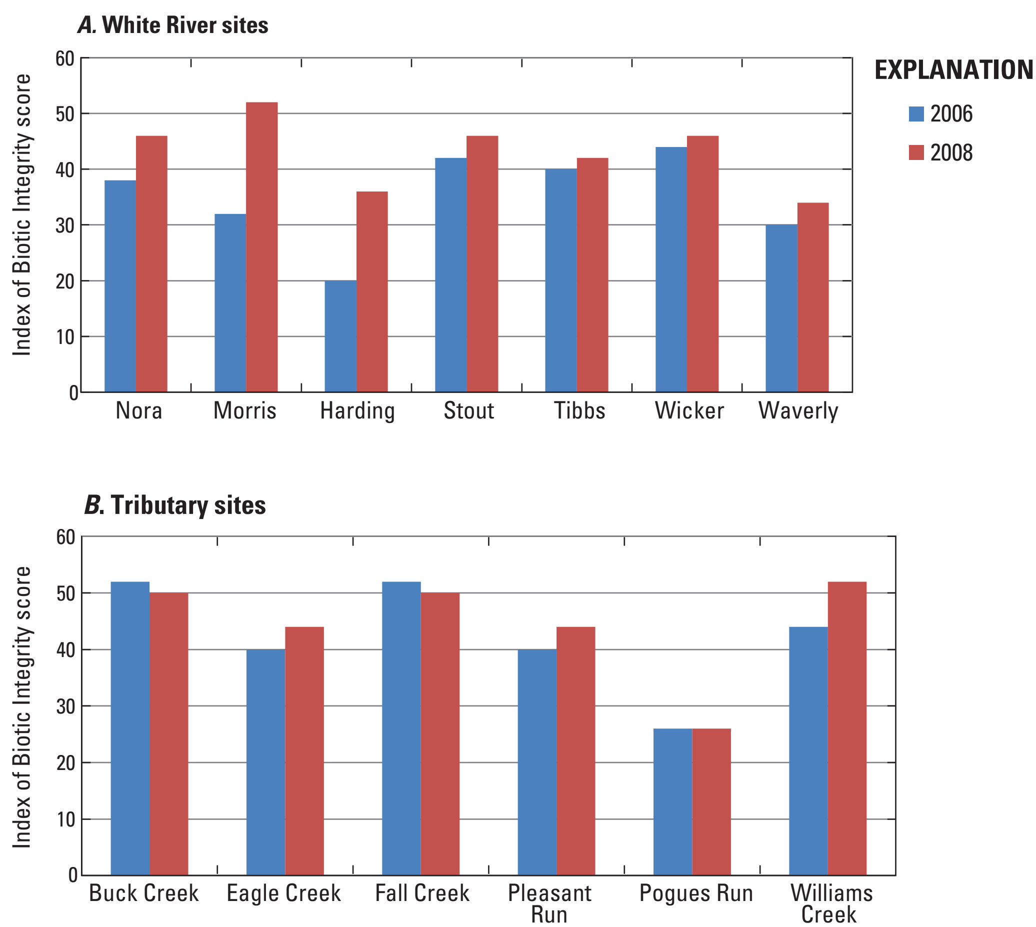


Figure 7. Index of Biotic Integrity (IBI) scores, 2006 and 2008. *A*, Sites on the White River. *B*, Tributary sites.

Table 11. Freshwater-sediment Threshold Effect and Probable Effect Levels for the protection of aquatic life (modified from Canadian Council of Ministers of the Environment, 1995).

Chemical constituent	Threshold Effect Level[1] (TEL)	Number of sites where TEL exceeded	Probable Effect Level[2] (PEL)	Number of sites where PEL exceeded	Observed range in concentrations
Metals, in micrograms per gram					
Arsenic	5.9	13	17	2	7.7–21
Cadmium	0.596	13	3.53	2	0.5–6.7
Chromium	37.3	13	90	4	42–160
Copper	35.7	13	197	0	29–150
Lead	35	11	91.3	8	21–190
Mercury	0.174	9	0.486	2	0.05–1.16
Nickel	18	13	35.9	8	22–55
Zinc	123	13	315	4	110–480
Pesticides, in micrograms per kilogram					
Chlordane	4.5	2	8.9	0	<1–7
p,p′-DDD	3.54	2	8.51	0	<1–5
p,p′-DDE	1.42	1	6.75	0	<1–4
Dieldrin	2.85	2	6.67	0	<1–4
Miscellaneous organics, in micrograms per kilogram					
PCB’s, total	34.1	7	277	1	30–440
Semivolatile organic compounds, in micrograms per kilogram					
Benzo[*a*]anthracene	31.7	13	385	8	<50–2,600
Benzo[*a*]pyrene	31.9	13	782	2	<50–2,800
Chrysene	57.1	13	862	2	<50–3,200
Fluoranthene	111	13	2,355	1	33–4,800
Phenanthrene	41.9	12	515	7	21–2,200
Pyrene	53	13	875	8	29–4,100

[1]Threshold Effect Level (TEL): the concentration below which adverse effects on aquatic life occur rarely.

[2]Probable Effect Level (PEL): the concentration above which adverse effects are predicted to occur frequently.

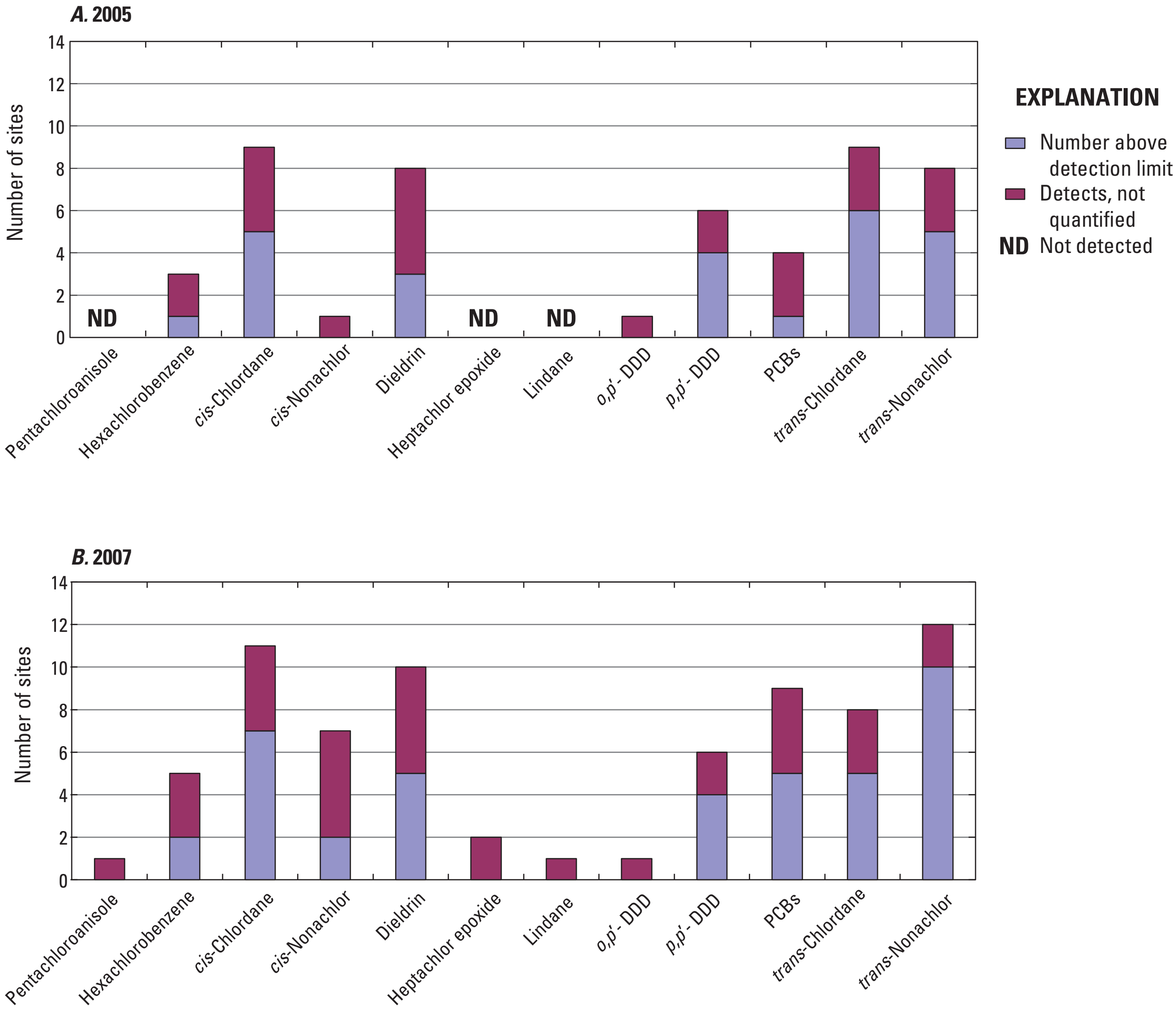


Figure 8. Number of sites at which chlorinated pesticides were detected in streambed-sediment samples. *A*, 2005. *B*, 2007.

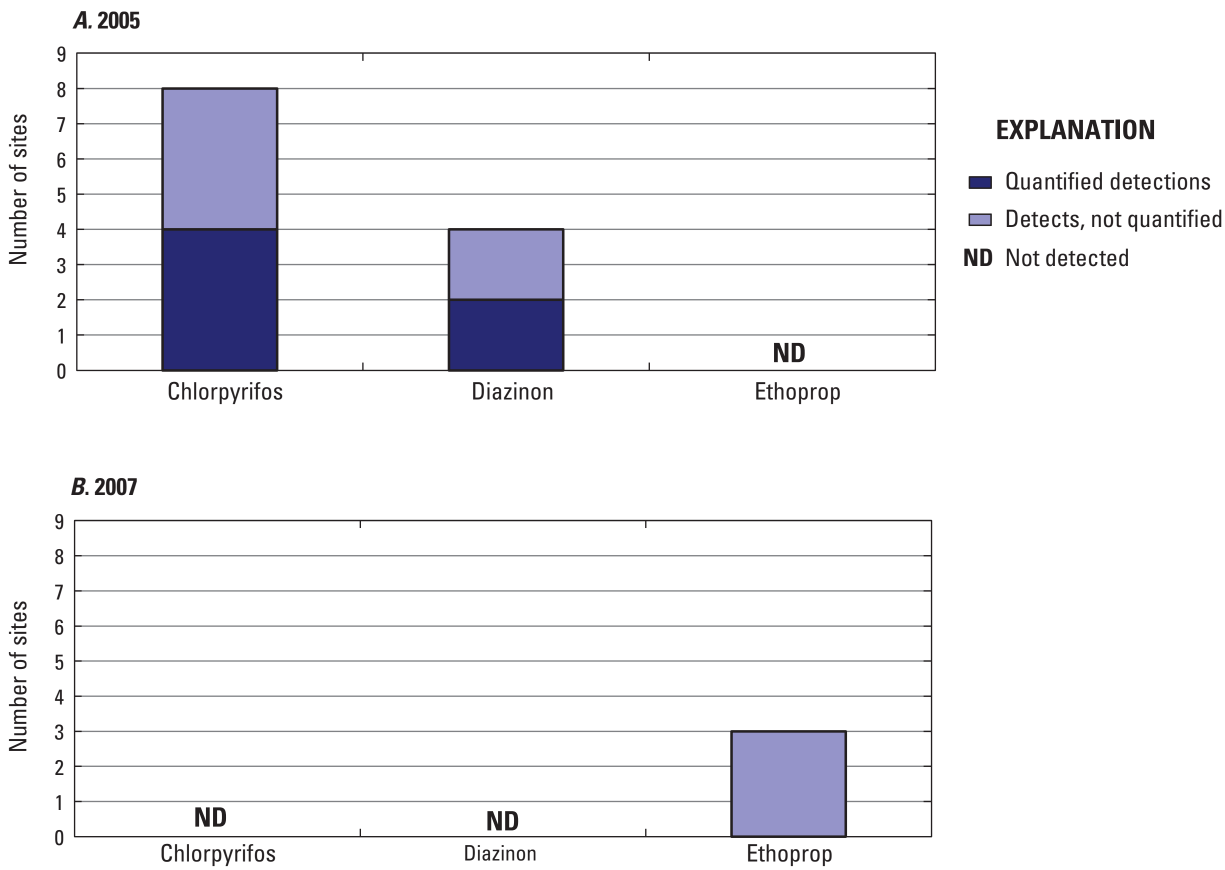


Figure 9. Number of sites at which organophosphate pesticides were detected in streambed sediment samples. *A*, 2005. *B*, 2007.

