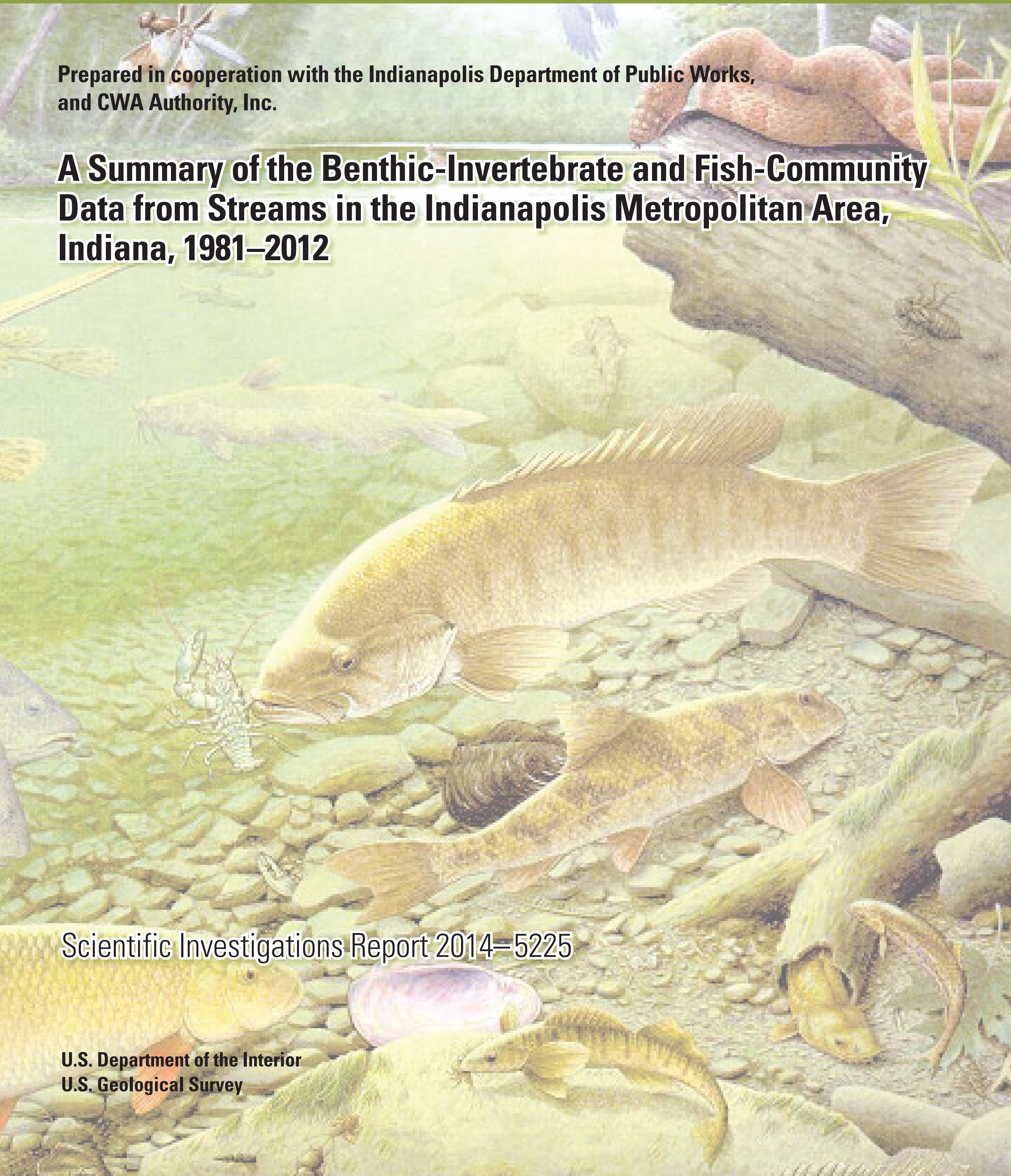

Prepared in cooperation with the Indianapolis Department of Public Works, and CWA Authority, Inc.

A Summary of the Benthic-Invertebrate and Fish-Community Data from Streams in the Indianapolis Metropolitan Area, Indiana, 1981–2012

Scientific Investigations Report 2014–5225

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

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
square meter (m^2)	0.0002471	acre
	Flow rate	
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

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

Abbreviations used in this report

CSO	combined-sewer overflows
CSS	combined-sewer system
DPW	Department of Public Works
EPT	Ephemeroptera, Plecoptera, and Trichoptera
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
NAWQA	National Water-Quality Assessment
USGS	U.S. Geological Survey
WWTF	wastewater-treatment facility
µm	micrometer

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Abstract

Intermittently, during 1981–2012, the U.S. Geological Survey sampled sites in the White River and several tributaries in the Indianapolis metropolitan area of Indiana for benthic invertebrates and fish communities. During 1981–87, one study focused on benthic-invertebrate data collection at three sites along the White River. During 1994–96, 21 sites were sampled for benthic invertebrates; after 1999, up to 13 sites were sampled for benthic invertebrates and fish communities. The information collected during these studies was used in conjunction with the Indianapolis Department of Public Works and CWA Authority, Inc.,[1] programs to help improve overall health of the White River and its tributaries by reducing combined sewer overflows and other point and non-point sources of pollution in the Indianapolis area.

Beginning in 1994, the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index and Hilsenhoff Biotic Index (HBI) were calculated. Beginning in 1999, the Invertebrate Community Index (ICI) also was calculated from the benthic-invertebrate data. Fish-community data were collected periodically from 1999 to 2012, from which an Index of Biotic Integrity (IBI) was calculated.

Introduction

The Indianapolis Department of Public Works (DPW) was responsible for managing the combined-sewer system (CSS) in Indianapolis until 2009, when CWA Authority, Inc., took over the responsibilities for water and wastewater services in Indianapolis. A CSS is designed, constructed, and operated to carry both sanitary sewage and stormwater runoff in the same system. These entities are responsible for implementing control strategies to mediate the effects of combined-sewer overflows (CSOs) on water quality of receiving streams in and around Marion County, Indiana, including the city of Indianapolis.

The U.S. Environmental Protection Agency (EPA; U.S. Environmental Protection Agency, 1999), in its guidance document for monitoring and modeling of CSOs, states that baseline conditions of the receiving water need to be defined. Therefore, the Indianapolis DPW proposed using biological indicators for monitoring 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 because the aquatic organisms are affected by long-term exposure to a variety of environmental changes. It would be difficult to attribute existing biological conditions directly to the CSOs alone because biological sampling reflects the overall effects from all pollution sources entering the receiving waters. Therefore, the EPA has indicated that investigators generally should limit the use of diversity indexes as general indicators of environmental effects to comparisons within the study where sampling and sample analysis methods are consistent. Receiving waters in the study area include the White River, Pogues Run, Pleasant Run, Eagle Creek, and Fall Creek. Williams Creek and Buck Creek do not contain CSOs but can be subject to input from septic systems or sanitary-sewer failures. The Nora (or Westfield Boulevard) site on the White River and the Williams and Buck Creek sites are considered for the purposes of this study to be the control (or reference) sites when comparing data within the study area, because of the limited amount of input from the Indianapolis sewer system.

Biotic integrity was 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. Biological integrity provides a key means of assessing stream ecosystems 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. To

[1] CWA Authority Inc., is a broad-based utility service company that operates as a Public Trust. More information can be found at https://www.citizensenergygroup.com.

achieve the objectives of the Clean Water Act (http://www.epa.gov.r5water/pdf/ecwa_t1.pdf, accessed on April 10, 2002), comprehensive information about the ecological integrity of aquatic environments is needed. Biological criteria can help to identify water-quality impairments, support regulatory controls that address water-quality problems, and assess improvements in water quality from regulatory efforts. Measures of stream biota complement water-quality programs that focus on direct measures of chemical water quality and physical properties of the aquatic environment.

Benthic invertebrates are used to assess stream quality because they occupy all stream habitats and have a wide range of feeding preferences. They also are good indicators of overall stream quality because they are not very mobile and react quickly to environmental stresses, and can be found in all but the most severely polluted habitats. Benthic invertebrates occupy the middle of the aquatic food chain and are a major food source for fish and other aquatic life. They are excellent indicators of biological integrity in aquatic environments (Ohio Environmental Protection Agency, 1989) according to our knowledge of their life cycles and tolerance to environmental stresses.

While fish communities are more mobile than benthic invertebrates, they were sampled because they also are sensitive to water-quality conditions, with limited options to escape stressors in their environment. Fish communities also can represent water-quality conditions in a stream because of their sensitivity to a wide variety of environmental factors such as habitat degradation, siltation, pesticides, nutrients, and changes in streamflow. Diversity can be affected by colonization rates, the presence of suitable habitat, extinction rates, competition, predation, physical disturbances, pollution, and other factors (Crowder, 1990).

In the early 1980s, the U.S. Geological Survey (USGS), in cooperation with the Indianapolis DPW, began a study to assess benthic-invertebrate communities in the White River in response to changes and upgrades in wastewater-treatment facilities (WWTFs) in Indianapolis (Crawford and others, 1992). In the 1990s, a second study was begun to assess biological communities in the White River and selected tributaries relative to CSO issues that the City was assessing (Renn, 1998; Voelker and Renn, 2000). During 1999–2001, a third study was conducted that included benthic invertebrates and fish communities (Voelker, 2004). During 2003–4, the USGS continued to collect benthic-invertebrate samples; during 2005–12, comparative studies remained in place to collect benthic-invertebrate and fish-community information (Voelker, 2012, 2014). While the biological conditions of these streams cannot be solely attributed directly to effects from CSOs, the integrity of the biological communities do reflect overall effects from all sources entering the receiving waters.

Purpose and Scope

This report presents the summary statistics for the benthic-invertebrate and fish communities at 13 sites for which there are long-term data available in and around Marion County, Ind. (fig. 1), with emphasis on data collected during 1994–2012, although 3 of the sites have data that extend back to 1981. The report presents the biological data using indexes to assess the general health of the aquatic environment. Benthic-invertebrate communities are summarized using the Ephemeroptera, Plecoptera, and Trichoptera (EPT) index, Hilsenhoff Biotic Index (HBI), and Invertebrate Community Index (ICI). The ICI data are available only for samples collected during 1999–2012. Fish communities are summarized using an Index of Biotic Integrity (IBI), which was calculated during 1999–2012. Biological indexes are described, and the results of the index calculations are presented.

