

# **An Assessment of Threats to the Biological Condition of the Wabash River Aquatic Ecosystem of Indiana**

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## **Preface**

A lot of things have changed since European settlers moved to the Northwest Territory and began to farm and build towns and cities. The landscape would be unrecognizable to anyone brought forward in time from that period. Not only have the magnificent forests and prairies been reduced to a mere glimmers of glories past, but the land itself has been reshaped and streams have been “straightened” to allow for rapid drainage of the agricultural lands. In addition to the “engineered” streams so common throughout the Midwest, the condition of the yet natural streams has suffered from a variety of threats. In some places they have been dammed and in most places they receive more than their share of nutrients, sediments, and organic chemicals to the point that “handling the load” has become almost impossible.

The Wabash River has been around since the end of the last glacial period. It has changed and suffered as the land was transformed and used. Improvements have been made, particularly during the 1970s and 1980s, to clean up discharges from point sources. However, much remains to be done. Having a “healthy” Wabash River is in best interest of everyone who uses it for commerce, for recreational activities, and as a water source. It is never prudent to waste money, and this is particularly true during periods of economic distress. Money spent to improve the health of the Wabash River Watershed should be expended where the return is maximal and the outlay minimal. That’s not always easy to do. However, to do it, you have to have good information so you can make wise decisions.

The purpose of the work presented in this public report and a second technical report is to condense all the pertinent, historical information on the Wabash River and its biology so that good decisions can be made about spending money to improve this magnificent body of free-flowing water. This report was prepared by the Midwest Biodiversity Institute, Inc. for The Nature Conservancy - Indiana Chapter. Primary funding for this project was received from Alcoa Corporation.

## **Acknowledgements**

First, we are indebted to the Indiana Chapter of The Nature Conservancy for securing funds from Alcoa Corporation to make this report possible. Second, we are beholden to a wide array of state and federal agencies, non-profit organizations, and individuals for providing the data we required to do this project. These include, but are not limited to, the Indiana Department of Natural Resources - Fisheries, the Indiana Department of Environmental Management, the Indiana Department of Natural Resources - Nature Preserves and Heritage Program, the Ohio Environmental Protection Agency, the Midwest Biodiversity Institute, the Ohio River Valley Water Sanitation Commission, the U.S. Geological Survey, the U.S. Fish & Wildlife Service, Dr. James Gammon, and Dr. Mark Pyron. We are also appreciative of the organizational efforts and hosting by six communities along the Wabash River that accommodated our public meetings.

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# **An Assessment of Threats to the Biological Condition of the Wabash River and lower White River Aquatic Ecosystems of Indiana**

## **Executive Summary**

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Large River ecosystems are among the most threatened aquatic ecosystems in the world because of dams, pollution, loss or disconnection with floodplain wetlands, introductions of exotic species, flow alterations, and other anthropogenic alterations to these waters (Dudgeon 1992; Dudgeon et al. 2006). In North America aquatic organisms (fish, mussels, crayfish, and caddisflies) are imperiled at a higher rate than terrestrial organisms and many of these are associated with large river ecosystems (Ricciardi and Rasmussen 1999; Williams et al. 1989, 1993). The Wabash River system of Indiana is unique among Midwest Rivers in being undammed on its mainstem for most of its length (greatest length of free-flowing river east of the Mississippi River). Although the Wabash River, like most Midwest rivers has been historically impaired from municipal, industrial and agricultural pollution, it has recovered from the worst municipal and industrial impacts (Gammon 1998). Gammon has studied this river since the 1960s and documented the biological responses to changing stressors, including those listed above, over a 30 year period (Gammon 1971, 1973, 1976, 1980, and 1983). Many of these trends were summarized in his book, "The Wabash River Ecosystem" (Gammon, 1998). The Wabash River and lower White River still contains a relative large proportion of its original fish fauna, although most are reduced in abundance compared to historical abundance and seven fish species have been extirpated (Gammon 1998, Crawford et al. 1996, Simon 2006.). Unionid mussel diversity has been reduced 55% in the Wabash River mainstem and 24% in the watershed including tributaries (Fisher 2006). Although there have been losses in biodiversity, the Wabash and White Rivers still have the foundations for substantial ecological rehabilitation. The White River system for example, the largest tributary to the Wabash, contains the last population of Lake Sturgeon in the Mississippi River basin (Drauch et al. 2008) and the mainstem Wabash River maintains a commercial fishery for shovelnose sturgeon

(Kennedy et al. 2007). Other sensitive species such as blue sucker and other sucker species maintain viable populations along large reaches of these rivers and do many darters, minnow, catfish, sunfish/bass and other important species groups. Although numerous mussel species have been extirpated or are rare, 30 species still maintain reproducing populations in the Wabash River (Fisher 2006). The contrast between the historical biological assemblages of the Wabash and White Rivers (Gammon 1998, Fisher 2006) and recent data on these assemblages (1999-2006) provides the foundation for quantifying the current stressors that are limiting biological assemblages. This provides a sound, scientific basis for considering what types of watershed rehabilitation might be feasible for this ecosystem.

Our goal in this study was to apply recent existing data on biological assemblages and threats (stressors) within and outside the mainstem Wabash and lower White Rivers with the ambitious goal of identifying actions that could be applied within the mainstem Wabash and White Rivers or in upstream watersheds to enhance the biodiversity and biological condition of these rivers. We compiled a large database of biological, stressor and threat data from the Wabash and White Rivers in Indiana to allow us to 1) identify segments of these rivers where biodiversity and biological condition is impaired, 2) to identify anthropogenic stressors and threats in these segments, and 3) to identify the likely sources of threats including whether they arose from within the main rivers or originated from watersheds confluent to these rivers. Our goal was not to re-do the pioneer work of Gammon and others who documented the Wabash River's response to a mix of industrial, municipal and agricultural stressors from the 1960s through the 1990s (Gammon 1998). Our approach was to use the most recent, complete data we could obtain and apply some novel analytical tools to understand and provide some guidance on reducing

stressors in these rivers. We used a watershed and river segment approach based on major confluences as an organizing framework for data compilation, analysis and assessment. We then used several multivariate tools to understand the influence of important stressors throughout the entire Wabash River watershed (Part I of Report), and a weight of evidence stressor identification approach within HUC-8 and HUC-11 watersheds (Part II).

Although the influence of watershed degradation has been implicated in phenomenon such as the Gulf of Mexico anoxia zone, less is known of the influence of upstream watersheds on the condition of large rivers. Biological studies are often local and data is typically examined without sufficient stressor data or in relation to only one or several well-known stressors. Similarly, restorative actions typically focus on a few stressors, and fail to include important watershed-scale stressors (e.g., flow, sediments) and are more strictly considered rehabilitation rather than restoration (Gore and Shields 1995). The compilation of large databases of biological (Rankin and Armitage 2005) and stressor data (e.g., Bryce and Hughes 2003) across multiple spatial and spatial scales can provide a comprehensive assessment of species patterns and their relationships with stressors and threats not possible at a small spatial or temporal scale.

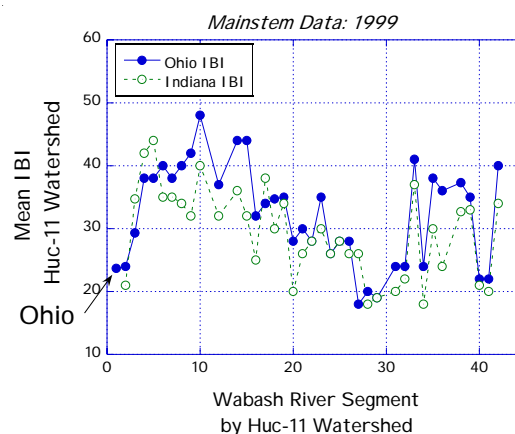
### Historical Background

We constructed a biological condition gradient (BCG) anchored in a hypothetical fish assemblage from pre-settlement conditions (ca 1800) to help visualize how far existing conditions are from “natural” conditions (Appendix 6). The purpose of this was not to set a pre-Columbian goal for the Wabash River, but rather to allow us to quantify how biological conditions might change along a stressor gradient from existing conditions to natural. With this gradient we can make quantitative, testable predictions of the outcome of various enhance scenarios. As links between stressor and biodiversity are improved, cost consequences, and time horizons for various enhancement actions can be scrutinized. The technical volume of this report summarizes the science underlying this approach.

## Results

The patterns of fish assemblage condition and identification of specific threats or stressors in the

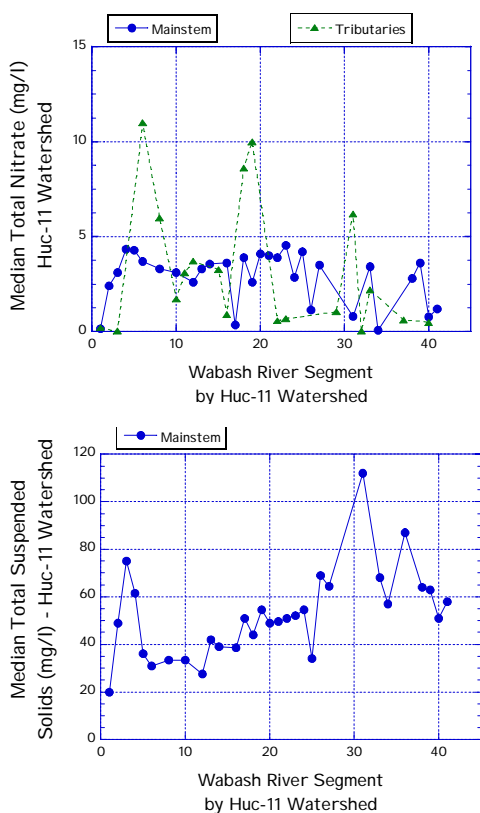
Wabash and lower White River were in general not “point” type of impacts where there is a sharp biological response of a river assemblage to a discrete input of pollutants as was commonly identified in river studies in the 1960s through 1990s (Gammon 1998, Yoder et al. 1995). There was no “smoking gun” whereby an immediate source of impairment was identified that could be quickly removed to restore this system. The fish assemblages of the Wabash River were initially impacted by the polluted runoff, highly altered flow regimes and degraded habitat conditions that characterize the Ohio portion of the Wabash as well as similarly degraded tributaries in Indiana (e.g., Limberlost Creek). The fish assemblages improved as local habitat conditions improved in the Wabash River (see Figure 1) and then generally declined with distance downstream until some slight improvement in the lower reaches. There was a similar and less variable pattern when important ecological metrics such as the number of sensitive fish species were similarly examined (Part I, Figure 7). Sensitive fish species, as well as freshwater mussel species richness, did not show this improvement in the lower reaches (see Appendix 10).



**Figure 1.** Plots of median total nitrate concentrations (top) and totals suspended solids (bottom) vs. Wabash River mainstem Huc-11 watershed segments for mainstem (solid circles) and tributaries (green triangles [insufficient tributary data for TSS]) Data obtained from IDEM and ranges in date from 1996 to 2006

### Stressors

The pattern of stressor conditions in the Wabash generally reflected the initial enrichment of the Wabash from the very upstream tributaries in Ohio and in Indiana and the persistence of these enriched conditions the length of the river. This pattern is illustrated on a plot of nitrate concentrations by



**Figure 2.** Plots of mean mainstem IBIs by Huc-11 watershed segments of the Wabash River for fish assemblage data collected in 1999, the most spatially complete year of data. IBIs depict Ohio boatable versions (solid circles) and Indiana Large and Great River IBI versions (open circles)

HUC-11 watershed along the mainstem (Figure 2, top), which identified high and very high tributary nitrate concentrations in the upper river and typically lower concentrations in downstream tributaries.

Total suspended solids (TSS) initially increased in the Wabash River from Ohio and upper Indiana tributary inputs, declined as habitat improved and then gradually increased as the Wabash River flowed downstream (Figure 2, bottom). The increase in TSS is likely due to increasing algal activity in the Wabash River related to high nutrient loads and changing habitat features (more pool habitats) which promote production of algal cells. This is the same pattern described by Gammon (1998).

Numerous authors have identified that high nitrogen export from agricultural activities in the Midwest (e.g., Baker and Richards 2003; Bernot et al. 2006; Goolsby 1999) is contributing substantially to eutrophication and coastal anoxia problems

(Rabalais et al. 2002). Although the some of the local eutrophication implications of high nutrients in large rivers are known, all of the mechanisms of nutrient effects on biota in large rivers are not yet well understood. In any case, this study confirmed persistently high nitrate concentrations along the Wabash River and lower White River with the highest export of nitrates in the watershed associated with agricultural and agricultural drainage (Frey et al. 2006). The increase export of nutrients from drainage agricultural landscapes matches the conclusions of a USGS study in the White River watershed (Frey et al. 1997).