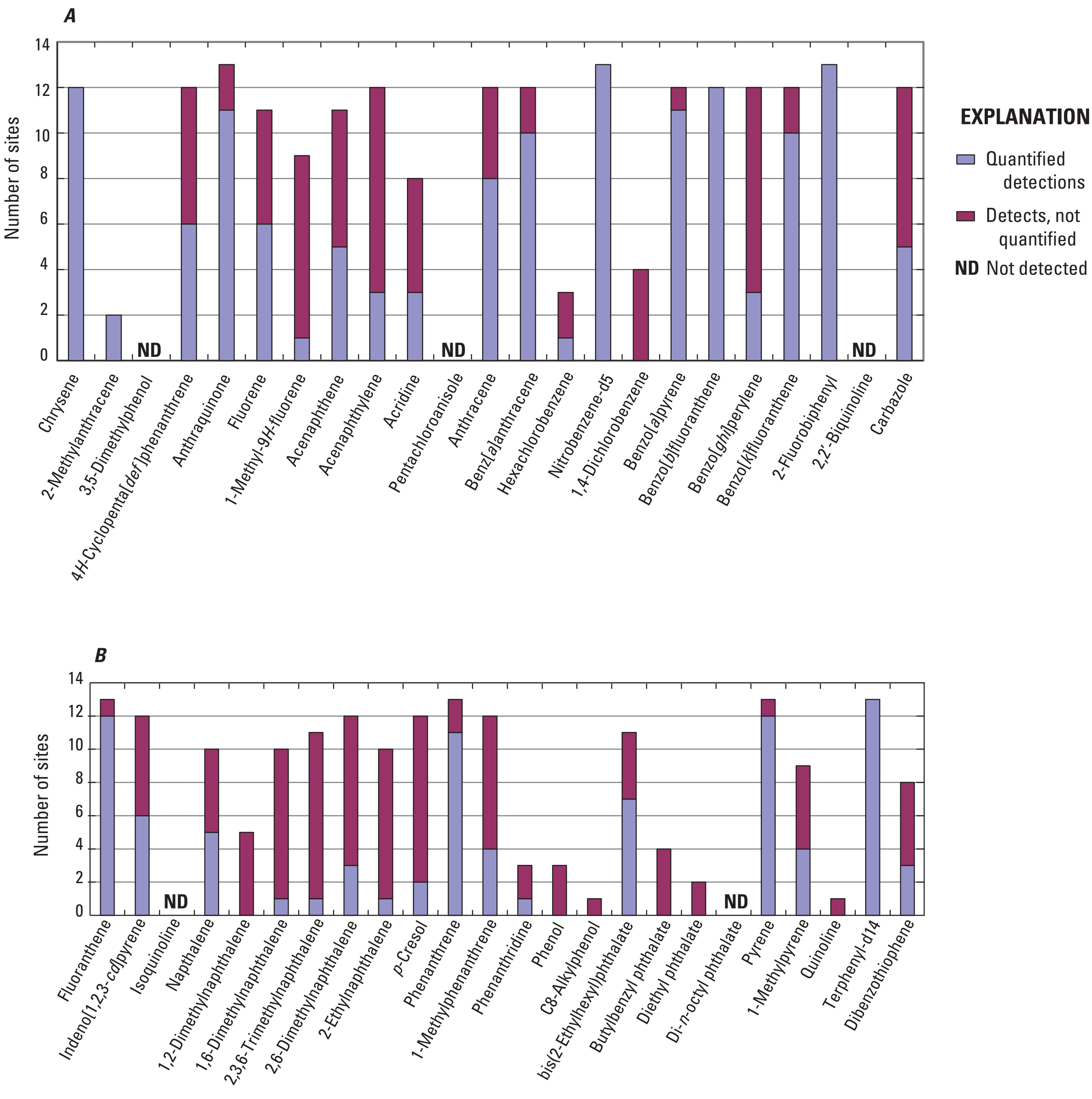


Figure 10. Number of sites at which selected semivolatile organic compounds (SVOCs) were detected in streambed sediments, 2005.

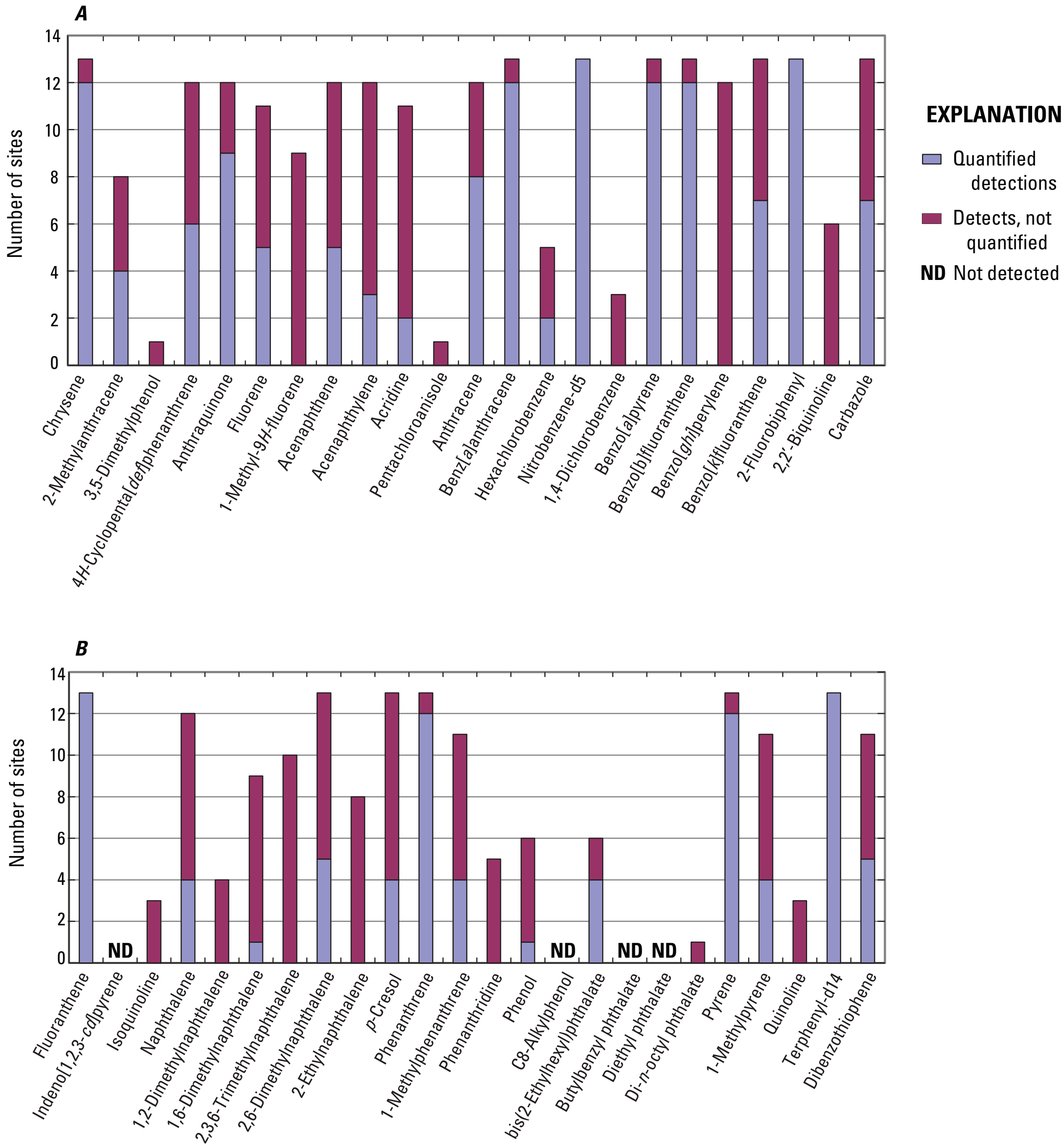


Figure 11. Number of sites at which selected semivolatile organic compounds (SVOCs) were detected in streambed sediments, 2007.

Temporal Patterns

Intermittent collection of benthic-invertebrate data in the study area began in 1981 with a study by Crawford and others (1992) at or near three current study sites (Nora, Stout, and Waverly). That study collected data from those sites through 1987. From 1994 through 1996, 12 of the 13 sites in the current study were sampled, with the results reported by Voelker and Renn (2000). That study also included streambed-sediment analyses. From 1999 through 2001, a third cooperative program between the USGS and DPW collected benthic-invertebrate and fish-community data (Voelker, 2004). From 2003 through 2008, benthic-invertebrate, fish-community, and streambed-sediment data were again collected by the USGS. In the following section, a historical perspective of the available data is presented.

Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index

EPT scores were calculated at 3 sites from 1981 through 1987 (Crawford and others, 1992), 12 sites from 1994 through 1996 (Voelker and Renn, 2000), 12 sites from 1999 through 2001 (Voelker, 2004), and 13 sites since 2003 for this study. The results of the EPT scores are listed in table 4. EPT scores at most sites have generally increased, with the highest scores commonly in the years since 2003. In contrast, the scores at the Buck Creek site have indicated a downward trend in stream quality since sampling began there in 1999. The increases in these scores at most of the sites indicate that conditions supporting these pollution-intolerant taxa have improved over time. On the White River, the highest number of these taxa consistently were found at the Nora site, whereas the lowest numbers were found at the Harding site (fig. 12). For the tributaries, Buck Creek consistently had the highest number of these taxa, and Pogues Run had the lowest.

Hilsenhoff Biotic Index (HBI) Scores

HBI scores were calculated at 3 sites from 1981 through 1987 (Crawford and others, 1992), 12 sites from 1984 through 1996 (Voelker and Renn, 2000), 12 sites from 1999 through 2001 (Voelker, 2004), and 13 sites since 2003 for this study. The results of the HBI calculations are shown in table 5. HBI scores fluctuated fairly randomly over the course of the study, although many of the lowest scores—indicating the least amount of organic pollution—occurred in the mid-1990s for sites on the White River. HBI results indicate that the Morris and Harding sites likely had the highest levels of organic pollution whereas Nora had the least (fig. 13). For the tributaries, the three sites with the most CSOs—Fall Creek, Pleasant Run, and Pogues Run—had the highest amounts of organic pollution, whereas Buck and Williams Creeks had slightly lower amounts.

Invertebrate Community Index (ICI) Scores

ICI scores have been calculated from data collected since 1999 (Voelker, 2004). In general, scores have been increasing since 1999 (table 6), with the highest scores observed at 10 of the sites since October 2006. On the White River, ICI scores were generally highest at the Nora site, whereas the scores were typically lowest at the Morris and Harding sites, indicating the poorest invertebrate-community conditions (fig. 14). Of the tributary sites, results were similar for Buck and Williams Creeks, indicating the best invertebrate community conditions, while scores at Fall Creek were the lowest among the tributaries; however, the trend for scores at both the Buck Creek and Williams Creek sites shows a decrease over time.

Changes in Pollution-Tolerant and Pollution-Intolerant Benthic-Invertebrate Populations

Three sites on the White River were originally selected to observe changes in the benthic-invertebrate population with changes to the City's WWTFs. The Nora and Waverly sites have shown an increase in the percentage of pollution-tolerant invertebrates over pollution-intolerant species since 1981 (fig. 15). At the Nora site, there was also an overall downward trend in the number of pollution-intolerant benthic invertebrates with a corresponding increase in the pollution-tolerant numbers. From 1981 through 1989, the intolerant species predominated except in 1983 and 1985. From 2000 through 2008, the opposite was true; more tolerant invertebrates were present in samples, with the exception of 2006. This change may have been partially due to an upstream chemical release into the White River and resultant fish kill in late 1999 (Indiana Department of Environmental Management, 2000).