Description of Study Area

Indianapolis is the capital of Indiana and the largest city in the State. The city is incorporated with Marion County and covers approximately 402 square miles (mi^2). Approximately 55 mi^2 of the metropolitan area has been serviced by a CSO system (fig. 1). In 2007, this system had approximately 130 CSOs that discharged into the White River directly or via several of its tributaries in the area. An additional 220 mi^2 of the metropolitan area uses separate sanitary and storm sewers. The remaining portion of Indianapolis utilizes private septic systems, but most of these areas are gradually being converted to sanitary sewers (http://www.citizensenergygroup.com/Our-Company/Our-Projects/Septic-Tank-Elimination-Program). The study area is in the central climate division of Indiana, which is characterized by hot, humid summers and cold, wet winters (Newman, 1966). The study area is encompassed by the Eastern Corn Belt Plains ecoregion (Woods and others, 1998), and crop production 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. The most downstream site sampled is Waverly, with a drainage area of 2,026 mi^2. The most upstream site referred to in this report is the White River at Nora, with a drainage area of 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

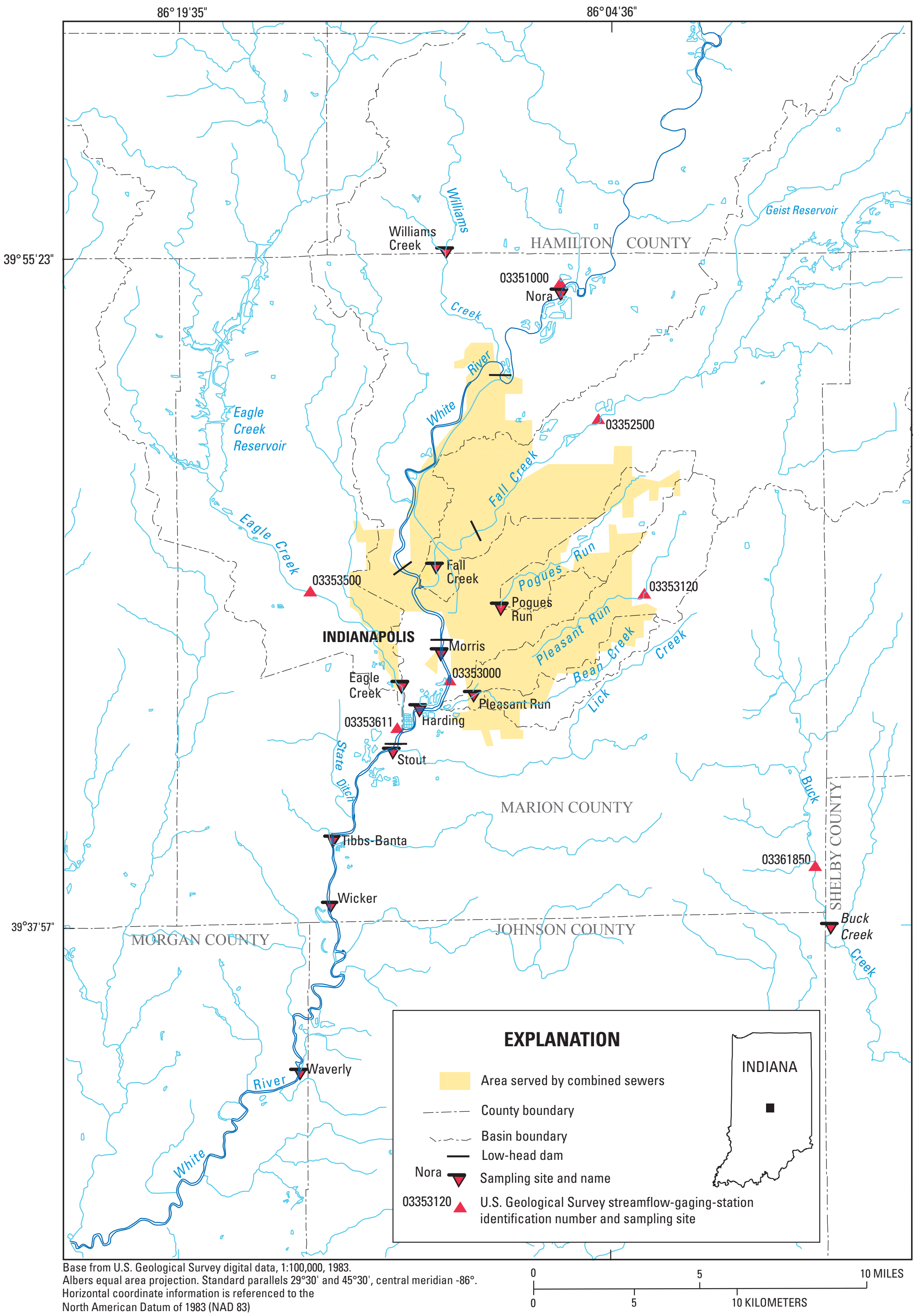


Figure 1. Location of the study area and site locations on the White River and tributaries in the Indianapolis metropolitan area, Indiana.

Southport facility can handle 125 Mgal/d, with peak flows to 180 Mgal/d. This is about twice the flow capacity of the mid-1980s (Crawford and others, 1992). Together, the two Indianapolis WWTFs treat over 70 billion gallons of wastewater each year (www.citizensenergygroup.com/Wastewater.aspx). With the completion (in 2025) of mediation measures to reduce sewer overflows, an additional 3.5 billion gallons of raw sewage is expected to be captured and treated (www.citizensenergygroup.com/Wastewater.aspx).

History of the Cooperative Studies

The USGS has conducted biological sampling in the study area intermittently since 1981. The results of these studies were presented by Crawford and others (1992), Renn (1998), Voelker and Renn (2000), and Voelker (2004, 2012, 2014). Study sites remained consistent throughout the entire period (1981–2012) with the exception of the most upstream site on the White River, which was originally sampled at Westfield Boulevard (1981–87), but was moved to the nearby Nora site for sampling during 1994–2012. These studies all included benthic invertebrates collected at least yearly during 1981–87, 1994–96, 1999–2001, and 2003–12. Fish-community assessments were completed during 1999–2001, 2006, 2008, 2010, and 2012.

Table 1. Sites included in this report that were sampled for benthic invertebrates and fish communities, 1981–2012.

[ddmmss, degrees minutes seconds; Ind., Indiana; mi, miles; DS, downstream; nr, near]

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

[1]**BOLD** type indicates short name used throughout text to identify sites.

Methods of Investigation

Initially, three sites were sampled by Crawford and others (1992), then 21 sites by Renn (1998), 12 sites by Voelker (2004), and lastly, 13 by Voelker (2012, 2014). These sites were selected in coordination with the Indianapolis DPW, which was responsible for monthly surface-water sampling at or near those sites. In addition, several sites were selected to provide continuity of data collection from previous studies that would allow for a historical comparison of data at some sites. For this report, 13 sites that have long-term data are used to summarize the biological communities in the White River and its tributaries in and around Indianapolis (table 1).

Benthic Invertebrates

Benthic invertebrates were collected once per year in late summer/early fall by Crawford and others (1992) and then twice a year during subsequent studies (Voelker and Renn, 2000; Voelker, 2004, 2012, 2014). Samples for the latter studies were collected during periods of relatively low-flow, steady-state streamflow conditions in the spring (May or June), and in the late summer/early fall (September and October) unless streamflow conditions resulted in sampling-schedule changes. These time periods were selected to coincide with the aquatic stages of most benthic-invertebrate species. Three individual samples were collected from habitats where the greatest diversity and abundance of invertebrates was expected to occur. High diversity habitats are usually riffle sections, although when those sections were not available the best available habitat was sampled (see Voelker, 2004, for a description of where sampling occured). During 1981–87, Crawford and others (1992) collected benthic invertebrates using a Surber sampler, which had a 0.0929 square-meter (m^2) sample grid and a 1.024 micrometer (µm) mesh size, following the methods described by Greeson and others (1977). This was a fairly large mesh size, and some of the smaller invertebrates may not have been adequately represented in the samples. Since 1994, benthic-invertebrate samples were collected at each site using a Surber sampler and a collection-net mesh opening of 210 µm. Sampling followed the guidelines set forth in Britton (1988) and described in Renn (1998) and Voelker (2004).

Benthic invertebrates were picked in the field for the study by Crawford and others (1992) and then sent to a laboratory for analysis, but the Renn (1998) and Voelker (2004, 2012, 2014) studies submitted the entire sample to a contract laboratory where they were sorted and identified to the lowest possible taxonomy—generally genus and species. The laboratory calculated the number of organisms in the sample, the number of taxa, and the HBI for each set of three samples. The results of the three individual samples were combined to determine the EPT index, HBI (Hilsenhoff, 1987), and ICI (Ohio Environmental Protection Agency, 1987, 1989) scores for each sample round at each site. The ICI was developed to provide a descriptive statistic that could be used to compare sites within a study area. The ICI consists of 10 structural and functional community metrics that describe the benthic-invertebrate community.

Fish

Fish communities were sampled during the summer months of 1999, 2000, 2001, 2006, 2008, 2010, and 2012, following guidelines established by the USGS National Water-Quality Assessment (NAWQA) Program (Meador and others, 1993). Fish were collected using pulsed direct-current electrofishing techniques. Specially designed electrofishing boats were used at all the White River sites; a backpack or tote-barge mounted equipment was used at the tributary sites. Taxonomic nomenclature followed that established by Robins and others (1991) and by Nelson and others (2004). Fish data were used to calculate an IBI for the site sampled.

Condition of Benthic-Invertebrate Communities

A complete list of benthic-invertebrate data for each sample was presented in Crawford and others (1992), Renn (1998), and Voelker (2004, 2012, 2014). From these data, the number of taxa (diversity) (table 2), the abundance (density) of benthic organisms (table 3), and various benthic-invertebrate indexes were calculated.

The number of benthic-invertebrate taxa identified at the White River sites ranged from 5 (Wicker, 1995) to 62 (Nora, 2011) during 1981–2012 (table 2). The median number of taxa at sites along the White River ranged from a high of 40 at the most upstream site (Nora), to a low of 27 at the most downstream site (Waverly) (fig. 2). On the tributary sites, the number of taxa ranged from 5 at Pogues (1995) to 62 at Buck (1999). The median number of taxa on the tributaries ranged from 32 at Pleasant to 53 at Buck (table 2, fig. 2).

The median abundance (or density) of benthic-invertebrate organisms calculated using the data showed that the lowest sites on the White River were Wicker Road (6,552/m^2) and Tibbs (24,162/m^2) (table 3). Pogues had the lowest median abundance (5,431/m^2), and Fall had the highest median abundance (18,033/m^2) of the tributary sites.