In Table 1, we have summarized selected biological condition measures for the six mainstem HUC-8s for the Wabash River and Lower White River mainstems. The colors (see color key on the first row of the table) represent either condition or stress risk based on mean values in the mainstem only or in the immediate upstream reaches of the HUC-8 watershed. Risk levels for stressors are based on biologically associated values from the Eastern Cornbelt Plains Ecoregion in Ohio for large river (mainstem data) or wadeable streams (upstream data).

### Habitat

Within the Wabash River watershed, habitat features are strongly associated with biological assemblages in the upstream tributaries at the local and watershed scales. Biological assemblages in HUC-11 reaches of the Wabash River also are associated with habitat conditions in these waters. Based on descriptions of early settlers and explorers in Indiana and existing high quality sites across the Midwest we reconstructed the habitat conditions in a hypothetical mainstream reach using the QHEI. Comparison of existing habitat conditions in the Wabash and White Rivers with hypothetical habitat components help us describe why local habitat might be limiting in these waters. Habitat conditions in the Wabash River ranged from very poor (Ohio) to excellent (upper higher gradient reaches); however most sites were rated as fair to marginally good. In particular, QHEI riparian metric scores were low as were instream cover (structure) scores and substrates score. In particular the lower substrates score in the lower Wabash River have been attributed to loss of coarse substrates (Gammon 1998, Pyron and Lauer 2004) perhaps due to channel meandering (Simon 2006).

**Table 1.** Summary of selected biological condition measures and stressor measures by mainstem Wabash HUC-8 watershed. Colors represent either condition or stress risk based on mean values in the mainstem only or in the immediate upstream reaches of the HUC-8 watershed. “Risk” levels for stressors are based on biologically associated values from the Eastern Cornbelt Plain Ecoregion in Ohio for large river (mainstem data) or Wadeable streams (upstream data).

HUC-8 Wabash River Watershed						
Data/Location	Upper Wabash R. 05120101	05120105	05120108	05120111	Lower Wabash R. 05120113	Lower White R. 5120202
Risk Level Color Key	None	Slight	Moderate	High	Extreme	
Mean IBI - Mainstem	30.4 (47)	41.0 (44)	32.5 (368)	30.5 (135)	32.7 (24)	31.4 (11)
Mean IBI – Upstream	24.6 (180)	40.7 (6)	37.5 (105)	37.8 (23)	31.3 (11)	38.8 (26)
Mean Sensitive Fish Species - Mainstem	4.6 (47)	7.1 (44)	3.5 (368)	2.5 (135)	2.5 (24)	2.36 (11)
Mean Sensitive Fish Species - Upstream	0.8 (180)	9.2 (6)	3.7 (105)	3.5 (23)	1.64 (11)	3.04 (26)
Mean Percent Tolerant - Mainstem	31.9 (47)	3.5 (44)	5.0 (368)	8.9 (135)	14.4 (24)	5.8 (11)
Mean Percent Tolerant - Upstream	64.1 (180)	38.7 (6)	43.7 (105)	36.7 (23)	33.3 (11)	28.66 (26)
Mean QHEI – Mainstem	52.1 (27)	69.5 (3)	56.9 (19)	59.0 (16)	55.6 (16)	60.8 (5)
Mean QHEI – Upstream	28.1 (180)	78.3 (6)	56.4 (105)	61.2 (23)	49.8 (11)	56.2 (26)
Mean Substrate Score – Mainstem	13.7 (270)	16.8 (3)	12.4 (19)	13.8 (16)	11.4 (16)	13.0 (5)
Mean Substrate Score – Upstream	5.8 (180)	16.2 (6)	12.1 (105)	12.1 (23)	9.1 (11)	11.0 (26)
Mean Channel Score – Mainstem	9.8 (270)	13.0 (3)	12.4 (19)	13.0 (16)	11.1 (16)	13.2 (5)
Mean Channel Score – Upstream	5.4 (180)	15.5 (6)	12.2 (105)	13.2 (23)	10.7 (11)	12.7 (26)
Mean Percent Drained Land Index (HUC-8)	4.6	4.0	1.7	1.5	3.8	2.2
Mean Agricultural Landuse	88.2	93.2	81.2	69.7	80	60.1
Mean Forested Landuse	9.3	4.8	16	23.4	13.7	35.9
Mean Developed Landuse	1.1	0.4	0.6	2.1	1	0.9
River Hydrology – Flashiness (Mainstem)	0.28	0.19	0.14	0.09	0.08	na
Dissolved Oxygen – Mainstem	9.4 (783)	10.9 (253)	10.7 (671)	9.8 (319)	9.0 (49)	9.34 (364)
Dissolved Oxygen – Upstream	7.0 (703)	9.7 (206)	9.1 (785)	8.0 (484)	7.6 (53)	7.93 (599)
Total Phosphorus – Mainstem	0.38 (667)	0.23 (221)	0.22 (562)	0.20 (236)	0.22 (20)	0.28 (323)
Total Phosphorus - Upstream	0.50 (584)	0.11 (96)	0.16 (465)	0.14 (307)	0.14 (28)	0.19 (78)
Total Nitrate - Mainstem	4.7 (642)	3.5 (221)	3.8 (549)	3.3 (224)	1.7 (8)	1.63 (280)
Total Nitrate - Upstream	5.4 (577)	4.4(124)	3.5 (489)	1.33 (222)	1.7 (22)	0.896 (37)
TDS – Mainstream	480 (683)	342 (223)	368 (557)	355 (237)	365 (22)	412 (273)
TDS – Upstream	683 (492)	409 (124)	361 (530)	605 (334)	383 (29)	363 (83)
TSS – Mainstream	61.5 (672)	55.3 (218)	53.4 (561)	74.3 (239)	76.3 (21)	81.1 (324)
TSS – Upstream	46.5 (563)	33.7 (94)	30.7 (453)	24.3 (296)	56.5 (25)	23.1 (58)
Total Chloride - Mainstem	57.8 (670)	33.1 (223)	36.9 (563)	33.6 (239)	40.1 (22)	59.7 (273)
Total Chloride - Upstream	114.7 (589)	33.6 (124)	26.9 (534)	19.7 (332)	35.5 (25)	14.8 (83)

These riparian and cover features of the QHEI that are lacking are associated with some of the most striking changes to the river compared to historical conditions. The Wabash River floodplain had been described as having one of the most impressive bottomland forests east of the Mississippi River (Jackson 2006). The original forests were dominated by large trees up to 150 feet tall with certain trees such as American Sycamore reaching 200 ft in

height and a diameter of 15 feet (Jackson 2006). The importance of mature riparian forests and their contribution to woody cover is likely underestimated in the Wabash and White Rivers and other Midwestern large rivers. Studies of Western climax forests have identify the key role of large stable wood as cover, for reducing erosion and increasing channel depth and diversity. Large stable wood structure could provide substantial

channel and habitat heterogeneity that is lacking in the current these rivers. Rehabilitation of native tree species that once reached tremendous sizes along the Wabash and White Rivers would have substantial benefits on low cover and riparian scores observed in these rivers.

The lower Wabash and White Rivers in particular lost many unique connected wetland type habitats with the filling of oxbows, sloughs and backwater channels and the loss of Cypress swamps in the lower reaches. Levees in along the lower Wabash River in particular resulted in the disconnection of the mainstem river from these habitats. Table 2 lists species that have some parts of their life histories associated which such features. A few of these species are relatively tolerant or found in the margins of small streams with some of these features and have a wide distribution (e.g., blackstripe topminnow). Other species, however are more closely associated

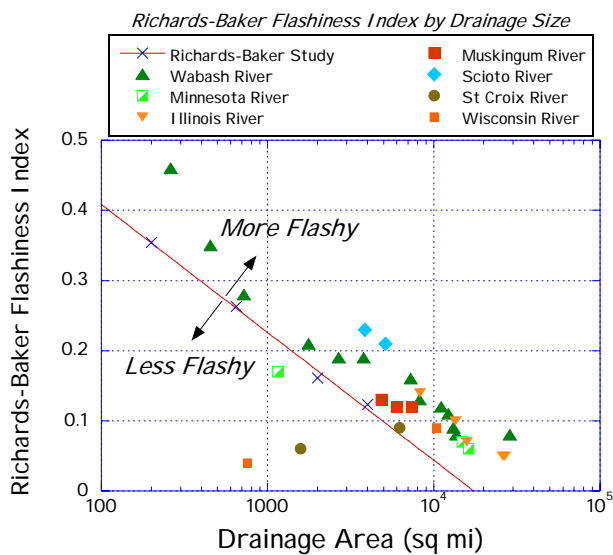
with more well developed and unique habitat features (e.g., cypress swamps) and have shown a declining distribution with the loss of these features (Smith 1979, Simon 2006).

#### Hydrology

Aside from the lack of large stream size forests and riparian trees, the lack of instream cover may also be related to the greatly altered hydrology in the Wabash River. In a study associated with the development of the Richards-Baker flashiness index, Richards et al. (2004) concluded that streams in the Corn-Belt ecoregion were among the flashiest in the Midwest and also found increasing flashiness in Indiana streams that could be related to continued drainage improvements. Figure 3 compares sites flashiness for sites on the Wabash to similarly sized Midwest streams. Altered hydrology has also been implicated in the changes in forest trees species in riparian habitats with cottonwood and silver maple

**Table 2.** List of fish species recorded from the Wabash and lower White River that are generally associated with wetland features such as sloughs, backwaters, oxbows, cypress swamps and other similar features. Distribution trend of (—) refers to a declining species distribution compared to historical data (from Smith 1979, Simon 2006, Crawford et al. 2006)

Family Code	Species Code	Common Name	Latin Name	Distribution Trend	IN ETS	IL ETS	OH ETS
10	001	Alligator Gar	<i>Lepisosteus spatula</i>	—	X		X
15	001	Bowfin	<i>Amia calva</i>				
37	003	Northern Pike	<i>Esox lucius</i>	—			
37	004	Muskellunge	<i>Esox masquinongy oh.</i>	—			S
40	019	Lake Chubsucker	<i>Erimyzon sucetta</i>	—			T
43	003	Golden Shiner	<i>Notemigonus crysoleucas</i>				
43	019	Pugnose Minnow	<i>Opsopoeodus emiliae</i>	—			E
43	038	Pugnose Shiner	<i>Notropis anogenus</i>	—	S	E	X
43	114	Weed Shiner	<i>Notropis texanus</i>	—		E	
43	116	Cypress Minnow	<i>Hybognathus hayi</i>	—		E	
47	013	Tadpole Madtom	<i>Noturus gyrinus</i>				
54	003	Northern Studfish	<i>Fundulus catenatus</i>	—			
54	006	N. Starhead Topminnow	<i>Fundulus dispar</i>	—		T	
57	001	Western Mosquitofish	<i>Gambusia affinis</i>				
68	001	Pirate Perch	<i>Aphredoderus sayanus</i>	—			E
77	002	Black Crappie	<i>Pomoxis nigromaculatus</i>				
77	007	Warmouth Sunfish	<i>Lepomis gulosus</i>				
77	031	Flier	<i>Centrarchus macropterus</i>	—			
77	032	Bantam Sunfish	<i>Lepomis symmetricus</i>	—			
77	040	Banded Pygmy Sunfish	<i>Elassoma zonatum</i>	—	S		
77	041	Redspotted Sunfish	<i>Lepomis miniatus</i>	—		T	
80	021	Iowa Darter	<i>Etheostoma exile</i>	—		T	S
80	025	Least Darter	<i>Etheostoma microperca</i>				S
80	028	Mud Darter	<i>Etheostoma asprigene</i>	—			
80	031	Slough Darter	<i>Etheostoma gracile</i>	—			
80	032	Bluntnose Darter	<i>Etheostoma chlorosoma</i>	—			