In 1983, Indianapolis upgraded its two WWTFs to tertiary treatment, including ozonation of the final effluent (Crawford and others, 1992). Soon after this, two sites downstream from the WWTFs showed signs of improved conditions in the benthic-invertebrate population (fig. 15). Ozonation was replaced with chlorination in 1994 (Paul Werderitch, DPW, oral commun., 2011). In 1996, pollution-tolerant invertebrates again predominated at the Stout site, and since then their numbers have remained comparable to the pollution-intolerant invertebrates at that site. The Waverly site, downstream from all CSO and wastewater outputs, showed an increase in pollution-tolerant invertebrates in data from all years since 1999, with the exception of 2007.

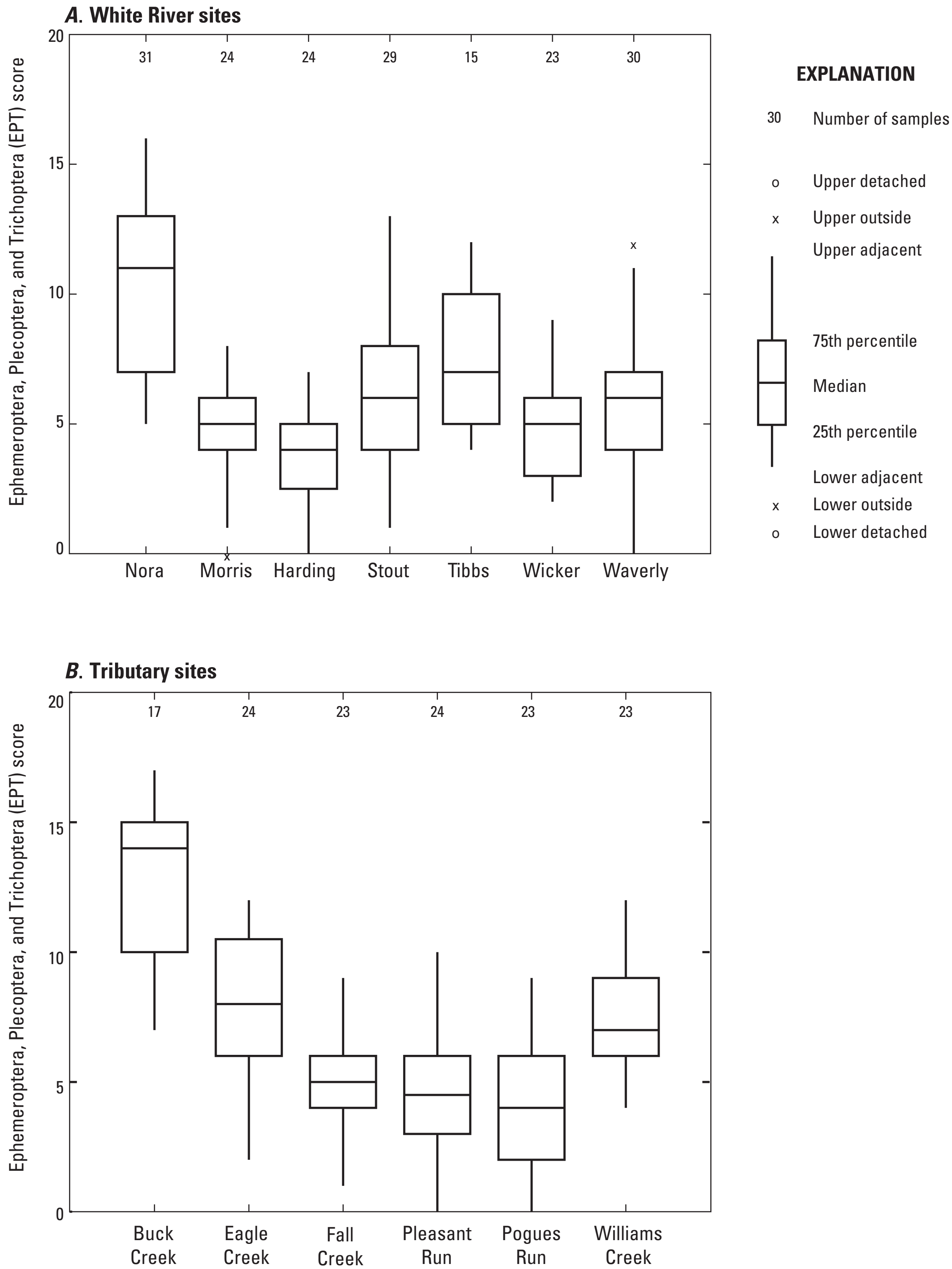


Figure 12. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores, 1981–2008.

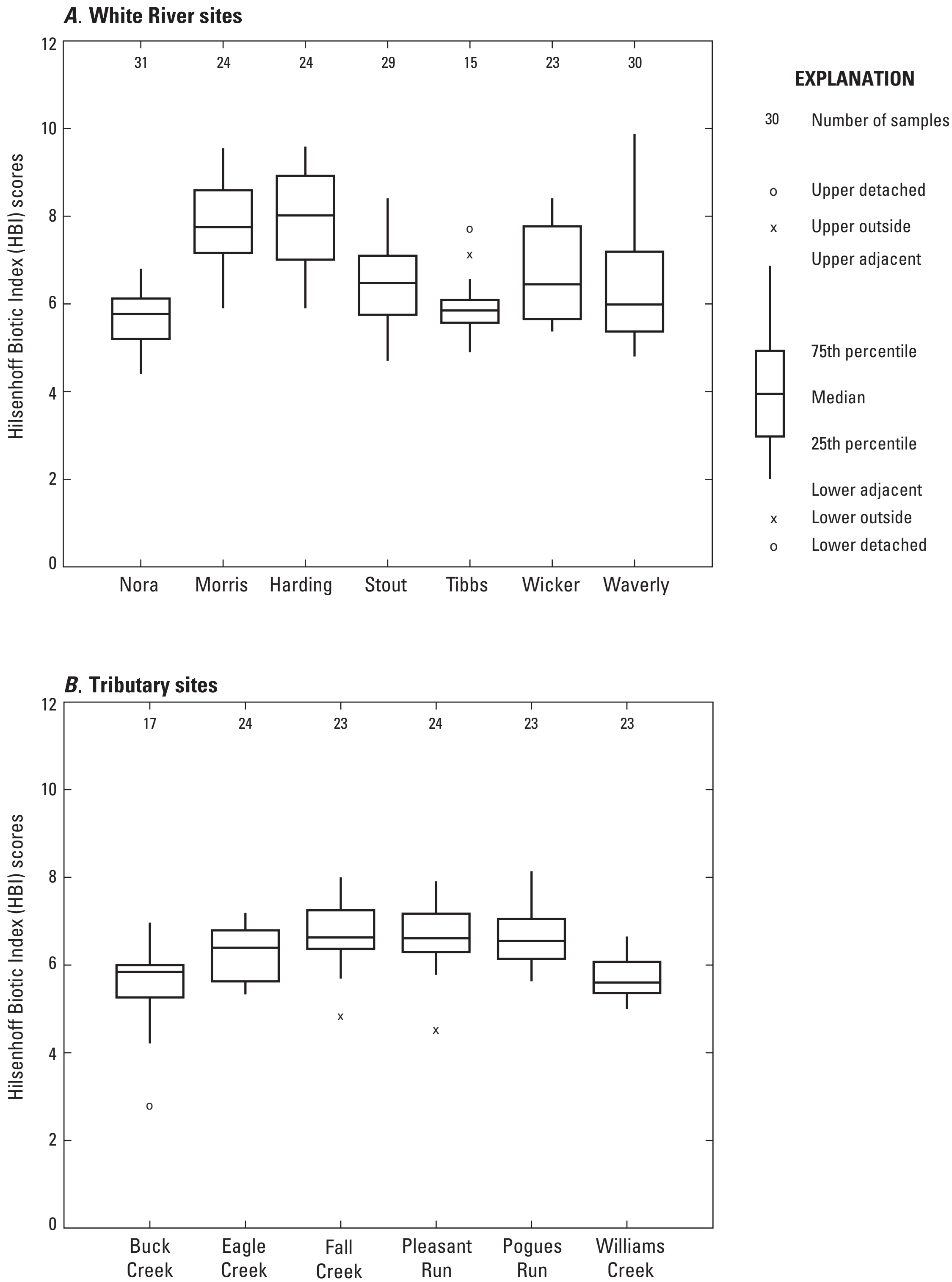


Figure 13. Hilsenhoff Biotic Index (HBI) scores, 1981–2008.

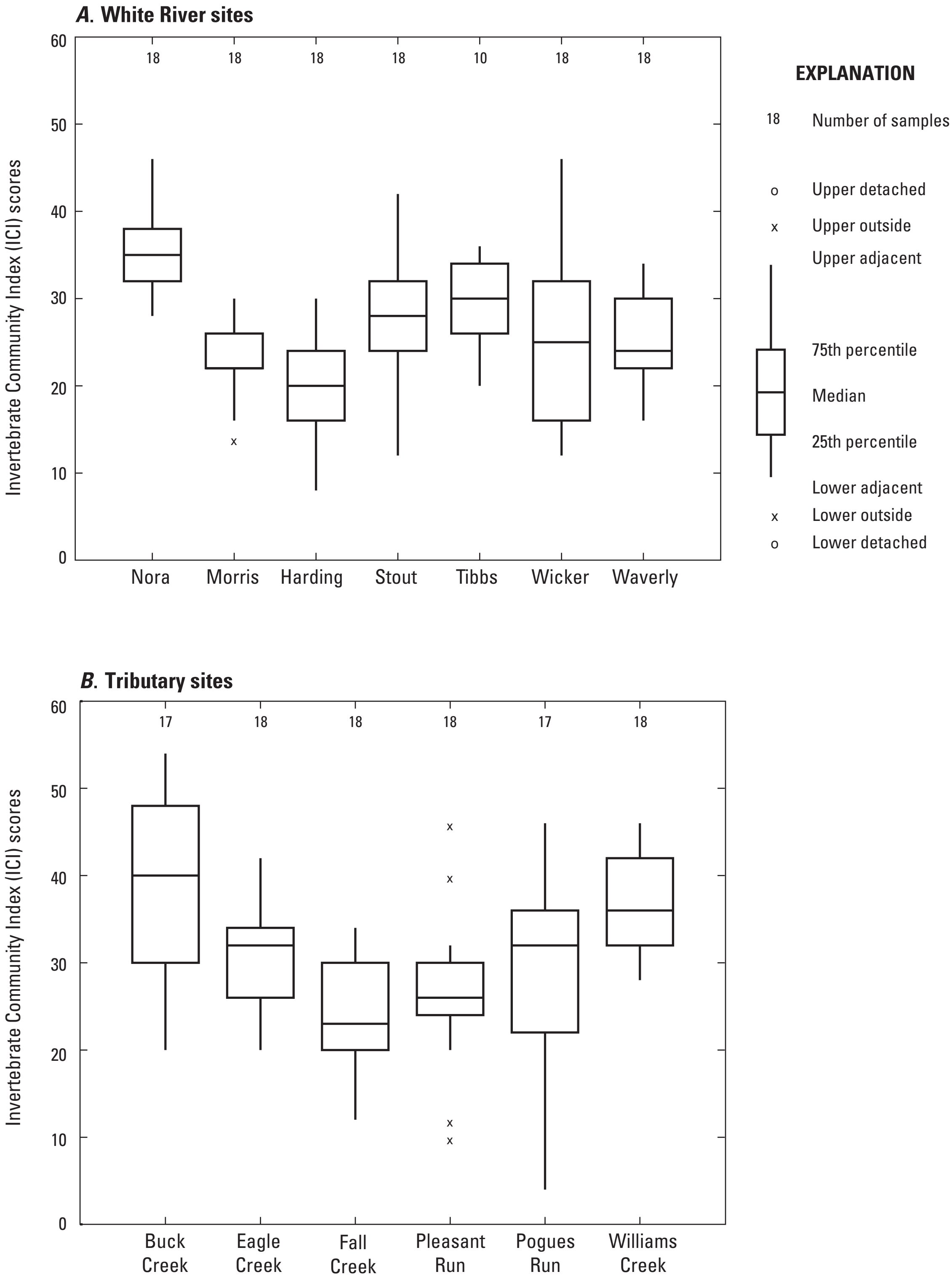


Figure 14. Invertebrate Community Index (ICI) scores, 1999–2008.

