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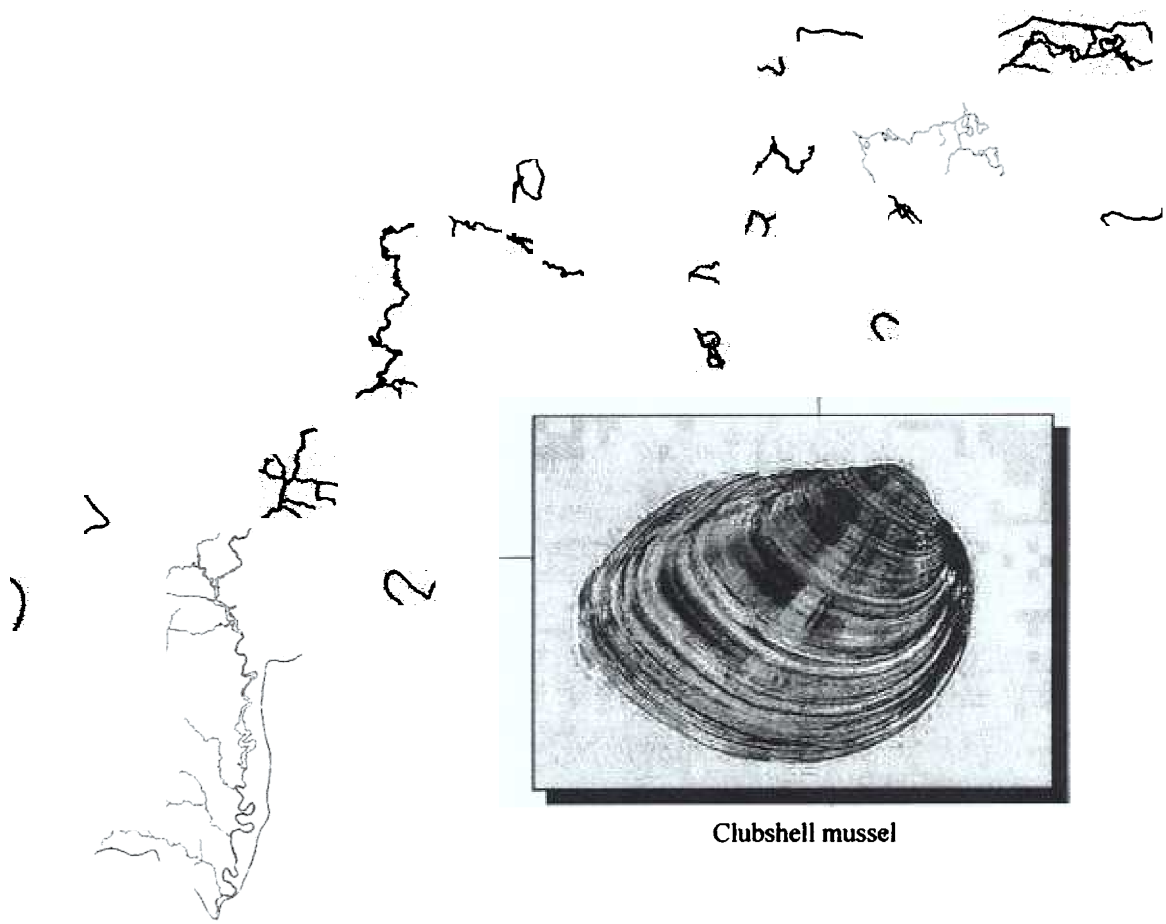
Tippecanoe River, Indiana: Defining Point Source Threats to Rare and Endangered Mussels



Clubshell mussel

U.S. Fish and Wildlife Service
U.S. Department of Interior

Tippecanoe River, Indiana: Defining Point Source Threats to Rare and Endangered Mussels

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Chapter 1

Project description and background information for the Tippecanoe River Off-Refuge Investigation: Defining point source threats to rare and endangered mussels.

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1.0 Introduction

Healthy ecosystems are a primary component of preserving our native plants and animals. Stein and Flack (1997) reviewed the status of native plants and animals in the United States and found that many organisms that depend on freshwater habitats are seriously imperiled. These include mussels, crayfish, fishes, and amphibians. The review indicated that 55% of North America's mussels are classified as extinct or imperiled (Stein and Flack 1997). During the last 30 years, numbers of both individuals and species diversity of native mussels have declined throughout the United States and Canada (Williams et al. 1993). The leading cause of imperilment is habitat degradation and destruction caused by anthropogenic activities.

Anthropogenic activities have long been recognized as a threat to mussels (Ortmann 1909; Ellis 1931; Fuller 1974). Erosion caused by poor land management practices has caused increased silt loads and shifting, unstable stream bottoms, and increased turbidity. Contaminants such as heavy metals, pesticides, and acid mine drainage have increased the likelihood of elimination of mussel species due to toxic concentrations of chemicals and accumulation of those contaminants in sediments. Since mussels are sessile organisms they are considered good indicators of healthy aquatic systems. Mussels are dependent on good water quality and physical habitat conditions and an environment that will support populations of host fish species (Cummings and Mayer 1992).

With a rapidly expanding world population and an increased dependence on fresh water for various processes, an extraordinary demand is being placed on our freshwater resources. The Great Lakes Water Quality Initiative (GLWQI) is a joint agreement among the states around the Great Lakes and the U.S. Environmental Protection Agency (EPA) to use similar water quality standards and criteria in order to prevent producers and industry from seeking more lenient standards in other Great Lakes states. Species that spend an inordinate amount of time in a benthic lifestyle are more likely to be exposed to a higher level of chemical contaminants than water column species. Consequently, the proposed water quality standards that have been put into place by some states may not be protective of freshwater mussels. This is especially disconcerting since adoption of sediment quality criteria by the EPA is not anticipated. The U.S. Fish and Wildlife Service (FWS) issued a biological opinion to the EPA that indicated the metal concentrations in the GLWQI would not be protective of mussel species. Furthermore, the FWS issued EPA a mandate to generate additional information on the toxicity of dissolved metals to juvenile mussels and glochidia. Currently, no information is available on the impact that current discharge levels, although they may be meeting National Pollution Discharge and Elimination System (NPDES) permit limits, may be having on mussel populations downstream of point sources. Impacts could include reproductive failure, acute or chronic toxicity, feminization of males by hormone disruption, and loss of recruitment classes through the toxicity to more sensitive younger life stages.

1.1 Project Background

The freshwater mussel community of the Tippecanoe River consists of 49 extant species and 57 known historical species (ESI 1993; R. Anderson, IN Department of Natural Resources, unpubl. data). Recently, the Nature Conservancy (TNC) ranked the Tippecanoe River as the eighth most important river in the entire country for preserving imperiled aquatic species (TNC 2000). This globally significant community includes 2 federally endangered species: the clubshell (*Pleurobema clava*) and fanshell (*Cyprogenia stegaria*) mussels. In addition, six other mussel species and one fish species were previously considered federal "Category 2" candidate species. Although this designation is not officially used anymore, federal and state resource agencies still have concern for these organisms. Recent evidence of a 3rd endangered species, the northern riffleshell (*Epioblasma torulosa rangiana*), has been reported (ESI 1993). The Tippecanoe River clubshell population is believed to be the largest and most significant of this species in the world, and thus, critical to its recovery (FWS 1993).

Declines have been observed in the main stem of the river, and the tributaries are no longer supportive of sensitive rare species (ESI 1993). Anthropogenic environmental stresses and habitat degradation associated with the decline include industrial point source discharges of metals and other chemical pollutants, poultry waste, and municipal sewage; increased erosion and sedimentation; extensive macrophyte die-offs (R. Anderson, per. comm.); increased turbidity; urban runoff; and agricultural non-point pollution.

In 1991, the FWS and the Indiana Department of Natural Resources (IDNR) funded a two-year study (1991 -1992) of the fish, unionids, and habitat in the Tippecanoe River. Management recommendations from this two-year study included closely monitoring water quality and unionid and fish populations, and identifying problem discharges in order to curtail declining water quality before species limited to the area were extirpated. Subsequently, several surveys were conducted and an Environmental Contaminant Program, Off-refuge Investigation proposal was developed to address these recommendations and to further investigate the impacts permitted discharges have on freshwater mussels.

1.2 Project Description

This study was originally designed as an iterative 6 year effort, with data from each year being used to refine the study plan for the subsequent year(s). Biomonitoring techniques have been developed and tested for macroinvertebrates and fish (Plafkin et. al. 1989), but are generally lacking for unionid mussels. The first year objective, therefore, was to define fish and macroinvertebrate communities upstream and downstream of point source throughout the Tippecanoe River, and, based on this data, determine problem areas. Since the Bloomington, Indiana Field Office (BFO) considered this project high-priority, funding for this portion was provided through the BFO base funds.

The second year objective was to identify patterns or associations between point source pollution and unionid communities and diversity, as well as, determine if unionid community parameters correlated with those of the fish and macroinvertebrates. The FWS contracted Ecological Specialist, Inc. (ESI) to do mussel surveys in the river, upstream and downstream of 16 tributaries with known point source discharges. This portion of the investigation was funded with Region 3 Endangered Species discretionary funding.

Year three (1996) involved synthesizing and collating year one and two data and further identifying problem areas and discharges. This was funded through the Environmental Contaminants Program.

Year four (1997) provided funding for sediment collection, sediment chemical analysis, general water quality data collection at all sites studied in years 1-3, mussel toxicity tests using sediment from problem areas identified in years 1-3, and desk-top reviews of point source discharges in the problem areas. This portion of the study was also funded through the Environmental Contaminants Program.

Due to personnel changes and extremely slow turnaround times for chemical analyses and contracted reports, two years lapsed before funding was requested for the final report preparation.

Although this project has experienced a lapse in time, little has changed in the Tippecanoe River watershed. Only a limited number of additional point source dischargers have been added to the system, while a couple have ceased operation. Site conditions, most likely, have not changed significantly since the original field work was completed. Based on this, and considering the sedentary lifestyle and longevity of mussels, the observations and management recommendations made as a result of this project will still be useful and valid in helping to conserve this endangered fauna.

1.3 Management Implications

This investigation examined the attributes of the decline in individual unionids and species diversity in the Tippecanoe River. It specifically focused on a potentially major threat to federally endangered species (point source pollution) and will provide information necessary to help protect and reverse the decline of freshwater mussels, particularly listed species, in the Tippecanoe River system.

Information evaluated for this report will aid the FWS, along with other natural resource agencies and conservation groups, in managing this remarkable system, as well as freshwater mussels in general. As part of this project, the following management objectives were developed:

1) This project will directly address the Ohio River Valley Ecosystem Team's (ORVET) #1 resource priority by defining threats to sensitive species (including Federally listed species) residing in the Tippecanoe River. The ORVET has ranked 6 resource issues for priority focus in their draft ecosystem plan (FWS 1994). The # 1 resource priority addressed in the ecosystem plan is to reverse the decline of native aquatic mollusks within the Ohio River Valley Ecosystem (ORVE) with emphasis on endangered, threatened, and candidate species, and species of concern. The ORVET, Mussel Sub-group has designated the Tippecanoe River as a focus area based on the mussel species richness and diversity (1998). The ORVE encompasses FWS Regions 3, 4, and 5, and portions of several states, including Indiana, Illinois, Ohio, Pennsylvania, Kentucky, and West Virginia.

2) This investigation will aid the FWS in defining specific causes for the decline in freshwater

mussels throughout the U.S. As the decline in mussel diversity continues, the list of threatened and endangered mussels grows. Approximately 14% are federally listed, and 24% are candidates for listing. About 6% of our native mussel species are already extinct. No other wide-ranging faunal group in the U.S. has suffered such a dramatic decline in recent history (Shannon et. al. 1993).

3) The information gained from this contaminant investigation will be valuable for general sensitivity knowledge of mussel communities, as well as, for the development of biotic indices for scoring and ranking the ecological health of a system. Mussels are considered good indicators of the health of aquatic ecosystems and are dependent on good water quality and aquatic habitat..

4) The data collected from this study will determine if NPDES permits are protective of sensitive mussel species in the Tippecanoe River. The U.S. Environmental Protection Agency (EPA), in the 1990 technical support document for water quality-based toxins control, suggested a comprehensive approach to establishing effluent guidelines under the NPDES. This approach includes evaluation of chemical-specific standards, whole effluent toxicity limitations based on bioassay results using standardized test methodology, and in-stream biosurvey information to evaluate the impact of effluent releases on the various components of the aquatic community in the receiving stream. At present, both acute and chronic standardized whole effluent test procedures have been adopted by EPA using surrogate organisms, such as *Ceriodaphnia dubia*, to evaluate benthic community response to industrial releases. The nationwide decline in freshwater mussels may indicate that currently accepted bioassay methodologies are inadequate to evaluate the response of mussels to complex whole effluents or selected contaminants.

5) Information gathered from this project will more clearly define relative roles of various factors causing declines, which will be critical to Endangered Species Act (ESA) Section 7 consultations in determining how future actions may affect listed mussels. Freshwater mussels, especially early life stages, have been shown to be more sensitive than other aquatic organisms to contaminants (Goudreau et. al. 1993) and siltation. Very little data is currently available on mussel toxicity to specific contaminants. Results of risk assessment analyses conducted for the ESA Biological Opinion on the Great Lakes Initiative (GLI) indicate that the GLI's criteria still may not be protective enough for listed mussels, especially with respect to metals. During that consultation, EPA was reluctant to acknowledge that contaminants have played a role in mussel declines.

6) Toxicity data from this project is necessary for determining specific effects to listed mussels in Section 7 consultations on water quality issues and for developing discharge limits for NPDES permits. Such information will be applicable to the protection of listed mussels range-wide and across FWS Regions and will be important in the development of national aquatic life criteria.

7) Information gained from this project will be essential to any future development of an aquatic ecosystem management plan for the protection of all aquatic resources in the Tippecanoe River watershed.

8) Finally, data gathered during this investigation will provide excellent baseline information in the event of an environmental catastrophe, such as an oil spill, or chemical release within the

watershed.

1.4 Changes to Original Proposal

The original proposal included effluent monitoring and chemical analysis; however, that task was not completed. Future studies should include effluent testing, particularly for those areas with impaired aquatic communities. Furthermore, due to the low levels and numbers of contaminants detected in the chemical analyses of sediment samples, individual toxicity tests using specific chemicals of concern were not conducted. Perhaps analysis of effluent water would reveal potential chemicals of concern and more adequately address the management issues previously listed.

1.5 Partnerships

The BFO Contaminants Program has cooperated with Indiana University, the Indiana Department of Natural Resources (IDNR), the USEPA, and the BFO and Chicago Illinois Field Office (CIFO) Endangered Species Programs to complete this investigation. Indiana University, School of Public Environmental Affairs (SPEA), has provided several volunteer students to assist with fieldwork and data management (estimated value of prior contributions to project to date - $10,000). Dr. Thomas P. Simon, (formerly USEPA), assisted in fish collection and fish data interpretation (estimated value of prior contributions to project - $7,000). The Region 3 Endangered Species Program awarded $20,000 to the BFO and CIFO for the mussel survey work in 1995. Brant Fisher, IDNR, assisted with field work during the mussel survey for an estimated $1,500 in-kind contribution.

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Chapter 2

Study area and habitat description in the Tippecanoe River watershed.

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2.0 Introduction

The Tippecanoe River is located in northcentral Indiana and is one of the largest tributaries of the Wabash River (Figure 2.1). The river originates from two groups of lakes in southwestern Noble County and northern Whitley County including: Crooked and Crane Lakes; and Goose, New and Loon Lakes, respectively (Scovell 1909). The river is approximately 166 miles long (Wright 1932) and drains a watershed of roughly 1,890 square miles. It flows west-southwest to its confluence with the Wabash River near Lafayette, Indiana.

The Tippecanoe River system was described by Wright (1932) as 3 distinct sections. The upper river was defined as the headwaters at Crooked Lake to the Marshall-Fulton County line; the middle river was described as that part of the river from the Marshall-Fulton County line to the town of Norway in White County; and the lower river, as the segment between Norway and the mouth, in northeastern Tippecanoe County. Based on Homoya et al.'s (1985) natural region descriptions for Indiana (Appendix I), these 3 segments fall roughly within the following 3 regions: the Northern Lakes Natural Region, the Kankakee Sand Section of the Grand Prairie Natural Region, and the Tipton Till Plain Section of the Central Till Plains Natural Region, respectively. For discussion purposes of this report the river was therefore divided into 3 regions based on Wright's (1932) paper and Homoya et al.'s natural regions: upper Tippecanoe River (sites 1-18 for mussels and invertebrates and sites 94101-94118 for fish), middle Tippecanoe River (sites 19-33 for mussels and invertebrates and sites 94119-94133 for fish), and lower Tippecanoe River (sites 34-45 for mussels and invertebrates and 94139-94145 for fish). Sample locations for all surveys are roughly the same (Table 2.1).

2.1 Study Area

2.1.1 Upper Tippecanoe River

The Tippecanoe River originates from several glacial lakes in Noble and Whitley counties (southeast of the town of Ormas) and flows through the Northern Lakes Natural Region (Homoya et al. 1985). Although this portion of the state probably has the highest concentration of lakes and ponds, many have been drained. Most of the swampy and marshy regions in the watershed are remnants of lakes that once covered the landscape (Wright 1932). According to a report by Ecological Specialists, Inc. (1993) most of the tributaries in this reach have been channelized. The river has a low to medium gradient and consists of sediments primarily of Wisconsin outwash and gravel (Homoya et al. 1985; Wright 1932; and ESI 1993). Sites 1-18 (94101-94118 for fish) are considered in this report to be upper river stations. Site 1 is located near the town of North Webster and site 18 is just north of the town of Talma.

A report prepared by the Agricultural Stabilization and Conservation Service (ASCS), Purdue Cooperative Extension Service, and the Soil Conservation Service (1990) indicated that the principal aquifer along the Tippecanoe River in the upper reaches consists of "valley train or outwash deposits of sand and gravel." This area is characterized as having a shallow water table and relatively high permeability. Consequently, contamination susceptibility is considered high compared to the till plain area, where aquifers are more isolated. Ground water is the major

Tippecanoe River

Tippecanoe River watershed

Figure 2.1 Location of the Tippecanoe River Study Area within the State of Indiana.

Table 2.1. List of corresponding sites from each of the Tippecanoe River faunal surveys, 1994-1995.