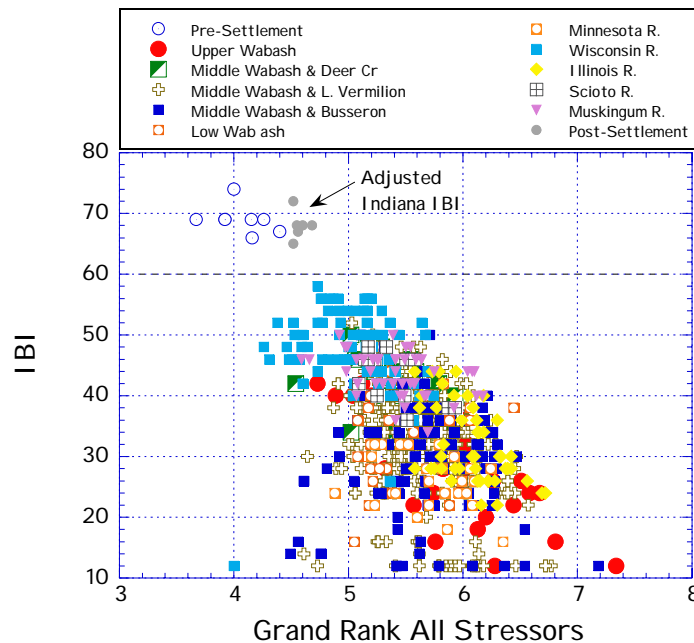
**Figure 3.** Plot of the R-B index for gage sites on the Wabash River and other Midwest Rivers vs. drainage area in sq mi. The line on the graph reflects a relationship between median values from Midwest Rivers from a study of the Richards et al. (2004).

now predominant species in the Wabash River floodplain but absent or uncommon in 1814 (Jackson 2006). The construction of levees along much of the lower Wabash cutoff floodwaters from the rivers natural flood prone areas, likely increasing shear stresses within the channel and levees. The extensive

agricultural drainage and flood control in upper reaches of the Wabash and White Rivers had profound consequences on the flow regimes of the rivers. Agricultural drainage is designed to move water off of productively agricultural land quickly and to export it downstream. This worsens downstream flooding and “flood-proofing” of downstream reaches through levees, etc., pushes the flow further downstream so that the frequency and magnitude of flows increase. Construction of dams can reduce flashiness depending on how the dam is operated, but in any case often still reflect regimes altered compared to natural conditions. We did not have the time to statistically examine the cumulative changes to flows from tributaries and could only perform cursory analyses of Index of Hydrological Alteration (IHA) indicators; however Pyron and Lauer (2004) identified associations of Wabash River fish species with a gradient of hydrological indicators.

### Conclusions and Management Implications

The Wabash River watershed has undergone substantial changes in land use, forest cover, flow regime, nutrient delivery, and in-river habitat features over the past 200 years. We established a



**Figure 4.** Plot of the grand rank of all stressor categories generated for individual fish sampling sites in the Wabash River, other Midwest Rivers and from a hypothetical, modeled fish assemblage for the Wabash River represent pre-settlement (circa 1800) and immediate post-settlement (circa 1860s) conditions. Ranking is based on TIV values for multiple stressor categories generated for large rivers.

baseline biological condition gradient (BCG) for fish assemblages that anchor the assemblage in a natural condition. This allows us to create a rehabilitation trajectory for planning restorative management strategies with predictable outcomes in terms of biodiversity and biological condition. We also created hypothetical pre-settlement assemblages, using real capture probabilities for species to re-create what environmental conditions were like. By comparing these assemblages and environmental conditions to existing Wabash River conditions and to other current Midwest assemblages of lesser (Illinois River) and higher (Wisconsin River) biological quality we can envision how the river could improve if various stressors are reduced (Figure 4).

#### *Enhancement Options*

Our analysis of stressors in the Wabash River identifies two broad classes of stressors in the Wabash and White Rivers. The first is related to the degradation of local habitat conditions in reaches of these rivers. Part II of this report identifies more site specific issues related to habitat limitations. In broad terms, however the changes in bottomland forests, especially in the immediate riparian areas along the river has results in local bank erosion that delivers fine sediments to the river, degrading substrates and littoral areas and a reduction in large wood and other cover features that provide habitat for many fish species and for the production of many invertebrates. The loss of large stable wood also decreases the hydrological complexity of reaches and makes habitat geomorphically monotonous. Reestablishing stable riparian forests and protecting or restoring oxbow and other wetland habitat types (sloughs, cypress swamps) perhaps provides the greatest opportunities for short-term benefits biodiversity benefits for this river. As illustrated in Table 2, many of the species that have been extirpated or reduced in number are associated to one degree or another with such habitat types.

The second major category of impact is related to how we management headwater streams throughout the Midwest, but especially when paired with agricultural drainage. As managed today these streams export high amount of nutrients, sediment and greatly alter the flow regimes of these waters. In the Wabash the strongest empirical evidence of this comes from the upper watershed in Ohio and Indiana where nutrients and dissolved materials are

highest and flow is the most flashy (Figure 3). There is now substantial evidence that opportunities to transform or assimilate nitrates and phosphorus are greatest in small headwater streams (Peterson et al. 2001) and decreases with downstream distance. Over 1 billion dollars per year is being spent across the U.S. to “restore” streams, however, a recent review concluded < 10 % of these projects were done with monitoring data or evaluated the success of the project (Palmer and Allan 2006). A data base to track such restoration efforts has been established (National River Restoration Science Synthesis - <http://nrrss.nbio.gov/>) in order to advance the science of stream restoration. A number of methods or approaches have been proposed to gradually rehabilitate headwater streams while maintaining agricultural drainage and productivity. Some of these focus on specific goals such as reducing nitrogen (Craig et al. 2008) or flow (Palmer and Bernhardt 2006). We suggest that rehabilitation of headwater stream systems in Ohio and Indiana would be an essential endpoint for the recovery in the mainstem Wabash and lower White Rivers. It would be important to accomplish this in a way that addresses the stressors we identified here as being important to biodiversity and biological condition which include habitat, nutrients, sediment, and flow rather than most Midwest stream restoration have been conducted (Alexander and Allan 2006). The science of stream restoration is still in its early stages and it is important to assess the efficacy of restoration efforts as urged by Palmer and Allan (2006). More detail can be provided, based on the analyses conducted in this effort, on the types of projects that might prove most useful and ways to monitor incremental progress towards success.

The stressors we identified above are those for which some concrete actions, albeit long-term, could help improve the Wabash and lower White Rivers. There is another major threat to these systems where management actions may be more limited – the increases in invasive species in these rivers. Some alien species have been established since the 1800s (e.g., Common Carp) and although they have influenced native aquatic assemblages, they have not likely caused the extirpation or extinction of any native species. In fact, natural assemblages and habitats are somewhat resistant to such species and these current exotic species are typically a minor component of the assemblages where water quality and habitat are in good condition. More recent

introductions however, including the Zebra Mussel, Silver Carp, and Bighead Carp have been more serious. The Silver Carp may well compete with young of keystone native species such Paddlefish and Shovelnose Sturgeon and already have reached incredible abundances in some pools of the Mississippi River. These species have been collected in both the Wabash and White Rivers. Another carp species, the Black Carp could be dangerous because it's crushing pharyngeal teeth and could pose a threat to native snail and mussel species. Control of such species may be limited once established and management efforts for such species would focus on keeping them out of Midwest waters as IDNR is attempting.

## Wabash River Study - Part I. Introduction

Large River ecosystems are among the most threatened aquatic ecosystems in the world because of dams, pollution, loss or disconnection with floodplain wetlands, introductions of exotic species, flow alterations, and other anthropogenic alterations to these waters (Dudgeon 1992; Dudgeon et al. 2006). In North America aquatic organisms (fish, mussels, crayfish, and caddisflies) are imperiled at a higher rate than terrestrial organisms and many of these are associated with large river ecosystems (Ricciardi and Rasmussen 1999; Williams et al. 1989, 1993). Despite the identified extinctions, extirpations and reduction of species in large rivers, knowledge of how large rivers function and the role of various stressors on biodiversity and condition is often qualitative and incomplete (Karr and Chu 2000). Although the influence of watershed degradation has been implicated in phenomenon such as the Gulf of Mexico anoxia zone, less is known of the influence of upstream watersheds on the condition of large rivers. Biological studies are often local and data is typically examined without sufficient stressor data or in relation to only one or several well-known stressors. Similarly, restorative actions typically focus on a few stressors, fail to include important watershed-scale stressors (e.g., flow, sediments) and are more strictly considered rehabilitation rather than restoration (Gore and Shields 1995). The compilation of large databases of biological (Rankin and Armitage 2004) and stressor data (e.g., Bryce and Hughes 2003) across multiple spatial and spatial scales can provide a comprehensive assessment of species patterns and their relationships with stressors and threats not possible at a small spatial or temporal scale.

In this study we compiled a large database of biological, stressor and threat data from the Wabash and White Rivers in Indiana to allow us to 1) identify segments of these rivers where biodiversity and biological condition is impaired, 2) to identify anthropogenic stressors and threats in these segments, and 3) to identify the likely sources of threats including whether they arise from within the main rivers or originate from watersheds confluent to these rivers. We used a watershed and river segment approach based on major confluences as an organizing framework for data compilation, analysis

and assessment. We then used several multivariate tools to understand the influence of important stressors throughout the entire Wabash River watershed (Part I of Report), and a weight of evidence stressor identification approach within HUC-8 and HUC-11 watersheds (Part II).

### Background

To better understand what is reasonably restorable in the Wabash River it is not only important to know the current status, but to have some quantification of historical conditions as an anchor for biodiversity goals, even if unachievable. To accomplish this we developed a Biological Condition Gradient (BCG; Davies and Jackson 2006) for the fish assemblage of the mainstem of the Wabash River as a reference anchor to describe the historic condition of the river. This information was gleaned from historic records, (e.g., Eigenmann and Beeson 1894, Gerking 1945; both cited in Gammon 1977, 1998) supplemented with extrapolations from recent data on the biodiversity and ecological condition and function from rivers across the Midwest. We then used a similar process to understand and describe the stressors that control biodiversity and biocondition as they deviate from the anchor in the natural condition (e.g., flow, Poff et al. 1997). The combination of a robust statistical exploration of stressor data along existing gradients of stress within the Wabash (at multiple spatial scales) and extended to similar nearby rivers in the Midwest and historical data provides a conceptual framework for assessing various rehabilitation and enhancement actions. This approach provides predictable and measureable ecological endpoints rather than general predictions related to improving biological diversity and condition in the Wabash River watershed.

### Data

This study was entirely based on existing data and no additional data was collected for this study. One of our goals was the pulling together of sometimes disparate data sets so that future researches could access this information for multiple research or assessment purposes. Our goal was the assessment of important stressors to the Wabash River and we did not have the resources to examine all data. Others, particularly Gammon (1998) conducted an

in depth assessment of trends and impairment in the Wabash River from the 1960s through the mid-1990s. We focused on subsets of data that were most complete in a longitudinal sense along the mainstem Wabash River and provided the most robust recent biological and stressor data collected since the assessments of Dr. James Gammon.

To facilitate communication regarding biological condition and for identifying the influence of individual stressors we are used narrative ranges of biological condition (excellent, good, fair, poor and very poor) and narrative ratings of environmental stress (“reference”, low, moderate, high, very high, extreme) to each of the stressor variables we used. This makes the interpretation of the statistical patterns more comprehensible even though they can be based on rather complex interactions of multiple stressors.

Information about the fish assemblage is the most detailed and complete recent biological component available throughout the watershed. In 1999 the entire length of the Wabash River mainstem was sampled, including Ohio and in 2004-2006 most of the Indiana portions were sampled. Mark Pyron has sampled much of the middle Wabash River yearly during these periods, building on the previous work of Jim Gammon. Numerous scientific papers have been produced on the basis of this work (Gammon 1976, 1980, 1983, 1998, Gammon and Reidy 1981, Gammon and Simon 2000, Pyron 2006, Pyron et al. 2006, Pyron and Neumann 2008, Pyron et al. 2008).

For the major statistical efforts we used recent fish data and used other organism groups (mussels, macroinvertebrates) in a supporting role. Qualitative Habitat Evaluation Index (QHEI) are most typically recorded during fishery surveys, thus the need to use this important stressor variable limited much of our statistical approach to fish as well. We felt it was important to include data from rivers other than the Wabash River in the Midwest and available datasets existed for fish in Ohio, Illinois, Wisconsin and Minnesota (which also had matching habitat data) which supported fish as a primary assessment tool. Similarly, the best historical records exist for fish in the Midwest with historical accounts that extended back into the 1700’s and 1800’s in Indiana (Gerking 1947; Gammon 1999), Illinois, Ohio (Trautman 1981) and other Midwestern states.