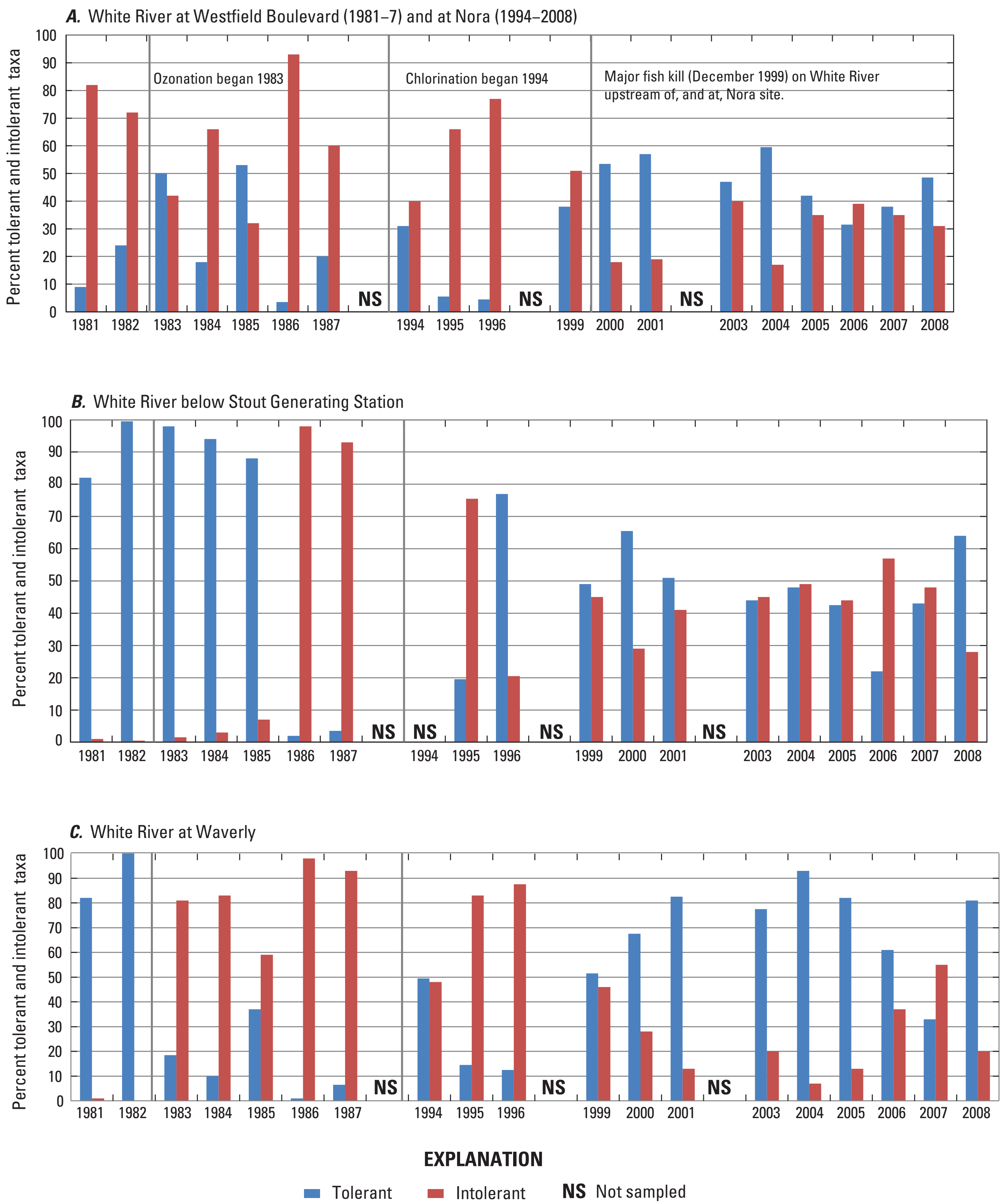


Figure 15. Historical percentage of pollution-tolerant and pollution-intolerant benthic invertebrates at selected sites on the White River, 1981–2008.

Data since 1994 are available for most other sites on the White River, except for the Tibbs site, where these values have been calculated only since 2004. At those sites, the graphs show downward trends in the percentage of pollution-tolerant benthic invertebrates present. Both the Morris and Harding sites are predominated by pollution-tolerant invertebrates, with virtually no pollution-intolerant invertebrates present (fig. 16). The Tibbs site had a predominance of pollution-intolerant benthic invertebrates in 2005 and 2006, unlike other White River sites during the study period.

Three tributary sites—Buck Creek, Pogues Run and Williams Creek—had increasing numbers of pollution-tolerant benthic invertebrates (fig. 17). Of these three sites, the Pogues Run site has been predominated by pollution-tolerant invertebrates, and their numbers have been slowly increasing since 1984. Similarly, the Pleasant Run site has been predominated by pollution-tolerant benthic invertebrates; but unlike the Pogues Run site, their numbers have been trending downward over the study period. Both the Pleasant Run and Pogues Run sites have had minor, yet steady, increases in pollution-intolerant benthic invertebrates since the mid-1990s.

Index of Biotic Integrity (IBI) scores

IBI scores were calculated for samples collected in 1999 and later (Voelker, 2004) (table 12). IBI scores calculated from the fish-community data collected in 1999–2001, 2006, and 2008 are shown in figure 18. Since 1999, six of the seven White River sites and the three of the six tributary sites had the lowest scores during 2006. Low-flow conditions (table 2) during 2006 may have contributed to the lower scores that year.

Streambed-Sediment Chemistry

Streambed-sediment chemistry data collected by this study were compared with data from Voelker and Renn (2000). The maximum concentrations of most metals and SVOCs were higher in samples collected during 2005 and 2007 than in samples collected during 1994–96. The highest concentrations of these constituents among all sites were measured in samples from the White River sites. Data relative to pesticide analyses indicated that concentrations were similar between the two studies, with no evident variation. Because of the mobility of the fine-grained sediments from which these concentrations were determined, their transient nature in the stream, and the intermittent sampling schedule, additional comparison with data from the previous study is not made here.

Combining Metrics to Evaluate Biological Response to CSOs

Combining biological metrics provides a more nuanced understanding of the biological response to CSOs than considering the metrics individually. If each of the median metric scores by site is ranked, with 1 representing the best response, this ranking technique helps assess the relative biological condition at each site. Use of this approach underscores the individual findings that the biological communities at the non-CSO-affected sites on the tributaries—Buck Creek and Williams Creek—and the Nora site on the White River had the most pollution-intolerant taxa (table 13). Biological communities were most affected at the Harding and Waverly sites on the White River and at the Pogues Run, Pleasant Run, and Fall Creek sites on the tributaries. The three most affected tributary sites also had the greatest number of CSOs in their watershed.

The invertebrate community seemed to show a more uniform response to CSO influences than the fish community, especially at the tributary sites. The two non-CSO-affected tributaries had the lowest scores, and the three streams with the most CSOs had the highest scores. These combined findings were supported by the number of taxa and the EPT, HBI, and ICI indexes (table 13). Although, among the White River sites, Nora consistently had the lowest score (representative of a non-CSO-affected site), the other metrics were less effective at consistently identifying affected sites. For example, both Stout and Tibbs are downstream from most CSOs and one WWTF but have the second and third lowest scores, suggesting better biological conditions there. This could be the result of aeration from the low-head dam just upstream from the Stout site (positive effects) or possibly an indicator of the continued effects of the 1999 fish kill in the upper reaches of the study area.

Although the relative abundance of biota or number of taxa are valuable assessment tools, these metrics do not necessarily reflect the stress on the biological communities from CSOs. The greatest abundance of benthic invertebrates was found at sites directly below or downstream from one WWTF (Tibbs and Stout) or with the most CSOs discharging into the tributaries (Fall Creek). The WWTF and CSO outflows provide the nutrients to support the higher invertebrate abundance, although the invertebrate populations may not reflect that the best biological conditions are present at those sites. By using multiple indexes, a better assessment and more complete understanding of the biological conditions in the stream and possible stressors is achieved.

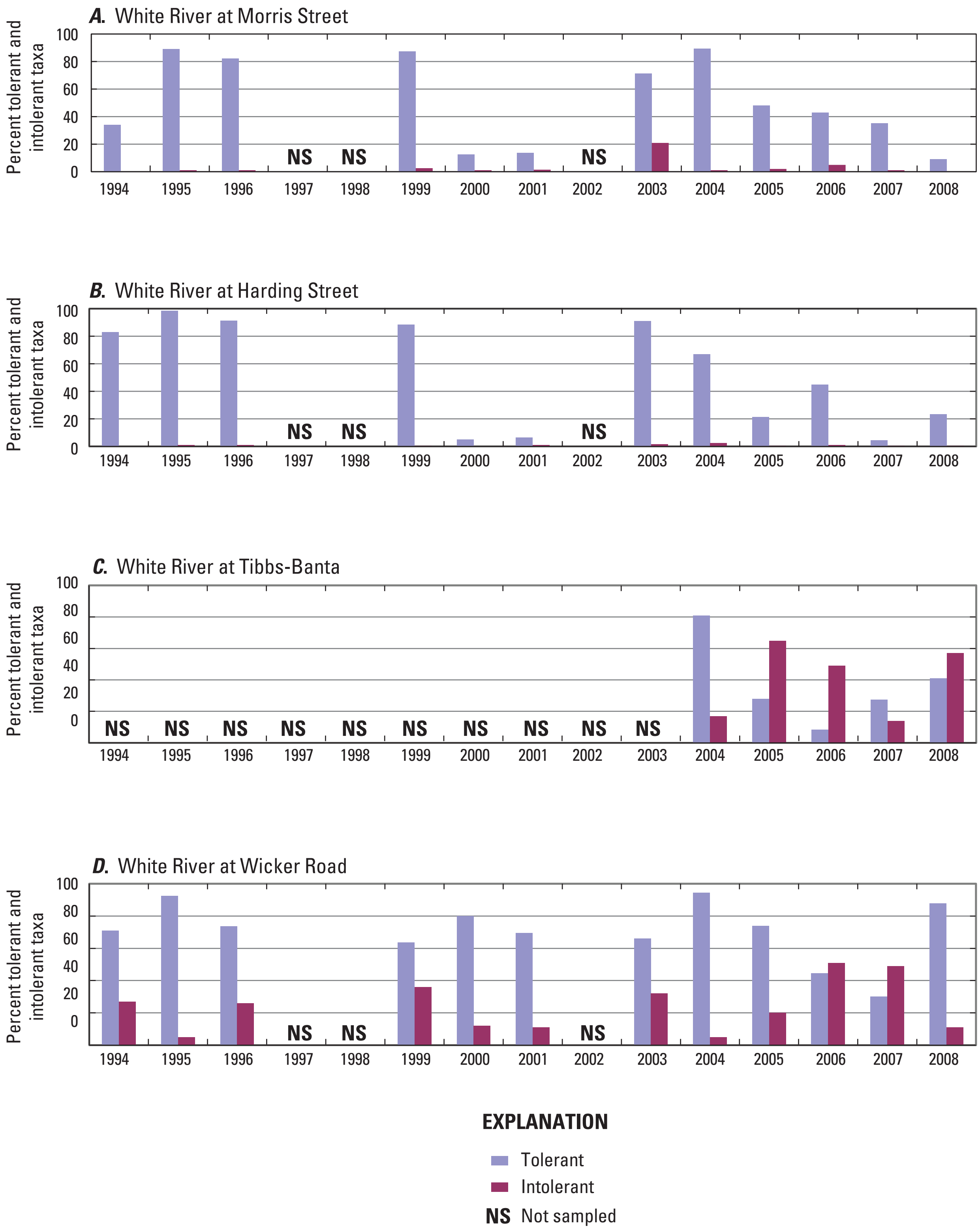


Figure 16. Historical percentage of pollution-tolerant and pollution-intolerant benthic invertebrates at White River sites, 1994–2008.