Macroinvertebrate stations	Fish stations	Mussel stations	Tributary/point source evaluated
1	94101	1	Up of Kuhns Ditch
2	94102	2	Down of Kuhns Ditch
4	94104		Up of Waste Management
5	94105		Down of Waste Management
6	94106		Up of Walnut Creek
7	94107		Down of Walnut Creek
8		8	Up of Marsh Ditch
9	94109	9	Down of Marsh Ditch
10	94110		In Trimble Creek, above Palestine Lake
11	94111		In Trimble Creek, below Palestine Lake
12	94112	12	Up of Trimble Creek
14	94113	13	Down of Trimble Creek
		46	Up of Ridenour Ditch
		47	Down of Ridenour Ditch
15	94115	15	Up of Baker Ditch
16	94116	16	Down of Baker Ditch
17		17	Up of Yellow Creek
	94117		Shatto Ditch
18	94118	18	Down of Yellow Creek
19	94119		In Chippewanuck Creek
	94120	48	Up of Chippewanuck Creek
		49	Down of Chippewanuck Creek
21	94121	21	Up of Blair Ditch
22	94122	22	Down of Blair Ditch
		50	Up of Mill Creek
23	94123		In Mill Creek
24	94124	51	Down of Mill Creek
25		25	Up of Wilson Ditch
26	94126	26	Down of Wilson Ditch
	94127		Up of Tippecanoe River State Park
28	94128		Down of Tippecanoe River State Park
		28	Up of Winamac
		29	Down of, Winamac
	94129		Down of Winamac/Up of Mill Creek
30	94130		In Mill Creek
		52	Up of Indiana Creek
31			In Indian Creek
		53	Down of Indian Creek
32	94132	32	Up of Liberty Landfill
33	94133	33	Down of Liberty Landfill
34			Up of Honey Creek
35			Down of Honey Creek
37		37	Up of Big Creek
38			In Big Creek
39	94139	39	Down of Big Creek
40	94140	40	Up of Spring Creek
41	94141		In Spring Creek
		42	Down of Spring Creek
43	94143	43	Up of Moots Creek
44	94144		In Moots Creek
45	94145	45	Down of Moots Creek

mydoc/tippe/sitecompare.xls

source for all municipal supplies except for Warsaw, which obtains about 30% of its water from Center Lake (ASCS et al. 1990) .

The primary land use in the upper watershed is agriculture. Marshall and Kosciusko counties encompass most of the drainage area. Based on figures from the U.S. Census Bureau (2000), in 1992, 73% of the land in Kosciusko County and 75% of the land in Marshall County was in farms. The upper Tippecanoe River watershed also drains small portions of Whitley, Noble, and Miami counties. The average percent-farmland in harvested cropland in 1992 for these 4 counties was about 75 % (Purdue University 1997); the main crops are corn, soybeans, wheat and hay (ASCS et al. 1990).

Approximately 30% of the upper watershed was identified as being in Major Erosion Problem Areas (MEPA) as determined during the 1987, 18-county Northeast Indiana Erosion Study (ASCS et al. 1990). The report indicated that "The 30% of the MEPA that is cropland has sheet and rill erosion rates of approximately 11 tons/acre/year or 425,000 tons/year and ephemeral gully erosion at the rate of 65,000 tons/year. The total erosion from all sources in the MEPA is equivalent to nearly 13 tons/acre/year."

There are several small towns including North Webster, Oswego, Monoquet, Lakeside Park, Etna Green, Mentone, Old Tip Town, Tippecanoe, and Talma, and one larger city, Warsaw, that lie alongside the river in the upper reaches. Warsaw's population, based on figures from the 1990 Census, was approximately 11,000 people. The total population for Kosciusko and Marshall counties, based on 1995 estimates, was 69,210 and 44,879, respectively (U.S. Census Bureau 2000).

2.1.2 Middle Tippecanoe River

The middle segment of the Tippecanoe River includes sites 19-33 (94119-94133 for fish). Site 19 is located in Chippewanuck Creek, just north of the City of Rochester in Fulton County; site 33 is just north of the small town of Buffalo, about 1 mile from the Pulaski-White County line. This portion of the river flows through some of the Northern Lakes Natural Region (in Fulton County) and then into the Kankakee Sand Section of the Grand Prairie Natural Region (Homoya et al. 1985). The Kankakee Sand Section consists mostly of dune and outwash plain sediments and is characterized by the presence of natural communities associated with sandy soils. Wright (1932) described the land along the southern part of the river in Fulton County as a "sand plain" that extends (in varying widths) from near the town of Talma to Leiter's Ford. From Leiter's Ford to Monterey the plain is on the north side of the river. "The region bordering the Tippecanoe River through Pulaski and northern White counties is nearly all covered with sand..."(Wright 1932). As it enters Pulaski County, the river takes a sharp southward turn near the village of Ora and flows through 25 miles of "boulder-strewn depressions which the sand did not fill..." (Wright 1932). From Winamac to Monticello the gradient of the river increases significantly.

Land use in this portion of the watershed is also primarily agricultural and most tributaries appear to have been channelized (ESI 1993). The middle river drains portions of 7 counties, with Fulton and Pulaski accounting for the majority of the drainage. In 1992, the average percent of land in farms for Fulton County was 82%; the average for Pulaski County was 88% (U.S. Census Bureau 2000). In these two counties, approximately 81% of the acreage in farms in 1992 was harvested cropland (Purdue University 1997). The primary crops are corn, soybeans and wheat.

Both Fulton and Pulaski counties are very rural. Based on 1995 estimates, the total population for Fulton County was roughly 20,000; Pulaski County's population estimate for 1995 was around 13,000 (U.S. Census Bureau 2000). Rochester, the largest city in Fulton County (population of approximately 6,000 based on the 1990 Census) is located along the Tippecanoe River. In Pulaski County, the largest town is Winamac, with a population of about 2,200 according to the 1990 Census. Winamac is also located along the river. Other towns that occur near the Tippecanoe River in this section include Leiters Ford, Delong, Monterey, Ora, Beardstown, Pulaski, and Buffalo. The river also runs through the Tippecanoe River State Park, located at Beardstown.

Two large impoundments, Lake Shafer and Lake Freeman, occur at the transitional area between the middle and lower river (i.e. between the Kankakee Sand Section of the Grand Prairie Natural Region and the Tipton Till Plain Section of the Central Till Plain Natural Region). These two reservoirs were created by the Norway and Oakdale dams and appear to have been constructed in the 1920's (ESI 1993). Due to their construction, land use in the area directly adjacent to the reservoirs is primarily recreational and residential; however, agriculture is still prominent beyond this immediate area. Because of the significant impact dams and their associated impoundments and tailwaters have on faunal distribution, sampling was limited in this stretch of the river.

2.1.3 Lower Tippecanoe River

The lower river flows primarily through the Tipton Till Plain Section of the Central Till Plain Natural Region (Homoya et al. 1985). The Tipton Till Plain Section is characterized by loamy Wisconsinan till and is "...mostly undissected plain formerly covered by an extensive beech-maple-oak forest."(Homoya et al. 1985). Wright (1932) describes the river in southeastern White and western Carroll counties as "...a ground moraine interspersed with a network of bowlder (sic) belts and sandy knolls. This section of the river's course is the only place within the system that the channel reaches bed rock." After reaching bedrock near Monticello, it is near the bedrock for the remainder of its course. For the last few miles, beginning near the village of Springboro, the river has eroded a shallow winding channel in a sand plain (Wright 1932).

Land use in the lower river watershed is primarily agricultural. White County makes up most of the lower watershed, with small portions of Benton, Carroll and Tippecanoe counties included. Based on figures from 1992, 92% of land in Carroll County was in farms, 88% of land in White County was in farms, and 80% of land in Tippecanoe County was in farms (U.S. Census Bureau 2000). Of the land in farms in these 3 counties, 86% was harvested cropland (i.e. crops such as corn, soybeans, wheat and hay) (Purdue University1992).

Monticello is on the northernmost edge of this section of the river and is the largest town near the river in the lower watershed. Monticello has a population of approximately 5,200 based on the 1990 Census. Norway and Springboro are the only other towns located near the river in this reach, although vacation homes and subdivisions are abundant (ESI 1993). The total population estimate for White County in 1995 was 24,505 (U.S. Census Bureau 2000).

Sample points in this section include sites 35-45 (94139-94145 for fish). Site 35 is near the village of Norway, and site 45 is less than a mile above the confluence with the Wabash.

2.1.4 Climate

The average monthly maximum temperature for northcentral Indiana ranges from -.6° Celsius (C) [30.8° Fahrenheit (F)] in January to 29.1° C (84.4° F) in July. The average minimum ranges from -9.8°C (14.3° F) in January to 16.5° C (61.7° F) in July. The overall average for this section of Indiana varies from -5.2° C (22.7° F) in January to 22.8° C (73.1° F) in July. The average annual precipitation is 95.1 centimeters (cm) (37.45 inches), most of which falls between April and September. The average precipitation ranges from 10.0 cm (3.94 inches) in June to 4.4 cm (1.73 inches) in February (Purdue University 2000).

2.2 Sample Site Selection

The purpose of the study was to determine the impacts that point source discharges have on freshwater mussels in the Tippecanoe River, specifically those species that are listed as Federally threatened or endangered. A comprehensive list of permitted National Pollutant Discharge Elimination Systems (NPDES) facilities, as well as permitted solid waste facilities, was obtained from the Indiana Department of Environmental Management. Tables 2.2 and 2.3 list the facilities that were considered during the sample site selection process.

Once facilities were located on topographic maps, sites were selected in the main stem river upstream and downstream of the tributaries that received effluent from the permitted facilities (Figure 2.2). Occasionally a facility discharged directly to the Tippecanoe River and sample sites were located upstream and downstream of the facility. In several instances samples were collected within the tributary itself. Other factors that influenced site selection included accessibility, water depth, and habitat.

Where possible, the same sample site locations were used for each survey (Figure 2.2). For example, macroinvertebrate site 2 is the same location as mussel site 2 and fish site 94102 (all fish site identification numbers begin with 941--). Occasionally, different sites were added or deleted during a particular survey. For specific location descriptions during each survey, refer to the chapter in which that survey is discussed. Table 2.1 lists all station numbers for each survey and how they correspond to each other.

2.3 NPDES and Solid Waste Permitted Facilities

There are over 65 NPDES permitted facilities and 17 (11 active and 6 closed) solid waste facilities within the Tippecanoe River watershed (Tables 2.2 and 2.3). Figure 2.3 is a map of all the NPDES permitted facilities in operation as of February 2000 and the permitted solid waste facilities (active and inactive) as of December 2000. Although a few of the facilities in operation

Table 2.2. National Pollutant Discharge Elimination System (NPDES) permitted facilities in the Tippecanoe River Watershed during the U.S. Fish and Wildlife Service Contaminant Investigation Study, 1994-1997. *

NPDES ID#	Facility name	Address	County
IN0036943	Landings Mobile Home Park	1100 N. Rt. 2 West, Monticello, IN 47960	Carroll
IN0051110	Talma Fastener Corporation	RR 5 Hwy 25, Rochester, IN 46975	Fulton
IN0038725	Sonoco Products Co.	RR 1, Box 338, Akron (?), IN 46910	Fulton
IN0003522	Sealed Power Technologies, L.P.	1552 N. Wentze, Rochester, IN 46975	Fulton
IN0001716	Dean Foods	31N & SR 3, Rochester, IN 46975	Fulton
IN0003662	Rochester Water Works	E. 8th St., Rochester, IN 46975	Fulton
IN0021661	Rochester Municipal STP	120 E. 7th, Rochester, IN 46975	Fulton
IN0048097	Four County Landfill	CR 550 N, 1/4 mi. West of SR 17, Rochester, IN	Fulton
IN0031798	Caston Educational Center	SR 25 & CR 1000 N, Fulton, IN 46931	Fulton
IN0025232	Akron Municipal STP	SR 14 W & Noyer Dr., Akron, IN 46910	Fulton
IN0001678	Warsaw PWS United Water Indiana	350 N. Buffalo St., Warsaw, IN 46580	Kosciusko
IN0059081	Flint Ink Corp.	3025 W. Old Rd. 30, Warsaw, IN 46580	Kosciusko
ING080045	ABC Industries, Inc.	Warsaw, IN 46580 (do not have street address)	Kosciusko
IN0003387	R. R. Donnelly & Sons Company	Old Route 30 W, Warsaw, IN 46580	Kosciusko
IN0003760	Kralis Bros. Food, Inc.	SR 25 & Tinkey Rd., Mentone, IN 46539	Kosciusko
IN0004189	Coretech Inc.	542 E. CR 200 N, Warsaw, IN 46580	Kosciusko
IN0004278	Warsaw Black Oxide Co., Inc.	310 S. Walnut St., Burket, IN 46508	Kosciusko
IN0020541	Pierceton Municipal STP	529 S. 1st., Pierceton, IN 46562	Kosciusko
IN0024805	Warsaw Municipal STP	794 W. Center St., Warsaw, IN 46580	Kosciusko
IN0025208	Suburban Acres M.H.P.	3699 N. 175 E., Warsaw, IN 46580	Kosciusko
IN0030881	Hide-Away Hills M.H.P.	2441 CR 250 S., Warsaw, IN 46580	Kosciusko
IN0030911	Yogi Bear's Jellystone Park	1916 N. 850 E., Pierceton, IN 46562	Kosciusko
IN0036412	Mikel Mobile Estates	SR 19 N. & CR 250, Etna Green, IN	Kosciusko
IN0037044	Tippecanoe Valley High School	Box 338, SR 19 S., Mentone, IN 46539	Kosciusko
IN0039870	Claypool Municipal STP	SR 15 & CR 700 S, Claypool, IN 46510	Kosciusko
IN0040002	Etna Green Municipal STP	10950 W. US 30, Etna Green, IN 46524	Kosciusko
IN0040347	Mentone Municipal STP	SR 19, .5 mi. N of town, Mentone, IN 46539	Kosciusko
IN0040444	North Webster Municipal STP	SR 13 & CR 650 N, N. Webster, IN 46555	Kosciusko
IN0041726	Westhaven Estates MHP	3762 N old US 30, Warsaw, IN 46580	Kosciusko
IN0041742	Vin-Lee-Ron Meat Packaging (Formerly Provimi Veal)	SR 25 & SR 331, Mentone, IN 46539	Kosciusko
IN0045578	Dalton Foundaries, Inc.	Lincoln & Jefferson Sts., Warsaw, IN 46580	Kosciusko

IN0054640	Sun Metals Products, Inc.	2156 N. Detroit St., Warsaw, IN 46580	Kosciusko
IN0054704	Mecks Whispering Pines, Inc.	340 E. Levi Lee, Warsaw, IN 46580	Kosciusko
IN0056162	Zimmer, Inc. Corp. Ofc. Bldg.	727 N. Detroit St., Warsaw, IN 46580	Kosciusko
ING250021	Zimmer, Inc. Corp. Ofc. Bldg.	(found 2 permit #'s for this name)	Kosciusko
ING250016	Zimmer, Inc.	Warsaw, IN 46580 (do not have street address)	Kosciusko
IN0056456	YCL Camp/Ministry Center	6750 W. 900 S., Claypool, IN 46510	Kosciusko
IN0057185	Applied Thermal Technologies	2169 N. CR 100 E, Warsaw, IN 46580	Kosciusko
ING080045	BP Scent Saver	Warsaw, IN 46580 (do not have street address)	Kosciusko
IN0022438	Bourbon Municipal STP	Elm & 13th St., Bourbon, IN 46504	Marshall
IN0021288	Culver Municipal STP	1200 South St., Culver, IN 46511	Marshall
ING250025	Culver Education Foundation	Culver, IN 46511 (do not have street address)	Marshall
IN0049930	Ward Stone, Inc.	CR 700 & US 421, Francesville, IN 47946	Pulaski
IN0003263	Vulcan Materials, #342 Frances	US 421, Francesville, IN 47946	Pulaski
IN0004847	Plymouth Tube Co.	700 W. 11th St., Winamac, IN 46996	Pulaski
IN0040037	Francesville Municipal STP	121 E. Montgomery St., Francesville, IN 47946	Pulaski
IN0020516	Winamac Municipal STP	US 35 & Plymouth Rd., Winamac, IN 46996	Pulaski
IN0039209	West Central Jr-Sr High School	RR 2, Box 15, Francesville, IN 47946	Pulaski
IN0052221	Parkview Haven Retirement Home	Constitution Dr., PO Box 797, Francesville, IN	Pulaski
IN0050652	Tippecanoe River State Park	RR4, Box 95A, Winamac, IN 46996	Pulaski
IN0049042	IN Dept. of Highways, Winamac	901 S. Monticello, PO Box 187, Winamac, IN 46996	Pulaski
IN0003255	Vulcan Materials, #341 Monon	U.S. 421, Monon, IN 47959	White
IN0042501	Chalmers Public Water Supply	SR 43 & E. Main, Chalmers, IN 47929	White
IN0021580	Monon Municipal STP	100 Pine St., Monon, IN 47959	White
IN0020974	Brookston Municipal STP	205 E. 3rd, Brookston, IN 47923	White
IN0020176	Monticello Municipal STP	750 East St., Monticello, IN 47960	White
IN0030589	Reynolds Municipal STP	US 24 & CR 100, Reynolds, IN 47980	White
IN0040797	Wolcott Municipal STP	100 W. North St., Wolcott, IN 47995	White
IN0030571	Chalmers Municipal STP	SR 43, Chalmers, IN 47929	White
IN0050326	Pineview Motel & Golf Course	905 W. Norway Rd., Monticello, IN 47960	White
IN0054445	White Oaks on the Lake	RR 2, Box 333, Monticello, IN 47960	White
IN0052078	Indiana Beach	306 Indiana Beach Rd., Monticello, IN 47960	White
IN0030031	Tri-County Middle-Sr. High School	RR1 Box 130A, Wolcott, IN 47995	White
IN0052426	Wolcott Rest Area I-65	I-65 5mi. N of US 231, Wolcott, IN 47995	White
ING340013	Amoco Petroleum Products Terminal	Brookston, IN 47923	White

* Source: Indiana Department of Environmental Management, Office of Water Management, Permitting Branch.

Table 2.3. Permitted hazardous waste, solid waste, and Superfund landfills in the Tippecanoe River Watershed.