#### *Mainstem Fish Data*

We obtained fish assemblage data from a number of key sources. Dr. Gammon has performed an extensive assessment of the large fish data set he has collected dating back to the 1960s. His data is represented in our database and used to identify indicator species along the river; however we relied on two periods of more recent data in which the entire length of the river was sampled. In 1999, IN DNR collected data from the entire length of the river and a similar, but less intense sampling was completed by ORSANCO for U.S. EPA in 2004. That sampling was part of the a larger study of Midwest rivers sampled from 2005-2007 including data from Ohio (Scioto, Muskingum, and Tuscarawas Rivers), Illinois (Illinois River), Wisconsin (St Croix and Wisconsin Rivers) and Minnesota (Minnesota River) which is part of our dataset used for this report. Data from these two primary periods was supplemented from data collected by Mark Pyron, IDEM, and others between 1999 and 2006. Ohio EPA has extensively monitored the Wabash River in Ohio since with 1980s and we used both boatable and wadeable data from them as well.

We used both Ohio and Indiana boatable/great river Index of Biotic Integrity (IBI) scores as response variables in our analyses as well the IBI metrics number of sensitive and intolerant species, percent tolerant species, percent omnivores, and other metrics. Indiana and Ohio IBI scores and metrics for the mainstem sites collected from 1999-2006 are listed in Appendices 1a (boatable), 1b (wadeable), 1c (headwaters), and 1d (night sampling data from 2004). Other data is in the GIS database that we have constructed.

We used narrative ratings [with color codes] of the IBI to provide an understandable way to illustrate areas of biological quality and impairment: Excellent [blue,  $\geq 50$ ]; Good [green, 40-49]; Fair [yellow 30-39]; Poor [orange, 20-29]; Very Poor [red,  $< 20$ ].

#### *Watershed (Upstream) Fish Data*

We obtained fish data collected by IDEM collected in tributaries to the Wabash from 1996 to 2006 that were collected as part of their probability assessment for a statewide assessment and during intensive watershed surveys at bridge crossings as part of their stressor identification process for impaired waters (IDEM 2006). Our goal with this data is to provide

statistics on condition by HUC11 watershed that might contribute to our understanding of biological assemblages in the mainstem Wabash River. We also obtained similar data from Ohio EPA collected in the Ohio portion of the Wabash River and its tributaries collected from 1984-2006. The data set we obtained from IDEM had Indiana wadeable IBI scores and metrics for each sample.

*Extrapolation of Fish Assemblages to Pristine and Pre-Settlement Historical Conditions in the Wabash River*

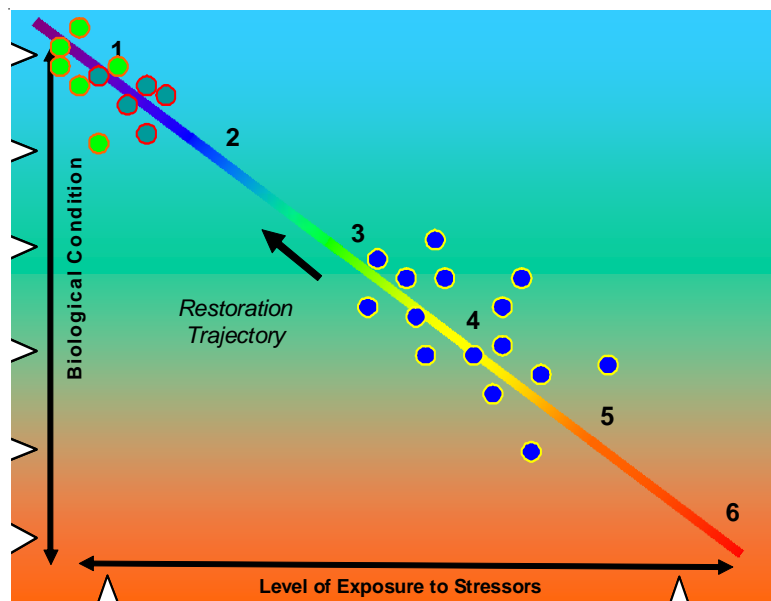
One of our goals for this project was to be able to understand the historical fish assemblage condition and biodiversity in the Wabash River to provide an endpoint or anchor point for extrapolating existing conditions. This concept is illustrated in Figure 1. The dark blue points represent the existing conditions in the Wabash River along an abstract “stressor gradient” (x-axis). The green and grey points reflect pre-settlement and post-settlement conditions in the Wabash River. Because of the great landscape changes that have occurred these conditions may not be realistic or even desirable societal goals depending on what would have to be changed on the landscape to attain such goals.

Another goal, as a component of this work, was to generate a “synthetic,” computer-derived estimate of

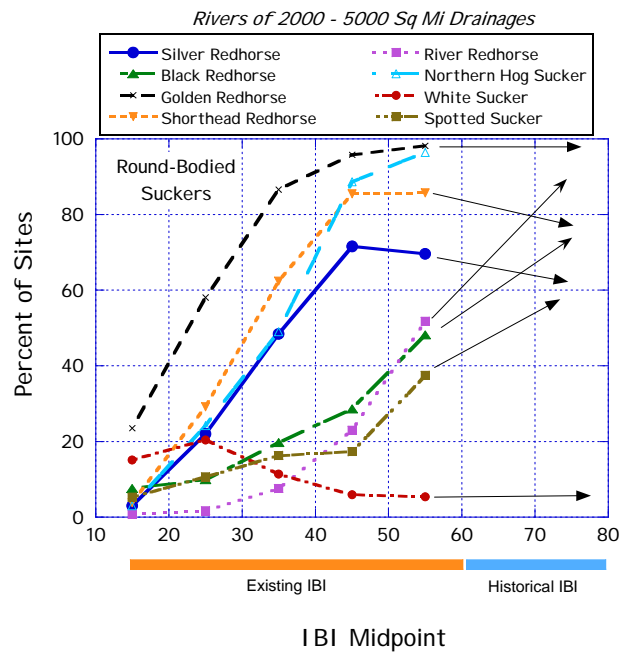
condition data (e.g., species populations and presence/absence) along with measures of species-stressor associations, to enable us to predict how we can change stressors to enhance the biodiversity of the Wabash River ecosystem.

*Constructing the Synthetic Fish Community (circa 1800)*

In association with our identification of species-specific, weighted stressor taxa intolerance values (TIVs) for fish species of the Wabash River, we generated hypothetical sampling results for reaches of the Wabash River. We used a computer program to randomly “fish” a fish assemblage based on probability of capture trajectories we generated by examining species probability of capture rates along existing gradient of conditions as measured by the IBI. For this project we focused on what we would consider likely historical assemblages in the lower half of the river and did not account for expected changes that might occur with stream size. We calculated probability of capture curves and average numbers collected for each species at IBI ranges of 12-20, 21-30, 31-40, 41-50 and 51-60 (Figure 2). This represents an increasing biological quality gradient. Sensitive species generally showed an increasing probability of capture as IBI scores increases and tolerant species a decreasing probability of capture. We then extrapolating these trajectories back in time to create Tier 1 and Tier 2 BCG stream data sets for fish by stream size for



**Figure 1.** U.S. EPA hypothetical plot of biological condition (y-axis) vs. a stressor gradient (x-axis) (Modified from U.S. EPA 2005). On this graph we have superimposed points presenting existing conditions in the Wabash River mainstem (blue points) and two groups of points representing pre-settlement (green points) and post-settlement conditions (grey points).



**Figure 2.** Graph illustrating capture probabilities for redhorse species used to generate a historical, synthetic fish assemblage dataset. Arrows illustrate potential changes in probability of capture with increases in condition.

hypothetical assemblages based on these capture probabilities. Tier 1 streams would represent pre-Columbian conditions and Tier 2 as intermediate between Tier 1 and Exceptional assemblages that we can define with existing data. Tier 1 assemblages are likely un-attainable given present day population and land uses and Tier 2 would might represent a hypothetic assemblage given best use of land and water management strategies.

For very rare, extirpated and extinct species we generated probabilities based on surrogates in Level 3 conditions (e.g., species at sites with IBI scores 51-60) and information from various historical data descriptions of fauna. Based on probability of capture curves (for Tier 1 and 2) we created a pool or all available species and then randomly selected or “fished” this data to create an assemblage that would be expected given modern sampling techniques.

This synthetic data set was used to generate historical IBIs. We also back calculated stressor levels based on species-specific stress tolerance values we generated from extant data. For species that are extirpated and not in our data set we assigned stress tolerance values based on life history data and historical information. We also adjusted the Indiana IBI scoring criteria (based on numbers) to

accommodate what would have been more species rich data collections at reference sites to allow it to score above 60 which would be the maximum score based on existing conditions. This is discussed in more detail in Appendix 6.

#### Habitat Data

The QHEI is a visual habitat assessment tools that relies of narrative descriptions of habitat features or metrics using well-defined categories of habitat quality (Rankin 1989, 1995). It is comprised of seven metrics: substrate type and quality, instream structure, channel condition, riparian and back condition, pool and current features, riffle features, and stream gradient score adjusted for stream size. Some recent work has defined the overall score as a precise measure of habitat quality and individual metrics as precise or moderately precise variables (Rankin et al. in preparation). Habitat and related impacts has been shown to be a prevalent stressor in Midwest streams and rivers (U.S. EPA 2007).

Our primary source of data on aquatic habitat in Indiana streams and rivers is the QHEI which we obtained primarily from IDEM (upstream reaches and mainstem), ORSANCO/MBI (mainstem) and Ohio EPA (Ohio portion of the Wabash and tributaries). The most complete year of data for the QHEI in the Wabash Mainstem is from 2004 during

the ORSANCO study. Because QHEI does not generally change substantially between years unless direct modifications are made of major storm events occur, we combined all recent QHEI for most analyses. QHEI data and metrics with narrative assessments used in the statistical analyses are listed in Appendix Table 2. We are also using IDEM tributary QHEI data collected between 1996 and 2006 and summarized by HUC11 watershed to provide information on the influence of upstream and headwater habitat conditions on mainstem biological condition; this data is included in the GIS database and summarized during watershed specific summaries in the second part of this technical report.

We used narrative ratings [with color codes] of the QHEI developed by Ohio EPA (2006) to provide an understandable way to illustrate areas of habitat stress and quality: Excellent [blue,  $\geq 75$ ]; Good [green, 60-74]; Fair [yellow 46-59]; Poor [orange, 30-45]; Very Poor [red,  $< 30$ ].

#### *Hydrological Data*

Hydrological alterations, compared to natural flow regimes, have been implicated as co-factors in many of the widespread biological changes that have been observed in the rivers of North America. Perhaps the strongest effects of flow alteration on aquatic life have been observed with increases in urbanization (Booth et al. 2002; Pomeroy et al. 2008). Poff et al. (1997) identify five major components of flow in relation to effects on aquatic life: 1. Magnitude of discharge, 2. Frequency of discharge, 3. Duration, 4. Timing or predictability of flows, and 5. Rate of change, or flashiness of flow. The Nature Conservancy constructed a system (Indicators of Hydrologic Alteration) to generate statistics on river flow from U.S.G.S. gauge or other daily flow data to characterize aspects of the magnitude, timing, frequency, duration and rate of change of discharge. We used selected statistics from gaging stations on the Wabash River mainstem to help us determine the degree of alteration of flow in various reaches of

the Wabash River. Mainstem gaging stations used in the statistical analyses are listed in Appendix 3. We used the results of Olden and Poff (2003) to help choose a subset of variables that should identify the key variation expected to potentially influence biology in rivers like those in Indiana and Ohio which have been largely classified as: perennially flashy or runoff dominated Olden and Poff (2003). In addition to the variables in the IHA, we calculated the Richards-Baker Flashiness index (R-B Index) at each station with daily flow data. Their work on this measure identified Indiana as having among the highest R-B Indices in the Midwest (Baker et al. 2004). We used data from 1970 - 2007 as a period for classifying the flow regime at a site and watershed for both the IHA indicators and the R-B Index.

#### *Water Chemistry Data*

There is a fairly long record of historical chemical data on the Wabash River. We focused on the most recent water chemistry data that we obtained from IDEM and Ohio EPA that was collected in Ohio and Indiana in the mainstem and upstream watersheds in the Wabash River drainage. The majority of this data was obtained from IDEM and ranged in date from 1990 to 2007; Ohio data extended back to 1984, but most was from an intensive survey in 1999. For most analyses we used data collected from June 15 – October 15 when instream conditions are generally most harsh and limiting to aquatic life. We also excluded data that was not part of an ambient sampling protocol. For example, we excluded data that was described as being collected in a discharge channel.