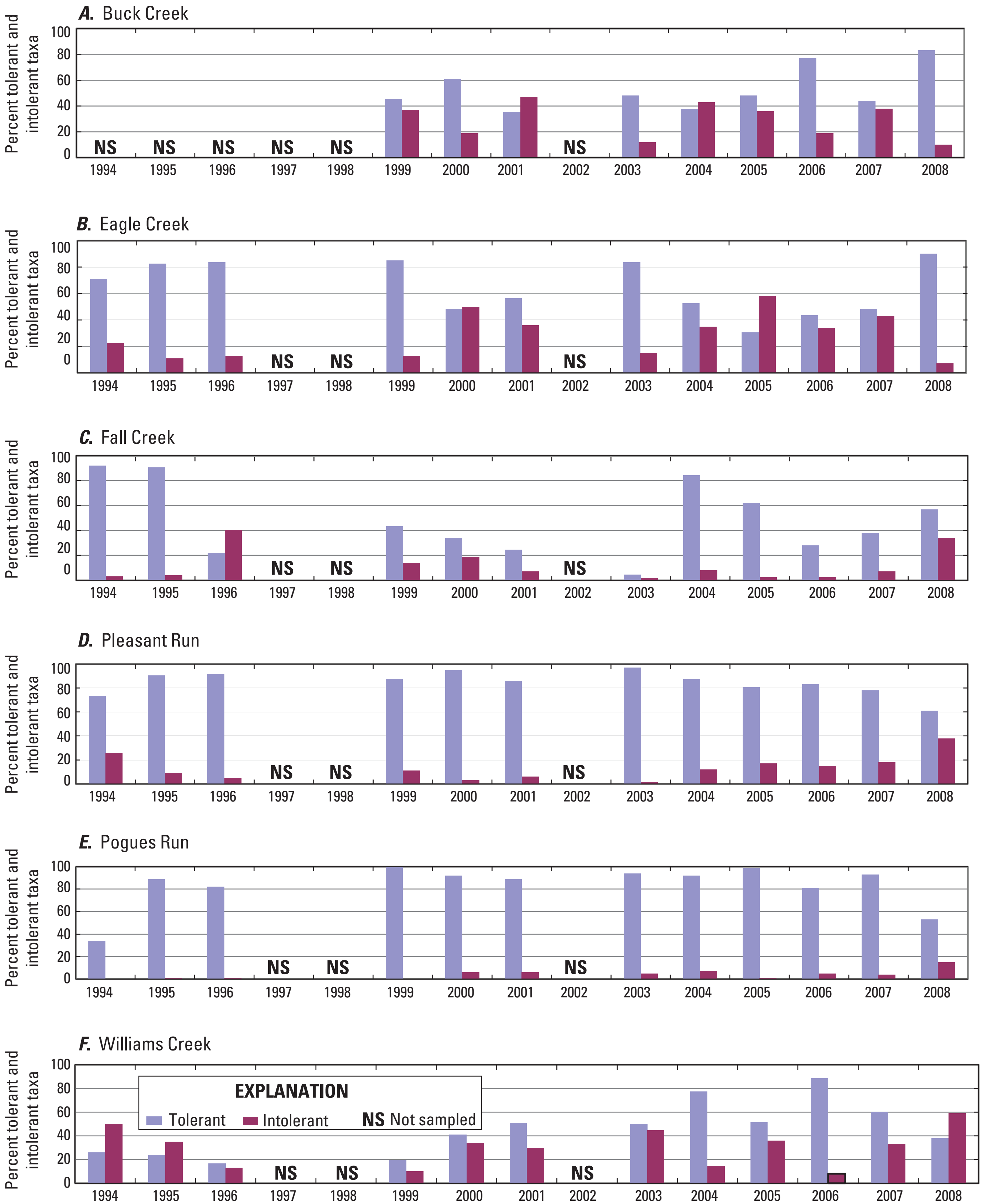


Figure 17. Historical percentage of pollution-tolerant and pollution-intolerant benthic invertebrates at tributary sites, 1994–2008.

Table 12. Index of Biotic Integrity (IBI) scores at all sites in the Indianapolis metropolitan area, 1999–2008.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck Creek	Eagle Creek	Fall Creek	Pleasant Run	Pogues Run	Williams Creek
Data from Voelker, 2004													
1999	44	40	38	42	--	38	38	--	48	54	36	30	44
2000	34	46	42	50	--	46	40	52	48	52	32	34	50
2001	44	46	42	44	--	40	36	52	48	52	30	28	48
Data from this study													
2006	38	32	20	42	40	44	30	52	40	52	40	26	44
2008	46	52	36	46	42	46	34	50	44	50	44	26	52
Median values													
2006–2008	42	42	28	44	41	45	32	51	42	51	42	26	48
1999–2008	44	46	38	44	41	44	36	52	48	52	36	28	48

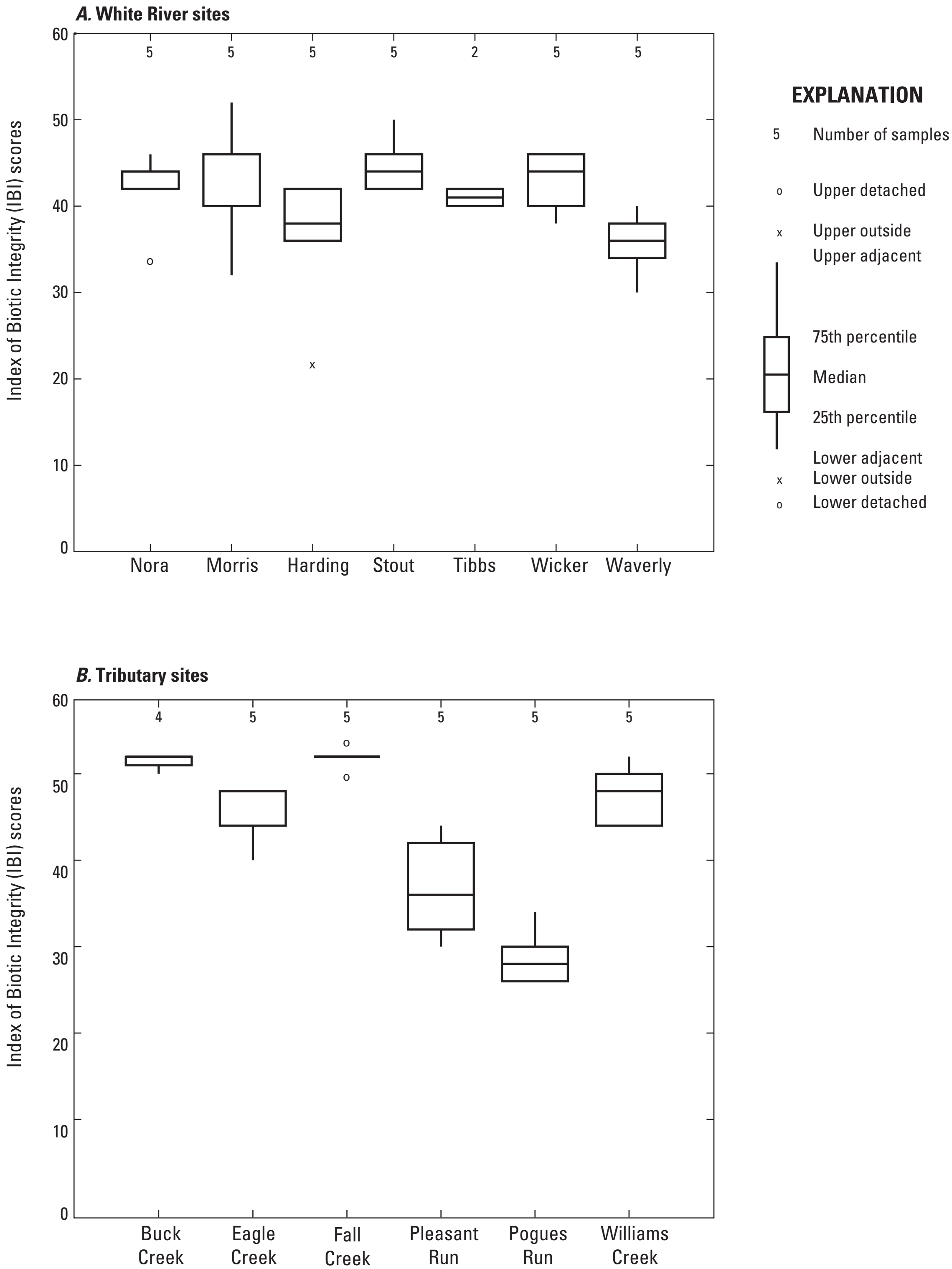


Figure 18. Historical Index of Biotic Integrity (IBI) scores, 1999–2008. *A*, Sites on the White River. *B*, Tributary sites.

Table 13. Ranking of sites by benthic invertebrate and fish metrics and index scores for sites on the White River and tributary sites in the Indianapolis metropolitan area, 1981–2008.

[CSO, combined-sewer overflow; EPT, Ephemeroptera, Plecoptera, and Trichoptera; HBI, Hilsenhoff Biotic Index; ICI, Invertebrate Community Index; IBI, Index of Biotic Integrity]

Site	Site type (number of CSOs)	Benthic invertebrates					Fish				Summary rankings		
		Number of taxa	Relative abundance	EPT Index score	HBI scores	ICI scores	Relative abundance	IBI scores	Number of taxa	Total	Benthic invertebrates only	Fish only	Both
White River sites													
Nora	Non-CSO	1	3	1	1	1	6	3	7	23	1.4	5.3	2.9
Morris		2	7	5.5	6	6	2	1	2	31.5	5.3	1.7	3.9
Harding		3	5	7	7	7	5	6	4.5	44.5	5.8	5.2	5.6
Stout		4	2	2.5	5	3	3	3	1	23.5	3.3	2.3	2.9
Tibbs		7	1	2.5	2	2	1	5	3	23.5	2.9	3.0	2.9
Wicker		5.5	6	5.5	4	4	4	3	4.5	36.5	5	3.8	4.6
Waverly		5.5	4	4	3	5	7	7	6	41.5	4.3	6.7	5.2
Tributary sites													
Buck Creek	Non-CSO	1	3	1	2	1	3	1.5	1	13.5	1.6	1.8	1.7
Eagle Creek	5	2	5	2	3	4	4	3.5	3	26.5	3.2	3.5	3.3
Fall Creek	49	4	1	4.5	6	6	5	1.5	2	30	4.3	2.8	3.8
Pleasant Run	27	6	4	4.5	5	5	1	5	5	35.5	4.9	3.7	4.4
Pogues Run	24	5	6	6	4	3	6	6	6	42	4.8	6.0	5.3
Williams Creek	Non-CSO	3	2	3	1	2	2	3.5	4	20.5	2.2	3.2	2.6

Summary

The U.S. Geological Survey, in cooperation with the Indianapolis Department of Public Works (DPW), assessed biological communities and streambed-sediment chemistry in the White River and selected tributaries in the Indianapolis metropolitan area during 2003 through 2008. Thirteen sites (seven on the White River and six on tributaries) were sampled biannually for benthic invertebrates and in alternating years for fish communities or streambed-sediment chemistry. This study continued a long-term cooperative program between the two agencies to collect biological and streambed-sediment data and complement the DPW surface-water monitoring program. The information gathered is being used in the City's programs to reduce combined-sewer overflows (CSOs) and other point and nonpoint sources of pollution in the Indianapolis area.

During this study, 233 benthic-invertebrate taxa were identified, with 17 to 60 taxa being identified in samples from individual sites. Dipterans, a pollution-tolerant group of taxa, tended to be the predominant taxa in most samples. Three benthic-invertebrate indexes were calculated from the data collected at each site: the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index, the Hilsenhoff Biotic Index (HBI), and the Invertebrate Community Index (ICI).