Table 2. Number per square meter of benthic invertebrate taxa in samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Crawford and others, 1992													
1981	34	--	--	19	--	--	23	--	--	--	--	--	--
1982	34	--	--	15	--	--	13	--	--	--	--	--	--
1983	23	--	--	16	--	--	17	--	--	--	--	--	--
1984	18	--	--	19	--	--	16	--	--	--	--	--	--
1985	30	--	--	22	--	--	20	--	--	--	--	--	--
1986	24	--	--	20	--	--	17	--	--	--	--	--	--
1987	29	--	--	23	--	--	21	--	--	--	--	--	--
Data from Voelker and Renn, 2000													
May 1994	28	17	18	--	16	11	12	--	19	7	12	9	25
Sept. 1994	20	13	10	--	13	19	15	--	26	14	10	10	16
July 1995	13	8	5	11	7	5	7	--	12	10	9	6	12
Sept. 1995	17	18	15	18	15	15	12	--	18	13	15	15	--
July 1996	26	26	30	28	--	--	--	--	29	--	18	19	21
Sept. 1996	22	19	22	28	24	19	17	--	29	11	22	13	29
Data from Voelker, 2004													
May 1999	41	40	38	23	--	19	32	--	32	30	20	18	51
Sept. 1999	40	33	23	28	--	41	32	62	37	32	34	--	37
May 2000	43	28	31	39	--	29	33	56	50	34	25	25	43
Sept. 2000	46	43	43	29	--	42	29	57	42	40	32	37	48
May 2001	48	36	33	38	--	41	38	58	37	32	37	32	48
Sept. 2001	42	45	29	39	--	43	31	61	41	35	34	44	42
Data from Voelker, 2012													
June 2003	46	45	33	32	--	37	28	48	47	43	31	32	44
Nov. 2003	38	45	27	28	--	17	23	48	45	35	33	46	40
May 2004	38	38	39	31	26	18	28	52	42	34	28	34	34
Sept. 2004	34	32	30	31	26	31	23	53	48	34	29	32	36
May 2005	51	43	47	38	20	28	26	49	44	31	30	27	34
Sept. 2005	50	51	49	39	39	41	42	60	39	46	38	43	38

Table 2. Number per square meter of benthic invertebrate taxa in samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.—Continued

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2012—Continued													
June 2006	39	43	36	37	30	24	24	45	48	39	27	39	42
Oct. 2006	46	49	41	50	37	39	33	54	41	37	30	38	37
May 2007	38	44	37	33	38	26	29	53	42	30	30	39	45
Sept. 2007	44	35	37	31	37	43	35	59	40	40	38	34	41
June 2008	42	36	49	39	30	33	31	46	34	29	33	34	44
Sept. 2008	31	34	45	43	40	31	37	51	40	41	38	44	32
Data from Voelker, 2014													
July 2009	46	37	39	46	32	28	30	53	40	38	37	39	33
Sept. 2009	46	39	42	35	30	29	26	37	41	34	44	47	37
Aug. 2010	41	35	35	29	27	26	26	53	31	38	32	38	33
Sept. 2010	43	41	33	33	32	34	26	52	49	42	31	--	44
July 2010	62	52	51	37	43	40	38	43	42	40	46	32	32
Sept. 2011	45	31	57	31	32	42	37	61	56	38	39	50	49
May 2012	48	59	49	49	47	39	42	58	50	39	49	43	54
Sept. 2012	46	49	41	50	32	50	39	60	52	43	53	41	49
Minimum	13	8	5	11	7	5	7	37	12	7	9	6	12
Median	40	38	37	31	30	31	27	53	41	35	32	34	38
Maximum	62	59	57	50	47	50	42	62	56	46	53	50	54

Table 3. Abundance per square meter of benthic invertebrates in samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Crawford and others, 1992													
1981	3,130	--	--	2,790	--	--	2,260	--	--	--	--	--	--
1982	3,000	--	--	6,110	--	--	9,920	--	--	--	--	--	--
1983	2,880	--	--	1,920	--	--	2,320	--	--	--	--	--	--
1984	3,660	--	--	646	--	--	658	--	--	--	--	--	--
1985	3,950	--	--	1,410	--	--	1,870	--	--	--	--	--	--
1986	3,020	--	--	5,700	--	--	4,780	--	--	--	--	--	--
1987	4,710	--	--	26,500	--	--	3,510	--	--	--	--	--	--
Data from Voelker and Renn, 2000													
May 1994	2,400	1,800	2,000	--	3,500	3,300	4,500	--	2,400	440	4,200	620	6,200
Sept. 1994	4,000	4,000	950	--	5,900	2,000	2,500	--	1,300	1,500	1,900	690	6,500
July 1995	8,400	290	420	2,100	1,400	540	2,400	--	620	890	780	130	600
Sept. 1995	5,500	5,000	5,700	8,200	8,600	3,800	6,500	--	1,600	1,600	2,600	610	--
July 1996	42,000	18,000	11,000	24,000	--	--	--	--	15,000	--	2,200	5,300	12,000
Sept. 1996	3,900	7,800	3,700	140,000	4,100	1,200	12,000	--	3,500	1,000	5,400	700	2,400
Data from Voelker, 2004													
May 1999	36,084	5,145	18,873	17,370	--	15,758	14,621	--	27,416	79,140	26,031	36,684	24,388
Sept. 1999	33,655	49,755	22,009	64,864	--	11,119	46,454	11,406	28,546	46,095	29,694	--	7,380
May 2000	129,778	6,021	7,675	10,434	--	8,988	13,807	35,453	22,364	39,568	27,391	20,319	65,610
Sept. 2000	21,205	28,865	70,300	11,962	--	3,606	1,224	11,022	12,228	30,990	5,070	8,127	9,400
May 2001	30,864	14,621	20,344	73,281	--	6,326	6,448	15,766	48,406	15,109	13,218	4,377	20,010
Sept. 2001	16,401	32,303	30,717	20,017	--	3,599	6,706	14,761	9,092	15,726	3,513	3,287	29,425
Data from Voelker, 2012													
June 2003	14,804	10,936	15,719	18,338	--	4,062	6,354	26,591	9,888	30,932	31,104	25,464	19,630
Nov. 2003	3,132	3,663	743	1,381	--	682	710	3,197	18,396	32,816	1,952	4,790	5,795
May 2004	39,267	2,720	7,420	25,539	18,991	20,161	14,499	27,172	35,281	5,644	16,315	10,298	10,764
Sept. 2004	10,172	2,709	1,478	10,872	18,198	10,664	24,976	10,875	6,591	14,660	10,290	3,398	11,804
May 2005	8,177	9,361	6,003	28,801	41,883	7,829	15,590	22,550	6,484	17,061	20,297	3,229	17,671
Sept. 2005	9,508	5,443	10,699	13,150	16,580	2,598	3,111	3,976	9,483	12,070	2,723	6,168	13,179

Table 3. Abundance per square meter of benthic invertebrates in samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.—Continued

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2012—Continued													
June 2006	3,696	1,611	1,198	15,866	33,853	6,552	13,236	4,682	6,466	21,144	7,341	8,410	15,683
Oct. 2006	8,227	2,504	12,436	11,934	8,410	6,501	5,956	9,863	10,423	6,641	11,625	3,075	5,891
May 2007	23,620	4,463	8,522	29,102	23,304	9,476	9,716	12,798	20,236	28,639	16,659	21,044	46,942
Sept. 2007	15,059	23,469	29,766	11,177	24,162	8,661	13,522	11,130	10,064	27,054	15,766	1,188	18,858
June 2008	4,556	9,451	4,840	17,603	6,677	7,126	8,457	19,067	21,058	14,273	19,167	16,860	16,896
Sept. 2008	12,737	80,088	20,609	11,535	28,539	13,530	11,438	10,803	18,589	18,033	15,464	5,382	39,723
Data from Voelker, 2014													
July 2009	26,544	11,708	3,688	12,533	39,726	13,975	9,530	11,883	16,325	17,104	18,274	19,497	35,697
Sept. 2009	69,909	121,378	1,067,068	36,967	39,852	39,558	32,920	26,896	27,753	52,693	22,716	3,706	19,734
Aug. 2010	12,590	4,410	38,872	27,190	59,514	22,106	13,842	12,170	29,440	9,178	25,518	3,344	7,287
Sept. 2010	36,583	25,776	33,404	78,401	58,617	4,657	28,592	20,556	8,145	19,730	27,179	--	23,566
July 2010	19,214	12,540	6,526	26,967	34,240	3,911	29,956	47,124	27,782	22,540	7,861	7,721	23,286
Sept. 2011	50,763	159,741	325,589	71,907	114,012	26,354	40,867	35,805	13,810	33,207	24,341	20,972	29,515
May 2012	29,960	15,644	15,683	19,199	46,063	10,061	14,808	65,517	18,105	45,162	106,768	55,529	66,098
Sept. 2012	44,254	8,672	13,645	24,832	67,045	4,313	13,247	17,664	22,446	24,718	5,475	11,988	16,745
Minimum	2,400	290	420	1,381	6,677	540	658	3,197	620	440	780	130	600
Median	12,590	9,017	10,850	17,370	24,162	6,552	9,623	14,761	14,405	18,033	14,341	5,341	16,896
Maximum	129,778	159,741	1,067,068	140,000	114,012	39,558	46,458	65,517	48,406	79,140	106,768	55,529	66,098

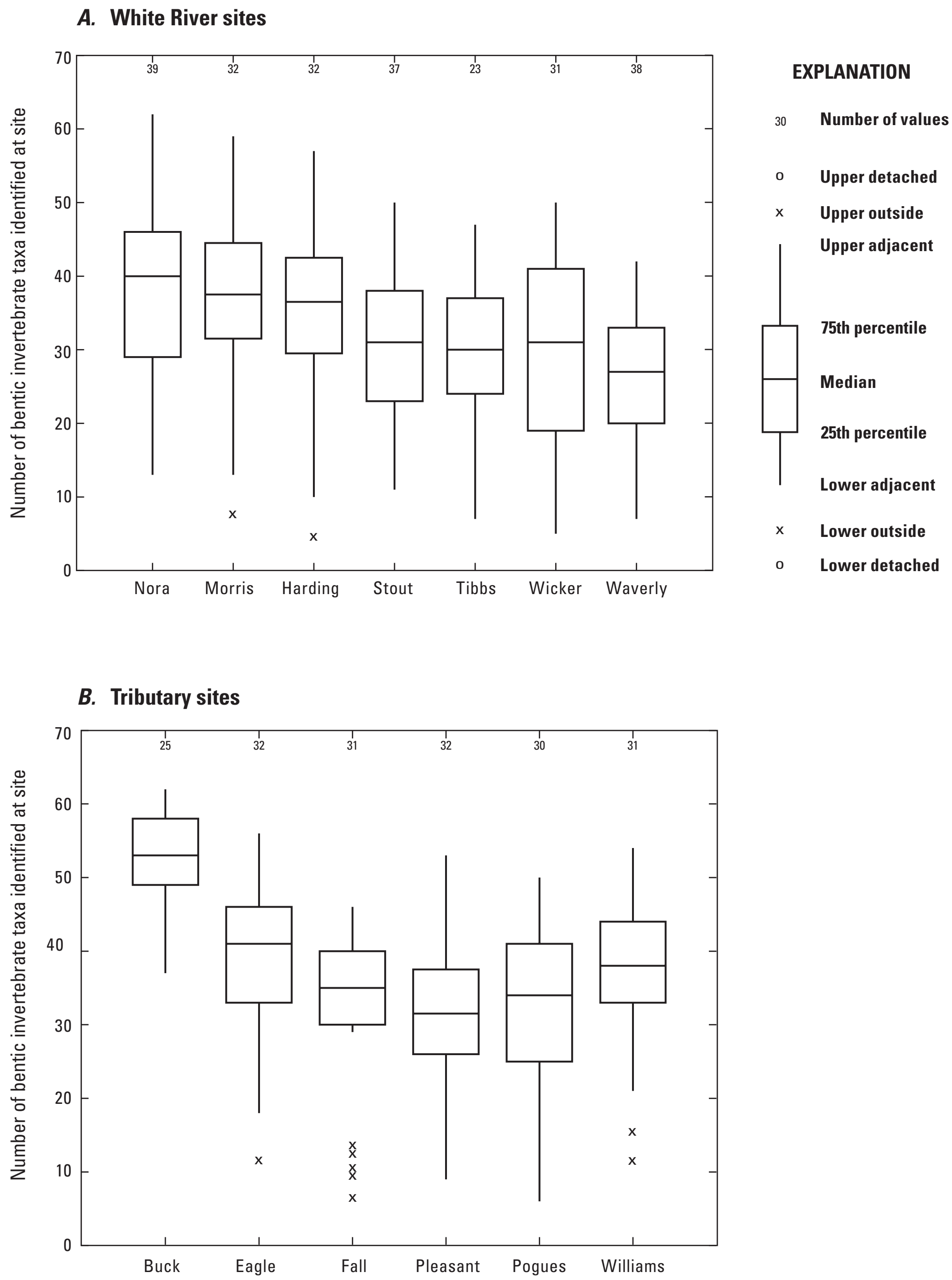


Figure 2. Number of taxa of the benthic-invertebrate population, 1981–2012. *A*, White River sites. *B*, Tributary sites.