Sites from the Wabash River mainstem used in the statistical analyses of this report are listed in Appendix 4. Data exists for many parameters, but we selected parameters for analysis that were abundant in the dataset and that reflect the stressors likely to be important to agricultural watersheds like the Wabash (Table 2). Use of some less commonly sampled parameters would have resulted in missing values in multivariate analyses.

We used a study of background chemical conditions in streams and large rivers in the Eastern Cornbelt Ecoregion of Ohio to assign narrative ratings related to how elevated water quality parameters are in the this study compared to reference sites and sites

**Table 1.** Hydrological regime indicators used in this study.

Richards-Baker flashiness index (R-B Index)
Mean Annual Flow
Annual Flow - Coefficient of Variation
Flow Predictability
Other IHA Indicators

**Table 2.** List of chemical stressor values (and some commonly used acronyms) examined in this study. STORET parameter codes in parenthesis.

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·	Water Column Chemistry
o	Dissolved oxygen – DO (299)
o	BOD-5 Day – BOD (310)
o	Total Suspended Solids – TSS (70030)
o	Total Ammonia – TA (610)
o	Total Kjeldahl Nitrogen – TKN (625)
o	Total Nitrate – TN (630)
o	Total Phosphorus – TP (665)
o	Total Copper (1042)
o	Total Zinc (1092)
o	Total Dissolved Solids – TDS (530)
o	Chloride (940)
o	Sulfate (945)
·	Other
o	pH (400)
o	Conductivity (94)
o	Temperature (10)

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attaining biological goals in Ohio (Ohio EPA 1999). We also incorporated information on Indiana water quality criteria for a parameters where it existed. Narrative ratings [and associated color codes] for the degree concentrations for a parameter are elevated compared to background are: “background” (not elevated) [blue], low [green], moderate [yellow], high [orange], very high [magenta] and extreme [red]. These data are summarized by HUC-11 watershed in Part 2 of this technical report by HUC-11 watershed.

For our statistical analyses we summarized data for the mainstem of the Wabash by HUC-11 watershed (the watershed through which the river passes) and separately for all HUC-11 watersheds, excluding mainstem data as a measure of upstream chemical stress. For statistical analyses we chose statistics for summarizing multiple samples based on the known mode of effect for each parameter. For parameters where projected impacts are from chronic or long-term exposure to these compounds we used median values as our indicator of stress. For parameters where the mode of impacts is acute or “toxic” exposure we used 75<sup>th</sup> percentile values as our measure of stress.

#### *Water Quality Index*

Individual chemical parameters were part of our statistical analyses, however we are also constructed

a Water Quality Index (WQI) approach to create and overall stressor parameter for plotting and illustrating the influence of water quality variables. We took a different approach compared to traditional WQIs because we calibrated it based on ambient threshold relationships between individual chemical stressors and IBI as a biological response variable. Traditional indices relate a water quality component of an index to a water quality criterion or other benchmark and then assume a linear or curvilinear relationship to develop a method of scoring the index. Our approach used the results of a threshold or ambient response to each variable to generate a score of each parameter in the index. Details of this approach are summarized in Appendix 4

#### *Taxa Weighted Stressor Values (WSVs), Taxa Indicator Values (TIVs), and Inferring Environment Conditions based on Species Assemblage Data*

Historical data linking a taxon’s abundance to measured stressors such as water chemistry values or habitat values is a valuable tool for understanding current and historical distributions of species in relation to stressors (Yuan 2004). Weighted stressor values are calculated by estimating for each combination of taxon and stressor the average value of the environmental variable in sites where the taxon was collected, weighted by the species abundance. To create a system for comparing taxa sensitivities, Meador and Carlisle (2007) ranked these WSVs and ranked on an ordinal scale of 1–10 to create a taxa indicator value (TIV), where a 1 is the most sensitive and 10 indicates most tolerant. We calculated such TIV values for the stressors listed in Table 2 for boatable river data from Ohio and some additional Midwest streams. We created average TIVs for categories of individual TIV stressors including nutrients, habitat, ionic strength parameters and metal and also a “grand” total averaging TIVs for all stressors with sufficient data. WSVs for each fish species and stressor value are listed in Appendix 5a and TIVs for stressor categories for each species are listed in Appendix 5b.

A novel, additional approach to discriminate among the influence of multiple stressors on the Wabash River fish assemblage was use assemblage data to infer environmental conditions using the TIVs for each species collected at a site. The value of an environmental variable at site is estimated as the weighted average of the TIVs at the site weighted by the abundance of each species. Thus even where

no stressor data is available we can estimate the relative condition of these stressors by inferring their value based on the abundance of each species. Thus for an assemblage predominated by sensitive species for a stressor category we would infer the actual stressors were low. In contrast, at a site predominated by tolerants we would infer that stressors were high. This is especially insightful in the historical assemblages we created where no data, other than the anecdotal exists or perhaps can only be inferred indirectly by core samples, etc.

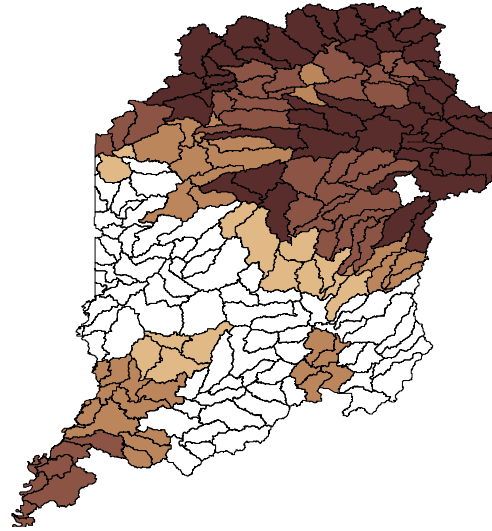
#### *Land Use Data*

We calculated percentages of each mainstem Wabash River HUC-11 watershed and all HUC-8 watersheds in the Wabash River watershed using National Land Cover Database information from 2001 which was obtained from the US Geological Survey (USGS 2007) and the land coverage was determined using ArcGIS. The HUC-11 data was used to represent “local” land use conditions and HUC-8 was used to represent upstream or more spatially broad land use data. We also examined tables from the 1960s Census of Agriculture to derived a simple rank estimate of percent of HUC-8 and HUC-11 watersheds as drained land (typically agricultural drainage; Map 1). This was estimated in 20 percentile categories and for a scale of 1 (low or no drainage, 0-20%) to 5 (> 80 percent drainage).

#### *Statistical Analyses*

We used a combination of descriptive and multivariate statistics to 1) identify meaningful biologically-derived river segments along the mainstem of the Wabash River and to 2) discriminate among the stressors in the Wabash River watershed that explain important variation in the biological condition and biodiversity of the Wabash River. We used the fish community data from 1999 and 2004, where most of the length of the river was sampled to examine community similarity among various levels of segmentation including HUC11-segments, HUC8-derived segments, and level 3 ecoregion-derived segments. We used indicator species comparisons at these various strata to assess whether which segmentation scheme would be a meaningful way to divide the river for stressor analyses and subsequent management recommendations.

Our approach to distinguishing among multiple stressors was to use some of the methodologies in the WERF-published Integrated Impact Analysis



**Map 1.** Percentage of HUC-11 watersheds subject to agricultural drainage activities range from < 20% drainage (white) to > 80% drainage (darkest).

(IIA) as outlined by Paulson et al. (2001). This approach uses multiple statistical methods to extract biological meaningful stressors from the dataset. We used PCA to reduce the number of variables to a biological sound subset. We then applied a multivariate tool to identify important explanatory variables. The tool we used was Regression Tree Analyses (RTA) part of the S-Plus 8.0 statistical software. With this tool we chose the IBI and the IBI metric the number of sensitive species (SENS) as the response variables and the variables identified with PCA as the independent measures.

#### *HUC-11 Stressor Identification*

We used the entire watershed data set to identify important stressors over a broad spatial scale using the Regression Tree analysis. Active watershed management, however, will be at a reach or at a HUC-14 or HUC-11 watershed scale. Analyses at too small of a scale alone, however, typically have too little range in stressor or biological condition values to accurately derive meaningful stressor-response relationships. Thus, our strategy was to identify the relationships with the large scale analyses and then summarize the data at HUC-11 scales using stressor identification techniques to identify limiting stressors in the watershed and reaches of the mainstem (see Part II).

## Results and Discussion

### Ohio vs. Indiana Great River IBI Scores

Figure 3 illustrates a plot of Ohio boatable IBI scores vs. the Indiana Great River IBI scores based on numbers. This graph includes data collected from 1999 to 2006. None of these sites needed adjustment for low end scoring for the Great River IBI that would have been needed if relative numbers would have been less than 10/km (Gammon 1998). The relationship is generally positive with the most variation at the lower end of the IBI scale.

### Longitudinal Patterns in Fish Assemblages

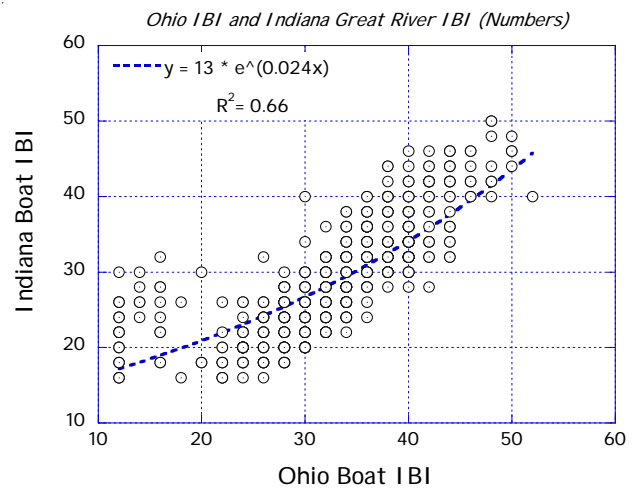
There was a longitudinal pattern in fish species assemblages along the mainstem of the Wabash River, particularly for the lowest 100 miles as is illustrated by a cluster analysis of fish assemblages similarities based on Bray-Curtis similarity measures (Figure 4). The clusters are coded by 50-mile river mile increments. The two lower segments show a strong cluster as do the upper two segments that represent the headwaters and which were sampled with wadeable methods in Ohio. There is less of a gradient in fish assemblage similarity in the middle river reaches compared with the upper and lower reaches.

The assemblages also generally differ with level 4 ecoregion which is confounded with river size (Figure 5). The Wabash River Lowlands ecoregion is relatively distinct as is the upper wadeable portion of the Clayey, High Lime Till Plains level IV ecoregion. Although adjacent sites tend to group together, the pattern is less clear for the other ecoregions.

### Indicator Species Analyses

One way to explore these longitudinal spatial patterns is to conduct an “indicator species analysis” that examines patterns in species occurrence among groups of river segments or along an upstream to downstream gradient. The historical data we examined during derivation of the BCG identified a fairly obvious pattern of species change from large river sections to upstream reaches of the mainstem Wabash River. Many of the large river species are now relatively rare and we wanted to examine current patterns in species distributions.