EPT Index scores ranged from 2 at the Harding and Wicker sites to 16 at Nora on the White River. On the tributaries, the scores ranged from 2 at the Eagle Creek, Fall Creek, and Pogues Run sites to 17 at Buck Creek. EPT Index scores indicate that pollution-intolerant taxa are more prevalent upstream from and away from the combined-sewer areas. HBI scores ranged from 4.67 (good) at Nora to 9.55 (very poor) at the Morris sites on the White River. On the tributaries, HBI scores ranged from 4.21 (very good) at Buck Creek to 8.14 (poor) at Pogues Run. Lower HBI scores indicate less organic pollution, and again, sites upstream from and away from CSOs had lower scores. ICI scores on the White River ranged from 12 at Harding and Wicker to 46 at Nora, indicating better conditions upstream from the CSO area. On the tributaries, ICI scores ranged from 12 at Fall Creek to 52 at the Buck Creek site. The highest scores were generally at sites unaffected by CSOs.

Fish-community data collected during this study identified 65 taxa. Fifty-one fish species were identified on the White River, and 53 fish species were identified on tributaries. The number of fish species identified by site ranged from 16 at Waverly to 27 at Stout on the White River and from 8 at Pogues Run to 34 at Buck Creek on the tributaries. The Centrarchidae (sunfishes) composed 20 percent of the specimens caught on the White River, whereas the Cyprinidae (carps and minnows) composed about 30 percent of the specimens on the tributaries. Index of Biotic Integrity (IBI) scores for the White River ranged from 20 at Harding to 52 at Morris. Tributary IBI scores ranged from 26 at Pogues Run to 52 at Buck Creek, Fall Creek, and Williams Creek.

Streambed sediments were collected twice during the study period to assess chemical constituents that may affect the biological communities at the study sites. More chlorinated pesticides were detected in 2007 than in 2005, with *trans*-nonachlor, *cis*-chlordane, dieldrin, *trans*-chlordane, and PCBs being most frequently detected. Only three organophosphate insecticides were detected. More than 30 semivolatile organic compounds (SVOCs) were detected at more than half the sites sampled. The Harding site had the highest concentrations and the Buck Creek site had the lowest concentrations among all sites sampled.

For sites on the White River, available historical data for each of the three indexes (EPT, HBI, and ICI) all show that the benthic-invertebrate conditions are least impaired at the Nora site. The Nora site is the most upstream study site, near where the White River enters Indianapolis and upstream from the CSO area. The highest number of pollution-tolerant taxa within the benthic-invertebrate communities are at the Morris and Harding sites, which are in the most urban reach of the river. There is some improvement in the benthic-invertebrate metrics at the Stout and Tibbs sites, and to a lesser extent at the Wicker and Waverly sites, further downstream from the CSOs and wastewater treatment facilities.

Results from this study continue to describe the Buck Creek and Williams Creek sites—which have no CSOs entering them—as having more pollution-intolerant benthic-invertebrate communities than the other tributary sites. Only the Eagle Creek site had scores higher than the Williams Creek site with regard to EPT index scores. Fall Creek, Pleasant Run, and Pogues Run consistently scored poorest of the tributary sites, with the Pogues Run site having the greatest range in ICI scores.

Three sites on the White River have had a longer history of benthic-invertebrate data from which numbers of pollution-tolerant and pollution-intolerant invertebrates have been calculated. Dominance by pollution-tolerant invertebrates was reversed at the two downstream sites (Stout and Waverly) after the wastewater treatment facilities upgraded to tertiary treatment with ozonation. That trend lasted until ozonation was replaced by chlorination of effluents in the mid-1990s. The only other change in benthic-invertebrate conditions occurred in late 1999, when a chemical spill resulted in a major fish kill on the White River and pollution-tolerant taxa again became the predominant benthic invertebrates present.

Historical fish-community data for the period 1999–2008 indicate that most of the study sites have fairly stable fish communities, with some minor variations from year to year. Only the Waverly site on the White River and the Pogues Run tributary site appear to have downward trends in IBI scores. Median IBI scores show that the Harding and Waverly sites on the White River and the Pleasant Run and Pogues Run tributary sites have the poorest fish-community conditions overall.

Acknowledgments

The author thanks everyone who assisted in the timely and successful completion of this project. Especially noteworthy in this regard are the USGS employees who worked with such dedication toward this goal. Amanda Egler and Chad Menke were especially helpful with the benthic-invertebrate and fish-community fieldwork associated with this project. Amanda Egler was also instrumental in collecting and processing the streambed sediments for analysis. Brian Caskey and Jeffrey Frey assisted with the electrofishing activities.

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Supplemental Data

Table 3. Benthic-invertebrate taxa collected at all sites in the Indianapolis metropolitan area, 2003–2008.

[sp., species; cf., closely comparable to; w.h.c., with hair chaetae; w.o.h.c., without hair chaetae; gp., group]

Phylum	Class	Order	Family	Taxon
Coelenterata	Hydrozoa	Hydroida	Hydridae	*Hydra americana*
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Cura foremanii*
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia tigrina*
Platyhelminthes	Turbellaria	Tricladida	Dugesiidae	*Girardia tigrina*
Nematoda	unidentified	unidentified	unidentified	unidentified
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula fluminea*
Mollusca	Bivalvia	Veneroida	Sphaeriidae	*Musculium transversum*
Mollusca	Bivalvia	Veneroida	Sphaeriidae	*Pisidium* sp.
Mollusca	Bivalvia	Veneroida	Sphaeriidae	*Sphaerium* cf. *simile*
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	*Amnicola* sp.
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	*Somatogyrus* sp.
Mollusca	Gastropoda	Mesogastropoda	Pleuroceridae	*Elimia* sp.
Mollusca	Gastropoda	Mesogastropoda	Pleuroceridae	*Pleurocera* sp.
Mollusca	Gastropoda	Mesogastropoda	Pleuroceridae	*Pleurocera* cf. *canaliculata*
Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia rivularis*
Mollusca	Gastropoda	Basommatophora	Lymnaeidae	*Fossaria* sp.
Mollusca	Gastropoda	Basommatophora	Planorbidae	*Gyraulus parvus*
Mollusca	Gastropoda	Basommatophora	Planorbidae	*Menetus dilatatus*
Mollusca	Gastropoda	Basommatophora	Physidae	*Physella* sp.
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae	unidentified
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae	*Lumbriculus* sp.
Annelida	Oligochaeta	Lumbriculida	Lumbricidae	unidentified
Annelida	Oligochaeta	Tubificida	Naididae	*Chaetogaster* sp.
Annelida	Oligochaeta	Tubificida	Naididae	*Dero* sp.
Annelida	Oligochaeta	Tubificida	Naididae	*Nais bretscheri*
Annelida	Oligochaeta	Tubificida	Naididae	*Nais communis*
Annelida	Oligochaeta	Tubificida	Naididae	*Ophidonais serpentina*
Annelida	Oligochaeta	Tubificida	Naididae	*Pristina leidyi*
Annelida	Oligochaeta	Tubificida	Naididae	*Slavina appendiculata*
Annelida	Oligochaeta	Tubificida	Naididae	*Stylaria lacustris*
Annelida	Oligochaeta	Tubificida	Tubificidae	unidentified
Annelida	Oligochaeta	Tubificida	Tubificidae w.h.c.	*Quistradrilus multisetosus*
Annelida	Oligochaeta	Tubificida	Tubificidae w.o.h.c.	*Branchiura sowerbyi*
Annelida	Oligochaeta	Tubificida	Tubificidae w.o.h.c.	*Limnodrilus claparedianus*
Annelida	Oligochaeta	Tubificida	Tubificidae w.o.h.c.	*Limnodrilus hoffmeisteri*
Annelida	Hirudinea	Branchiobdellida	unidentified	unidentified
Annelida	Hirudinea	Arhynchobdellida	Erpobdellidae	unidentified
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	*Helobdella stagnalis*
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	*Helobdella triserialis*
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	*Placobdella parasitica*
Arthropoda	Arachnoidea	Acariformes	Hygrobatidae	*Atractides* sp.
Arthropoda	Arachnoidea	Acariformes	Lebertiidae	*Lebertia* sp.
Arthropoda	Crustacea	Ostracoda	unidentified	unidentified
Arthropoda	Crustacea	Cladocera	Chydoridae	*Chydorus* sp.
Arthropoda	Crustacea	Cladocera	Daphnidae	*Ceriodaphnia* sp.
Arthropoda	Crustacea	Cladocera	Daphnidae	*Daphnia* sp.
Arthropoda	Crustacea	Cladocera	Sididae	*Sida crystillina*
Arthropoda	Crustacea	Copepoda	unidentified	unidentified
Arthropoda	Crustacea	Calanoida	unidentified	unidentified

Table 3. Benthic-invertebrate taxa collected at all sites in the Indianapolis metropolitan area, 2003–2008.—Continued

[sp., species; cf., closely comparable to; w.h.c., with hair chaetae; w.o.h.c., without hair chaetae; gp., group]

Phylum	Class	Order	Family	Taxon
Arthropoda	Crustacea	Cyclopoida	unidentified	unidentified
Arthropoda	Crustacea	Isopoda	Asellidae	*Caecidotea* sp.
Arthropoda	Crustacea	Isopoda	Asellidae	*Lirceus* sp.
Arthropoda	Crustacea	Amphipoda	Crangonyctidae	*Crangonyx* sp.
Arthropoda	Crustacea	Amphipoda	Gammaridae	*Gammarus* sp.
Arthropoda	Crustacea	Amphipoda	Talitridae	*Hyalella azteca*
Arthropoda	Crustacea	Decapoda	Cambaridae	*Orconectes* sp.
Arthropoda	Insecta	Collembola	Isotomidae	unidentified
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acentrella ampla*
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis* cf. *flavistringa*
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis intercalaris*
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Heterocloeon* sp.
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Plauditus* sp.
Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis* sp.
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Heptagenia* sp.
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Leucrocuta* sp.
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium (Stenonema) exiguum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium (Stenonema) femoratum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium (Stenonema) mediopunctatum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium (Stenonema) terminatum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenacron interpunctatum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema femoratum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema integrum*
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema terminatum*
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia* sp.
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* sp.
Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	*Ephoron leukon*
Arthropoda	Insecta	Ephemeroptera	Potamanthidae	*Anthopotamus* sp.
Arthropoda	Insecta	Ephemeroptera	Potamanthidae	*Anthopotamus myops*
Arthropoda	Insecta	Ephemeroptera	Tricorythidae	*Tricorythodes* sp.
Arthropoda	Insecta	Odonata	Calopterygidae	*Calopteryx* sp.
Arthropoda	Insecta	Odonata	Calopterygidae	unidentified
Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia* sp.
Arthropoda	Insecta	Odonata	Coenagrionidae	*Enallagma* sp.
Arthropoda	Insecta	Odonata	Coenagrionidae	*Ischnura* sp.
Arthropoda	Insecta	Odonata	Corduliidae	*Neurocordulia* sp.
Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus* sp.
Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus designatus*
Arthropoda	Insecta	Odonata	Gomphidae	*Gomphus* sp.
Arthropoda	Insecta	Odonata	Gomphidae	*Ophiogomphus/Erpetogomphus* sp.
Arthropoda	Insecta	Odonata	Libellulidae	*Libellula* sp.
Arthropoda	Insecta	Plecoptera	Leuctridae	*Leuctra* sp.
Arthropoda	Insecta	Plecoptera	Perlidae	*Neoperla* sp.
Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta placida*
Arthropoda	Insecta	Plecoptera	Perlidae	*Perlinella ephyre*
Arthropoda	Insecta	Plecoptera	Perlodidae	unidentified
Arthropoda	Insecta	Plecoptera	Taeniopterygidae	*Taeniopteryx* sp.
Arthropoda	Insecta	Hemiptera	Corixidae	unidentified

Table 3. Benthic-invertebrate taxa collected at all sites in the Indianapolis metropolitan area, 2003–2008.—Continued

[sp., species; cf., closely comparable to; w.h.c., with hair chaetae; w.o.h.c., without hair chaetae; gp., group]