Facility ID#	Facility name	Date closed (if applicable)	County
25-02	Four County Landfill (Superfund site)	Oct-83	Fulton
25-03	County Line Landfill		Fulton
43-16	Dalton Foundries (Dave Carey site)		Kosciusko
43-06	Dalton Foundries (RWS II) - not shown on map		Kosciusko
IND064703200	Lakeland Disposal (Superfund site)		Kosciusko
43-13	Likens Landfill		Kosciusko
43-01	Ransbottom Landfill		Kosciusko
**	Warsaw City Landfill	Jan-81	Kosciusko
43-05	Waste Management of Warsaw Transfer Station		Kosciusko
66-01	Old Pulaski County Landfill	Oct-82	Pulaski
66-02	Pulaski County Transfer Station		Pulaski
**	Fleck Open Dump		White
91-04	Liberty Landfill		White
91-03	Miller Landfill	Mar-83	White
**	Monticello Landfill	Jan-83	White
91-01	Segal Landfill	May-85	White
**	Stevenson Solid Fill Site		White

* Source: Indiana Department of Environmental Management, Office of Land Quality, Indianapolis, IN

** Information not available

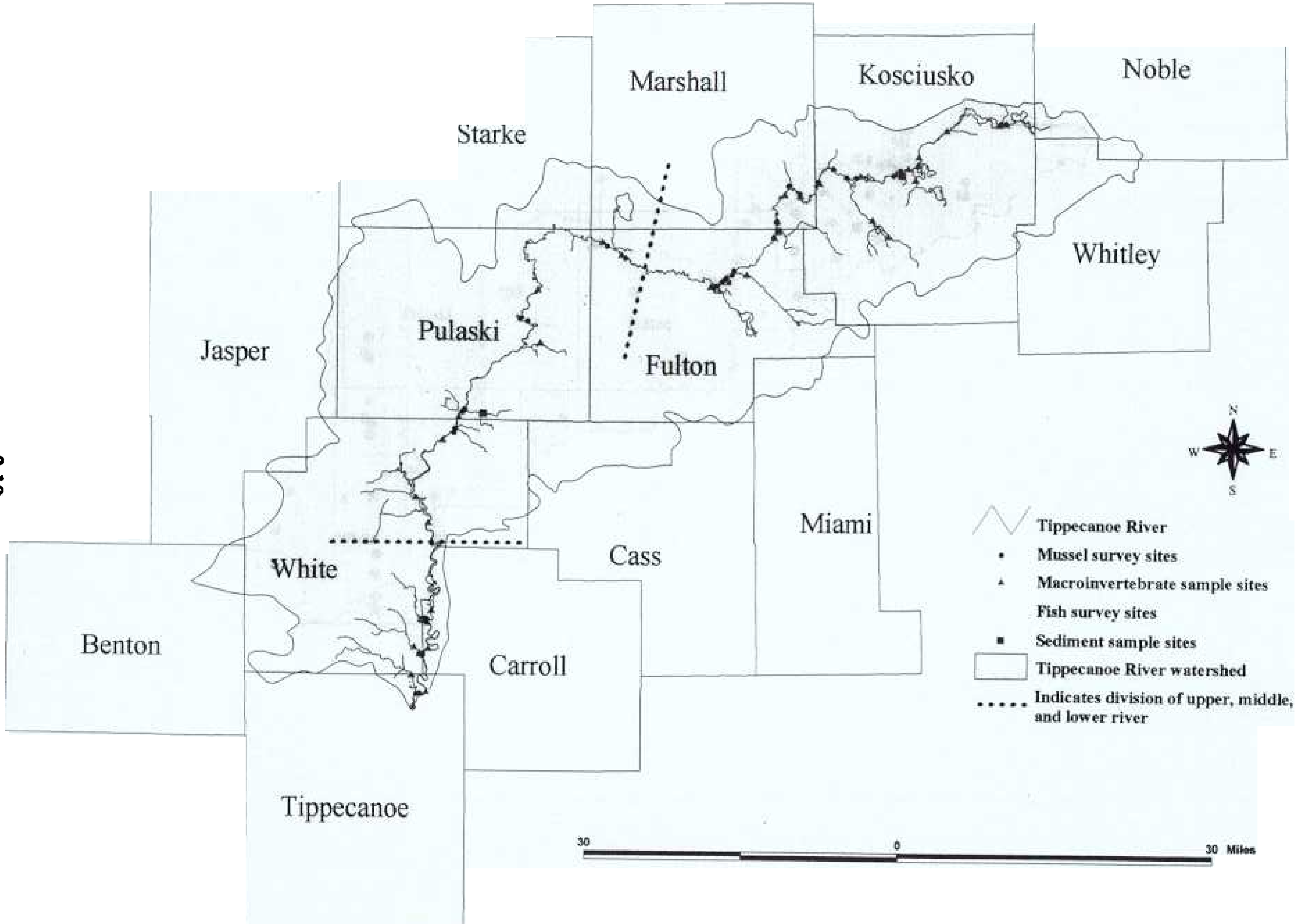

Figure 2.2. Study area and survey locations for the 1994-1997 Tippecanoe River field collections.

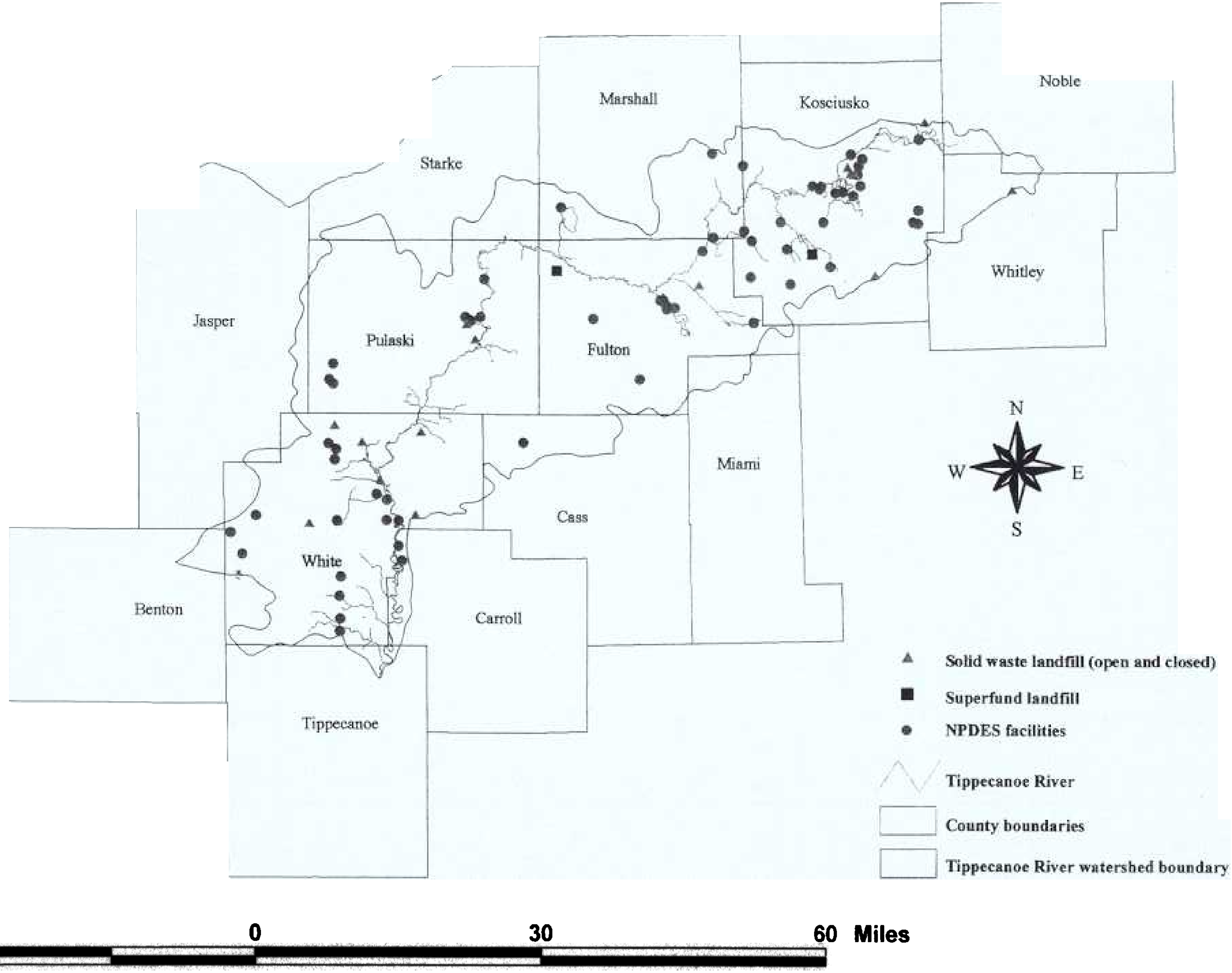

Figure 2.3. Locations of permitted National Pollutant Discharge Elimination Systems (NPDES) facilities, solid waste facilities, and Superfund landfills.

during the study are now closed, and several others are new in the watershed, the map illustrates the overall concentration and general locations of NPDES and solid waste facilities in the watershed.

Of the 14 counties the Tippecanoe River drains, Kosciusko County has the largest number of permitted NPDES discharges and solid waste facilities. There are approximately 31 NPDES permitted facilities and 7 solid waste facilities (including one Superfund site, the Lakeland Disposal Facility). The NPDES facilities in Kosciusko County account for roughly 46% of the permitted discharges in the entire watershed. White County has the next highest number of NPDES permitted facilities (14), accounting for about 21%. With regard to solid waste facilities, both Fulton and Pulaski counties have 1 active and 1 closed facility (including the Four County Landfill Superfund site in Fulton County), and White County has 3 active and 3 inactive facilities.

2.4 Habitat in the Tippecanoe River Watershed

The Tippecanoe River flows through one of the densest agricultural regions in the state. Although the river itself generally has a riparian zone (although sometimes very minimal) throughout it's entire length, most of the watershed is in agricultural row crop production (Figures 2.4). 1992 vegetation data from the Gap Analysis Project (Indiana Gap Analysis Project 2000) indicates that over 80% of the entire watershed is used for row crop farming; an additional 6% is used for pasture and grassland. Approximately 6% is classified as deciduous forest and the remaining 8% is primarily distributed between urban areas, wetland habitats, other forest types, and water (Table 2.4).

In ESI's 1993 report, habitat of the upper Tippecanoe River upstream of Warsaw was characterized as primarily gravel riffle/run, with streambank tree cover generally greater than 50%. The substrate in this section was described as sand and gravel. Below Warsaw, a decrease in habitat quality was noted. In addition, channel substrate was more sandy and silty. In one instance, a site that had been described in a separate study in 1985 as "vegetated rubble riffle" was found, during the ESI study to be covered under a foot or more of shifting sand (ESI 1993). According to ESI (1993), a few sites in the upper river still maintained a predominantly cobble and gravel substrate. Habitat evaluations during the 1995 mussel survey (ESI 1998; included as chapter 5 of this report) indicated that most of the upper river sites were run habitat, with an average of 40% tree cover.

Habitat in the middle section of the river in Fulton County was described by ESI (1993) as cobble and gravel riffles and runs, with sand and silt in deeper pools. Changes to a more shifting sand substrate were noted near the Tippecanoe River State Park. Near Winamac, the habitat changed again to a more gravel and cobble run. This change is possibly due in part to an increase in gradient and a lowhead dam below the Tippecanoe River State Park (ESI 1993). During ESI's 1995 mussel survey, habitat in the middle river was primarily characterized as run (with several sites being classified run/pool) and had an average tree cover of 37% (ESI 1998).

Finally, the lower river was described as riffle, run, and shallow pools, with cobble, gravel and sand substrate (ESI 1993). During the 1995 survey, all of the sample sites (6) were characterized

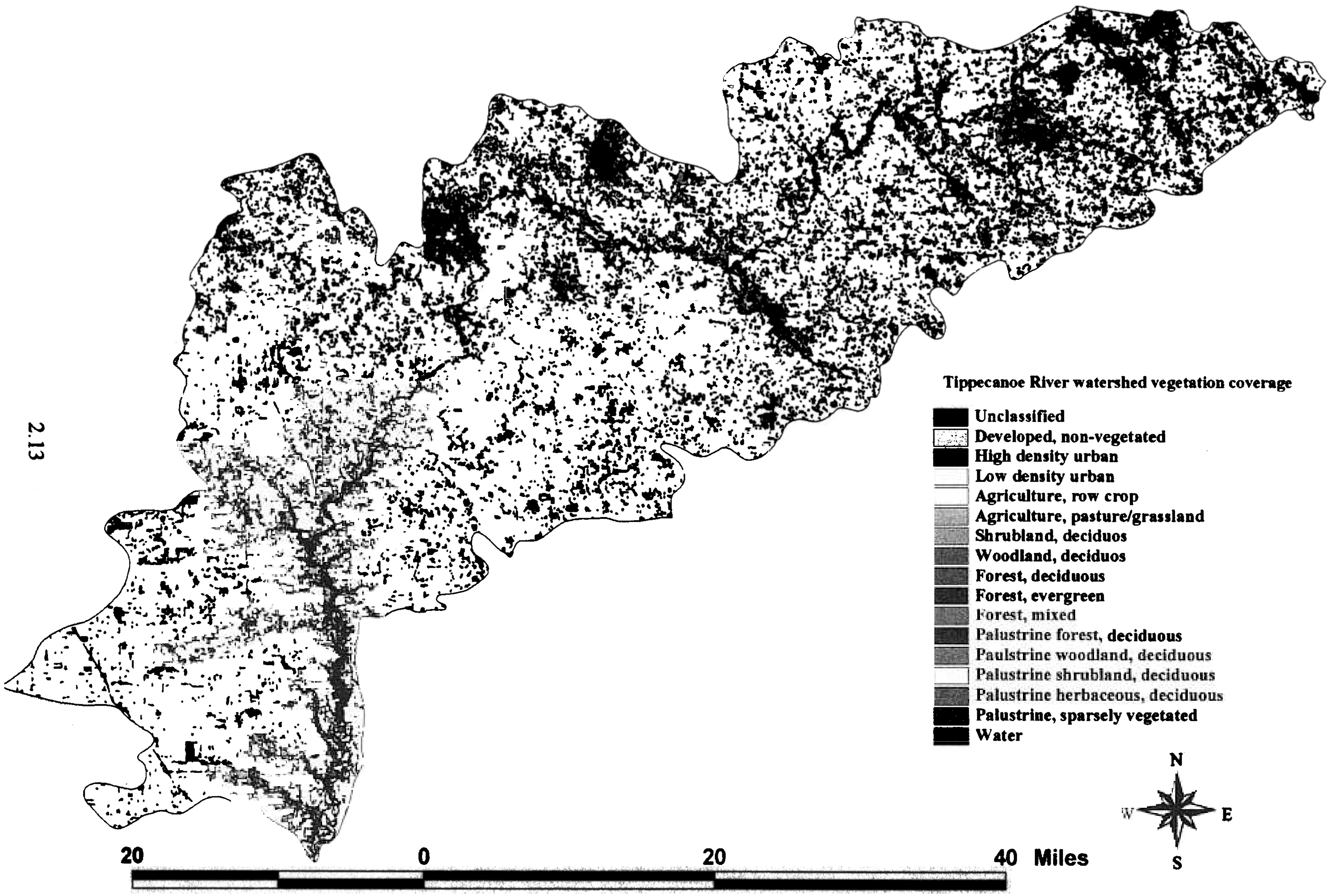

Figure 2.4. 1992 vegetation data for the Tippecanoe River watershed. Source: Indiana Gap Analysis Project, 2000.

Table 2.4. Tippecanoe River watershed vegetation analysis based on 1992 data.
Source: Indiana Gap Analysis Project, 2000.

Vegetation class	Area (hectares)	Percent coverage
Non-vegetated	1,702	0.3%
High-density urban	1,309	0.3%
Low-density urban	2,653	0.5%
Agriculture, row crop	410,399	80.9%
Agriculture, pasture/grassland	29,800	5.9%
Shrubland, deciduous	2,538	0.5%
Woodland, deciduous	1,621	0.3%
Forest, deciduous	28,574	5.6%
Forest, evergreen	558	0.1%
Forest, mixed	30	0.0%
Palustrine forest, deciduous	10,674	2.1%
Palustrine woodland, deciduous	36	0.0%
Palustrine shrubland, deciduous	3,915	0.8%
Palustrine herbaceous, deciduous	6,286	1.2%
Palustrine sparsely vegetated (or non-vegetated)	841	0.2%
Water	6,156	1.2%
Total area analyzed	507,092	

as run habitat with boulder, cobble, and sand substrate. Tree cover at these sites was approximately 45%; however, as previously mentioned, this portion of the river is much more residential than the other sections, and most likely has less riparian cover overall.

2.4.1. Habitat Quality Assessment using the Qualitative Habitat Assessment Index (QHEI)

In order to evaluate habitat at the survey locations, Qualitative Habitat Evaluation Indices (QHEI) were determined during the 1994 fish survey field work. The QHEI is a multimetric index based on key attributes of habitat. The index was originally developed by Ohio EPA (Rankin 1989) and has been broadly applied in a variety of states and watersheds. The QHEI is based on a visual estimate of habitat features. Each habitat attribute is ranked based on select categories of increasing presence. The original scoring for the QHEI was calibrated using reference streams designated by Ohio EPA. Rankin (1995) indicated that stream flow data (periodicities, peaks, and minimums) were not an explicit part of the QHEI. The flow regimes that a stream is subject to are fundamental considerations for interpreting habitat and biological data. Flow is not a limiting factor in either Ohio or Indiana streams as it would be in the western United States, and is therefore excluded as a part of the index (Poff et al. 1997). The flow regimes of streams are implicitly measured since they influence many of the habitat attributes of streams.

The QHEI is based on a variety of habitat features important in riverine systems. The index measures substrate type and quality; instream physical structure and cover; channel structure, stability, and modifications; riparian width and quality; bank erosion; riffle-run and pool-glide quality and characteristics; and stream gradient. A single modification of the index application was made for this project. The original intention of the stream gradient score was to compare streams across different ecoregions. Since the Tippecanoe River Study occurred completely within one watershed, this metric was dropped from the evaluation. Little difference in stream gradient scores would have been observed within the Tippecanoe River, with the exception of the areas in the immediate vicinity of the two dams in the lower Tippecanoe River. Due to this change in scoring, the QHEI scores for this study were calculated out of a total of 90 points and then adjusted to reflect a score based on 100 points.

Ideally an index should minimize measurement error and be cost-effective to implement. Data from training sessions that have been held by the State of Indiana's Department of Environmental Management has shown that when the QHEI was generated independently by field staff and other trainees, a strong, significant correlation existed between individual scoring and scoring by the instructor. Rankin (1995) has shown a strong positive relationship between biological data and habitat quality at reference site biological integrity." QHEI scores are interpreted based on whether or not they meet reference condition expectations by comparing reference stream scores to the study site scores. The QHEI is easily conducted by walking the stream channel and visually observing the habitat categories described above. The index score is calculated by checking a series of boxes on the habitat sheet that best describe the condition of the individual site.

Rankin (1995) has determined that the QHEI must score a minimum of 64 points in order to be considered "least-impacted" based on comparisons of reference sites and test sites in Ohio. We have further trisected this category to suggest that sites scoring less than 33 are not meeting designated uses based on poor physical habitat. Sites scoring between 33 and 64 are slightly impaired but are meeting designated uses, while sites scoring greater than 64 are meeting the expectations for that stream reach.

The Tippecanoe River, for the most part, has excellent instream habitat features; decreases in QHEI scores were primarily a result of external factors such as bank erosion, riparian corridor disturbance, and channel modification (Table 2.5). Based on our criteria for ranking streams, 70.6% were considered least-impacted, 23.5% were slightly impaired but still meeting designated uses, and 5.9% were poor habitat and did not meet designated uses. Of the 10 sites that did not meet the scoring criteria for "least impacted", 9 were in the upper Tippecanoe River segment. The reason for these declines was due to either poor pool/glide habitat quality or lack of riffle development.

Table 2.5. Qualitative Habitat Evaluation Index (QHEI) (OEPA 1989) individual metric scores and total QHEI scores for the Tippecanoe River, 1994. Scores were adjusted to reflect a score out of 100.