Benthic-Invertebrate Indexes

Three benthic-invertebrate indexes were calculated to describe the benthic-invertebrate population at sites. These include the EPT index, the HBI, and the ICI.

Ephemeroptera, Plecoptera, Trichoptera (EPT) Index

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

During the 1981–2012 study period, the EPT scores on the White River ranged from 0 at Morris (1994, 1995), Harding (1994, 2000), and Waverly (1982) to 17 at Nora (2010) (table 4). The median scores at the White River sites ranged from 4 to 10 at sites downstream of the CSO influence, and was 13 at Nora—the only site upstream of CSOs (fig. 3).

On the tributaries, EPT scores ranged from lows of 0 at Pleasant (1994) and Pogues (1994, 1995, 1999) to 17 at Buck (2007, 2010) (table 4). The median scores at these sites ranged from 7 at Fall, Pleasant, and Pogues to 14 at Buck (fig. 3).

The EPT scores indicate that the greatest diversity of these pollution-intolerant organisms are found upstream-from or away-from the combined-sewer areas. Sites directly affected by CSOs or those located in the more urbanized areas show decreased diversity among these species. One exception to this is the Stout site where the improved EPT scores may be due to the stream reaeration, as the water flows over the low-head dam just upstream of the sampling site.

The lowest number of observations of these pollution-intolerant species was at the Morris and Harding sites on the White River, and at the Fall, Pleasant, and Pogues sites on the tributaries (table 4). These sites all represent the more urbanized stream conditions and have the greatest impact from CSOs affecting water-quality conditions. The Harding site also was under very low-velocity conditions, and the substrate at the sample site was limited to silt and rip-rap. The Nora and Buck sites both had distinctly greater numbers of EPT organisms than the other sites.

Hilsenhoff Biotic Index

The HBI (Hilsenhoff, 1987) was developed to assess organic pollution through its effect on benthic-invertebrate species. It is calculated from pollution-tolerance values assigned to benthic-invertebrate species. The HBI is calculated 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 unlike the other indexes, the HBI score increases with decreasing water-quality conditions (table 5).

The HBI scores on the White River ranged from a low of 4.33 (very good) at Waverly (2009) to 9.88 (very poor) also at the Waverly site (1982). Median HBI scores on the White River ranged from 5.47 (good) at Waverly to 9.12 (very poor) at Harding (fig. 4). Median scores at the Nora, Tibbs, and Wicker sites all rated “fair,” indicating fairly significant organic pollution present. The Morris and Harding HBI scores rated “very poor,” indicating severe organic pollution, while the median score at Stout rated “fairly poor,” indicating significant organic pollution at that site. The Waverly site was the only site where the HBI scores rated conditions as “good,” indicating only some organic pollution present.

On the tributaries, HBI scores ranged from a low of 2.86 (excellent) at Buck (2001) to a high of 8.14 (poor) at Pogues (2004) (table 6). Median scores ranged from 5.35 (good) at Buck to 6.24 (fair) at Pleasant, while all other tributary (fig. 4) sites also rated “fair” indicating fairly significant organic pollution at those sites.

HBI scores at the tributary sites show that conditions at the Buck and Williams sites were better than those of the other tributary sites (fig. 4). The more urbanized sites at Fall, Pleasant, and Pogues all indicated the least favorable conditions for benthic invertebrates among the tributary sites.

Invertebrate Community Index

The ICI (Ohio Environmental Protection Agency, 1987, 1989) 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. The higher the ICI score, the better the water-quality conditions at that site. The ICI calculations were only done during the 1999–2012 studies.

The ICI scores on the White River ranged from a high of 46 at Nora (June 2008 and August 2010) to 8 at Harding (May 2008) (table 7). The median scores at the White River sites ranged from 35 at Nora to 20 at Harding. Figure 5 shows that the median ICI scores are all lower after the river flows through the CSO-affected areas than at the Nora site located upstream of the CSO influences.

On the tributaries, ICI scores ranged from 52 at Buck (September 2004) to 4 at Pogues (May 1999) during 1999–2012 (table 7). The median scores during this period ranged from 44 (Buck) to 27 (Fall) (fig. 5). The remaining tributary sites had median scores from 29 to 37, and these scores were higher than all sites on the White River except for Nora.

The ICI scores, which incorporate the EPT and HBI scores, also indicate that the best conditions in support of healthy benthic-invertebrate communities are at the Nora and Buck sites. On the White River, data support the observation that the most impaired communities are located at sites most impacted by CSOs and are located in the more urbanized areas.

Table 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
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
Sept. 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
Sept. 1995	7	3	3	5	5	4	4	--	5	4	4	2	--
July 1996	7	7	6	8	--	--	--	--	6	--	2	3	5
Sept. 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
Sept. 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
Sept. 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
Sept. 2001	12	5	5	8	--	6	6	16	10	6	5	4	9
Data from Voelker, 2012													
June 2003	12	7	4	6	--	3	4	15	11	5	5	3	7
Nov. 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
Sept. 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
Sept. 2005	14	6	5	7	7	7	8	14	11	7	7	8	6

Table 4. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.—Continued

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2012—Continued													
June 2006	15	6	6	9	12	6	12	7	11	9	4	6	8
Oct. 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
Sept. 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
Sept. 2008	9	5	6	10	12	6	6	8	10	8	8	9	9
Data from Voelker, 2014													
July 2009	15	6	3	14	9	8	8	13	7	7	7	7	7
Sept. 2009	9	6	2	8	9	5	8	13	9	6	8	8	9
Aug. 2010	17	6	7	10	8	8	9	17	9	8	6	8	5
Sept. 2010	14	8	6	10	12	9	8	14	9	11	10	--	11
July 2010	15	14	4	8	11	5	9	11	6	7	5	7	7
Sept. 2011	9	3	6	10	12	9	12	15	9	9	6	8	9
May 2012	11	8	4	7	7	4	9	13	6	7	6	5	7
Sept. 2012	11	4	1	9	7	7	8	16	9	7	9	4	10
Minimum	5	0	0	1	6	2	0	7	2	1	0	0	4
Median	13	6	4	10	9	8	9	14	9	7	7	7	8
Maximum	17	14	7	14	12	9	12	17	12	11	10	9	12

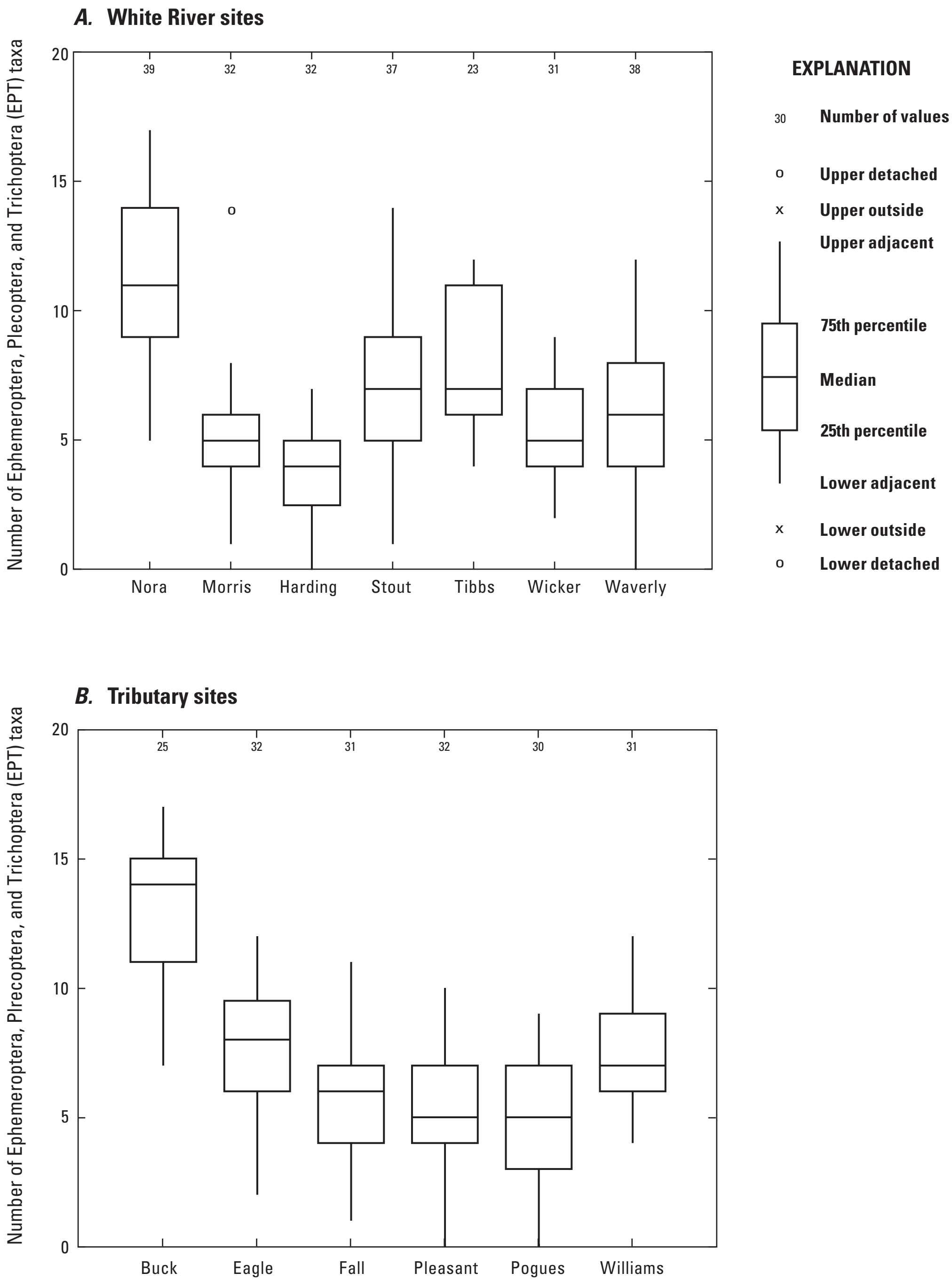
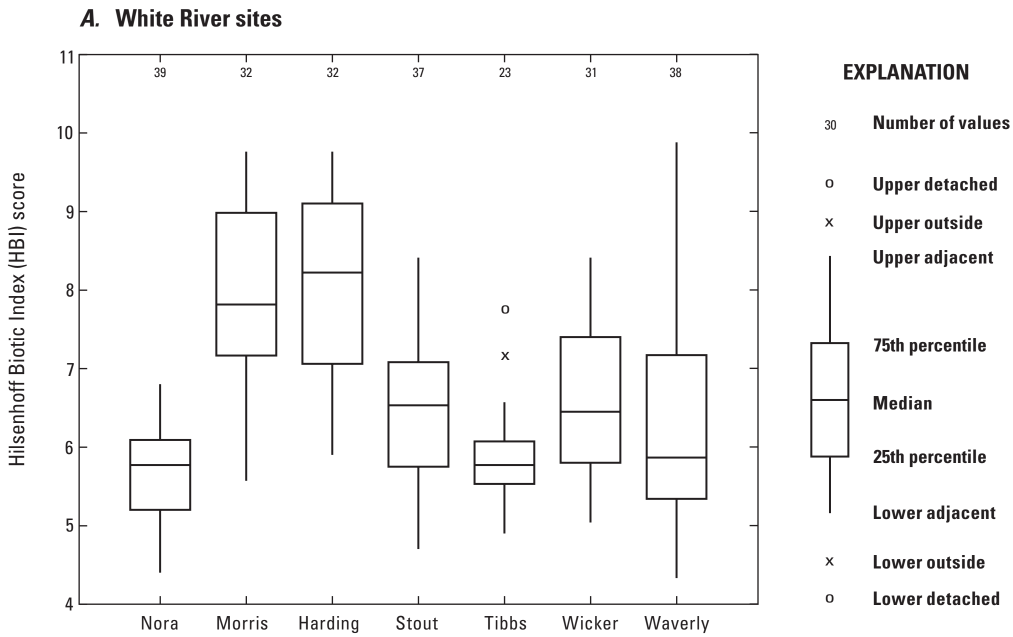