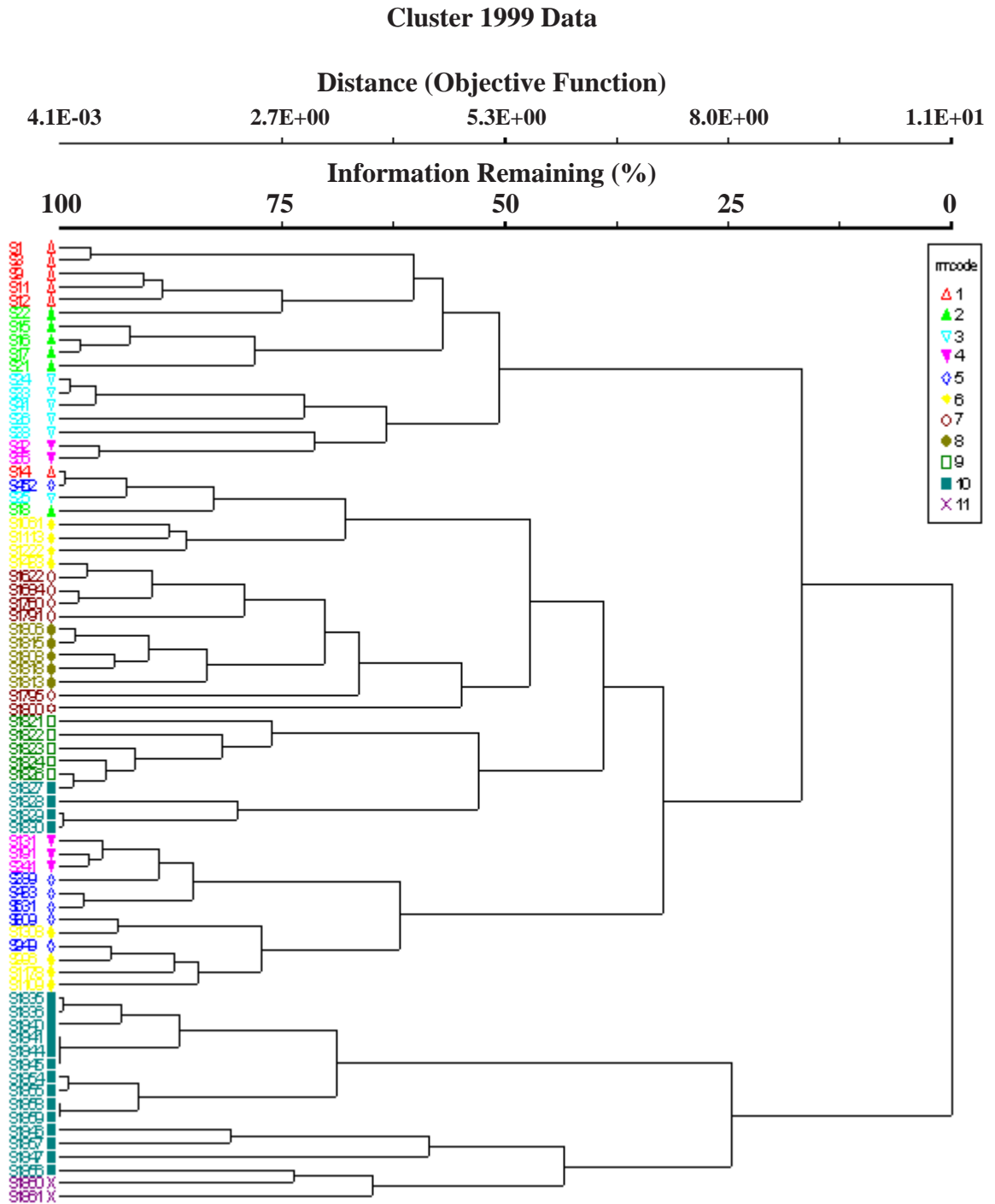
Tables 3 and 4 list species that were significant indicator species for different reaches of the Wabash that reflect HUC-8 watersheds (Table 3) or Level-



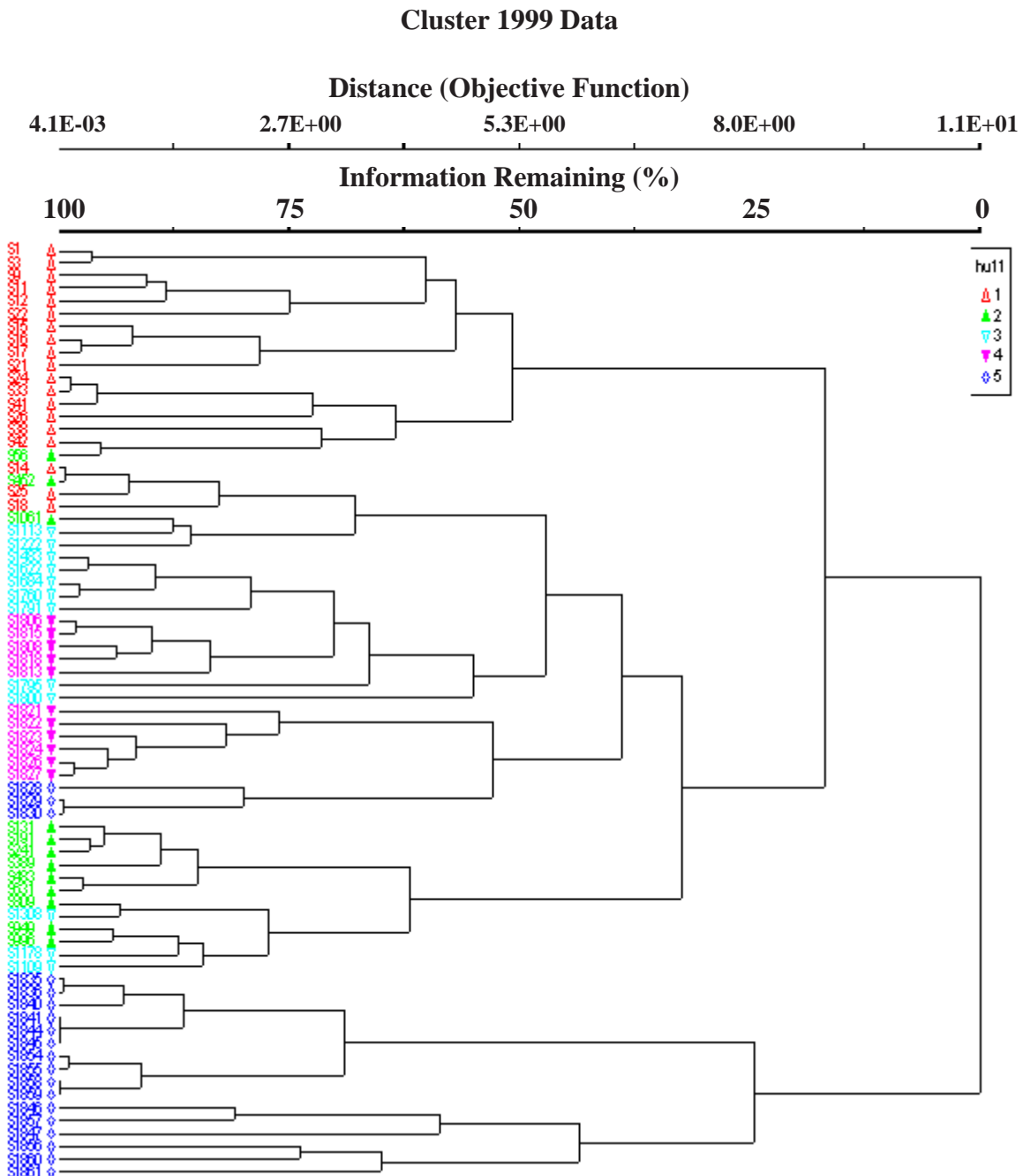
**Figure 3.** Plot of the Ohio boat IBI vs. the Indiana Great River IBI score based on numbers. Data from 1999-2006; excludes wadeable sites.

IV ecoregions (Table 4). High indicator values reflect high likelihood of capture in a watershed or sub-ecoregion relative to other watersheds or subecoregions examined. A value of 100 would indicate a species collected during each collection in one watershed and not captured in another.

The data in these tables reflects several patterns. First, many missing or rare (e.g., large river) species resulted in fewer indicator taxa than may have been expected historically. Species such as the alligator gar or other species associated with backwaters and bayous would have been strongly associated with the lower Wabash River. Second, the species currently identified as being strong indicators are generally of intermediate tolerance (lower watersheds or subecoregions) or tolerant (upper Wabash River) or exotic (e.g., Goldfish). If we had more recent data, silver carp would have been an indicator for the lower river. We would expect substantially different results based on historical data or if watershed improvement results in a reduction of limiting stressors (e.g., nutrients, habitat). In this case we would expect sensitive species to become more reliable indicators along a longitudinal gradient in the Wabash River.



**Figure 4.** Cluster analysis of fish assemblage data from the mainstem of the Wabash River from 1999. Site numbers are coded in 50-mile increments of river miles with the mouth at the top and source at the bottom.



**Figure 5.** Cluster analysis of fish assemblage data from the mainstem of the Wabash River from 1999. Site number are coded in level 4 ecoregions where 1 & 2 are from the Interior River Lowland Level 3 ecoregion: 1 = Wabash Bottomlands; 2 = Glaciated Wabash Lowlands; and 3-5 are from the Eastern Cornbelt Plains Level 3 ecoregion: 3 = Loamy, High Lime Till Plains; 4 = Clayey, High Lime Till Plains (boatable sites) and 5 = Clayey, High Lime Till Plains (wadeable sites and headwaters).

**Table 3.** Indicator species analyses by HUC-8 watershed for fish assemblage data from the Wabash River mainstem collected during 1999. Data collected by Indiana DNR in Indiana with boat methods and by Ohio EPA with wade-able methods. Species for which randomization test indicates a species provides significant indicator values for a Huc-8 watershed reach along the Wabash River mainstem. Letters after names indicate species tolerance (I – Intolerant, S- Sensitive, T – Tolerant).

Species (Latin Name)	Indicator Value	Randomized Mean	P Value
Lower Wabash (05120113)			
Goldfish ( <i>Carassius auratus</i> ) - T	56.8	18.4	<0.001
Blue Catfish ( <i>Ictalurus furcatus</i> )	27.3	9.7	0.016
Quillback Carpsucker ( <i>Carpionodes cyprinus</i> )	37.2	22.9	0.006
Mississippi Silvery Minnow ( <i>Hybognathus nuchalis</i> )	40.2	14.8	0.013
Middle Wabash-Busseron (05120111)			
No species	-	-	-
Middle Wabash-Little Vermilion (05120108)			
Mooneye ( <i>Hiodon tergisus</i> ) - I	39	10.9	0.011
Spotted Bass ( <i>Micropterus punctulatus</i> )	41.3	14.9	0.013
Middle Wabash-Deer (05120105)			
Shovelnose Sturgeon ( <i>S. platyrhynchus</i> )	60.0	13.7	<0.001
Silver Chub ( <i>Macrhybopsis storeriana</i> )	61.7	12.8	0.001
Sauger ( <i>Sander Canadensis</i> )	55.2	15.5	0.016
Blue Sucker ( <i>Cycleptus elongates</i> ) - I	31.2	13.7	0.024
River Carpsucker ( <i>Carpionodes carpio carpio</i> )	45.4	17.3	0.004
Largemouth Bass ( <i>Micropterus salmoides</i> )	49.5	15.0	0.002
Highfin Carpsucker ( <i>Carpionodes velifer</i> )	53.8	12.8	0.002
Silver Redhorse ( <i>Moxostoma anisurum</i> )	62.5	15.3	<0.001
Golden Redhorse ( <i>Moxostoma erythrurum</i> )	41.4	19.5	0.004
Emerald Shiner ( <i>Notropis atherinoides</i> )	53.9	17.6	0.002
River Shiner ( <i>Notropis blennius</i> )	62.0	16.3	0.001
Upper Wabash (05120101)			
Green Sunfish ( <i>Lepomis cyanellus</i> ) - T	55.7	19.7	<0.001
Fathead Minnow ( <i>Pimephales promelas</i> ) - T	50.0	15.6	0.003
Yellow Bullhead ( <i>Ameiurus natalis</i> ) - T	50.0	15.4	0.002
Blackstripe Topminnow ( <i>Fundulus notatus</i> )	31.2	13.4	0.033

**Table 4.** Indicator species analyses by Level IV ecoregion for fish assemblage data from the Wabash River mainstem collected during 1999. Data collected by Indiana DNR in Indiana with boat methods and by Ohio EPA with wade-able methods. Species for which randomization test indicates a species provides significant indicator values for level-4 ecoregion reach along the Wabash River mainstem. Letters after names indicate species tolerance (S- Sensitive, T – Tolerant).