Site ID	Substrate (20 max.)	Instream cover (20 max.)	Channel morphology (20 max.)	Riparian zone and bank erosion (10 max.)	Pool/glide quality (12 max.)	Riffle/run quality (8 max.)	Total QHEI Score
94101	16	10	16	9	3	3	63.3
94102	9	14	14	9	9	4	65.6
94104	14	14	17	9.5	10	3	75.0
94105	14	14	13	8	7	3	65.6
94106	14	5	4	4	0	0	30.0
94107	10	5	4	8	2	0	32.2
94109	11	9	10	7	3	2	46.7
94110	13	12	13	9	7	0	60.0
94111	12	13	18	8	7	0	64.4
94112	12	6	13	8	5	0	48.9
94113	10	9	16	9	7	0	56.7
94115	12	4	14	6.25	8	0	49.2
94116	15	10	15	5.5	10	3	65.0
94117	11	7	7	2	5		34.4
94118	13	14	19	7	12	5	77.8
94119	17	13	17	9	8	6	77.8
94120	18	16	19	6.5	9	6	82.8
94121	12	12	16	8.75	11	4	70.8
94122	14	10	19	7	8	5	70.0
94123	11	14	19	10	6	2	68.9
94124	16	15	17	8	10	5	78.9
94126	15	14	14	7	11	5	73.3
94127	11.3	11	17	7	9	4	65.9
94128	18	12	17	9	8	5.5	77.2
94129	18	20	20	9	11	7	94.4
94130	15	7	19	8	9	5	70.0
94132	20	14	19	8	9	6	84.4
94133	12	8	14	4	4	0	46.7
94139	16	13	16	7.5	11	6	77.2
94140	16	11	19	9	11	7	81.1
94141	18	16	20	10	9	7	88.9
94143	18	13	20	9	10	8	86.7
94144	18	16	20	8.5	11	7	89.4
94145	18.5	13	19.5	9	11	8	87.8

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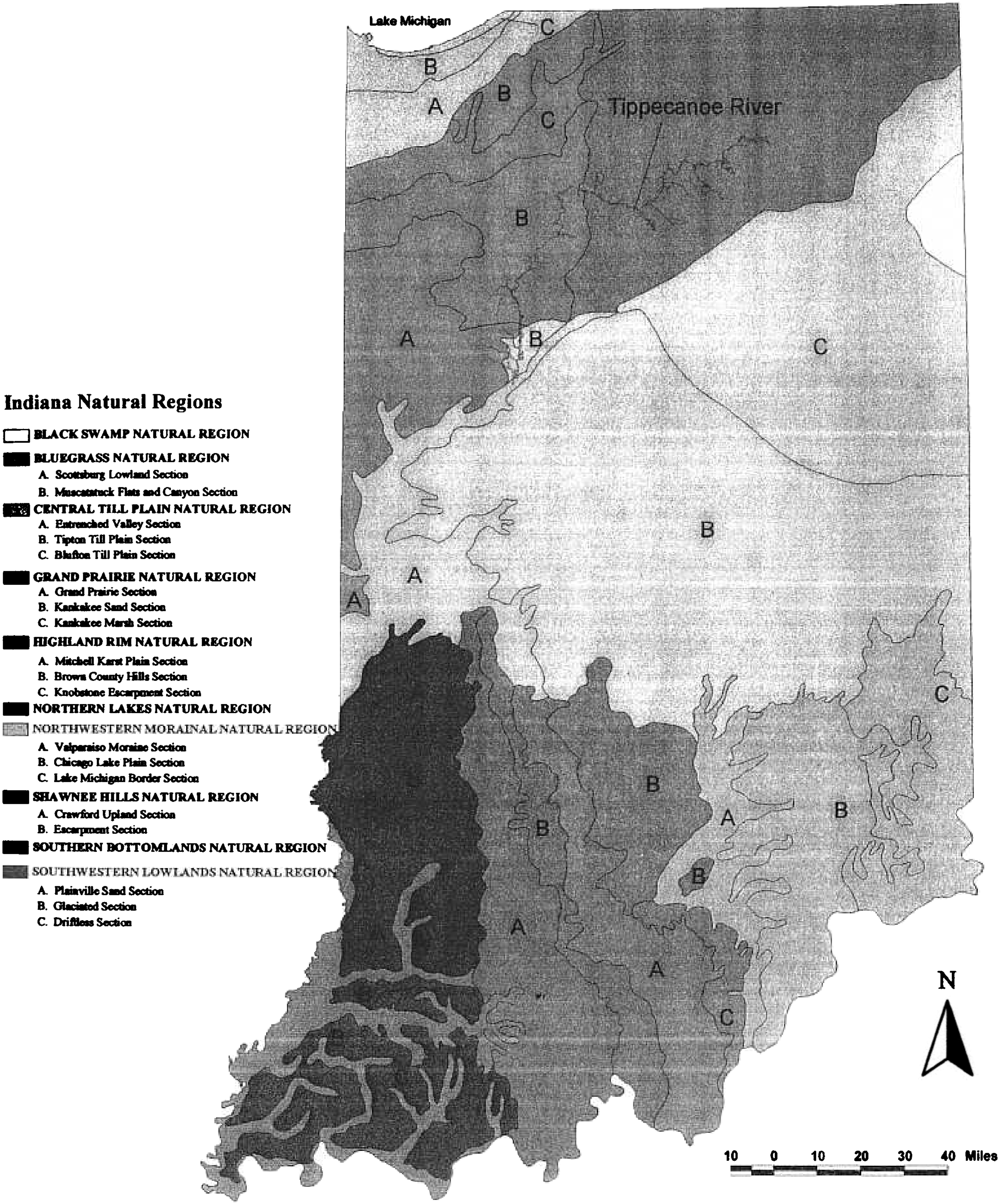

Appendix I. Homoya et. al.'s (1985) Natural Regions of Indiana.

Chapter 3

Macroinvertebrates in the Tippecanoe River watershed.

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Bloomington, Indiana 47403-2121

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3.0 Introduction

Biological communities reflect the overall health and integrity of the ecological system. One of the most widely used faunas in evaluating the biological integrity of streams is the macroinvertebrate community. Because of their importance as a primary food source and link between organic matter and fish and other wildlife, and because of their diversity and ubiquity, macroinvertebrates are often used as indicators of the quality of a stream's chemical and physical conditions. Macroinvertebrates are good indicators of localized conditions due to limited migration and fairly sessile lifestyles (Plafkin 1989); in addition, they are generally abundant and relatively easy to sample and identify to family level.

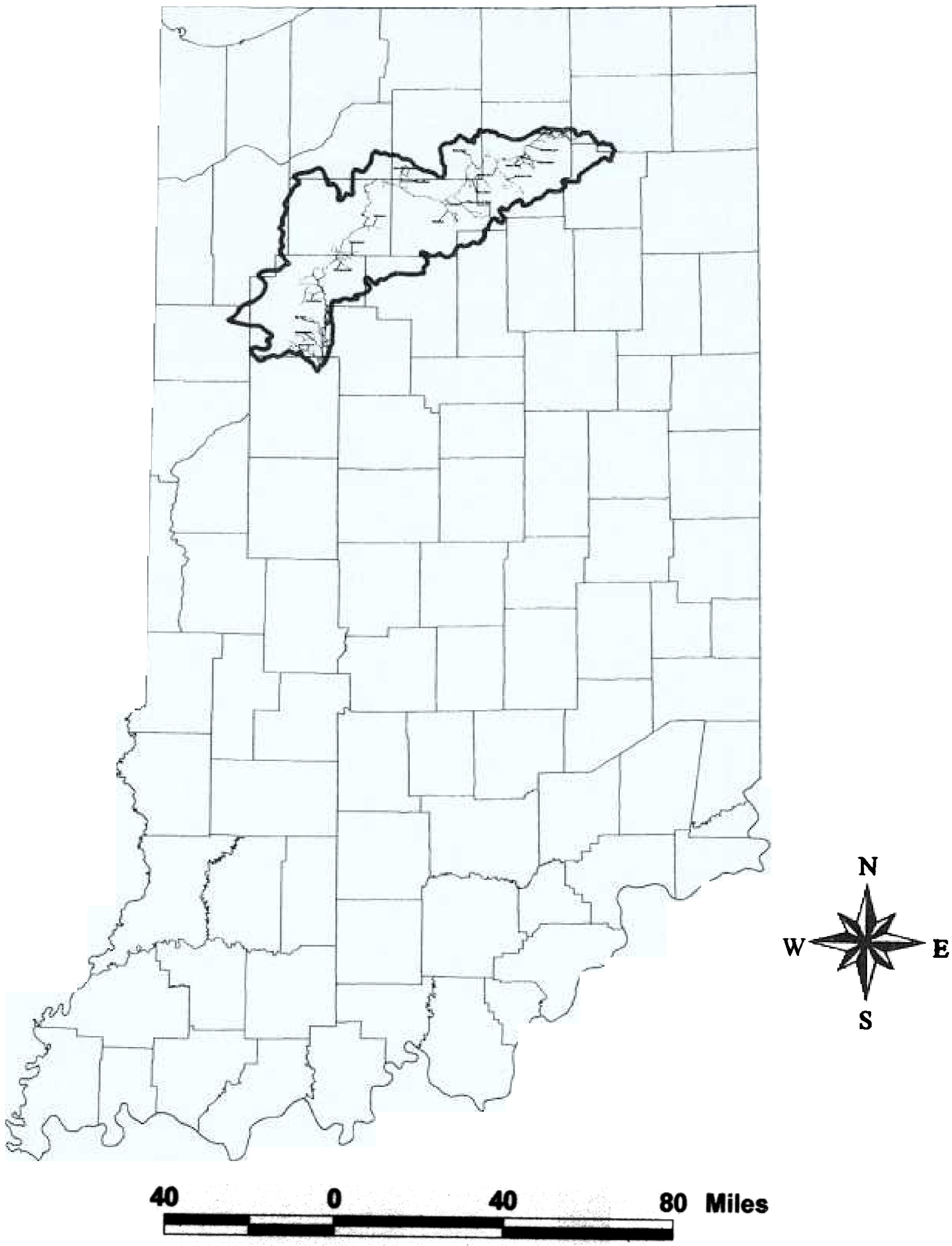
In 1991, the FWS and the Indiana Department of Natural Resources (IDNR) funded a two-year study of the fish, unionids, and habitat in the Tippecanoe River (ESI 1993). Following management recommendations made as a result of that investigation, the FWS initiated a study of the water quality in the Tippecanoe River upstream and downstream of tributaries with point-source discharges (primarily National Pollutant Discharge Elimination Systems (NPDES) permitted facilities and permitted solid waste facilities) (Figure 3.1). This study is part of a larger scale effort to evaluate the decline in freshwater mussels. Most stream invertebrates are associated with surfaces of the channel bottom or other stable surfaces (logs, roots, vegetation) rather than being free swimming (Hauer and Resh 1996). Artificial substrates were utilized in order to reduce sampling variability, minimize the affect of habitat quality on invertebrate sampling, and focus the investigation on water quality factors.

3.1 Materials and Methods

3.1.1 Invertebrate Community Sampling

Sample sites were determined using topographic maps, as well as a watershed list of NPDES facilities and Permitted Solid Waste facilities. Samples were collected upstream and downstream of tributaries with known permitted outfalls (Figure 3.2) along the entire length of the Tippecanoe River. Twelve different tributaries with permitted discharges located on them, and one point-source on the main stem were evaluated during this survey. In addition to the main stem, several of the tributaries themselves were sampled. A total of 38 sites was sampled. Table 3.1 describes the site locations.

The invertebrate sampling was based on the Ohio Environmental Protection Agency's (OEPA) methods described in Biological Criteria for the Protection of Aquatic Life: Volume III: Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (1989). Modified Hester-Dendy artificial substrate multi-plate samplers were constructed with slight alterations to the design described by OEPA (1989). Each sampler consisted of 5 circular discs (rather than square plates) constructed from 1/8 inch tempered hardboard (Figure 3.3). Each disc was 5.8 cm in diameter. Total available area (i.e. substrate) was .02468 square meters per sampler. With the exception that the constructed samplers were slightly smaller in scale, the multi-plate samplers were similar to those described in Standard Methods for the Examination of Water and Wastewater (APHA 1989).



Tippecanoe River and it's tributaries

Figure 3.1. Study area for the 1994 macroinvertebrate survey, Tippecanoe River watershed, Indiana.

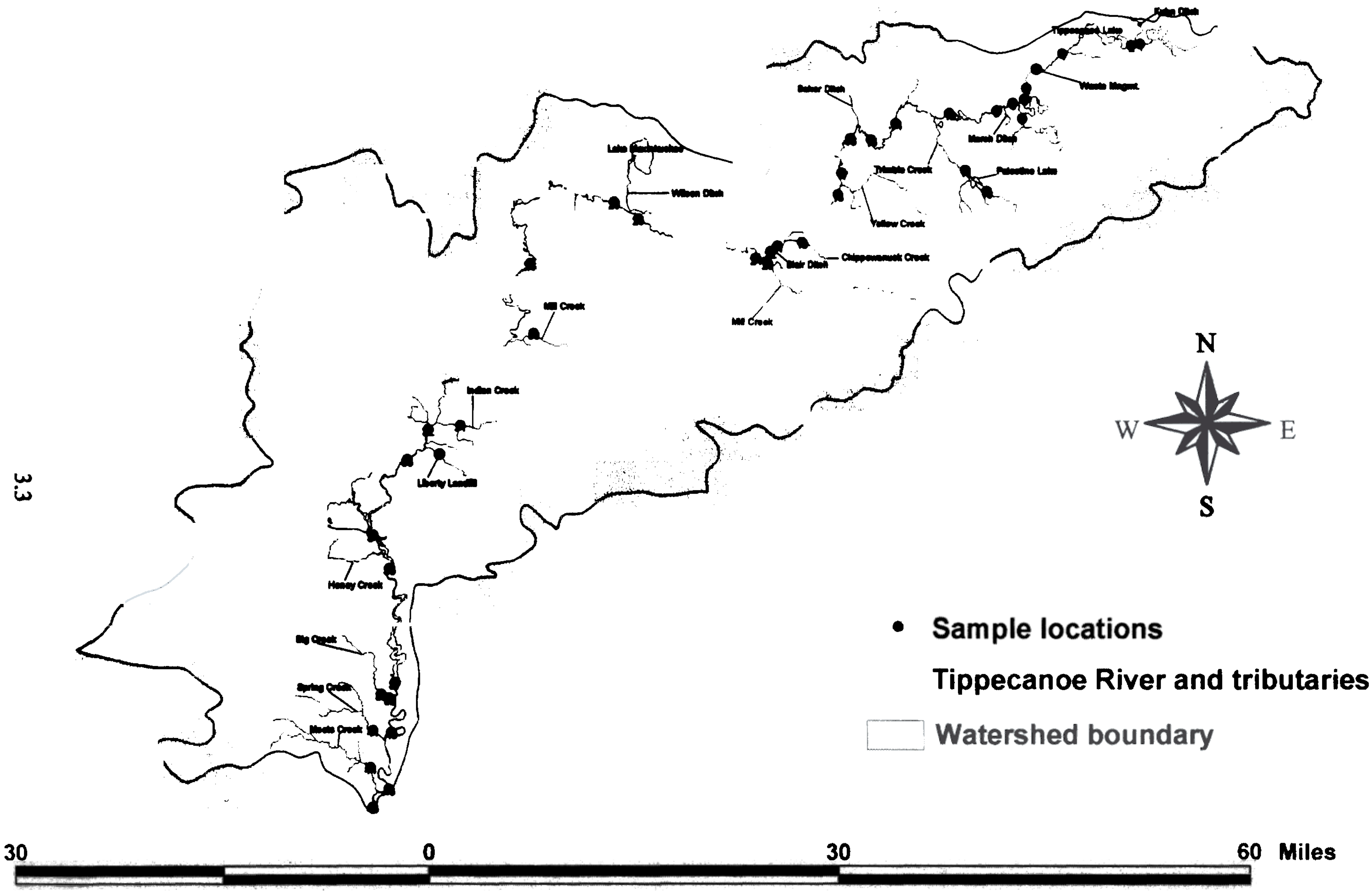


Figure 3.2. Macroinvertebrate sampling locations for the Tippecanoe River, 1994.

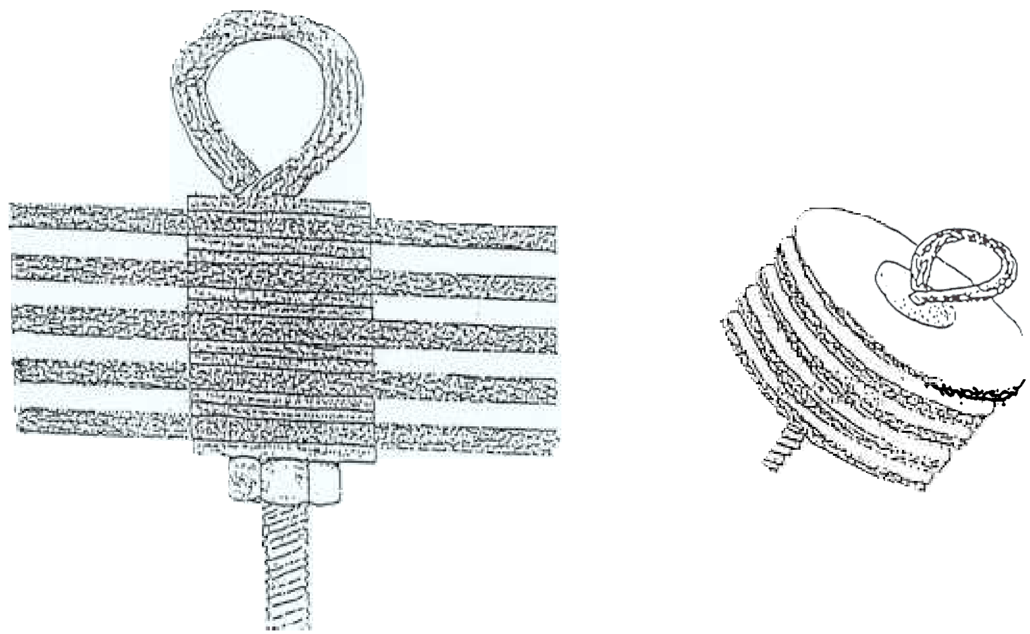


Figure 3.3. Diagram of the modified multi-plate artificial substrate sampler used in the Tippecanoe River macroinvertebrate survey.

Table 3.1 Sites assessed during the 1994 macroinvertebrate community surveys in the Tippecanoe River, upstream and downstream of tributaries with point source discharges.