Figure 3. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index scores, 1981–2012. *A*, White River sites. *B*, Tributary sites.



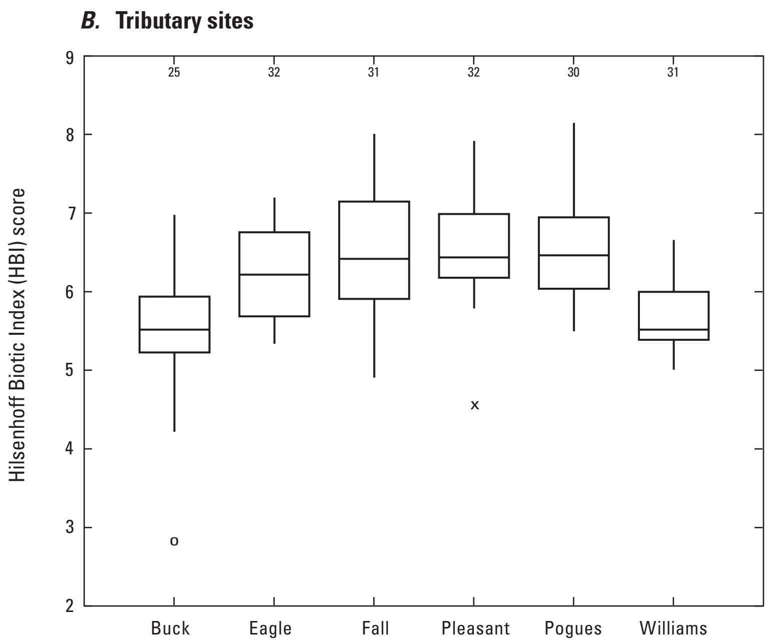


Figure 4. Hilsenhoff Biotic Index (HBI) scores, 1999–2012. *A,* White River sites. *B*, Tributary sites.

Table 5. Hilsenhoff Biotic Index as an evaluation of water quality (Hilsenhoff, 1987).

Biotic Index Score	Water-quality rating	Degree of organic pollution
0.00–3.50	Excellent	No apparent organic pollution.
3.51–4.50	Very good	Possible slight organic pollution.
4.51–5.50	Good	Some organic pollution.
5.51–6.50	Fair	Fairly significant organic pollution.
6.51–7.50	Fairly poor	Significant organic pollution.
7.51–8.50	Poor	Very significant organic pollution.
8.50–10.00	Very poor	Severe organic pollution.

Table 6. Hilsenhoff Biotic Index (HBI) scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
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
Sept. 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
Sept. 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
Sept. 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
Sept. 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
Sept. 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
Sept. 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 Voelker, 2012													
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
Nov. 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
Sept. 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
Sept. 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

Table 6. Hilsenhoff Biotic Index (HBI) scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1981–2012.—Continued

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
						Data from Voelker, 2012—Continued							
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
Oct. 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
Sept. 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
Sept. 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
						Data from Voelker, 2014							
July 2009	5.57	7.36	7.29	5.54	5.43	5.04	4.57	5.72	5.45	5.36	5.8	5.71	5.44
Sept. 2009	6.12	9.39	8.96	8.09	5.22	7.18	4.33	5.51	5.92	6	5.84	6.73	5.42
Aug. 2010	5	8.52	9.76	5.88	5.77	6.55	5.47	4.93	5.72	5.39	6.38	5.79	5.51
Sept. 2010	5.5	9.07	9.28	6.73	4.97	6.81	4.48	4.67	6.77	5.87	6.1	--	5.2
July 2010	5.39	5.57	6.5	5.67	6.03	5.84	5.47	5.47	5.86	5.7	6.42	5.49	5.74
Sept. 2011	5.78	9.76	9.35	6.69	5.61	6.28	5.81	5.12	6.22	5.98	6.38	6.49	5.51
May 2012	6.05	6.73	7.44	6.74	6.55	6.57	6.31	5.51	6.69	6.27	5.99	5.55	5.55
Sept. 2012	5.89	8.96	9.7	7.08	5.86	5.93	5.83	5.22	6.73	6.23	6.44	5.99	5.61
Minimum	4.4	5.57	5.9	4.7	4.9	5.37	4.33	2.86	5.33	4.9	4.59	5.49	5
Median	5.68	8.74	9.12	6.71	5.69	6.42	5.47	5.35	6.07	5.93	6.24	5.89	5.51
Maximum	6.73	9.76	9.76	8.09	6.57	8.41	9.88	6.97	7.19	7.76	7.91	8.14	6.33

Table 7. Invertebrate Community Index (ICI) scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1999–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2004													
May 1999	36	16	16	12	--	14	20	--	26	18	12	4	34
Sept. 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
Sept. 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
Sept. 2001	32	22	26	30	--	26	32	50	38	30	30	32	42
Data from Voelker, 2012													
June 2003	34	24	16	24	--	16	18	36	34	26	24	22	40
Nov. 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
Sept. 2004	32	22	16	30	28	26	24	52	38	20	24	34	30
May 2005	36	22	24	24	20	14	16	32	32	20	24	18	30
Sept. 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
Oct. 2006	42	22	22	42	36	34	32	40	28	24	30	38	28
May 2007	34	28	22	28	32	20	22	36	30	20	26	34	38
Sept. 2007	28	18	26	28	26	30	34	48	40	30	40	34	42
June 2008	46	30	20	36	24	26	24	28	20	20	26	32	32
Sept. 2008	34	26	30	30	34	22	24	32	32	34	46	46	40
Data from Voelker, 2014													
July 2009	42	22	16	34	26	26	24	38	34	28	40	46	34
Sept. 2009	30	28	22	26	28	20	28	48	36	38	40	44	42
Aug. 2010	46	28	22	30	28	26	30	50	24	34	28	42	34
Sept. 2010	38	28	22	32	42	26	26	50	32	34	42	--	42
July 2010	36	38	18	28	34	26	28	43	28	32	28	42	32
Sept. 2011	32	18	28	28	40	30	40	50	30	32	38	46	48
May 2012	30	26	18	26	28	20	28	44	26	28	30	32	38
Sept. 2012	34	18	16	26	26	28	32	46	34	26	34	34	42
Minimum	28	14	8	12	20	12	16	28	20	12	10	4	28
Median	35	22	20	28	28	25	26	44	32	27	29	34	37
Maximum	46	38	30	42	42	34	40	52	42	38	46	46	48