Species (Latin Name)	Indicator Value	Randomized Mean	P Value
Wabash Bottomlands [72a]			
Goldfish ( <i>Carassius auratus</i> ) - T	57.2	18.3	<0.001
Mississippi Silvery Minnow ( <i>Hybognathus nuchalis</i> )	52.8	13.8	<0.001
Quillback Carpsucker ( <i>Carpionodes cyprinus</i> )	41.7	25.0	0.002
Steelcolor Shiner ( <i>Cyprinella whipplei</i> )	44.6	23.0	0.001
Glaciated Wabash Lowlands [72b]			
Shortnose Gar ( <i>Lepisosteus platostomus</i> )	45.9	19.9	<0.001
Smallmouth Buffalo ( <i>Ictiobus bubalus</i> )	39.3	11.4	0.002
Flathead Catfish ( <i>Pylodictis olivaris</i> )	44.9	23.0	<0.001
Loamy, High Lime Till Plains [55b]			
Sauger ( <i>Sander Canadensis</i> )	48.2	14.4	< 0.001
Freshwater Drum ( <i>Aplodinotus grunniens</i> )	41.6	24.3	0.002
Shovelnose Sturgeon ( <i>S. platyrhynchus</i> )	36.9	12.2	0.003
Gizzard Shad ( <i>Dorosoma cepedianum</i> )	46.4	21/3	< 0.001
Black Buffalo ( <i>Ictiobus niger</i> )	25.6	8.6	0.008
Longnose Gar ( <i>Lepisosteus osseus</i> )	53.2	14.8	<0.001
Smallmouth Bass ( <i>Micropterus dolomieu</i> ) - S	55.6	14.5	<0.001
Spotted Bass ( <i>Micropterus punctatus</i> )	36.0	13.6	0.005
River Carpsucker ( <i>Carpionodes carpio carpio</i> )	64.3	16.7	<0.001
Silver Redhorse ( <i>Moxostoma anisurum</i> )	56.0	14.3	<0.001
Emerald Shiner ( <i>Notropis atherinoides</i> )	40.6	17.0	0.003
River Shiner ( <i>Notropis blennioides</i> )	35.3	15.4	0.006
Clayey, High Lime Till Plains [55a]			
Green Sunfish ( <i>Lepomis cyanellus</i> ) - T	67.7	20.2	<0.001
Fathead Minnow ( <i>Pimephales promelas</i> ) - T	51.6	14.5	<0.001
Yellow Bullhead ( <i>Ameiurus natalis</i> ) - T	51.6	14.4	<0.001
Blackstripe Topminnow ( <i>Fundulus notatus</i> )	32.3	11.8	0.006
Longear Sunfish ( <i>Lepomis megalotis</i> )	39.7	18.3	0.004
Creek Chub ( <i>Semotilus atromaculatus</i> ) - T	41.9	13.0	<0.001
Suckermouth Minnow ( <i>Phenacobius mirabilis</i> )	34.3	15.0	0.008
White Sucker ( <i>Catostomus commersoni</i> ) - T	41.3	16.6	0.002
Bluntnose Minnow ( <i>Pimephales notatus</i> ) - T	43.7	17.6	0.001

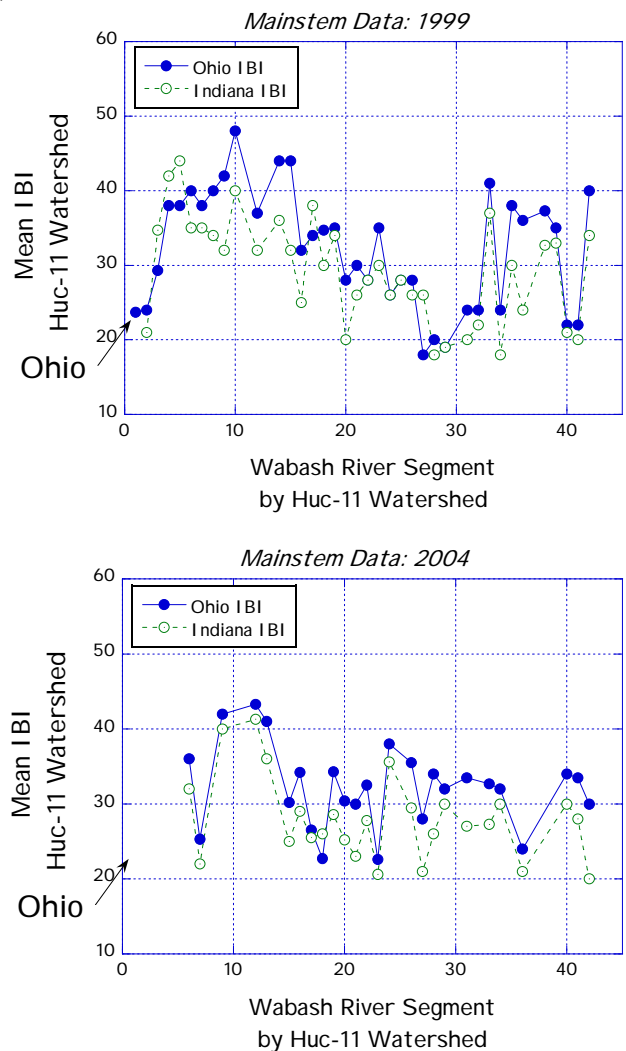
### Longitudinal Patterns in Fish Assemblage Condition

As an initial step in understanding biological conditions and patterns of biodiversity in the Wabash River we examined longitudinal plots of indices and metrics vs. river reach for key indicators. Previous work examining temporal trends in fish assemblages in the Wabash River found that there was significant variation when examining trends at individual sites, but stronger trends were identified when examining data at a reach scale (Pyron et al. 2006). Based on this much of the assessments we conducted were done at a reach scale, defined by HUC-8 or HUC-11 watersheds.

Plots of the Indiana and Ohio IBIs by HUC-11 watershed segment in 1999 identified a trend of increasing IBIs in the upper watershed as the river left Ohio, a peak in scores in the high gradient reaches of the Wabash at the downstream end of HUC-8 watershed 05120101 and in watershed 05120105, and then a steady decline until the lower reach of the river where scores rebounded slightly (Figure 6, top). This pattern was less pronounced with less of a dip in the middle river, but generally similar in 2004 (Figure 6, bottom). Ohio data was not collected in 2004, however, streams are likely still very degraded.

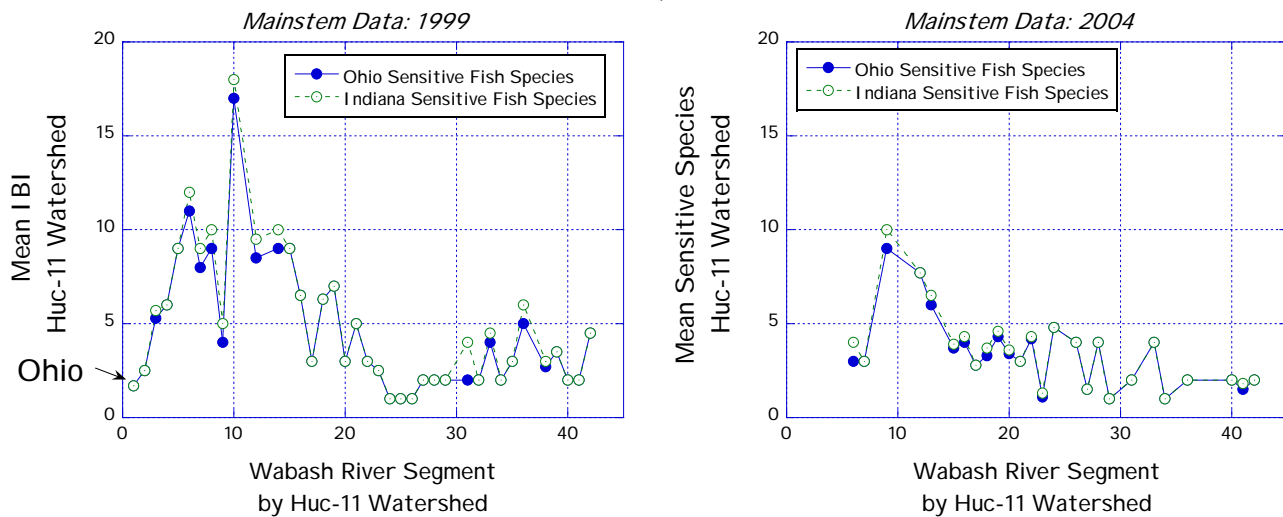
Studies by Gammon and Simon (2000) and Pyron et al. (2008) using historical data from the middle Wabash River available in this study, but not represented on the graphs in Figure 6 showed the same trend for the middle part of the Wabash. This pattern is higher IBIs in the upper reaches of the middle Wabash and a steady decline downstream. They did not extend their analyses to the lower river where we detected an increase, nor did they have data from the upper river.

To help characterize the biological basis of this pattern we plotted the number of sensitive species with river mile, using both the Ohio and Indiana lists for the same two years of data (Figure 7). Sensitive fish species lists were, as expected were very similar and patterns are nearly identical for these variables. The 1999 data reflected a higher peak at HUC-11 watershed 05120105010 (middle Wabash River with Burnetts Creek and Crooked Creek) which was not sampled in 2004 otherwise the pattern would have been similar. Segments 24-26 (05120111-050, -070, and 090) showed the fewest sensitive fish species



**Figure 6.** Plots of mean mainstem IBIs by HUC-11 watershed segments of the Wabash River for fish assemblage data collected during 1999 (top) and 2004 (bottom). Data in 1999 was largely collected in Indiana by IN DNR and in Ohio by Ohio EPA. IBIs depict Ohio boatable versions (solid circles) and Indian Large and Great River IBI versions (open circles).

during 1999, which was low, but not as low in 2004. In any case the pattern mirrored that of the IBI with a much degraded Ohio reach extending its effects into Indiana, a much higher number of sensitive species in the lower portions of the upper HUC-8 watershed (05120101) and through the HUC-8 watershed (05120105) which reflected higher gradient reaches of the river and better habitat and a gradual decline downstream. The pattern is not exactly the same in the very lower Wabash River; however, some of the site locations are not exact duplicates. Another confounding factor in the lower river between 1999 and 2004 included some methodological sampling



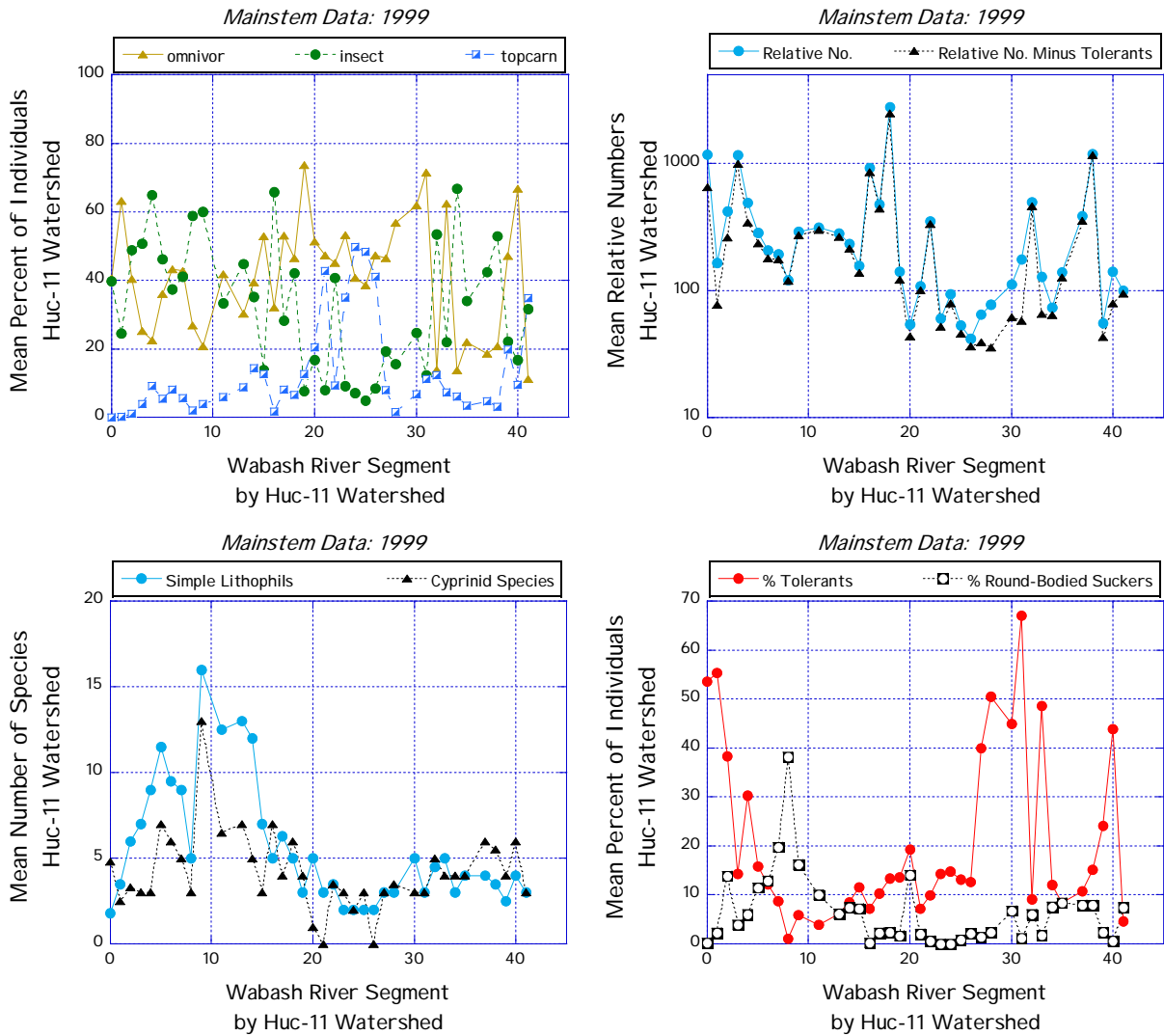
**Figure 7.** Plots of mean mainstem sensitive fish species by HUC-11 watershed segments of the Wabash River for fish assemblage data collected during 1999 (top) and 2004 (bottom). Data in 1999 was largely collected in Indiana by IN DNR and in Ohio by Ohio EPA. Sensitive fish species used for IBI metrics for Ohio IBIs (solid circles) and Indian Large and Great River IBIs (open circles).

differences. The 1999 had longer sampling distances; however, the 2004 data was collected at night in the lower Wabash which has been shown to capture more species in very large rivers (e.g., the Ohio River) that have diel movements into shoreline areas at night (Sanders 1992; Seegert 2000). With both collection methods sensitive species were low in the lower Wabash River (generally less than five species).