Station	Waterbody	Approx. Drainage Area (sq. mi.)	County	Quadrangle	Township	Range	Section	Latitude (Deg., Min., Sec.)	Longitude
1	Tippecanoe River	50	Kosciusko	North Webster	33N	7E	15	41 18 54	85 42 12
2	Tippecanoe River	50	Kosciusko	North Webster	33N	7E	16	41 18 53	85 42 54
4	Tippecanoe River	100	Kosciusko	Leesburg	33N	6E	22	41 18 26	85 48 35
5	Tippecanoe River	100	Kosciusko	Leesburg	33N	6E	31	41 16 13	85 51 48
6	Tippecanoe River	200	Kosciusko	Leesburg	32N	6E	6	41 15 30	85 52 14
7	Walnut Creek	60	Kosciusko	Warsaw	32N	6E	7	41 14 23	85 52 13
8	Tippecanoe River	200	Kosciusko	Atwood	32N	5E	1	41 15 22	85 53 02
9	Tippecanoe River	300	Kosciusko	Burket	32N	5E	2	41 14 51	85 54 27
10	Trimble Creek	10	Kosciusko	Burket	31N	5E	1	41 09 55	85 55 09
11	Trimble Creek	30	Kosciusko	Burket	32N	5E	33	41 11 12	85 57 02
12	Tippecanoe River	300	Kosciusko	Burket	32N	5E	5	41 14 48	85 58 18
14	Tippecanoe River	400	Kosciusko	Mentone	32N	4E	10	41 14 11	86 02 48
15	Tippecanoe River	400	Marshall	Mentone	32N	4E	17	41 12 58	86 05 05
16	Tippecanoe River	400	Marshall	Mentone	32N	4E	18	41 13 11	86 06 50
17	Tippecanoe River	400	Marshall	Mentone	32N	4E	36	41 11 12	86 07 28
18	Tippecanoe River	500	Fulton	Argos	31N	3E	6	41 09 50	86 07 49
19	Chippewanuck Creek	40	Fulton	Rochester	31N	3E	27	41 06 43	86 11 07
21	Tippecanoe River	600	Fulton	Rochester	31N	3E	29	41 06 19	86 13 01
22	Tippecanoe River	600	Fulton	Rochester	31N	3E	29	41 06 08	86 13 32
23	Mill Creek	50	Fulton	Rochester	31N	3E	31	41 05 30	86 13 54
24	Tippecanoe River	600	Fulton	Rochester	31N	2E	36	41 05 49	86 14 48
25	Tippecanoe River	800	Fulton	Culver	31N	1E	10	41 08 39	86 24 52
26	Tippecanoe River	800	Fulton	Culver	31N	1E	8	41 09 22	86 26 36
28	Tippecanoe River	900	Pulaski	Winamac	31N	1W	32	41 05 29	86 33 47
30	Mill Creek	80	Pulaski	Winamac	30N	1W	31	41 01 24	86 33 34
31	Indian Creek	60	Pulaski	Buffalo	29N	2W	32	40 55 19	86 39 43
32	Tippecanoe River	1000	Pulaski	Buffalo	29N	3W	36	40 55 07	86 42 33
33	Tippecanoe River	1000	White	Buffalo	28N	3W	10	40 53 11	86 44 16
34	Tippecanoe River	2000	White	Monticello North	27N	3W	8	40 48 25	86 47 05
35	Tippecanoe River	2000	White	Monticello North	27N	3W	21	40 46 22	86 45 50
37	Tippecanoe River	2000	Carroll	Monticello South	26N	3W	33	40 39 06	86 45 26
38	Big Creek	70	White	Monticello South	25N	3W	5	40 38 19	86 46 29
39	Tippecanoe River	2000	Carroll	Monticello South	25N	3W	9	40 38 10	86 45 51
40	Tippecanoe River	2000	Carroll	Brookston	25N	3W	21	40 35 59	86 45 39
41	Spring Creek	20	White	Brookston	25N	3W	20	40 36 04	86 47 10
43	Tippecanoe River	2000	Tippecanoe	Brookston	24N	3W	9	40 32 29	86 45 54
44	Moots Creek	50	Tippecanoe	Brookston	24N	3W	5	40 33 03	86 47 18
45	Tippecanoe River	2000	Tippecanoe	Brookston	24N	3W	17	40 31 20	86 47 20

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Multi-plate artificial substrate samplers were deployed between June 14 - 16, 1994, and retrieved six weeks later between August 1 - 3. Three replicate samplers were placed at each of the 38 sites.

Upon collection, all macroinvertebrates were preserved in a solution of 70% ethyl alcohol and returned to the laboratory at the U.S. Fish and Wildlife Service, Bloomington, Indiana Field Office (BFO). Samples were processed and identified to the Family level using Merritt and Cummins (1984) and McCafferty (1981) (Table 3.2).

3.1.2 Data Analysis

3.1.2.1 Invertebrate Community Index (ICI)

Invertebrate data were primarily analyzed using a modified version of the ICI metrics described by OEPA (1987). The ICI was developed using data from over 230 reference sites in Ohio. In order to determine if biotic potentials varied according to ecoregion, OEPA compared reference sites from various ecoregions within the state. They concluded that discrete differences in the macroinvertebrate potential did not differ between ecoregions (OEPA 1987). Therefore, due to a lack of comparable reference data from Indiana, and based on Ohio's geographic proximity, OEPA's invertebrate metrics and scoring classifications were used to develop scores for this study (Table 3.3).

ICI metrics and scoring are based on identification to the lowest practical taxonomic level. Due to the degree of expertise required in invertebrate identification at the genus and species level, all specimens were identified to the Family level. Based on general knowledge of the system, water quality data, previous macroinvertebrate work done by the BFO (Sobiech et. al. 1994, Sobiech 1996), and best professional judgement the metrics and scoring for this study were slightly modified to reflect Family-level taxonomy (Table 3.3). For those modified metrics that were drainage-area dependent, a modified OEPA quadripartite chart was used (Appendix I). While this level of taxonomy may somewhat lessen the ability to discern subtle differences between sampling sites, the modified metrics and scoring should be sufficient to evaluate discrete differences in the ambient invertebrate communities upstream and downstream of the point source discharges. Following are explanations for the modifications made to the metrics:

1) The Percent Tribe Tanytarsini Midge Composition Metric is used by OEPA because of the tribe's sensitivity to pollution and predominance in unimpacted Ohio streams. Because of the Tanytarsini midges' sensitivity, they are a good indicator of pollutional stresses (OEPA 1987). For this evaluation, Hilsenhoff's (1988) Family Biotic Index (FBI) was substituted for the Percent Tribe Tanytarsini Midge Composition Metric since midges were not identified beyond the Family level (Table 3.3). The FBI provides a rapid assessment of a stream based on the pollutional tolerances of the invertebrates present in a sample. Each Family taxon is assigned a tolerance value (see Appendix II), and this value is then multiplied by the number in each family and then divided by the sample total. Table 3.4 provides the classifications assigned by Hilsenhoff (1988) for specific FBI ranges and the ICI scores used for this study in order to substitute the FBI for the percent tribe

Stations (downstream ---->)

Ephemeroptera	*Ephemerellidae*	1		8	6	8		2	21			48			11		26	27	3	35	2	35	27	6	17	9	26	27	29	13	49	17	53	28	27		42	55	3
	Heptagenildae				7	5		9	15			33		1	12	1	12	4	3	23	5	26	8	1	21	12	16	10	13	5	7	9	27	14	18		20	47	4
	Siphlonuridae					1																																	
	Tricorythidae	6	5			1			8					7	11		8	4	1			2	1		2				1		12		2	12			12	10	
	Neophemeridae						1	4	1					1							4				1			2	35	1	27								
	Caenidae							2						1			1							1						1									
	Potamanthidae								9			1								1											1						1		
	Polymitarcyidae																																				2		
	Leptophlebiidae																											1											
Odonata	*Coenagrionidae*	1																																					
	Lestidae										1																								1				
	Corduliidae																					1									1								
Plecoptera	*Chloroperlidae*		1																																				
	Pteronarcyidae																					4	4		1														
	Perlidae																						4		2				2								1		
Coleoptera	*Psephenidae*										5								1																				
	Haliplidae																				1																		
	Elmidae	3	5	8	4		2					2					2	8	4		2	1	5		1		2				4		12		1		5	9	
	Gyrinidae				1			1						1	1	2																							
	Dytiscidae																										1												
Megaloptera	*Sialidae*	3	3			1			2						3			2		1																			
	Corydalidae					2																																	
Diptera	*Culicidae*																	1																					
	Chironomidae	1	36	3	2	70	3	30	4		10	1		7	6	4	6	18	2	8	25	2	1	8	8	1	1	4	2	2	2	12		2	4	3	2	5	1
Tricoptera	*Glossosomatidae*				1																					2	1												
	Polycentropidae					3		2						1				3	2	2						3		8	3	1		3			8		3	2	1
	Brachycentridae														1			1	1																				
	Hydropsychidae	26		4	17	26	5	1	53	7		45			7		16	33	5	1	5	12	7				2	1			45	1	6	200	6		50	23	
Gastropoda	*Viviparidae*			7	3						4												8								1	2	1	2			2		
	Planorbidae			1																																			
	Lymnaeidae	2		3																			1																
	Ancylidae			4							2												10								3		1				1		
Annelida	*Hirudinea*		3																											3				2			5		
*Nematomorpha**	horsehair worms			10			11			15			6			1								3			1			1									
Isopoda	sowbugs		1								1	3					4								3	3	18	2	1	1			10					1	
Amphipoda	scuds		20								1			1										1					1										
	Total Individuals	43	74	48	41	117	22	51	113	22	24	133	6	20	52	8	75	101	22	71	44	83	76	20	56	30	68	55	87	28	152	44	112	260	65	3	146	152	11
	Total # of Taxa	8	8	9	8	9	5	8	8	2	7	7	1	8	8	4	8	10	9	7	7	8	11	6	9	6	9	8	9	9	11	6	8	7	7	1	13	8	5

* Nematomorpha is the Phylum name

Table 3.3. Invertebrate Community Index (ICI) metrics and scoring classification used to evaluate the Tippecanoe River in northcentral Indiana (modified from OEPA 1987).

	Scoring Classification			
ICI Metric	0	2	4	6
Total Number of Taxa	Varies with drainage area			
Total Number of Mayfly Taxa	Varies with drainage area			
Total Number of Caddisfly Taxa*	Varies with drainage area*			
Total Number of Dipteran Taxa	Varies with drainage area			
% Mayfly Composition*	0	>0,<10	>10, <25	>25
% Caddisfly Composition*	Varies with drainage area*			
Family Biotic Index (FBI)	Varies with FBI value (See Table 3.4)			
% Dipteran and Non-Insect Composition*	Varies with drainage area*			
% Tolerant Organisms*	Varies with drainage area*			
Total Number of Quantitative EPT Taxa	Varies with drainage area			

* OEPA (1987) scoring criteria were used in this evaluation.

Table 3.4. Characteristic attributes of the Family Biotic Index (FBI) values, associated Invertebrate Community Index (ICI) scoring typical water quality traits, and degree of organic pollution used for this evaluation (from Sobiech et. al. 1994).

FBI Value	ICI score	Water quality traits	Pollutional degree
0.00- 3.75	6	Excellent	Unlikely
3.76- 4.25	5	Very Good	Possibly slight
4.26- 5.00	4	Good	Some probable
5.01- 5.75	3	Fair	Fairly substantial
5.76- 6.50	2	Fairly Poor	Substantial
6.51- 7.25	1	Poor	Very Substantial
7.26-10.00	0	Very Poor	Severe

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Tanytarsini midge composition (Sobiech et. al. 1994). The Nematamorph taxon was not included in the FBI calculation due to lack of tolerance value data. The FBI scores will also be evaluated independent of the ICI.

2) In order to evaluate the Percent Other Dipterans and Non-Insect Metric at the Family level, this metric was modified to include all Dipterans (and non-insects) in the calculation. The original metric was designed to exclude the more sensitive Tanytarsini midge tribe; however, identification beyond the Family level was not performed. This modification should still accurately reflect the original intent of the OEPA's metric, which is to account for the predominance of Dipterans and non-insects under adverse water quality conditions. OEPA's scoring criteria were used to assign scores for this metric.

3) The calculation of the Percent Tolerant Organisms Metric was slightly modified to reflect a Family-level taxonomy. Taxa included in the pollution tolerant organisms are identified in Appendix III. This revised list goes only to the Family level. OEPA's scoring for this metric was not changed.

4) Finally, due to a lack of qualitative sampling data for each site (i.e. direct habitat sampling), the quantitative numbers obtained from the multi-plate samplers were used to calculate the total number of EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa at each station. The scoring for this metric was scaled to reflect Family-level taxonomy.

ICI scores were calculated based on the sum of the individual metric scores (Table 3.5). Each score was then assigned an integrity classifications. Table 3.6 describes the ICI scoring ranges and their associated integrity classifications.

3.1.2.2 Community Similarity Index (CSI)

For comparisons between the upstream and downstream invertebrate fauna, Community Similarity Indices (CSIs) (OEPA 1989) were calculated for each location as:

$$CSI = \frac{2C}{A + B}$$

where: A = number of taxa in sample 1
B = number of taxa in sample 2
C = number of taxa common to both samples

These results are presented in the form of a matrix to allow the comparison of all sites with each other (Appendix IV). For comparisons between upstream and downstream of tributaries and/or point-sources only, see Table 3.7.

Table 3.5. Invertebrate Community Index (ICI) metric evaluation of the Tippecanoe River, upstream and downstream of tributaries with point source discharges. Individual metric scores are reported followed by the actual metric value in parentheses.

Site Number	Total # Taxa	# of Mayfly Taxa	# of Caddisfly Taxa	# of Dipteran Taxa	% Mayfly	% Caddisfly	% Dipterans	% Tolerant Organisms	EPT Index	FBI	Total ICI Score	ICI Classification
1	4 (8)	2 (2)	4 (1)	2 (1)	4 (16.3)	6 (60.5)	6 (7.0)	6 (2.3)	2 (3)	5 (4.19)	41	Good
2	4 (8)	0 (1)	0 (0)	2 (1)	2 (6.8)	0 (0)	0 (81.1)	0 (48.6)	2 (2)	3 (5.47)	13	Poor
4	4 (9)	0 (1)	2 (1)	2 (1)	4 (6.7)	4 (8.3)	2 (58.3)	2 (14.6)	0 (2)	4 (4.32)	24	Fair
5	4 (8)	2 (2)	4 (2)	2 (1)	6 (31.7)	6 (43.9)	6 (12.2)	6 (4.9)	2 (4)	6 (3.73)	44	Good
6	4 (9)	4 (4)	4 (2)	2 (1)	4 (12.8)	6 (24.8)	0 (59.8)	0 (59.8)	4 (6)	4 (5.00)	32	Fair
7	2 (5)	0 (1)	4 (1)	2 (1)	2 (4.5)	6 (22.6)	0 (63.6)	2 (13.6)	2 (2)	4 (4.60)	24	Fair
8	4 (8)	4 (4)	4 (2)	2 (1)	6 (33.3)	2 (5.9)	2 (58.8)	0 (58.8)	4 (6)	3 (5.38)	31	Fair
9	4 (8)	6 (5)	2 (1)	2 (1)	6 (47.8)	6 (46.9)	6 (3.5)	6 (3.5)	4 (6)	6 (3.51)	48	Exceptional
10	0 (2)	0 (0)	4 (1)	0 (0)	0 (0)	6 (31.8)	0 (68.2)	6 (0)	0 (1)	5 (4.00)	21	Fair
11	2 (7)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (75.0)	0 (50.0)	0 (0)	3 (5.67)	7	Poor
12	2 (7)	4 (3)	2 (1)	2 (1)	6 (61.7)	6 (33.8)	6 (3.0)	6 (.8)	2 (4)	6 (2.98)	42	Good
14	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (100.0)	6 (0)	0 (0)	3*(NA)	9	Poor
15	4 (8)	4 (4)	2 (1)	2 (1)	6 (50)	2 (5)	2 (40.0)	0 (35.0)	4 (5)	3 (5.11)	29	Fair
16	4 (8)	4 (3)	4 (2)	2 (1)	6 (65.4)	4 (15.4)	6 (11.5)	0 (11.5)	4 (5)	6 (3.56)	40	Good
17	0 (4)	0 (1)	0 (0)	2 (1)	4 (12.5)	0 (0)	0 (62.5)	0 (50.0)	0 (1)	3 (5.43)	9	Poor
18	4 (8)	4 (4)	2 (1)	2 (1)	6 (62.7)	4 (21.3)	6 (13.3)	0 (80.0)	4 (5)	6 (3.27)	38	Good
19	6 (10)	4 (3)	6 (3)	4 (2)	6 (34.7)	6 (36.6)	6 (12.8)	2 (17.8)	6 (6)	6 (3.62)	52	Exceptional
21	4 (9)	4 (3)	4 (3)	2 (1)	6 (31.8)	6 (36.4)	6 (9.1)	0 (9.1)	4 (6)	5 (3.82)	41	Good
22	4(7)	4 (3)	4 (2)	2 (1)	6 (83.1)	2 (4.2)	6 (11.3)	0 (11.3)	4 (5)	6 (2.80)	38	Good
23	2 (7)	4 (3)	4 (1)	2 (1)	6 (25)	6 (11.4)	0 (56.8)	0 (56.8)	4 (4)	3 (5.18)	33	Fair
24	4 (8)	4 (3)	2 (1)	2 (1)	6 (75.9)	4 (14.5)	6 (2.4)	6 (2.4)	4 (5)	6 (2.60)	44	Good
25	6 (11)	4 (3)	2 (1)	2 (1)	6 (47.4)	2 (9.2)	4 (26.3)	0 (14.5)	4 (6)	6 (3.09)	36	Good
26	2 (6)	4 (3)	0 (0)	2 (1)	6 (40)	0 (0)	0 (60.0)	0 (40.0)	2 (3)	5 (4.12)	21	Fair
28	6 (9)	6 (4)	0 (0)	2 (1)	6 (73.2)	0 (0)	4 (19.6)	0 (14.3)	4 (6)	6 (3.29)	34	Good
30	2 (6)	2 (2)	4 (2)	2 (1)	6 (70)	6 (16.7)	6 (13.3)	6 (3.3)	2 (4)	6 (3.30)	42	Good
31	4 (9)	2 (2)	4 (2)	2 (1)	6 (61.8)	2 (4.4)	4 (29.4)	6 (1.5)	4 (4)	6 (3.37)	40	Good
32	6 (8)	6 (4)	2 (2)	2 (1)	6 (72.7)	4 (16.4)	6 (10.9)	0 (7.3)	6 (6)	6 (2.96)	44	Good
33	6 (9)	6 (4)	0 (1)	2 (1)	6 (89.7)	0 (3.4)	6 (4.6)	4 (2.3)	6 (6)	6 (2.46)	42	Good
34	6 (9)	6 (4)	0 (1)	2 (1)	6 (71.4)	0 (3.6)	2 (25)	0 (7.1)	4 (5)	6 (3.62)	32	Fair
35	6 (11)	6 (5)	0 (1)	2 (1)	6 (63.2)	4 (29.6)	6 (3.9)	4 (3.3)	6 (6)	6 (2.93)	46	Good
37	2 (6)	2 (2)	2 (2)	2 (1)	6 (59.1)	2 (9.1)	0 (31.8)	0 (27.3)	4 (4)	6 (3.61)	26	Fair
38	4 (8)	4 (3)	4 (1)	0 (0)	6 (73.2)	2 (5.4)	6 (10.7)	6 (.9)	4 (4)	6 (2.79)	42	Good
39	4 (7)	4 (3)	0 (1)	2 (1)	4 (20.6)	6 (76.9)	6 (2.3)	6 (.8)	4 (4)	6 (3.75)	42	Good
40	4 (7)	2 (2)	2 (2)	2 (1)	6 (69.2)	4 (21.5)	6 (6.2)	0 (6.2)	4 (4)	6 (3.20)	36	Good
41	0 (1)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	0 (100)	0 (100)	0 (0)	2 (6.00)	4	Poor
43	6 (13)	4 (3)	2 (2)	2 (1)	6 (52.9)	6 (37.9)	6 (5.0)	6 (1.4)	6 (6)	6 (3.40)	50	Exceptional
44	4 (8)	4 (3)	4 (2)	2 (1)	6 (73.7)	6 (16.4)	6 (3.9)	6 (3.3)	4 (5)	6 (3.02)	48	Exceptional
45	2 (5)	4 (3)	0 (1)	2 (1)	6 (81.8)	2 (9.1)	6 (9.1)	0 (9.1)	4 (4)	6 (3.44)	32	Fair

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Table 3.6. Total Invertebrate Community Index (ICI) scores and integrity classes. (OEPA 1987).