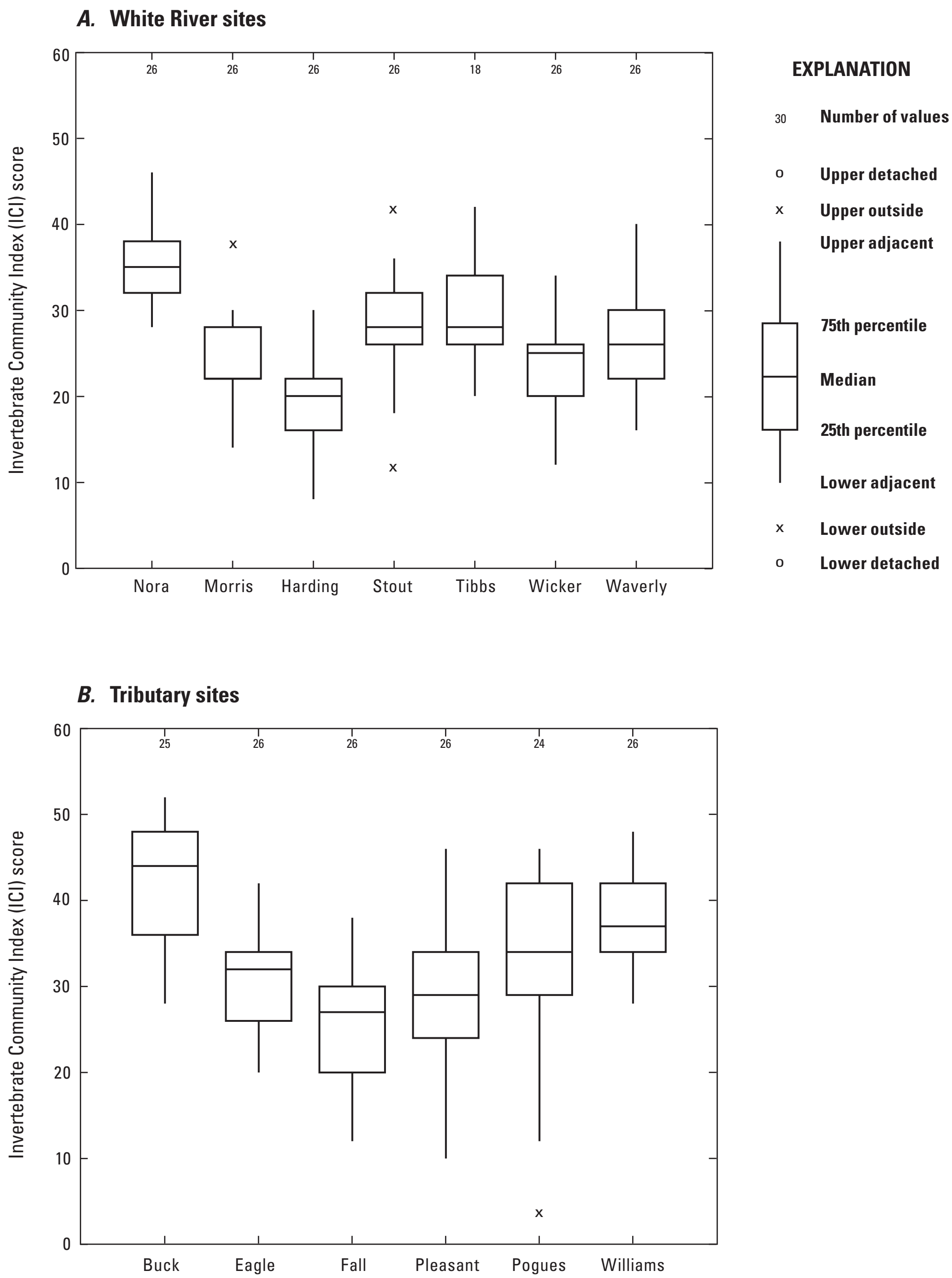


Figure 5. Invertebrate Community Index (ICI) scores, 1999–2012. *A*, White River sites. *B*, Tributary sites.

Pollution-Tolerant versus -Intolerant Benthic Invertebrates

Three sites on the White River (Nora, Stout, and Waverly; fig. 1) were originally selected to observe changes in the benthic-invertebrate population with changes to the City's WWTFs. A plot of the yearly (August through October) historical data showing the percentage of pollution-tolerant versus -intolerant benthic invertebrates, indicates that at the three sites having data since 1981 (fig. 6), the Nora and Waverly sites show an increase in the percentage of tolerant invertebrates. At the Nora site, there is an overall decrease in the number of pollution-intolerant benthic invertebrates with a corresponding increase in the pollution-tolerant numbers. During 1981–99, the intolerant species were predominant except for 1983 and 1985. During 2000–12, the opposite was true, where more tolerant invertebrates were present in samples with the exception of 2006, 2010, and 2011. This reversal may have been caused, in part, by a 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 sewage-treatment facilities to tertiary treatment, including ozonation of the final effluent (Crawford and others, 1992). Almost immediately, the two sites being monitored downstream of the WWTFs at that time (Stout and Waverly) showed signs of improved conditions in the benthic-invertebrate population. The ozonation of effluents was then replaced with chlorination in 1994 (Paul Werderitch, Indianapolis DPW, personal commun., 2011). Within 1 year of that conversion, increasing numbers of pollution-tolerant invertebrates were observed at Stout, and within 5 years at Waverly (fig. 6). In 2013, ultraviolet radiation of the effluent was introduced at the Belmont WWTF, supplemented with chlorination during wet-weather, high-flow events. However, no additional sampling was scheduled to determine how this change might affect biological communities downstream of the WWTFs.

The four additional sites on the White River, at which sampling began in 1994, all have predominantly larger numbers of pollution-tolerant species than pollution-intolerant species (fig. 7). Only at the Tibbs site, where sampling began in 2004, does there generally appear to be more pollution-intolerant benthic invertebrates present (fig. 7).

Sites on the tributaries show an increase in the number of pollution-tolerant benthic invertebrates at the Buck, Pogues, and Williams sites (fig. 8). Of these three sites, the Pogues site was predominantly pollution-tolerant invertebrates, and their numbers have been increasing since 1984. Similarly, the Pleasant site has been predominantly pollution-tolerant benthic invertebrates, but unlike the Pogues site, the numbers have been decreasing during the study period. At both the Pleasant and Pogues sites, the number of pollution-intolerant benthic invertebrates has increased since the mid-1990s, albeit in small numbers.

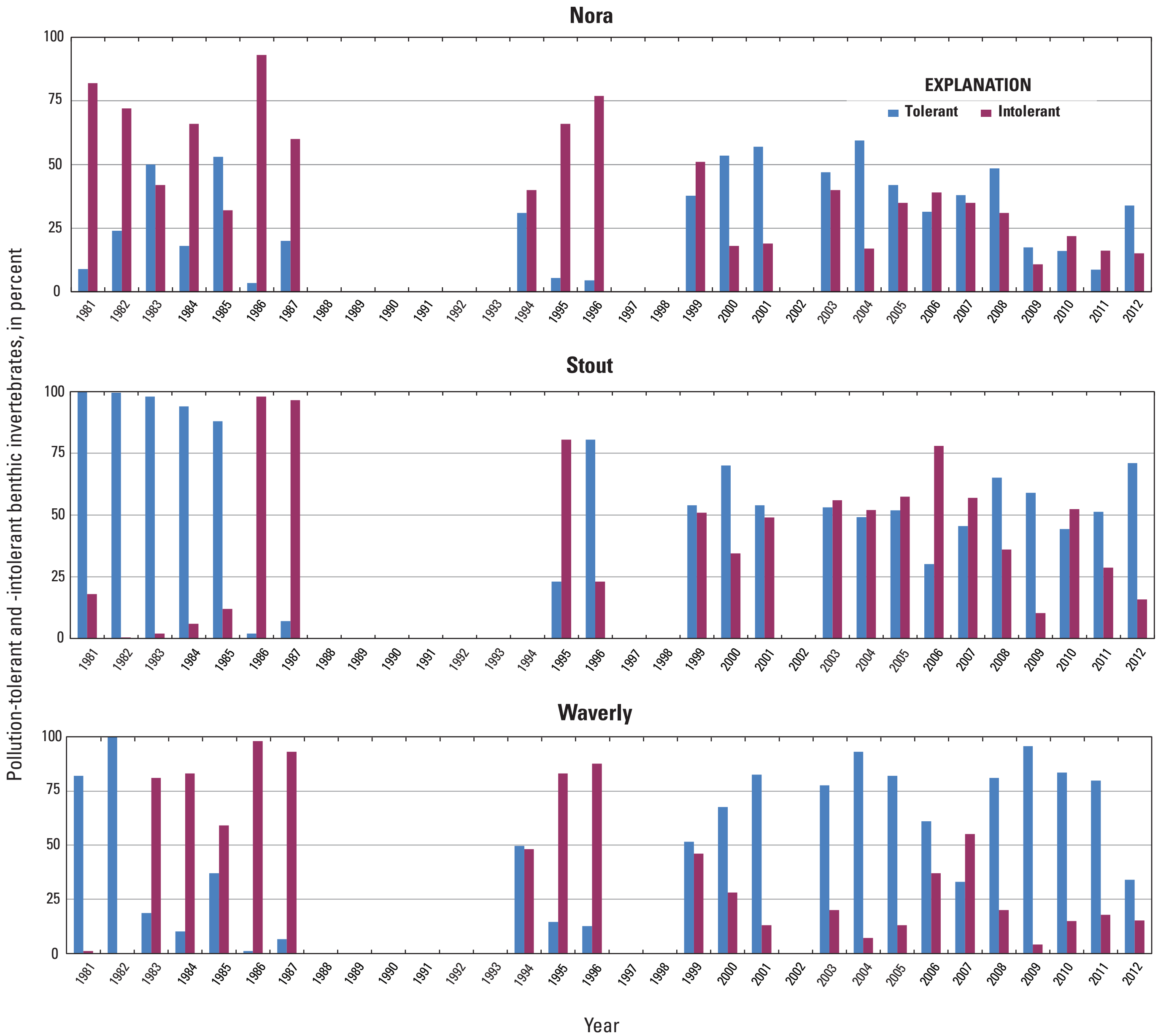


Figure 6. Historical percentages of pollution-tolerant and -intolerant benthic invertebrates at select sites on the White River, Indiana, 1981–2012.

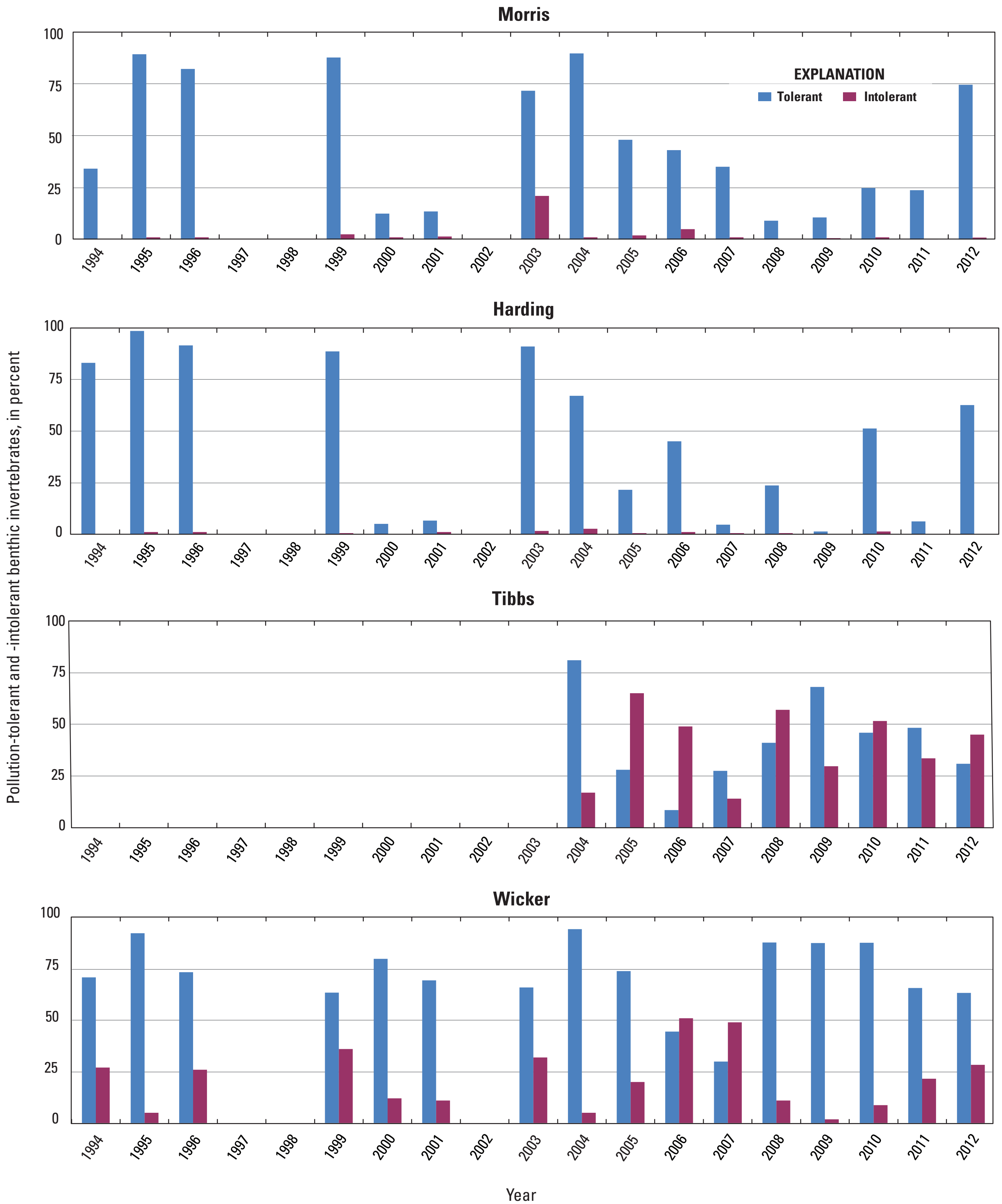


Figure 7. Historical percentages of pollution-tolerant and -intolerant benthic invertebrates at select sites on the White River, Indiana, 1994–2012.