Phylum	Class	Order	Family	Taxon
Arthropoda	Insecta	Hemiptera	Veliidae	*Microvelia* sp.
Arthropoda	Insecta	Hemiptera	Veliidae	*Rhagovelia* sp.
Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis* sp.
Arthropoda	Insecta	Trichoptera	Glossosomatidae	*Protoptila* sp.
Arthropoda	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche borealis*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Ceratopsyche morosa*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche aerata*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche betteni* gp.
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche bidens*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche orris*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche simulans*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche venularis*
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Potamyia flava*
Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Hydroptila* sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	*Ceraclea* sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	*Nectopsyche* sp.
Arthropoda	Insecta	Trichoptera	Leptoceridae	*Oecetis* sp.
Arthropoda	Insecta	Trichoptera	Limnephilidae	unidentified
Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra obscurus*
Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Cyrnellus fraternus*
Arthropoda	Insecta	Trichoptera	Polycentropodidae	*Neureclipsis* sp.
Arthropoda	Insecta	Trichoptera	Psychomyiidae	*Psychomyia flavida*
Arthropoda	Insecta	Trichoptera	Uenoidae	unidentified
Arthropoda	Insecta	Lepidoptera	Pyralidae	*Petrophila* sp.
Arthropoda	Insecta	Coleoptera	Coccinellidae	unidentified
Arthropoda	Insecta	Coleoptera	Curculionidae	unidentified
Arthropoda	Insecta	Coleoptera	Dytiscidae	*Hydroporus* sp.
Arthropoda	Insecta	Coleoptera	Elmidae	*Ancyronyx variegata*
Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia* sp.
Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia vittata*
Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia bivittata*
Arthropoda	Insecta	Coleoptera	Elmidae	*Macronychus glabratus*
Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus pusillus*
Arthropoda	Insecta	Coleoptera	Elmidae	*Optioservus ovalis*
Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis sexlineata*
Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyrinus* sp.
Arthropoda	Insecta	Coleoptera	Haliplidae	*Peltodytes* sp.
Arthropoda	Insecta	Coleoptera	Hydrophilidae	unidentified
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus* sp.
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus* sp.
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Helocombus bifidus*
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Hydrobius* sp.
Arthropoda	Insecta	Coleoptera	Psephenidae	*Psephenus herricki*
Arthropoda	Insecta	Coleoptera	Scirtidae	unidentified
Arthropoda	Insecta	Coleoptera	Staphylinidae	unidentified
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Atrichopogon* sp.
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Bezzia/Palpomyia* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia mallochi*

Table 3. Benthic-invertebrate taxa collected at all sites in the Indianapolis metropolitan area, 2003–2008.—Continued

[sp., species; cf., closely comparable to; w.h.c., with hair chaetae; w.o.h.c., without hair chaetae; gp., group]

Phylum	Class	Order	Family	Taxon
Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia parajanta*
Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia rhamphe* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Brillia flavifrons*
Arthropoda	Insecta	Diptera	Chironomidae	*Cardiocladius obscurus*
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Chaetocladius* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Cladotanytarsus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Conchapelopia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Corynoneura* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus bicinctus*
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus (l) "ozarks"*
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus sylvestris*
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus tremulus*
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus trifascia*
Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironomus fulvus*
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes lucifer*
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes neomodestus*
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes nervosus*
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes simpsoni*
Arthropoda	Insecta	Diptera	Chironomidae	*Endochironomus nigricans*
Arthropoda	Insecta	Diptera	Chironomidae	*Eukiefferiella claripennis* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Eukiefferiella devonica* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Glyptotendipes* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Labrundinia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Larsia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Limnophyes* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Lopescladius* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Microtendipes pedellus* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Nanocladius distinctus*
Arthropoda	Insecta	Diptera	Chironomidae	*Natarsia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Nilotanypus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Nilothauma* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Orthocladius (Euorthocladius)*
Arthropoda	Insecta	Diptera	Chironomidae	*Parachironomus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Paracladopelma* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Parakiefferiella bathophila*
Arthropoda	Insecta	Diptera	Chironomidae	*Parametriocnemus lundbecki*
Arthropoda	Insecta	Diptera	Chironomidae	*Paratanytarsus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Paratendipes* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Phaenopsectra* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Phaenopsectra punctipes* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum fallax*
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum flavum (convictum)*
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum halterale*
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum illinoense*
Arthropoda	Insecta	Diptera	Chironomidae	*Procladius* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Pseudochironomus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Psectrocladius* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Rheocricotopus robacki*

Table 3. Benthic-invertebrate taxa collected at all sites in the Indianapolis metropolitan area, 2003–2008.—Continued

[sp., species; cf., closely comparable to; w.h.c., with hair chaetae; w.o.h.c., without hair chaetae; gp., group]

Phylum	Class	Order	Family	Taxon
Arthropoda	Insecta	Diptera	Chironomidae	*Rheotanytarsus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Rheotanytarsus exiguus* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Saetheria tylus*
Arthropoda	Insecta	Diptera	Chironomidae	*Smittia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus caffrarius* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus devinctus*
Arthropoda	Insecta	Diptera	Chironomidae	*Sublettea coffmani*
Arthropoda	Insecta	Diptera	Chironomidae	*Tanypus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Tanytarsus* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Thienemannimyia* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Thienemanniella xena*
Arthropoda	Insecta	Diptera	Chironomidae	*Tribelos* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Tribelos jucundum*
Arthropoda	Insecta	Diptera	Chironomidae	*Tvetenia bavarica* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Tvetenia discoloripes* gp.
Arthropoda	Insecta	Diptera	Chironomidae	*Tvetenia paucunca*
Arthropoda	Insecta	Diptera	Chironomidae	*Tvetenia vitracies*
Arthropoda	Insecta	Diptera	Chironomidae	*Xenochironomus xenolabis*
Arthropoda	Insecta	Diptera	Chironomidae	*Zavrelia* sp.
Arthropoda	Insecta	Diptera	Chironomidae	*Zavrelimyia* sp.
Arthropoda	Insecta	Diptera	Dolichopodidae	unidentified
Arthropoda	Insecta	Diptera	Empididae	*Hemerodromia* sp.
Arthropoda	Insecta	Diptera	Ephydridae	unidentified
Arthropoda	Insecta	Diptera	Muscidae	*Limnophora* sp.
Arthropoda	Insecta	Diptera	Psychodidae	*Pericoma* sp.
Arthropoda	Insecta	Diptera	Psychodidae	*Psychoda* sp.
Arthropoda	Insecta	Diptera	Sciomyzidae	unidentified
Arthropoda	Insecta	Diptera	Simuliidae	*Simulium* sp.
Arthropoda	Insecta	Diptera	Tabanidae	*Chrysops* sp.
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Antocha* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Dicranota* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Hexatoma* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Limnophila* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Limonia* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Molophilus* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Ormosia* sp.
Arthropoda	Insecta	Diptera	Tipulidae	*Tipula* sp.

Table 7. Fish collected at the White River sites in the Indianapolis metropolitan area, 2006 and 2008.

[**N**, non-native species deliberately or accidentally introduced into the basin; --, not found]

Scientific name	Common name and status	Number of fish collected at White River sites													
		Nora		Morris		Harding		Stout		Tibbs		Wicker		Waverly	
		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
Lepisosteidae	**(gars)**														
Lepisosteus osseus (Linnaeus, 1758)[1]	longnose gar	--	--	--	--	--	--	--	--	2	--	--	--	--	--
Clupeidae	**(herrings)**														
Dorosoma cepedianum (Lesueur, 1818)	gizzard shad	9	3	8	3	14	2	--	4	16	4	7	1	6	--
Cyprinidae	**(carps and minnows)**														
Campostoma anomalum (Rafinesque, 1820)	central stoneroller	14	--	--	--	--	--	--	1	7	66	12	2	--	--
Cyprinella spiloptera (Cope, 1868)	spotfin shiner	21	3	18	--	11	4	22	34	43	26	4	60	1	6
Cyprinus carpio Linnaeus, 1758	common carp **N**	2	1	1	5	3	8	2	14	2	2	5	1	11	16
Luxilus chrysocephalus Rafinesque, 1820	striped shiner	--	--	--	--	--	--	--	--	2	--	--	--	--	--
Lythrusus umbratilus (Girard, 1856)	redfin shiner	--	--	--	4	--	--	--	--	--	--	--	--	--	--
Notemigonus crysoleucas (Mitchill, 1814)	golden shiner	--	--	--	2	--	15	--	--	--	--	--	--	--	--
Notropis buccatus (Cope, 1865)	silverjaw minnow	--	--	--	--	--	--	--	--	3	--	2	--	--	--
Notropis photogenis (Cope, 1865)	silver shiner	1	1	--	--	--	--	--	--	--	1	--	--	--	--
Notropis stramineus (Cope, 1865)	sand shiner	6	--	--	--	--	1	28	23	65	369	24	230	--	--
Phenacobius mirabilis (Girard, 1856)	suckermouth minnow	--	--	--	--	--	--	--	2	6	18	--	--	--	--
Pimephales notatus (Rafinesque, 1820)	bluntnose minnow	1	--	7	--	--	1	1	14	1	15	--	6	--	--
Pimephales vigilax (Baird & Girard, 1853)	bullhead minnow	--	--	--	--	--	--	2	--	--	--	--	--	--	--
Semotilus atromaculatus (Mitchill, 1818)	creek chub	2	--	--	--	--	--	--	--	--	--	2	--	--	--
Catostomidae	**(suckers and buffalo)**														
Carpiodes carpio (Rafinesque, 1820)	river carpsucker	--	--	8	11	13	5	6	19	7	4	5	4	31	18
Carpiodes cyprinus (Lesueur, 1817)	quillback	--	--	--	--	1	--	--	--	3	--	2	--	2	--
Carpiodes velifer (Rafinesque, 1820)	highfin carpsucker	--	--	--	1	--	1	--	4	--	1	2	1	--	--
Catostomus commersonii (Lacepede, 1803)	white sucker	1	--	1	--	1	--	--	--	--	--	--	--	--	--
Hypentelium nigricans (Lesueur, 1817)	northern hog sucker	11	11	7	3	--	--	35	32	43	29	24	18	--	--
Ictiobus bubalus (Rafinesque, 1818)	smallmouth buffalo	--	--	--	1	1	2	1	--	--	--	--	--	2	--
Ictiobus cyprinellus (Valenciennes, 1844)	bigmouth buffalo	--	--	1	--	1	--	1	--	--	--	--	--	--	--
Minytrema melanops (Rafinesque, 1820)	spotted sucker	2	2	6	13	5	10	--	1	--	--	--	--	3	--
Moxostoma anisurum (Rafinesque, 1820)	silver redhorse	--	1	--	6	--	1	2	5	11	3	15	14	12	1
Moxostoma duquesnei (Lesueur, 1817)	black redhorse	--	2	--	14	--	2	--	--	--	4	1	1	1	--
Moxostoma erythrurum (Rafinesque, 1818)	golden redhorse	8	10	6	13	3	1	7	3	--	2	1	14	--	3
Moxostoma macrolepidotum (Lesueur, 1817)	shorthead redhorse	--	--	--	7	--	--	5	21	17	17	8	17	2	23
Ictaluridae	**(bullhead and catfishes)**														
Ictalurus punctatus (Rafinesque, 1818)	channel catfish	3	8	8	7	4	8	24	4	10	2	1	1	9	3
Noturus flavus Rafinesque	stonecat	--	--	--	--	--	--	--	--	--	1	--	--	--	--
Pylodictis olivaris (Rafinesque, 1818)	flathead catfish	1	--	1	--	2	--	--	--	--	--	1	--	2	3

Table 7. Fish collected at the White River sites in the Indianapolis metropolitan area, 2006 and 2008.—Continued

[**N**, non-native species deliberately or accidentally introduced into the basin; --, not found]