Total ICI score	ICI integrity classification for artificial substrates
	Exceptional
	Good
	Fair
	Poor
0	Very Poor

Table 3.7. Summary of the 1994 invertebrate community evaluation for the Tippecanoe River and it's tributaries.

	1	2	4	5	6	7	8	9	10	11
Tributary/Point Source	Kuhn Ditch	Kuhn Ditch	Waste Mngmt.	Waste Mngmt.	Walnut Creek	Walnut Creek	Walnut Creek	Marsh Ditch	Trimble Creek	Trimble Creek
Upstream/Downstream Location	up	down	up	down	up	in	down	down	in**	in***
Total number of individuals	43	74	48	41	117	22	51	113	22	24
Total number of taxa	8	8	9	8	9	5	8	8	2	7
Invertebrate density (individuals/m^2)	581	999	648	554	1580	297	689	1526	297	324
Total ICI score	41	13	24	44	32	24	31	48	21	7
ICI integrity classification	Good	Poor	Fair	Good	Fair	Fair	Fair	Exceptional	Fair	Poor
Family Biotic Index	4.19	5.47	4.32	3.73	5.00	4.60	5.38	3.51	4	5.67
Shannon-Weiner Diversity Index (H)										
taxa composition	1.96	2.08	2.95	2.44	1.78	1.89	1.95	2.25	0.9	2.3
trophic composition	1.47	1.26	1.37	1.69	1.22	0.99	1.11	1.53	0	1.53
Equitability	0.65	0.69	0.93	0.81	0.56	0.81	0.65	0.75	0.90	0.82
Community Similarity Index (CSI)*	0.50		0.59		0.59				0	

	12	14	15	16	17	18	19	21	22	23
Tributary/Point Source	Trimble Creek	Trimble Creek	Baker Ditch	Baker Ditch	Yellow Creek	Yellow Creek	Chippewanuk Creek	Blair Ditch	Blair Ditch	Mill Creek
Upstream/Downstream Location	up	down	up	down	up	down	in	up	down	in
Total number of individuals	133	6	20	52	8	75	101	22	71	44
Total number of taxa	7	1	8	8	4	8	10	9	7	7
Invertebrate density (individuals/m^2)	1796	81	270	702	108	1013	1364	297	959	594
Total ICI score	42	9	29	40	9	38	52	41	38	33
ICI integrity classification	Good	Poor	Fair	Good	Poor	Good	Exceptional	Good	Good	Fair
Family Biotic Index	2.98	NA	5.11	3.56	5.43	3.27	3.62	3.82	2.8	5.18
Shannon-Weiner Diversity Index (H)										
taxa composition	1.88	0.00	2.36	2.64	1.75	2.51	2.53	2.95	1.79	2.02
trophic composition	1.68	0.00	1.12	1.67	1.38	1.58	1.29	1.49	1.23	1.15
Equitability	0.67	0.00	0.79	0.88	0.88	0.84	0.76	0.93	0.64	0.72
Community Similarity Index (CSI)*	0.00		0.50		0.33			0.63		67****

NA - Not applicable

* Comparisons between upstream and downstream sites only listed here. See matrix for other comparisons.

** In Trimble Creek, upstream of Palestine Lake.

*** In Trimble Creek, downstream of Palestine Lake.

**** No upstream site. Comparison between tributary and downstream of tributary.

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Table 3.7. (cont'd)

	24	25	26	28	30	31	32	33	34	35
Tributary/Point Source	Mill Creek	Wilson Ditch	Wilson Ditch	Tipp. River S.P.	Mill Creek	Indian Creek	Liberty Landfill	Liberty Landfill	Honey Creek	Honey Creek
Upstream/Downstream Location	down	up	down	down	in	in	up	down	up	down
Total number of individuals	83	76	20	56	30	68	55	87	28	152
Total number of taxa	3	11	6	9	6	9	8	9	9	11
Invertebrate density (individuals/m^2)	1121	1026	270	756	405	918	743	1175	378	2053
Total ICI score	44	36	21	34	42	40	44	42	32	46
ICI integrity classification	Good	Good	Fair	Good	Good	Good	Good	Good	Fair	Good
Family Biotic Index	2.60	3.09	4.12	3.29	3.30	3.37	2.96	2.46	3.62	2.93
Shannon-Weiner Diversity Index (H)										
taxa composition	2.08	2.87	2.10	2.33	2.14	2.19	2.19	2.11	2.43	2.46
trophic composition	1.72	1.81	0.64	1.47	1.71	1.78	1.48	1.12	1.58	1.27
Equitability										
Community Similarity Index (CSI)*		0.35					0.71		0.4	

	37	38	39	40	41	43	44	45
Tributary/Point Source	Big Creek	Big Creek	Big Creek	Spring Creek	Spring Creek	Moots Creek	Moots Creek	Moots Creek
Upstream/Downstream Location	up	in	down	up	in	up	in	down
Total number of individuals	44	112	260	65	3	146	152	11
Total number of taxa	6	8	7	7	1	13	8	5
Invertebrate density (individuals/m^2)	594	1513	3512	878	41	1972	2053	149
Total ICI score	26	42	42	36	4	50	48	32
ICI integrity classification	Fair	Good	Good	Good	Poor	Exceptional	Exceptional	Fair
Family Biotic Index	3.61	2.79	3.75	3.20	6.00	3.40	3.02	3.44
Shannon-Weiner Diversity Index (H)								
taxa composition	2.10	2.11	1.21	2.16	0.00	2.59	2.26	2.12
trophic composition	1.21	1.49	1.02	1.59	0.00	1.66	1.49	1.32
Equitability								
Community Similarity Index (CSI)*	0.77			0.25		0.44		

* Comparisons between upstream and downstream sites only listed here. See matrix for other comparisons

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3.1.2.3 Diversity Index

A diversity index (the Shannon and Wiener function) was calculated for each sampling location for both taxa and trophic guild diversity using the equation (Krebs 1978):

$$H = -\sum_{I=1}^{s} (p_i)(\log_2 p_i)$$

where: s = number of species
p_i = proportion of total sample belonging to the ith species

An equitability calculation was also made for each sampling site based on taxa composition. Equatability is the ratio of the calculated species diversity at a site to the species diversity under conditions of maximal equitability (if all species were equally represented in abundance).

3.1.2.4 Functional Feeding Groups

Functional feeding groups were assigned to each taxon identified (Appendix I). Group determinations were based on feeding habits described in Pennak (1989), Plafkin (1989), Merritt and Cummins (1996a), and Merrit and Cummins (1996b). Functional feeding group metrics were calculated and evaluated for each sampling location (Table 3.8). The adult form of the horsehair worm (Phylum Nematomorpha) does not feed (Pennak 1989) and was the only life stage encountered in this study; therefore, Nematomorphs were not included in the functional feeding group analysis.

Results from the various analyses are presented in a summary table (Table 3.7).

3.3 Water Quality Monitoring

Water quality data, along with stream characteristics such as average depth, width, and estimated flow, was collected during sampler deployment. Water quality information was obtained using a HYDROLAB H_2O Multi-parameter Water Quality Data Transmitter. Parameters measured in the field include temperature, pH, dissolved oxygen (D.O.), specific conductance, and redox. All measurements were recorded in the field on data collection sheets. See Appendix V for a summary of water quality data collected.

3.2 Qualitative Habitat Evaluation

Limited habitat observations were made and recorded on a habitat assessment field data sheet. See Appendix VI for copies of the raw data. See Chapter 2 for habitat evaluations based on the Qualitative Habitat Evaluation Index.

Table 3.8. Evaluation of the invertebrate trophic structure in the Tippecanoe River watershed, Indiana

	Station											
	1	2	4	5	6	7	8	9	10	11	12	14
Functional Feeding Group metric												
TOTAL NUMBER OF ORGANISMS*	43	74	38	41	117	11	51	113	7	24	133	0
NUMBER OF SHREDDERS	0	21	0	0	0	0	0	0	0	2	3	0
NUMBER OF COLLECTORS	37	46	23	29	109	11	41	96	7	10	97	0
FILTERING COLLECTORS	26	0	4	17	30	5	3	53	7	0	45	0
GATHERING COLLECTORS	11	46	19	12	79	6	38	43	0	10	52	0
NUMBER OF SCRAPERS	2	0	15	11	5	0	9	15	0	11	33	0
NUMBER OF PREDATORS	4	7	0	1	3	0	1	2	0	1	0	0
% SHREDDERS	0.0%	28.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%	2.3%	0.0%
% COLLECTORS	86.0%	62.2%	60.5%	70.7%	93.2%	100.0%	80.4%	85.0%	0.0%	41.7%	72.9%	0.0%
% FILTERING COLLECTORS	60.5%	0.0%	10.5%	41.5%	25.6%	45.5%	5.9%	46.9%	100.0%	0.0%	33.8%	0.0%
% GATHERING COLLECTORS	25.6%	62.2%	50.0%	29.3%	67.5%	54.5%	74.5%	38.1%	0.0%	41.7%	39.1%	0.0%
% SCRAPERS	4.7%	0.0%	39.5%	26.8%	4.3%	0.0%	17.6%	13.3%	0.0%	45.8%	24.8%	0.0%
% PREDATORS	9.3%	9.5%	0.0%	2.4%	2.6%	0.0%	2.0%	1.8%	0.0%	4.2%	0.0%	0.0%
SHREDDERS/COLLECTORS RATIO	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.03	ERR
SCRAPERS/COLLECTORS RATIO	0.05	0.00	0.65	0.38	0.05	0.00	0.22	0.16	0.00	1.10	0.34	ERR
FILTERING/GATHERING COLLECTORS RATIO	2.36	0.00	0.21	1.42	0.38	0.83	0.08	1.23	ERR	0.00	0.87	ERR
SCRAPERS/FILTERING COLLECTOR RATIO.	0.08	ERR	3.75	0.65	0.17	0.00	3.00	0.28	0.00	ERR	0.73	ERR

* Total number does not include the Nematomorpha taxon
ERR indicates the metric is undefined.

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Table 3.8. (Cont.)

	15	16	17	18	19	21	22	23	24	25	26	28	30	31
TOTAL NUMBER OF ORGANISMS*	20	52	7	75	101	22	71	44	83	76	17	56	30	67
NUMBER OF SHREDDERS	1	0	0	4	0	0	0	1	4	4	1	4	3	18
NUMBER OF COLLECTORS	17	36	4	59	95	18	47	38	52	41	15	29	13	31
FILTERING COLLECTORS	1	8	0	16	38	8	3	5	12	7	0	0	3	2
GATHERING COLLECTORS	16	28	4	43	57	10	44	33	40	34	15	29	10	29
NUMBER OF SCRAPERS	1	12	1	12	4	4	23	5	26	27	1	21	14	17
NUMBER OF PREDATORS	1	4	2	0	2	0	1	0	1	4	0	2	0	1
% SHREDDERS	5.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%	2.3%	4.8%	5.3%	5.9%	7.1%	10.0%	26.9%
% COLLECTORS	85.0%	69.2%	57.1%	78.7%	94.1%	81.8%	66.2%	86.4%	62.7%	53.9%	88.2%	51.8%	43.3%	46.3%
% FILTERING COLLECTORS	5.0%	15.4%	0.0%	21.3%	37.6%	36.4%	4.2%	11.4%	14.5%	9.2%	0.0%	0.0%	10.0%	3.0%
% GATHERING COLLECTORS	80.0%	53.8%	57.1%	57.3%	56.4%	45.5%	62.0%	75.0%	48.2%	44.7%	88.2%	51.8%	33.3%	43.3%
% SCRAPERS	5.0%	23.1%	14.3%	16.0%	4.0%	18.2%	32.4%	11.4%	31.3%	35.5%	5.9%	37.5%	46.7%	25.4%
% PREDATORS	5.0%	7.7%	28.6%	0.0%	2.0%	0.0%	1.4%	0.0%	1.2%	5.3%	0.0%	3.6%	0.0%	1.5%
SHREDDERS/COLLECTORS RATIO	0.06	0.00	0.00	0.07	0.00	0.00	0.00	0.03	0.08	0.10	0.07	0.14	0.23	0.58
SCRAPERS/COLLECTORS RATIO	0.06	0.33	0.25	0.20	0.04	0.22	0.49	0.13	0.50	0.66	0.07	0.72	1.08	0.55
FILTERING/GATHERING COLLECTORS RATIO	0.06	0.29	0.00	0.37	0.67	0.80	0.07	0.15	0.30	0.21	0.00	0.00	0.30	0.07
SCRAPERS/FILTERING COLLECTOR RATIO	1.00	1.50	ERR	0.75	0.11	0.50	7.67	1.00	2.17	3.86	ERR	ERR	4.67	8.50

* Total number does not include the Nematomorpha taxon
ERR indicates the metric is undefined.

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Table 3.8. (Cont.)

	32	33	34	35	37	38	39	40	41	43	44	45
TOTAL NUMBER OF ORGANISMS*	55	87	27	152	44	112	260	65	3	146	152	11
NUMBER OF SHREDDERS	2	2	1	0	0	10	0	0	0	0	1	0
NUMBER OF COLLECTORS	43	70	18	140	33	73	242	46	3	114	104	7
FILTERING COLLECTORS	9	3	1	45	4	6	200	14	0	54	25	1
GATHERING COLLECTORS	34	67	17	95	29	67	42	32	3	63	79	6
NUMBER OF SCRAPERS	10	13	5	11	11	29	16	18	0	23	47	4
NUMBER OF PREDATORS	0	2	3	1	0	0	2	1	0	6	0	0
% SHREDDERS	3.6%	2.3%	3.7%	0.0%	0.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%
% COLLECTORS	78.2%	80.5%	66.7%	92.1%	75.0%	65.2%	93.1%	70.8%	100.0%	78.1%	68.4%	63.6%
% FILTERING COLLECTORS	16.4%	3.4%	3.7%	29.6%	9.1%	5.4%	76.9%	21.5%	0.0%	37.0%	16.4%	9.1%
% GATHERING COLLECTORS	61.8%	77.0%	63.0%	62.5%	65.9%	59.8%	16.2%	49.2%	100.0%	43.2%	52.0%	54.5%
% SCRAPERS	18.2%	14.9%	18.5%	7.2%	25.0%	25.9%	6.2%	27.7%	0.0%	15.8%	30.9%	36.4%
% PREDATORS	0.0%	2.3%	11.1%	0.7%	0.0%	0.0%	0.8%	1.5%	0.0%	4.1%	0.0%	0.0%
SHREDDERS/COLLECTORS RATIO	0.05	0.03	0.06	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.01	0.00
SCRAPERS/COLLECTORS RATIO	0.23	0.19	0.28	0.08	0.33	0.40	0.07	0.39	0.00	0.20	0.45	0.57
FILTERING/GATHERING COLLECTORS RATIO	0.26	0.04	0.06	0.47	0.14	0.09	4.76	0.44	0.00	0.86	0.32	0.17
SCRAPERS/FILTERING COLLECTOR RATIO	1.11	4.33	5.00	0.24	2.75	4.83	0.08	1.29	ERR	0.43	1.88	4.00

* Total number does not include the Nematomorpha taxon

ERR indicates the metric is undefined.

3.4 Results and Discussion

3.4.1 General Overview

According to the assessment results, the invertebrate community in the Tippecanoe River and its tributaries appears to be in overall good condition. A total of 2,535 invertebrates belonging to 12 different Orders and representing 36 Families was collected from the 38 sampling stations along the Tippecanoe River and its tributaries (Table 3.2).

Invertebrates were abundant at all sites (>100 organisms/m^2) with the exception of sites 14 (downstream of Trimble Creek) and 41 (Spring Creek) which had densities of 81 and 41 organisms/m^2, respectively. The densities ranged from a low of 41 organisms/m^2 in Spring Creek (site 41) to 3512 organisms/m^2 (site 39) downstream of Big Creek Taxa richness was evaluated at the Family level and ranged from a single Family at sites 14 and 41 to 13 Families at site 43.

Most sites contained at least one or more of the sensitive EPT (Ephemeroptera, Plecoptera, and Trichoptera) (Figure 3.4) Orders. Although 36 of the 38 sites contained organisms from the Diptera Order (a more tolerant taxa), 34 of the 38 sites contained Ephemeroptera. Furthermore, 20 sites were dominated by Ephemeroptera, as compared to only 8 sites dominated by the Dipterans. In addition, Tricoptera were found at 31 sites (dominated 4 sites), followed by Coleoptera at 24 sites, Isopoda at 12, Gastropoda at 9 (dominated 1), Nematomorpha at 8 (dominated 3), Plecoptera at 7, Megaloptera at 7, Odonata at 5, and Annelida and Amphipoda both at 4. Three sites did not contain any of the EPT species. Those include: site 11, Trimble Creek; site 14, downstream of Trimble Creek; and site 41, Spring Creek. Species composition was also evaluated based on river segment. The upper river (sites 1-18) was dominated by Ephemeropterans (33%), followed by Trichopterans (25%) and Dipterans (22%). The middle river (sites 19-33) was also dominated by Ephemeropterans (62%) followed by Trichopterans (13%) and Dipterans (11%). Finally, the lower section (sites 34-45) was dominated by Ephemeropterans (54%) followed by Trichoptera (36%) and Dipterans (34%).

3.4.2 ICI Results

Table 3.5 summarizes the ICI metric evaluations and scoring for the sites assessed during this investigation. ICI scores ranged from 4 (site 41) to 52 (site 19) with an overall average of 34 and a median of 37. Both the average and the median would fall into the "good" integrity classification (Table 3.6). Four sites were classified as "exceptional", 18 as "good", 11 as "fair", and 5 as "poor". Of the 5 "poor" sites, 2 were downstream of a tributary with a known point source discharge and 2 were within the tributary itself. The fifth site, site 17, was upstream of Yellow Creek. All but 1 of the "poor" sites was in the upper river. Average ICI scores of 28, 39, and 36 were calculated for sites grouped as upper, middle, and lower river sites, respectively. The corresponding integrity classifications for those averages are "fair", "good" and "good".