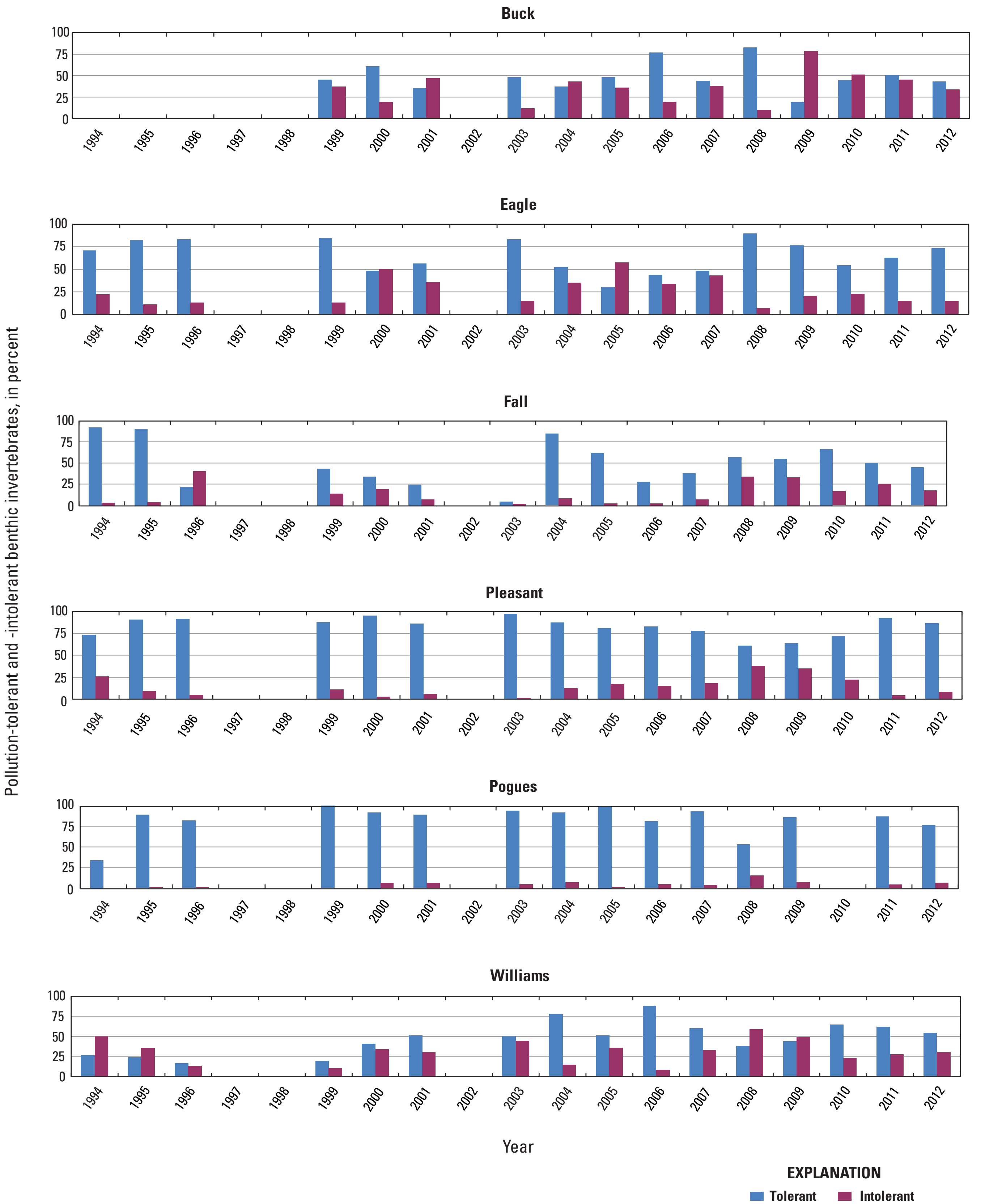


Figure 8. Historical percentages of pollution-tolerant and -intolerant benthic invertebrates at White River tributary sites, Indiana, 1994–2012.

Condition of Fish Communities

During the course of the studies by Voelker (2004, 2012, 2014), 69 distinct taxa and 1 hybrid were identified on the White River, and 69 taxa and 3 hybrids were identified on the tributaries. On the White River, the number of species identified ranged from 14 at Nora in 2001 to 34 at both Tibbs and Wicker in 2012 (table 8). The median number of taxa ranged from 16 at Nora to 27 at Stout (fig. 9). The number of individual fish collected during that same time period ranged from 61 at Nora in 2000 to 1,017 at Harding in 2012 (table 9). The median number of fish collected on the White River ranged from 136 at Waverly to 428 at Tibbs (table 9). On the tributaries, the number of species identified ranged from 6 at Pogues in 2010 to 41 at Buck in 2000 (table 8). The number of fish collected ranged from 62 at Pogues in 2012 to 2,697 at Pleasant in 1999. The median number of taxa collected on the tributaries during 1999–2012 ranged from 7 at Pogues to 33 at Buck.

Table 8. Invertebrate Community Index (ICI) scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1999–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2004[1]													
1999	16	22	22	25	--	24	22	--	25	33	14	7	25
2000	15	29	23	30	--	23	17	41	23	30	14	7	30
2001	14	27	23	32	--	21	16	36	23	32	14	7	21
Data from Voelker, 2012[1]													
2006	24	18	17	22	24	23	22	31	13	25	17	8	17
2008	23	25	23	27	23	21	16	34	20	26	19	11	18
Data from Voelker, 2014													
2010	18	23	20	26	26	20	24	32	22	24	17	6	13
2012	16	27	26	28	34	34	27	25	19	21	14	7	11
Minimum	14	18	17	22	23	20	16	25	13	21	14	6	11
Median	16	25	23	27	25	23	22	33	22	26	14	7	18
Maximum	24	29	23	30	34	34	27	41	25	33	19	11	30

[1]Some values have changed since previous publication due to changes in Indiana Department of Environmental Management methodologies.

Table 9. Number of fish collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1999-2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2004[1]													
1999	184	382	264	299	--	366	233	--	569	594	2,697	808	2,325
2000	61	1,012	805	719	--	304	84	1,241	1,288	658	1,151	474	1,487
2001	157	672	208	690	--	341	56	969	944	787	697	312	755
Data from Voelker, 2012[1]													
2006	176	120	95	178	269	132	110	475	212	346	809	412	1,108
2008	205	355	184	346	587	391	157	697	633	401	1,173	399	459
Data from Voelker, 2014													
2010	185	107	153	257	211	211	136	460	334	317	128	201	409
2012	136	488	1,017	516	932	534	408	169	567	539	345	62	346
Minimum	61	107	95	178	211	132	56	169	212	317	128	62	346
Median	176	382	208	346	428	341	136	586	569	539	809	399	755
Maximum	205	1,012	1,017	719	932	534	408	1,241	1,288	787	2,697	808	2,325

[1]Some values have changed since previous publication due to changes in Indiana Department of Environmental Management methodologies.

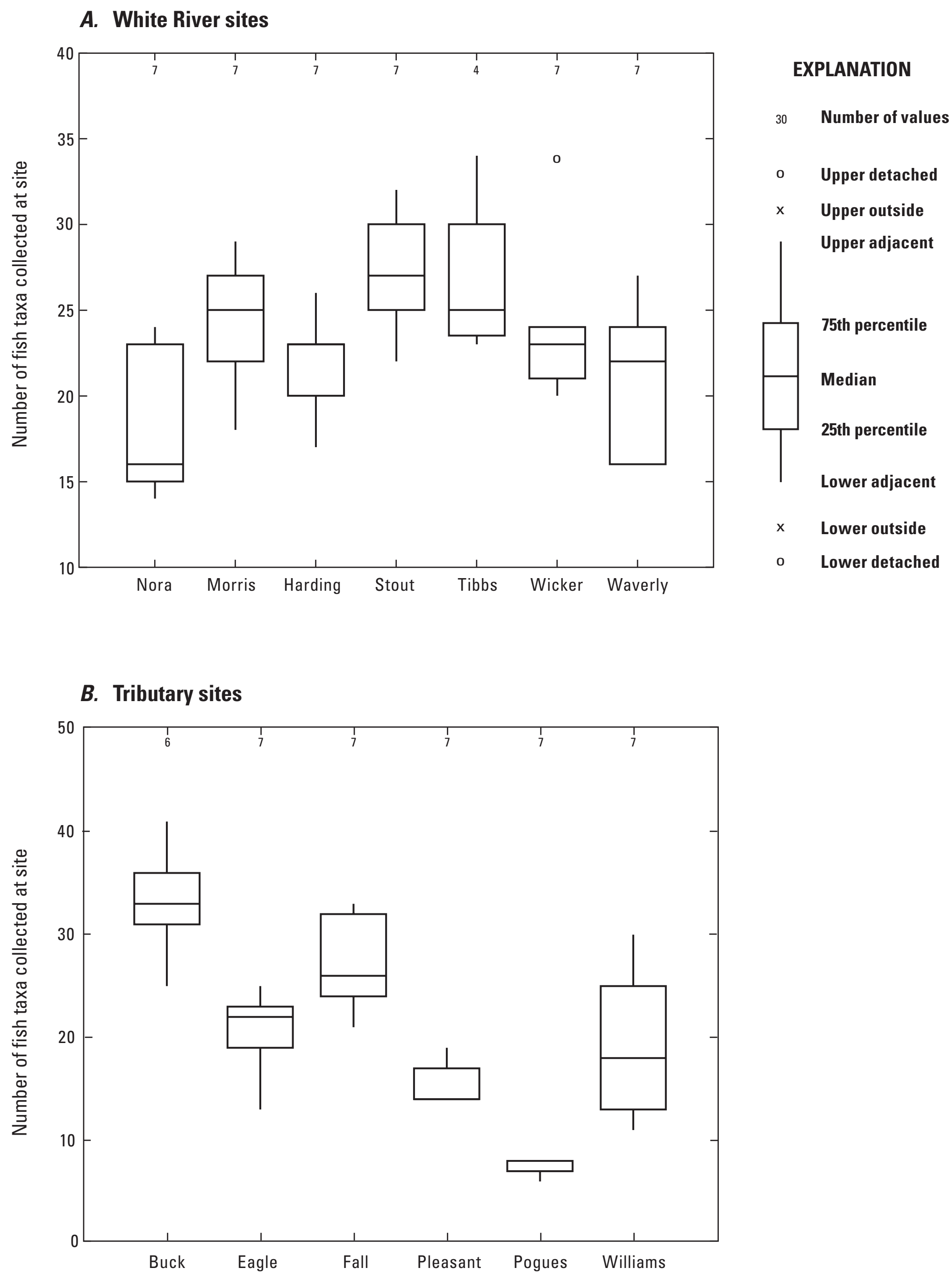


Figure 9. Number of fish taxa collected, 1999–2012. *A*, White River sites. *B*, Tributary sites.