Scientific name	Common name and status	Number of fish collected at White River sites													
		Nora		Morris		Harding		Stout		Tibbs		Wicker		Waverly	
		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
Poeciliidae	**(live bearers)**														
Gambusia affinis (Baird and Girard, 1853)	western mosquitofish **N**	--	--	--	--	--	--	--	--	--	--	4	--	--	--
Atherinidae	**(silversides)**														
Labidesthes sicculus (Cope, 1865)	brook silverside	--	--	--	--	--	--	--	3	7	--	--	--	--	--
Centrarchidae	**(sunfishes)**														
Ambloplites rupestris (Rafinesque, 1817)	rock bass	1	5	1	3	--	1	--	1	--	--	--	--	--	--
Lepomis cyanellus Rafinesque, 1819	green sunfish	1	1	--	2	--	--	--	--	--	--	--	--	--	--
Lepomis humilis (Girard, 1858)	orangespotted sunfish	--	--	--	--	--	1	--	--	--	--	--	--	--	--
Lepomis macrochirus Rafinesque, 1819	bluegill	30	86	14	58	9	44	12	43	6	7	3	2	6	20
Lepomis megalotis (Rafinesque, 1820)	longear sunfish	12	31	23	164	20	54	12	82	3	4	1	4	4	46
Lepomis macrochirus × *Lepomis megalotis*	HYBRID bluegill × longear sunfish	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Lepomis microlophus (Gunther, 1859)	redear sunfish	--	1	--	--	--	--	2	1	--	--	--	1	1	--
Micropterus dolomieu Lacepede, 1802	smallmouth bass	8	14	3	12	2	--	1	3	6	4	4	5	3	4
Micropterus punctulatus (Rafinesque, 1819)	spotted bass	--	9	2	5	1	4	2	2	--	4	--	2	6	8
Micropterus salmoides (Lacepede, 1802)	largemouth bass	23	3	--	11	4	13	5	9	6	2	3	--	2	2
Pomoxis annularis Rafinesque, 1818	white crappie	--	1	--	1	--	--	--	2	--	--	--	--	2	1
Pomoxis nigromaculatus (Lesueur, 1829)	black crappie	1	1	--	5	--	2	4	7	--	--	--	--	--	2
Percidae	**(perches and darters)**														
Etheostoma blennioides Rafinesque, 1820	greenside darter	--	2	--	1	--	--	--	--	--	--	--	--	--	--
Etheostoma caeruleum Storer	rainbow darter	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Etheostoma spectabile (Agassiz, 1854)	orangethroat darter	--	--	--	--	--	--	--	--	1	--	--	--	--	--
Percina caprodes (Rafinesque, 1818)	logperch	12	8	5	3	--	2	3	10	--	--	--	6	--	--
Sander canadense (Smith, 1834)	sauger	3	1	--	--	--	--	--	--	1	--	--	--	1	1
Sander vitreus (Mitchill, 1818)	walleye	--	--	--	--	--	--	--	--	1	--	1	--	1	--
Sciaenidae	**(drums)**														
Aplodinotus grunniens Rafinesque, 1819	freshwater drum	--	--	--	--	--	2	1	2	--	2	--	--	2	--
	Total number of fish:	176	205	120	355	95	184	178	346	269	587	132	391	110	157
	Number of species:	24	23	18	25	17	23	22	27	24	23	23	21	22	16
	Total weight, in kilograms:	27.3	41.5	32.0	42.8	36.8	47.7	47.2	60.1	47.7	22.8	38.9	18.0	79.6	82.5

[1] Authority and date of the original published proposal of the scientific name. The author's name follows the scientific name and without parenthesis if the species, when originally described, was assigned to the same genus in which it appears; if the species was described in another genus, the author's name appears in parenthesis (Robins and others, 1991).

Table 8. Fish collected at the tributary sites in the Indianapolis metropolitan area, 2006 and 2008.

[**N**, non-native species deliberately or accidentally introduced into the basin; --, not found]

Scientific name	Common name and status	Number of fish collected at tributary sites											
		Buck Creek		Eagle Creek		Fall Creek		Pleasant Run		Pogues Run		Williams Creek	
		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
Clupeidae	**(herrings)**												
Dorosoma cepedianum (Lesueur, 1818)[1]	gizzard shad	--	2	--	--	5	--	--	--	--	--	2	1
Cyprinidae	**(carps and minnows)**												
Campostoma anomalum (Rafinesque, 1820)	central stoneroller	79	260	--	--	4	15	485	714	61	152	588	49
Cyprinella spiloptera (Cope, 1868)	spotfin shiner	24	2	30	4	67	13	--	2	--	--	--	--
Cyprinus carpio Linnaeus, 1758	common carp **N**	--	--	--	1	2	--	--	--	--	--	--	--
Erimystax dissimilis (Kirtland, 1840)	streamline chub	3	11	--	--	--	--	--	--	--	--	--	--
Hybopsis amblops (Rafinesque, 1820)	bigeye chub	--	2	--	--	--	--	--	--	--	--	--	--
Luxilus chrysocephalus Rafinesque, 1820	striped shiner	1	13	--	--	--	--	--	--	--	--	26	8
Nocomis micropogon (Cope, 1865)	river chub	--	--	--	--	3	2	--	--	--	--	--	--
Notemigonus crysoleucas (Mitchill, 1814)	golden shiner	--	--	--	--	--	1	--	--	--	--	--	--
Notropis atherinoides Rafinesque, 1818	emerald shiner	18	7	--	--	--	--	31	64	--	--	2	--
Notropis boops Gilbert, 1884	bigeye shiner	14	--	--	--	--	--	--	--	--	--	--	--
Notropis buccatus (Cope, 1865)	silverjaw minnow	--	3	3	5	--	--	82	53	1	12	--	--
Notropis photogenis (Cope, 1865)	silver shiner	--	--	--	--	--	--	--	4	--	--	--	--
Notropis rubellus (Agissiz, 1850)	rosyface shiner	--	--	--	--	3	--	--	--	--	--	--	--
Notropis stramineus (Cope, 1865)	sand shiner	5	45	62	50	86	--	49	184	--	--	--	--
Phenacobius mirabilis (Girard, 1856)	suckermouth minnow	2	--	--	--	3	--	1	--	--	--	--	--
Pimephales notatus (Rafinesque, 1820)	bluntnose minnow	61	85	--	3	1	2	9	15	107	24	9	--
Rhinichthys obtusus (Hermann, 1804)	western blacknose dace	--	--	--	--	--	--	26	--	43	23	--	--
Semotilus atromaculatus (Mitchill, 1818)	creek chub	1	5	--	--	--	--	54	28	190	149	45	14
Catostomidae	**(suckers and buffalo)**												
Carpiodes cyprinus (Lesueur, 1817)	quillback	--	--	6	--	--	--	--	--	--	--	--	--
Catostomus commersonii (Lacepede, 1803)	white sucker	6	1	2	3	1	--	21	27	--	27	24	--
Hypentelium nigricans (Lesueur, 1817)	northern hog sucker	39	30	2	14	29	8	1	10	--	--	31	7
Minytrema melanops (Rafinesque, 1820)	spotted sucker	2	1	--	--	--	--	--	--	--	--	--	--
Moxostoma anisurum (Rafinesque, 1820)	silver redhorse	25	8	--	--	13	--	--	--	--	--	--	--
Moxostoma duquesnei (Lesueur, 1817)	black redhorse	--	--	1	--	10	13	--	--	--	--	--	--
Moxostoma erythrurum (Rafinesque, 1818)	golden redhorse	--	19	--	1	--	9	--	--	--	--	--	2
Moxostoma macrolepidotum (Lesueur, 1817)	shorthead redhorse	3	5	--	--	--	--	--	--	--	--	--	--
Ictaluridae	**(bullhead and catfishes)**												
Ameiurus natalis (Lesueur, 1819)	yellow bullhead	1	1	2	3	--	3	1	2	1	3	--	--
Ictalurus punctatus (Rafinesque, 1818)	channel catfish	--	--	4	1	--	1	--	--	--	--	--	--
Noturus flavus Rafinesque	stonecat	--	--	--	--	--	1	--	--	--	--	--	--
Pylodictis olivaris (Rafinesque, 1818)	flathead catfish	--	--	--	--	1	1	--	--	--	--	--	--

Table 8. Fish collected at the tributary sites in the Indianapolis metropolitan area, 2006 and 2008.—Continued

[**N**, non-native species deliberately or accidentally introduced into the basin; --, not found]

Scientific name	Common name and status	Number of fish collected at tributary sites											
		Buck Creek		Eagle Creek		Fall Creek		Pleasant Run		Pogues Run		Williams Creek	
		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
Poeciliidae	**(live bearers)**												
Gambusia affinis (Baird and Girard, 1853)	western mosquitofish **N**	--	--	--	--	--	--	--	--	--	1	--	--
Atherinidae	**(silversides)**												
Labidesthes sicculus (Cope, 1865)	brook silverside	3	1	--	--	--	--	--	--	--	--	--	--
Centrarchidae	**(sunfishes)**												
Ambloplites rupestris (Rafinesque, 1817)	rock bass	7	9	--	21	--	17	--	1	--	--	--	1
Lepomis cyanellus Rafinesque, 1819	green sunfish	29	10	--	24	3	6	1	3	4	6	19	4
Lepomis macrochirus Rafinesque, 1819	bluegill	63	61	22	113	36	109	5	4	5	1	146	73
Lepomis megalotis (Rafinesque, 1820)	longear sunfish	8	9	61	354	39	132	3	41	--	--	1	1
Lepomis microlophus (Gunther)	redear sunfish	--	--	--	6	--	2	--	--	--	--	--	--
Micropterus dolomieu Lacepede, 1802	smallmouth bass	4	3	3	11	8	13	--	14	--	--	4	2
Micropterus punctulatus (Rafinesque, 1819)	spotted bass	4	15	--	11	5	2	--	1	--	1	--	1
Micropterus salmoides (Lacepede, 1802)	largemouth bass	3	--	14	6	6	15	1	1	--	--	8	1
Pomoxis annularis Rafinesque	white crappie	--	1	--	1	--	1	--	--	--	--	--	--
Pomoxis nigromaculatus (Lesueur, 1829)	black crappie	--	--	--	--	--	1	--	--	--	--	--	--
Percidae	**(perches and darters)**												
Etheostoma blennioides Rafinesque, 1819	greenside darter	35	22	--	--	2	14	--	--	--	--	35	11
Etheostoma caeruleum Storer, 1845	rainbow darter	7	11	--	1	--	5	3	5	--	--	55	86
Etheostoma nigrum Rafinesque, 1820	johnny darter	3	16	--	--	--	--	--	--	--	--	--	1
Etheostoma spectabile (Agassiz, 1854)	orangethroat darter	--	--	--	--	1	--	36	--	--	--	--	--
Percina caprodes (Rafinesque, 1818)	logperch	5	4	--	--	12	13	--	--	--	--	1	5
Percina maculata (Girard, 1859)	blackside darter	4	2	--	--	--	2	--	--	--	--	--	--
Percina phoxocephala (Nelson, 1876)	slenderhead darter	1	1	--	--	--	--	--	--	--	--	--	--
*Percina sciera (*Swain, 1883)	dusky darter	--	--	--	--	4	--	--	--	--	--	--	--
	Total number of fish:	475	697	212	633	346	401	809	1,173	412	399	1,108	459
	Number of species:	31	34	13	20	25	26	17	19	8	11	17	18
	Total weight, in kilograms:	18.6	16.4	11.9	12.2	27.6	20.0	5.4	8.5	2.8	2.8	13.2	2.3

[1] Authority and date of the original published proposal of the scientific name. The author's name follows the scientific name and without parenthesis if the species, when originally described, was assigned to the same genus in which it appears; if the species was described in another genus, the author's name appears in parenthesis (Robins and others, 1991).

Appendixes

The appendixes are separate documents, available for downloading at—

http://pubs.usgs.gov/sir/2012/5096/

Appendixes:

1. Benthic-invertebrate data (tables 1-1 through 1-178)
2. Fish-community data (tables 2-1 through 2-26)
3. Streambed-sediment chemistry data (tables 3-1 through 3-6)

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David C. Voelker—**Biological Assessment and Streambed-Sediment Chemistry of Streams, Indianapolis, Ind., 2003–2008**—Scientific Investigations Report 2012–5096