Of the 38 sites sampled, 31 were used for specific upstream and downstream of point sources comparisons. The other 7 sites (sites 9, 19, 23, 24, 28, 30 and 31), due to site selection problems, are not included in the point source evaluations, but were used in overall river health assessment.

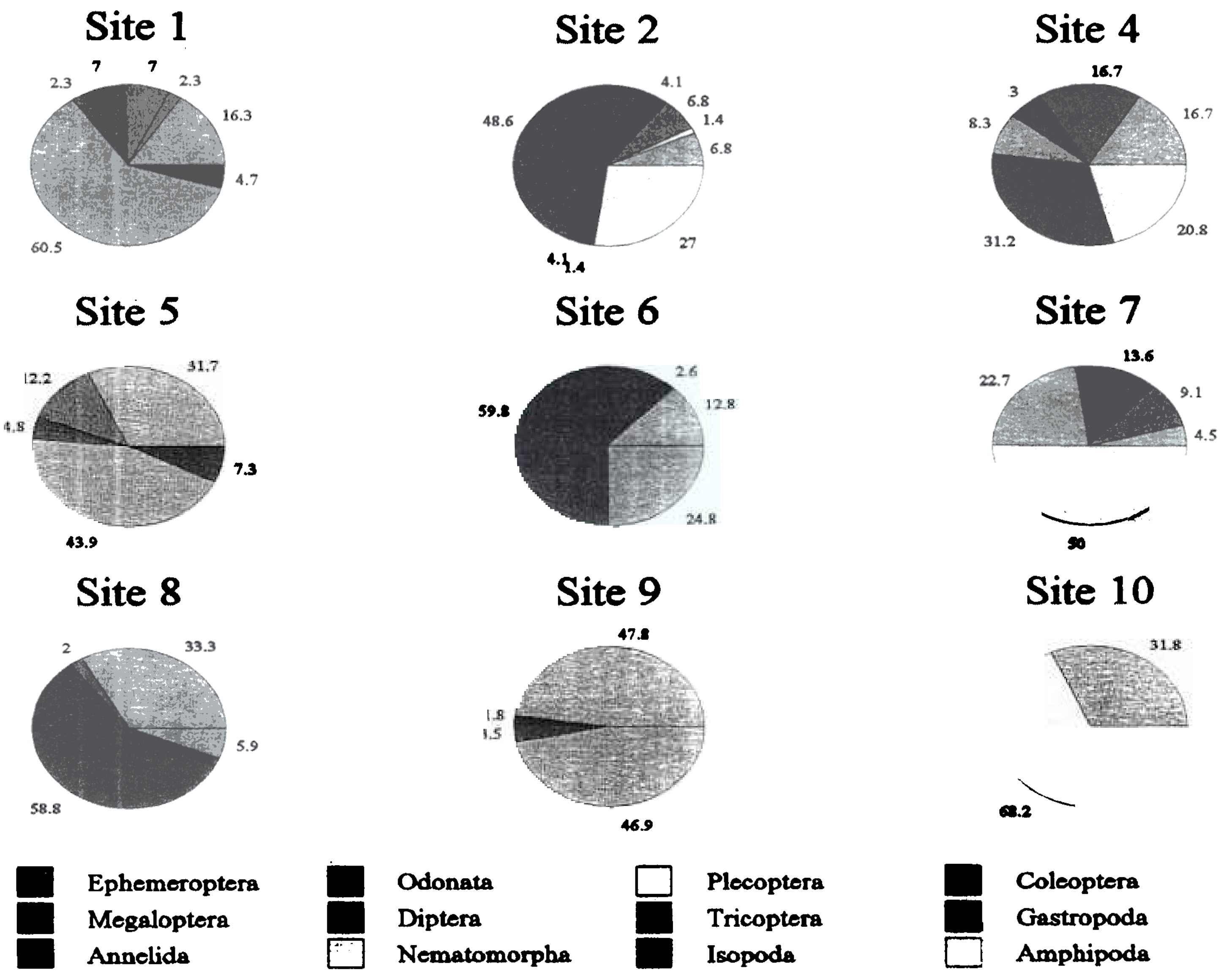

Figure 3.4. Percent composition of invertebrate Orders collected in the Tippecanoe River, 1994.

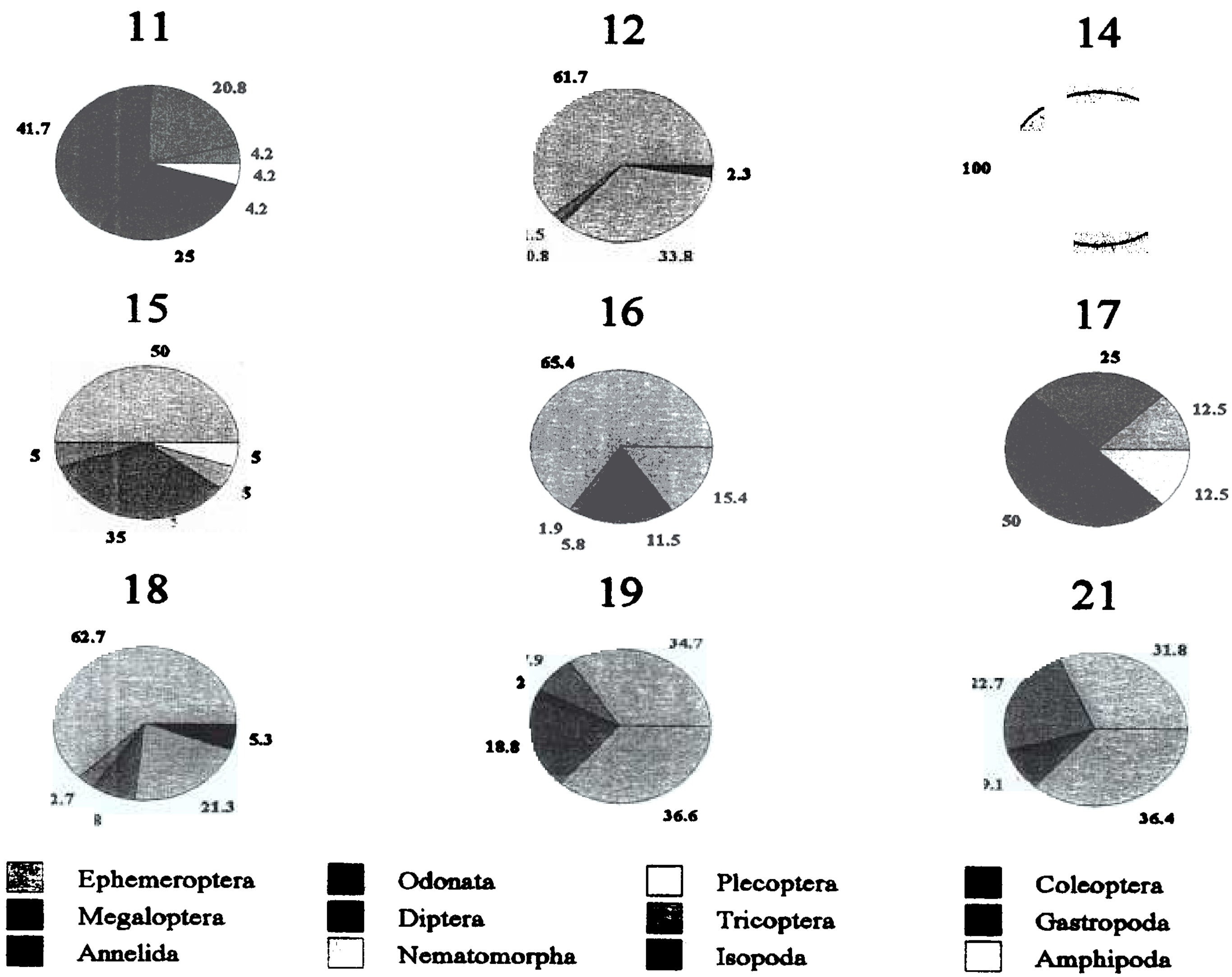

Figure 3.4. Continued.

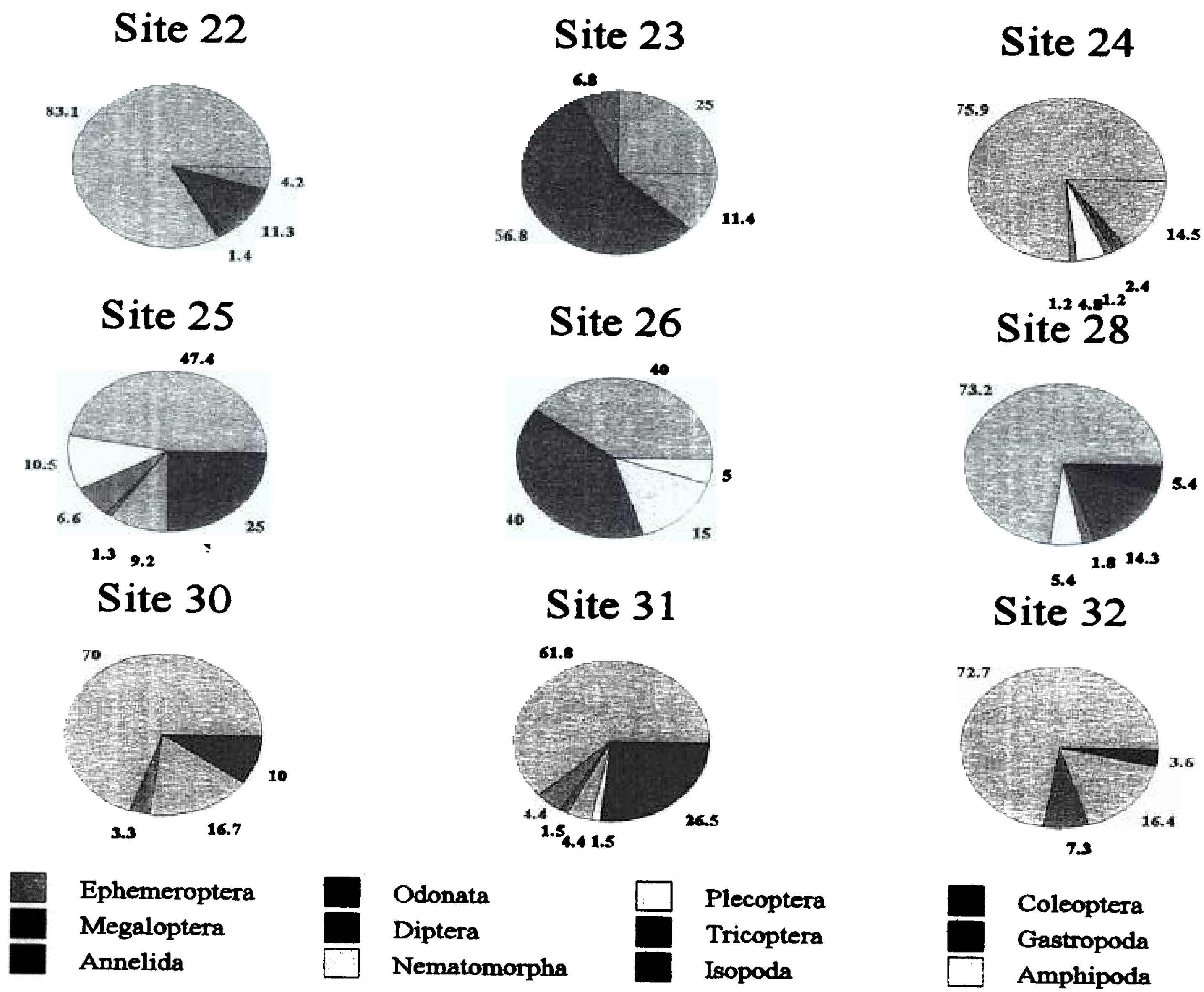

Figure 3.4. Continued.

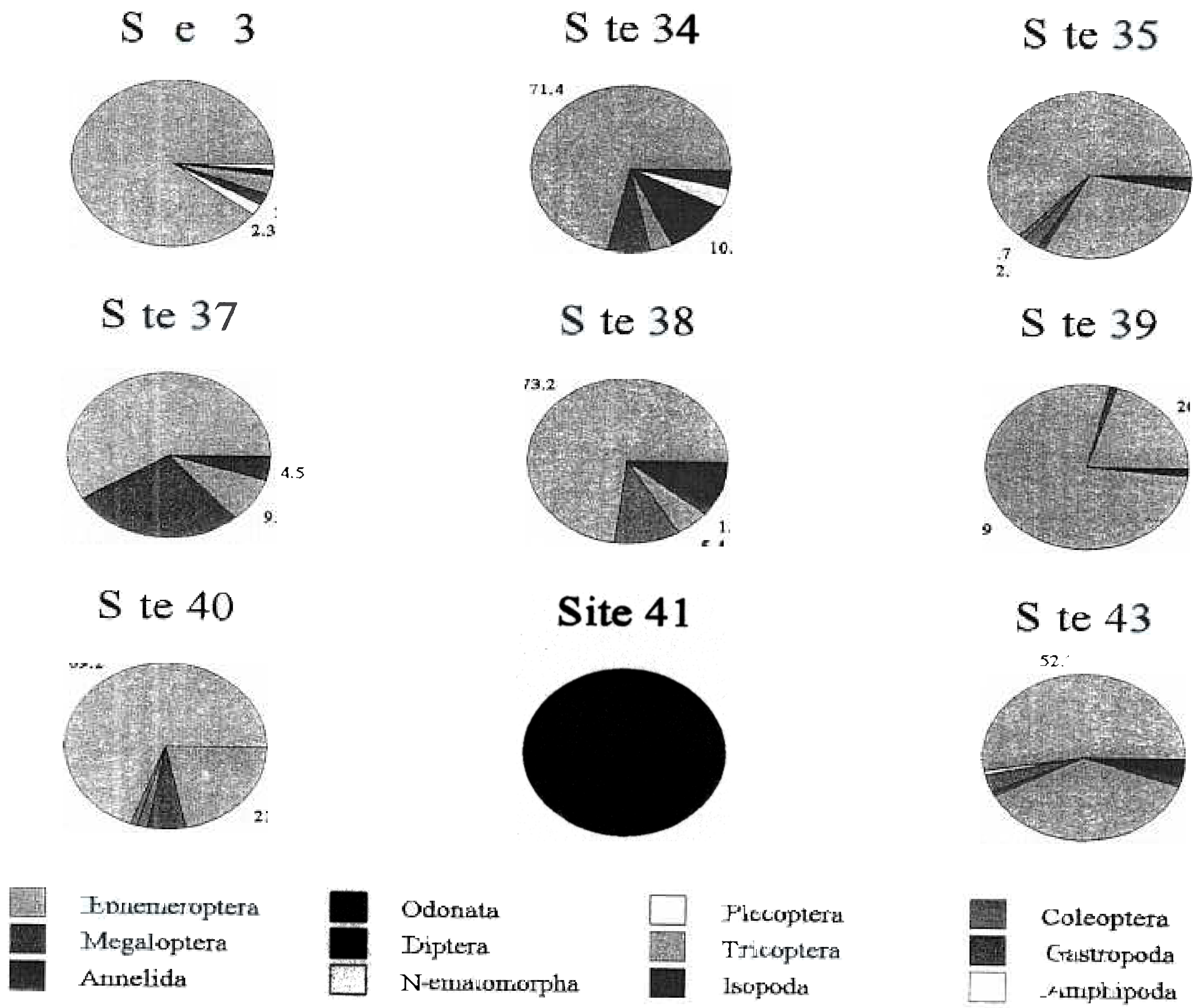

Figure 3. Continued.

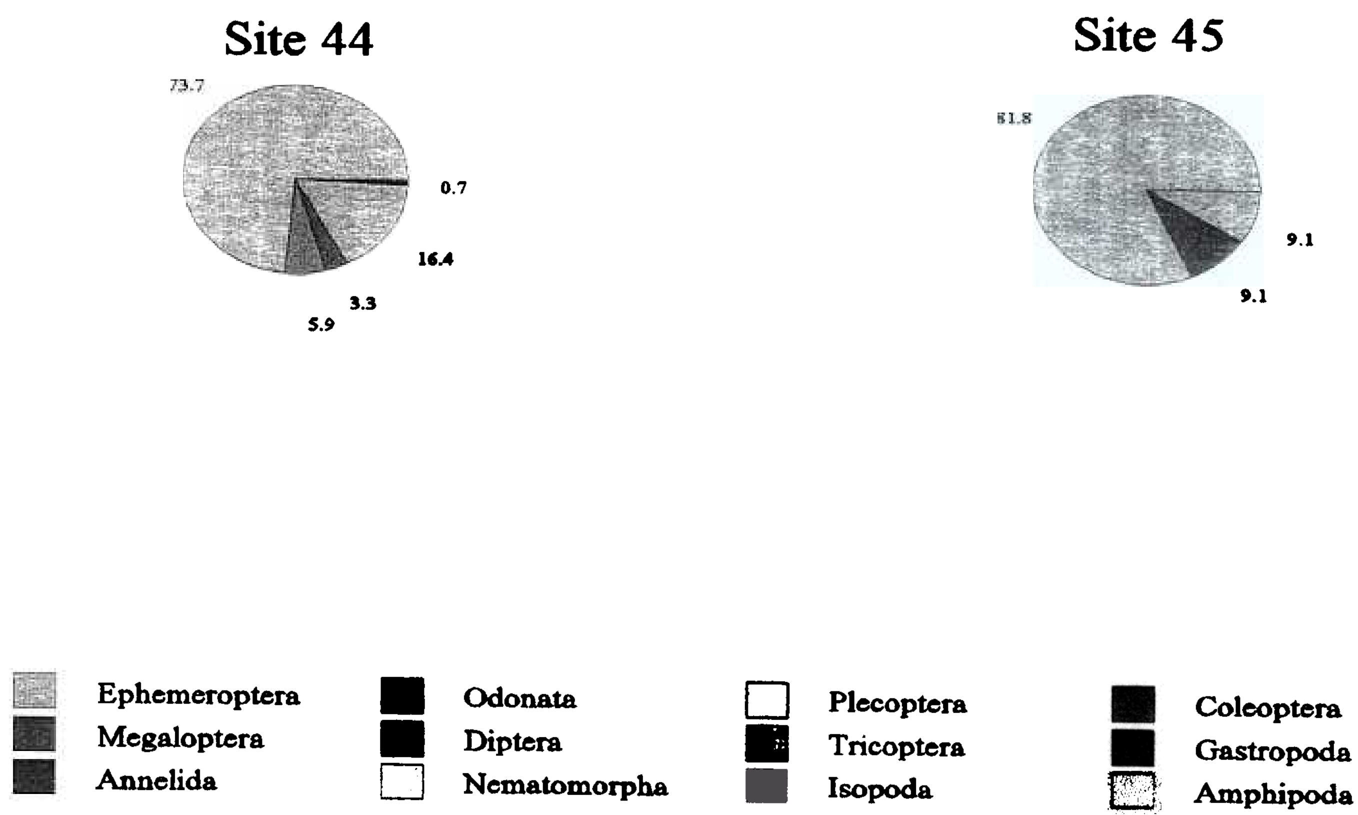

Figure 3.4. Continued.