Index of Biotic Integrity

Fish data were analyzed using the Indiana IBI developed by Simon and Dufour (1997) for sites in the Eastern Cornbelt Plains Ecoregion. The IBI incorporates various metrics including 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, and the higher the resultant score, the healthier the aquatic ecosystem (table 10).

The IBI scores in the White River ranged from 20 (very poor) at Harding in 2006 to 46 (good) at Tibbs in 2012 (table 11). Median IBI scores ranged from 34 at Harding to 42 at Morris and Stout (fig. 10). It should be noted that the low score of 22 at the Nora site came less than 1 year after the December 1999–January 2000 fish kill upstream because of a chemical release into the White River (Indiana Department of Environmental Management, 2000), which had a negative effect on the IBI at the site.

On the tributaries, the IBIs ranged from 24 (very poor) at Pogues in 2012 to 44 (good) at Buck, Fall, and Williams over several years (table 10). Median IBI scores on the tributaries ranged from 34 (poor) at Pogues to 42 (fair) at Buck, Fall, and Williams.

Table 10. Attributes of Index of Biotic Integrity (IBI) classification, total IBI scores, and integrity classes from Karr and others (1986).

Total IBI score	Integrity class	Attributes
58–60	Excellent	Comparable to the best situation without human disturbance; all regionally expected species for the habitat stream size, including the most tolerant forms, are present with a full array of age (size) classes; balanced trophic structure.
48–52	Good	Species richness somewhat below expectation, especially owing to the loss of the most tolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress.
40–44	Fair	Signs of additional deterioration including loss of intolerant forms, fewer species, highly skewed trophic structure; older age classes of top predators may be rare.
28–34	Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present. Repeated sampling finds no fish.
12–22	Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other abnormalities regular.

Table 11. Index of Biotic Integrity (IBI) scores for samples collected at the White River and tributaries in the Indianapolis metropolitan area, Indiana, 1999–2012.

[--, no sample collected]

Sample date	Nora	Morris	Harding	Stout	Tibbs	Wicker	Waverly	Buck	Eagle	Fall	Pleasant	Pogues	Williams
Data from Voelker, 2004													
1999	34	38	32	36	--	36	34	--	40	42	36	34	42
2000	22	44	36	40	--	38	24	44	40	42	30	34	42
2001	36	42	36	42	--	38	26	42	42	42	34	34	44
Data from Voelker, 2012[1]													
2006	36	30	20	34	34	38	36	42	38	44	38	34	44
2008	44	44	32	44	42	44	36	44	42	42	42	34	42
Data from Voelker, 2014													
2010	36	34	32	42	38	34	34	40	42	44	32	34	38
2012	40	42	40	42	46	44	42	36	34	42	38	24	36
Minimum	22	30	20	34	34	34	24	36	34	42	30	24	38
Median	36	42	34	42	40	38	34	42	40	42	36	34	42
Maximum	44	44	40	44	46	44	42	44	42	44	42	34	44

[1]Some values have changed since previous publication due to changes in Indiana Department of Environmental Management methodologies.

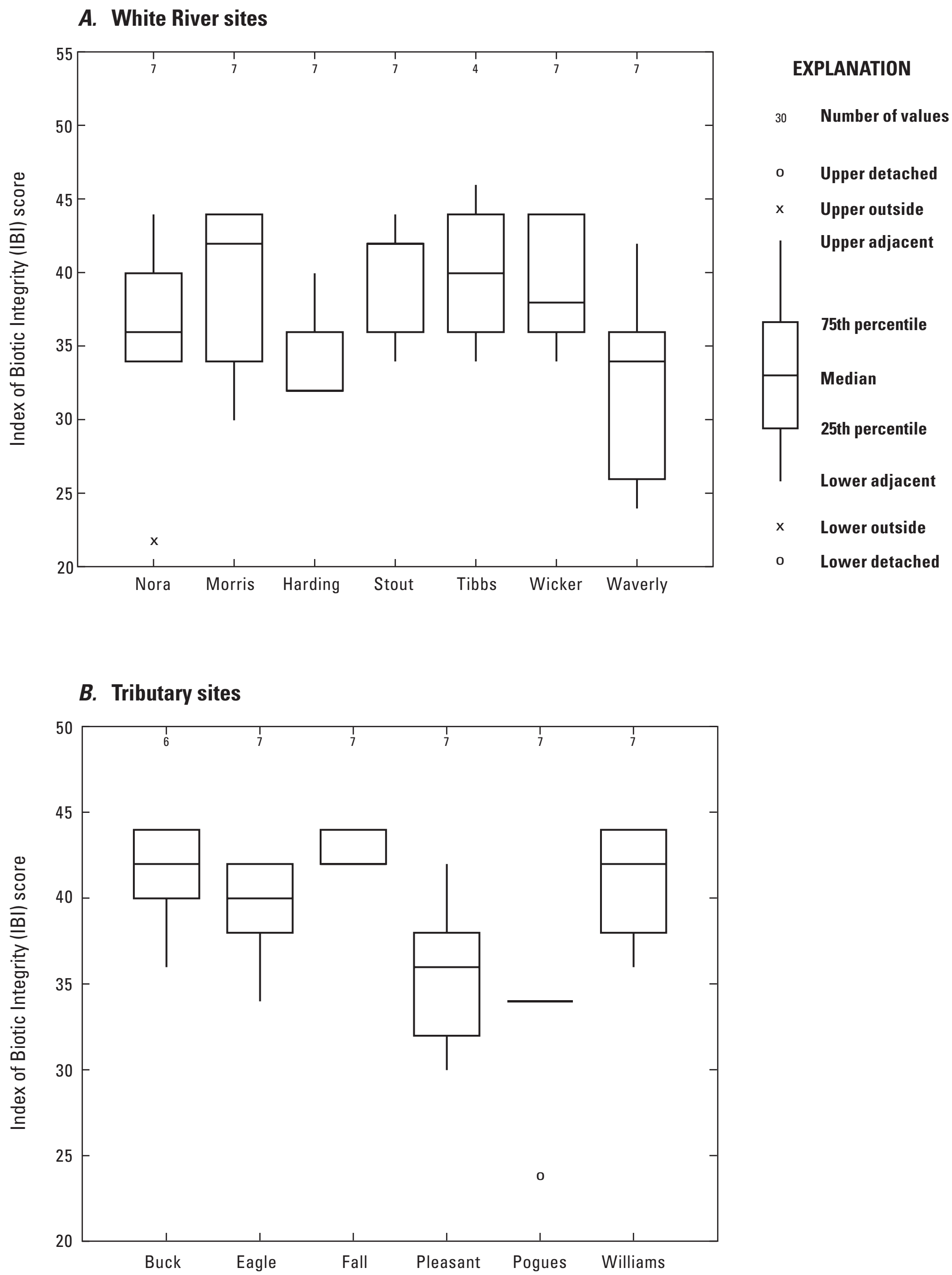


Figure 10. Index of Biotic Integrity (IBI) scores, 1999–2012. *A*, White River sites. *B*, Tributary sites.

Summary

The U.S. Geological Survey, along with the Indianapolis Department of Public Works (DPW), and eventually with CWA Authority, Inc., maintained a cooperative program intermittently during 1981–2012 to assess biological communities and streambed-sediment chemistry in the White River and selected tributaries in the Indianapolis metropolitan area of Indiana. Three sites were initially sampled in the 1981 study (Crawford and others, 1992), 21 sites were sampled by Renn (1998), and 13 sites (7 on the White River and 6 on tributaries) were sampled by Voelker (2004, 2012, 2014) biannually for benthic invertebrates, and during 1999–2001, 2006, 2008, 2010, and 2012 for fish communities. The data collected in these studies complement the Indianapolis DPW and CWA Authority, Inc., surface-water monitoring programs. The information gathered is being used in conjunction with the programs to reduce combined-sewer overflows (CSOs) and other point and non-point sources of pollution in the Indianapolis area.

Historical biological data were reviewed to describe the condition of the biological communities over time. For sites on the White River, available historical data for each of the three indexes (Ephemeroptera, Plecoptera, and Trichoptera [EPT], Hilsenhoff Biotic Index [HBI], and Invertebrate Community Index [ICI] all show that the benthic-invertebrate conditions are best at the Nora site. The Nora site is the most upstream study site, near where the White River enters Indianapolis (and Marion County), and upstream of the CSO area. The poorest conditions of the benthic-invertebrate communities are at the Morris and Harding sites, which are located in the more urbanized reach of the river where the CSOs are located. The indexes indicate some improvement in the benthic-invertebrate communities at the Stout and Tibbs sites, and to a lesser extent at the Wicker and Waverly sites further downstream of the CSOs and wastewater-treatment facilities (WWTFs).

For the tributary sites, historical data describe the Buck Creek and Williams Creek sites—which have no CSOs entering them—as having better benthic-invertebrate communities than other tributary sites. Only the Eagle Creek site scored slightly better than the Williams Creek site when reviewing the median EPT scores. HBI scores were fairly consistent among all tributary sites, falling in the “good” to “fair” categories. The ICI scores show that 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 had a longer history of benthic-invertebrate data from which numbers of pollution-tolerant and -intolerant invertebrates have been calculated. Dominance by pollution-tolerant invertebrates was reversed at the two downstream sites (Stout and Waverly) after the WWTFs upgraded to tertiary treatment with ozonation. That tendency 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 release resulted in a major fish kill on the White River, and pollution-tolerant species again became the predominant benthic invertebrates present in the upper reaches of the study area.

Historical fish-community data indicate that most of the study sites have stable fish communities, with some minor variations from year to year. 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 communities overall.

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