Twelve different tributaries with point source discharges located on them and one point source on the mainstem were evaluated for their contribution to the decline in water quality of the mainstem Tippecanoe River. ICI scores were calculated for sites above, occasionally within, and below each tributary or point source. Of the 13 tributaries or point sources investigated, 8 had downstream ICI scores that were lower than the upstream site. Of those 8, 5 resulted in a lower ICI integrity classification (e.g. "good" to "poor"). In 5 instances, ICI values were calculated within the tributaries themselves, below the suspect discharges. In those cases, 4 of the 5 showed a decreased score within the tributary itself when compared to the upstream main stem site (i.e. Walnut Creek, Spring Creek, Trimble Creek and Moots Creek). Walnut Creek scored a 24 while the upstream mainstem site scored a 32. Spring Creek scored a 4 compared to the upstream river site which scored 36. Trimble Creek itself was assessed in two locations, upstream and downstream of Palestine Lake. These 2 tributary ICI scores were significantly different from the upstream Tippecanoe River site with the upstream river site scoring a 42 and the tributary scoring a 19 above Palestine Lake and a 7 below. Above Moots Creek scored a 50, while within Moots Creek the score was 48.

As previously discussed in the Methods Section, the FBI was calculated to use as a substitute for the Percent Tanytarsini Midge Composition Metric in the ICI evaluation. However, it is also valuable as a stand-alone metric. It is used as a rapid field assessment of organic pollution, although it can provide a good overall indication of the ambient water quality conditions (Sobiech 1996). FBIs are generally reflective of the presence of pollution-tolerant taxa. The FBI scale ranges from 0.00 to10.00, with the former indicating organic pollution unlikely and the latter indicating severe organic pollution likely. FBI values ranged from 2.46 (site 33) to 6.00 (site 41) and are listed in Table 3.7. The overall average was 3.84, which would indicate "very good" water quality traits (Table 2.6). One site was classified as "fairly poor" water quality (site 41) and 6 were classified as "fair". The remaining sites ranged from good to excellent. The average FBI for the upper river was slightly worse (4.11) than the middle and lower river (3.38 and 3.58, respectively). The FBI scores generally followed along the same trend as the ICI scores (Figure 3.4); however, the associated FBI water quality classifications (i.e. good, fair, poor) tended to indicate a lessor degree of pollution than the ICI integrity classifications.

3.4.3 CSI Results

In order to compare the similarity of the communities, CSIs (OEPA 1989) were calculated upstream and downstream of point sources and are included in a summary table (Table 3.7). CSIs for comparisons of all sites are presented in a matrix format in Appendix IV. The CSIs ranged from 0 to .77 (on a scale of 0 to 1). Interestingly, only 4 of the 14 comparisons showed a similarity greater than 60%. This low level of similarity is most likely due to varying water quality influences, but may also include differences in habitat, stream size, and availability of colonizing invertebrates. Trimble Creek upstream and downstream of Palestine Lake scored a CSI of 0, as did sites 12 and 14, which were upstream and downstream respectively, of the Trimble Creek confluence. Sites 40 and 41 were also very different (CSI = .25). Although these two sites vary significantly in watershed size (41 is in Spring Creek), only 3 individuals of 1 taxa (Diptera) were found at site 41. Based on CSI values, sites upstream and downstream of Spring Creek, Trimble Creek, and Wilson Ditch, as well as within Trimble Creek above and below Palestine Lake, have the largest community structure discrepancies.

3.4.4 Diversity Indices for Taxa Composition

Diversity indices for taxa composition were calculated using the Shannon-Weiner function. Indices ranged from 0.0 - 2.95. The mean diversity index for all sites was 2.06 and the median was 2.13. Wilm and Dorris (1968) concluded that diversity indices <1 were generally indicative of heavily polluted areas. Three sites had indices <1: site 41, in Spring Creek; site 10, in Trimble Creek (upstream of Palestine Lake); and site 14 (Tippecanoe River downstream of Trimble Creek). Low diversity may be indicative of water quality problems at the above-mentioned sites.

3.4.5 Functional Feeding Groups

Functional feeding group evaluations are presented in Table 3.8. Assignment to a functional feeding group is based on the association between feeding adaptations and nutritional resource categories (Merrit and Cummins 1996b). There are 4 basic functional groups: shredders; collectors (filtering and gathering); scrapers; and predators (Merrit and Cummins 1996a). Each Family was assigned a functional feeding group based on various references (Appendix II). Percentages and ratios were calculated for each of the groups (Table 3.8). Seventy-five percent of all invertebrates obtained from the samplers were collectors. Within the collector group, 35% were filtering collectors and 65% were gathering collectors. Collectors were the dominant functional feeding group at 35 sites. Scrapers were the dominant functional feeding group at 2 sites (11 and 30) and accounted for 18% of all invertebrates. Approximately 3% of the analyzed invertebrates were shredders and 2% predators. (Site 14 had no functional feeding groups assigned in it because it contained only horsehair worms, which were not included in the functional feeding group analysis). Due to a lack of qualitative sampling, shredders, which are more likely to be found with coarse particulate organic matter (CPOM) such as leaf litter, may have been underestimated in this study.

Functional feeding group ratios are often used as indicators of stream ecosystem attributes (Merrit and Cummins 1996b). These attributes indicate whether fine particulate organic matter (FPOM) is in transport or storage. If the ratio of filtering collectors to gathering collectors is >.50, then the site is considered to have a greater than normal particulate load in suspension. Nine sites (1,5,7, 9,12,19,21,39 and 43) had a ratio >.50. This could be indicative of an increase in suspended particulate matter and could be the result of organic enrichment (Plafkin 1989) or sedimentation and siltation. Only 3 of those 9 sites were downstream of a tributary or in the tributary.

Decreases in filtering collectors is often attributed to the presence of water-borne toxicants that absorb to the FPOM (Plafkin 1989). Several sites showed a substantial drop in filtering collectors below the tributaries or point-sources: 2, 8, 11, 14, 22, 41, and 45. This could be the result of an influx of toxicants from point-sources along the Tippecanoe River or its tributaries. In addition, it may reveal a shift from sediment in transport to sediment in storage (on the bottom of the channel) (Merrit and Cummins 1996b). Decreases in the shredder community could be a result of toxicants bound to the CPOM. CPOM is more likely to accumulate toxicants of a terrestrial source, such as pesticides (Plafkin 1989). Only 3 sites indicated a decrease in the shredder community from upstream to downstream: 16, 33, and 35. These differences were very subtle.

3.4.6 Diversity Indices for Functional Feeding Group Composition

Finally, diversity indices were calculated at each site based on functional feeding group composition in order to look for shifts in food-type prevalence. The indices ranged from 0.0 (sites 10, 12, and 41) to 1.81 (site 25). Five sites were below 1 indicating low diversity and possible water quality problems. The average diversity index for all sites was 1.29. Several upstream and downstream sites showed dramatic changes between them. Site 12, upstream of Trimble Creek, had an index of 1.68, while site 14, downstream of Trimble Creek, was 0. Upstream of Wilson Ditch had an index of 1.84 and downstream was 0.64. Finally, upstream of Spring Creek had a diversity index of 1.59 and within Spring Creek was 0.

Figure 3.5 is a comparison of the ICI, FBI, and the 2 diversity indices for all sites.

3.5 Summary and Conclusions

In general, the health of the Tippecanoe River and several of it's tributaries appears to be good. However, some sections of the river seem to be negatively influenced by tributaries that serve as conduits for the discharge waters of various point-sources. This study was designed to determine if various NPDES and other permitted dischargers were affecting the water quality in the Tippecanoe River. This was accomplished via determining the biological integrity of the macroinvertebrate community in the river upstream and downstream of point-sources and/or tributaries with point-sources. Due to data limitations, the information generated from this study was used to develop a more qualitative picture, versus quantitative, of the invertebrate resources, and subsequently the water quality, in the Tippecanoe River watershed.

Biological impairment of the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate taxa such as Ephemeroptera, Plecoptera, and Trichoptera; excess dominance of pollution-tolerant taxa such as some Chironomids and Oligochaets; low taxa richness; shifts in community composition and functional feeding groups relative to reference sites; and low diversity, among others. The first 3 measures in addition to 7 others are incorporated into the ICI scoring method (OEPA 1989). This was the primary means for evaluating the macroinvertebrate data. Based on the ICI scoring, 5 sites received a "poor" integrity classification. Those sites were 2, 11, 14, 17, and 41.

Site 2 is below Kuhn Ditch in Kosciusko County. The North Webster Municipal Sewage Treatment Plant has a permitted discharge into Kuhn Ditch. Not only was the site low in pollution-sensitive species, it was also elevated in the tolerant Dipteran taxa. In addition, the upstream site supported a high percentage of filtering collectors and site 2 supported none. This may be indicative of water-borne pollutants binding fine, suspended particles and becoming available to the filtering collectors. The FBI was higher (worse) at site 2 than the upstream site and indicated fair water quality.

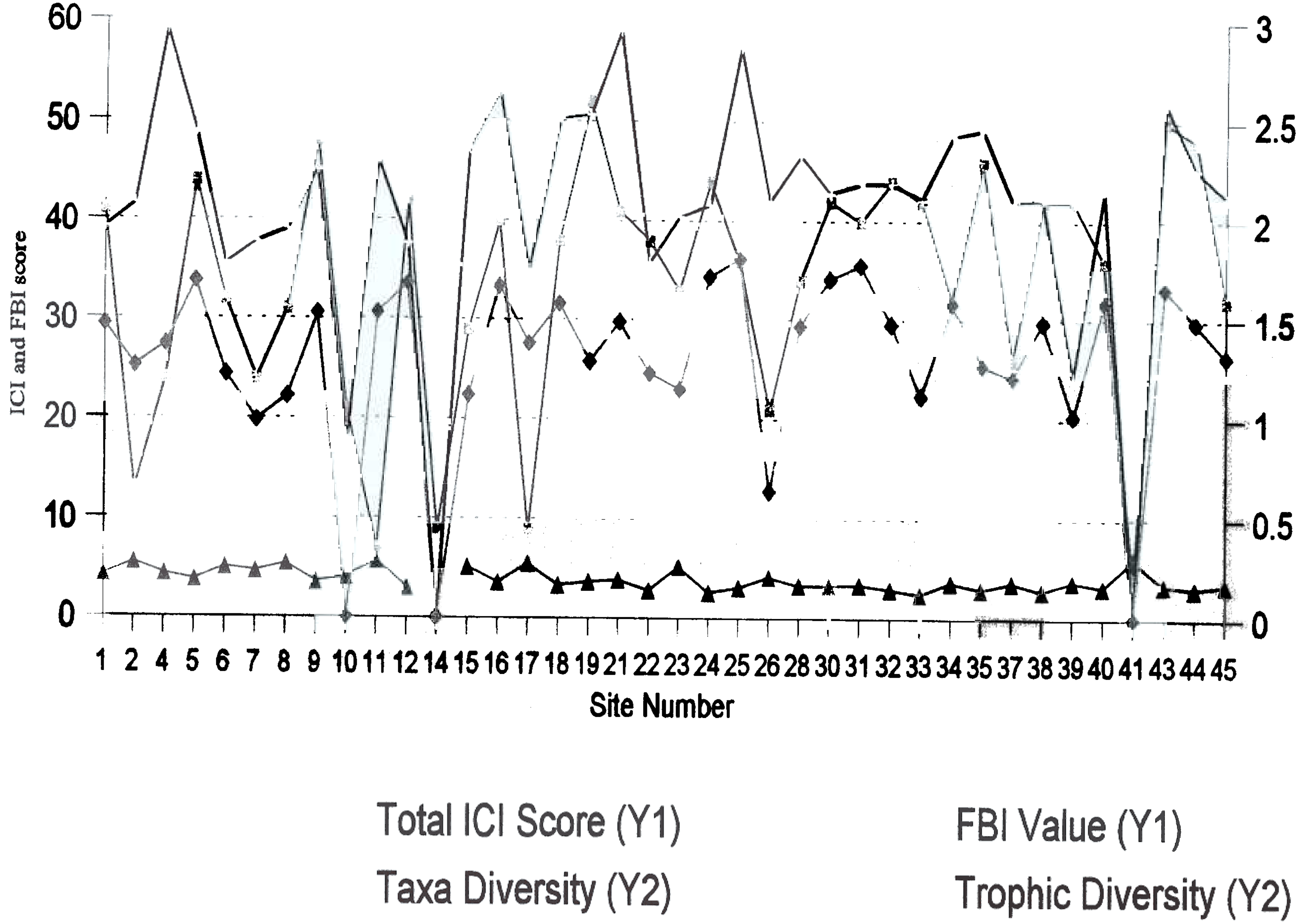

Figure 3.5. Comparison of the ICI, FBI, and 2 diversity indices for each site. Note: 2 Y-axes are used.

Site 11 is just downstream of Palestine Lake on Trimble Creek in Kosciusko County. The permitted dischargers upstream of the site include Warsaw Black Oxide and the former Lakeland Disposal Landfill. This site did not contain any of the sensitive EPT taxa and was dominated by Chironomids. Filtering collectors were also absent from this site. Trimble Creek and Palestine Lake have been the focus of numerous studies pertaining to metals contamination. Both Trimble Creek and Palestine Lake have been shown to have elevated concentrations of several metals, including zinc and cadmium in water and sediment samples (Adams 1980). Warsaw Black Oxide discharged effluent containing these metals into Williamson Ditch, which empties into Palestine Lake. The lakes only outlet stream is Trimble Creek.

Site 14 is downstream of Trimble Creek, as well as Ridenour Ditch, in Kosciusko County. One NPDES permitted facility, the Etna Green Sewage Treatment Plant (STP) is located along Ridenour Ditch. In addition, a privately owned duck farm is located upstream of the site along the Tippecanoe River. This site contained only 6 individual horsehair worms (Phylum Nematomorpha). Hence, diversity was 0 at this site. Horsehair worms do not feed as adults, and the larval forms are entirely parasitic (Pennak 1989); therefore, functional feeding information is not available. The lack of any other organisms at this site suggests that water quality has been greatly impacted. Low dissolved oxygen (4.2 mg/L) was recorded at this site during sampler deployment and could be the result of increased nutrient loading, possibly influenced by the duck farm upstream or the STP. In addition, contaminant loadings from Trimble Creek are probably contributing to the poor macroinvertebrate community at this site.

Site 17, just upstream of Yellow Creek in Marshall County, was the only site that was classified as "poor", according to the ICI score, that was not downstream of a known permitted discharge. Only 8 individuals were collected at this site, and only 1 was from the more sensitive Ephemeroptera Order. This site also lacked any filtering collectors and was dominated by gathering collectors and predators. Non-point source pollution may be affecting this area of the river.

Site 41 is located in the lower river watershed on Spring Creek in White County. At some point during the 6 week deployment period, the artificial samplers were buried in sandy sediment. This may account, at least in part, for the low numbers of organisms collected (however, 2 other sites (4 and 32) experienced similar circumstances without significant affects). Therefore, the "poor" rating for this site can not be used as a true indicator of water quality. The few organisms that were collected indicate that the sediment was at least of sufficient quality to support pollution-tolerant Chironomids. The buried samplers may signify other non-point source problems in the stream such as increased sediment loading.

Other sites that were possibly problematic based on other analytical tools, such as FBI, diversity indices, and functional feeding groups include sites: 7, 10, 22, and 26. Site 7 is within Walnut Creek in Kosciusko County. Walnut Creek runs along the western edge of the City of Warsaw and receives discharges from several permitted facilities including the Warsaw Municipal STP, Dalton Foundries, and ABC industries. Although it scored a 24 for the ICI, it was dominated by horsehair worms and had a trophic diversity of <1 (.99). Overall water quality at this site has probably been impacted by a variety of urban sources.

Site 10 is in the upper reaches of Trimble Creek, above Palestine Lake. The ICI score for this site was 21 (fair); however, the Family diversity was <1 (.90) and the trophic diversity was 0. This site contained only 7 organisms from a fairly tolerant caddisfly Family (Hydropsychidae), and 15 of the non-feeding horsehair worms. The caddisflies are filtering collectors and their sole presence at this site may be indicative of a disproportional amount of fine sediments in suspension and increased nutrients in the system. Filamentous algae (often seen in organically enriched areas) offers attachment sites for these organisms, and contributes to the FPOM (Plafkin 1989). The Claypool Municipal STP discharges into the upper reaches of Trimble Creek.

Site 22 (downstream of Bair Ditch in Fulton), was classified as "good" based on an ICI score; however, the diversity for taxa composition was substantially lower when compared to the upstream site. In addition, the number of filtering collectors decreased from 36.4% to 4.2%.

Site 26, downstream of Wilson Ditch, scored a 21 for ICI while the upstream site scored a 36. This site also had an increased (worse) FBI score and a significantly reduce trophic structure diversity. As with site 41, this site was covered in sediment at some point during the study. This may account for the decrease in the functional feeding group diversity. However, the more pollution-tolerant Chironomids also increased at this site. Wilson Ditch serves as the receiving waters for the Culver Municipal STP. In addition, a small outlet stream of King Lake enters into the Tippecanoe River upstream site 26. King Lake receives surface runoff from the former Four County Landfill and has been shown to have elevated levels of several contaminants (Steffeck 1988).

Although this study implicated several of the tributaries as potentially having adverse effects on the main stem Tippecanoe River's water quality, a clear connection to the various point sources in the watershed was not evident. In addition, due to the agricultural nature of the watershed and the increased urbanization, non-point source impacts were difficult to separate from potential point source problems. Although water chemistries (such as pH, D.O., specific conductance, etc.) appeared to be within the normal range for aquatic life uses, other problems such as sedimentation and siltation have been documented in the Tippecanoe River (ESI 1998). The overall dominance of gathering collectors in the watershed, and the problem with samplers becoming covered in sediment, indicates that the sediment load and movement in the system is becoming a significant problem. Sedimentation, siltation, and shifting, unstable stream bottoms have been documented as one of the major threats to freshwater mussels (Williams et. al.).

Further work recommended, based on these results, includes more focused sampling, specifically around outfalls suspected of adversely impacting the rivers water quality (in order to eliminate influences from non-point sources). In particular, additional sampling in Trimble Creek appears to be warranted. In addition, re-sampling of sites 4, 25, 26, 32, 40 and 41, should be conducted due to initial sedimentation problems. An additional site downstream of Spring Creek should also be added. If funds are available, future studies should consider collecting sediment and effluent samples near specific point sources, evaluating sediment load and transport, as well as performing QHEI sampling.

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