*Other Metrics*

Figure 8 depicts longitudinal plots for a number of other important IBI metrics including percent tolerants, total relative number (per km), relative number minus tolerants, percent round-bodied suckers, percent insectivores, number of simple lithophil species, cyprinid species, percent omnivores, and percent top carnivores.

The largest number of top carnivores were found in the middle reaches of the Wabash River (Figure 8, top, left) between segments 20-27 which also corresponds to the segments with the lowest total relative abundance of fish (Figure 8, top right), fewest cyprinids (Figure 8, bottom, left) and fewest round-bodied suckers (Figure 8, bottom, right). Percent of fish as tolerants peaked at the upper two segments, segments 27-33, and segment 40 (Figure 8, bottom right).



**Figure 8.** Plots of mean mainstem IBI metrics by HUC-11 watershed segments of the Wabash River for fish assemblage data collected during 1999. Metrics include omnivores, top carnivores and insectivores (top left); relative number and relative number excluding tolerants (top right), simple lithophils and cyprinid species (bottom left) and relative numbers and relative numbers excluding tolerants (bottom right). Data in 1999 was largely collected in Indiana by IN DNR and in Ohio by Ohio EPA.

*Stressors in the Wabash River Mainstem*

An initial step in identifying patterns of stressors along the mainstem Wabash River is to examine the longitudinal plots of stressor distribution from upstream to downstream. The plots we will discuss in this section will be plots of variables vs. river mile or HUC-11 watershed. Summarizing data by HUC-11 watershed reduces variability due to small samples sizes that might occur when individual sites are used. These plots illustrate data from upstream (left) to downstream (right).

*Habitat*

We treat stream habitat first because it represents the basic “environmental infrastructure” for the aquatic environment. It has been repeatedly found to be a key explanatory variable for fish and other organism groups in the Midwest (Rankin 1995, Rankin and Armitage 2004), and specifically in Indiana (Lau et al. 2006, Sullivan et al. 2004). The extensive change in land use from forested/wetland/

prairie landscapes to heavily agricultural land uses has exerted a strong impact on stream habitats throughout the Midwest.

Prior to settlement human impacts on habitat were likely very localized and did not approach the magnitude of change that occurred with European settlement. European farmers brought with them extensive experience with drainage of land to allow productive agricultural row crops. The father of modern geology, John Smith, for example, made most of his living from drainage and canal construction in England. These direct modifications to stream habitat had effects on the biological condition as they became widespread, accumulated in watersheds, and also influence the export of flow, nutrients and sediments into waterways.

Direct data on historical habitat features does not exist in any quantitative form, however, based on early explorers, biologists, and settlers writings (see Gammon

**Table 5.** Reconstructed historical estimation of habitat conditions in six reaches of the mainstem Wabash River, circa 1800. The reconstruction of this QHEI assumes conditions during early settlement of the Wabash River Valley in the 1800s and is provided as an “anchor” for interpreting habitat conditions. Feasible goals for habitat rehabilitation would likely be somewhere between these values and existing values shown in later tables.

River Mile	QHEI Metrics							Gradient (Score)	Narrative
	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle		
<b>HUC-8: 05120113</b>									
Year: 1800*									
113.0	93.5	19.0	22.0	19.0	10.0	12.0	7.5	0.50 - (6)	Excellent
<b>HUC-8: 05120111</b>									
Year: 1800*									
111	92.5	18.0	22.0	19.0	10.0	12.0	7.5	0.50 - (6)	Excellent
<b>HUC-8: 05120108</b>									
Year: 1800*									
108	93.5	19.0	21.0	19.0	10.0	12.0	7.5	0.50 - (6)	Excellent
<b>HUC-8: 05120105</b>									
Year: 1800*									
105	98.5	21.0	22.0	19.0	10.0	12.0	7.5	3.00 - (10)	Excellent
<b>HUC-8: 05120101-HW</b>									
Year: 1800*									
101	84.0	17.0	20.0	18.0	10.0	9.0	0.0	1.40 - (10)	Excellent
<b>HUC-8: 05120101-DST</b>									
Year: 1800*									
102	99.0	20.0	21.0	19.5	10.0	12.0	7.5	5.00 - (10)	Excellent

\* Historical Wabash River - "Natural"

1998) we were able to reconstruct what a “historical” QHEI may have looked like in different reaches of the Wabash River mainstem circa 1800 (Table 5).

With the exception of one small headwater site which had a QHEI score in the 80s, all of the other QHEI scores would score in the 1890s and be considered excellent habitat. It is likely that there would have been moderate variation in these numbers, however with intact vegetation, a natural flow regime, clear water, abundant aquatic vegetation, and mature bottomland, riparian woodlands lower scores would likely have been an exception to the rule.

Current mainstem habitat conditions, averaged by HUC-11 watersheds are illustrated in Figure 9. Habitat conditions were poor in Ohio where channelization on the mainstem is extensive and improved as the Wabash River flows into Indiana. The highest scores were located in the lower portions of HUC-8 watershed 05120101 (upper Wabash River) and 05120105 (middle Wabash River and Deer Creek). Habitat was rather mediocre through out the remainder of the river with scores ranging from the 50s and low 60s (fair to good), especially compared to historical estimates.

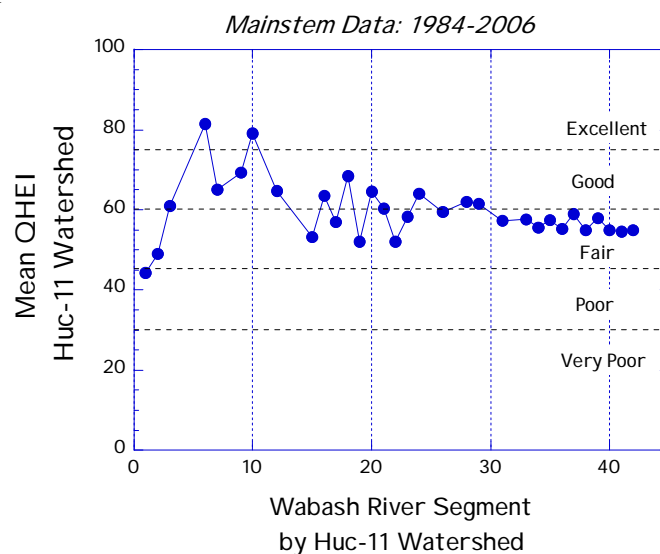
Plots of individual QHEI metrics are illustrated in Figure 10. With the exception of some of the HUC-11 segments within HUC-8 05120105 (middle Wabash and Deer Creek), most of these metrics

would be considered mediocre for such a large free-flowing river, especially in comparison to the reconstructed QHEI scores summarized in Table 5.

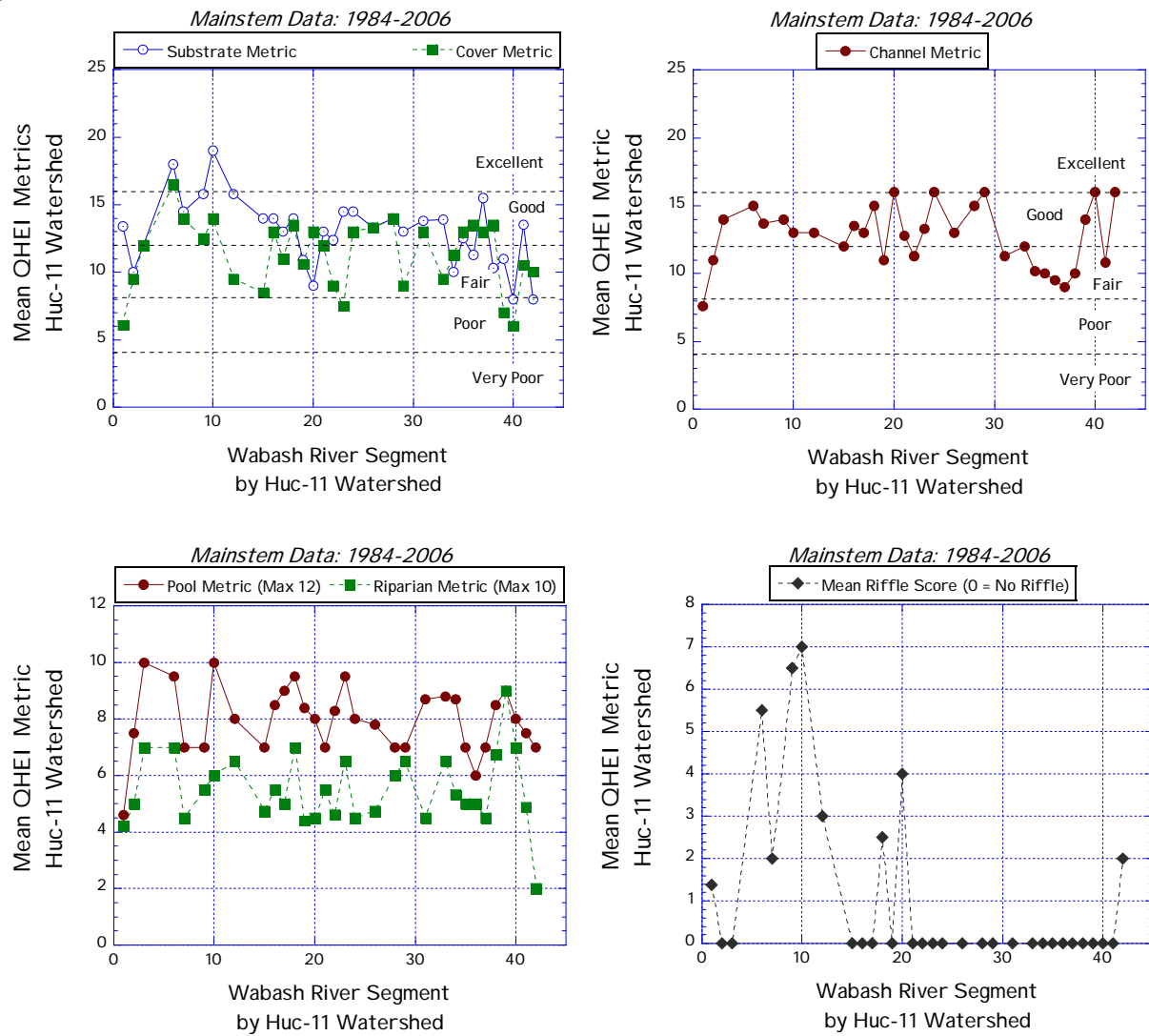
Three metrics in particular characterize habitat limitations in the mainstem: cover, riparian conditions, and the riffle metric. The riparian metric would be considered fair at best at most sites. This is related to loss of riparian forests and encroachment by agriculture and other land uses close to the banks of the river. Many sites have little or no riparian width. The mediocre condition of the riparian zones influences the instream cover metric by reducing the population of large stable wood and woody debris along the margins of the river. The low cover score is also influence by the loss of aquatic macrophyte growth that used to be relatively abundant in the river, but is now inhibited by high TSS, turbidity and potentially more scouring storms that act to remove aquatic plants or prohibit them from colonizing gravel bars. This more flashy flow regime documented in the Wabash River (Pyron et al. 2008) may also act to inhibit establishment of riffles and islands in the river. The riffle metric was not scored at many sites because riffles were not present.

*Correlation of IBI scores and QHEI*

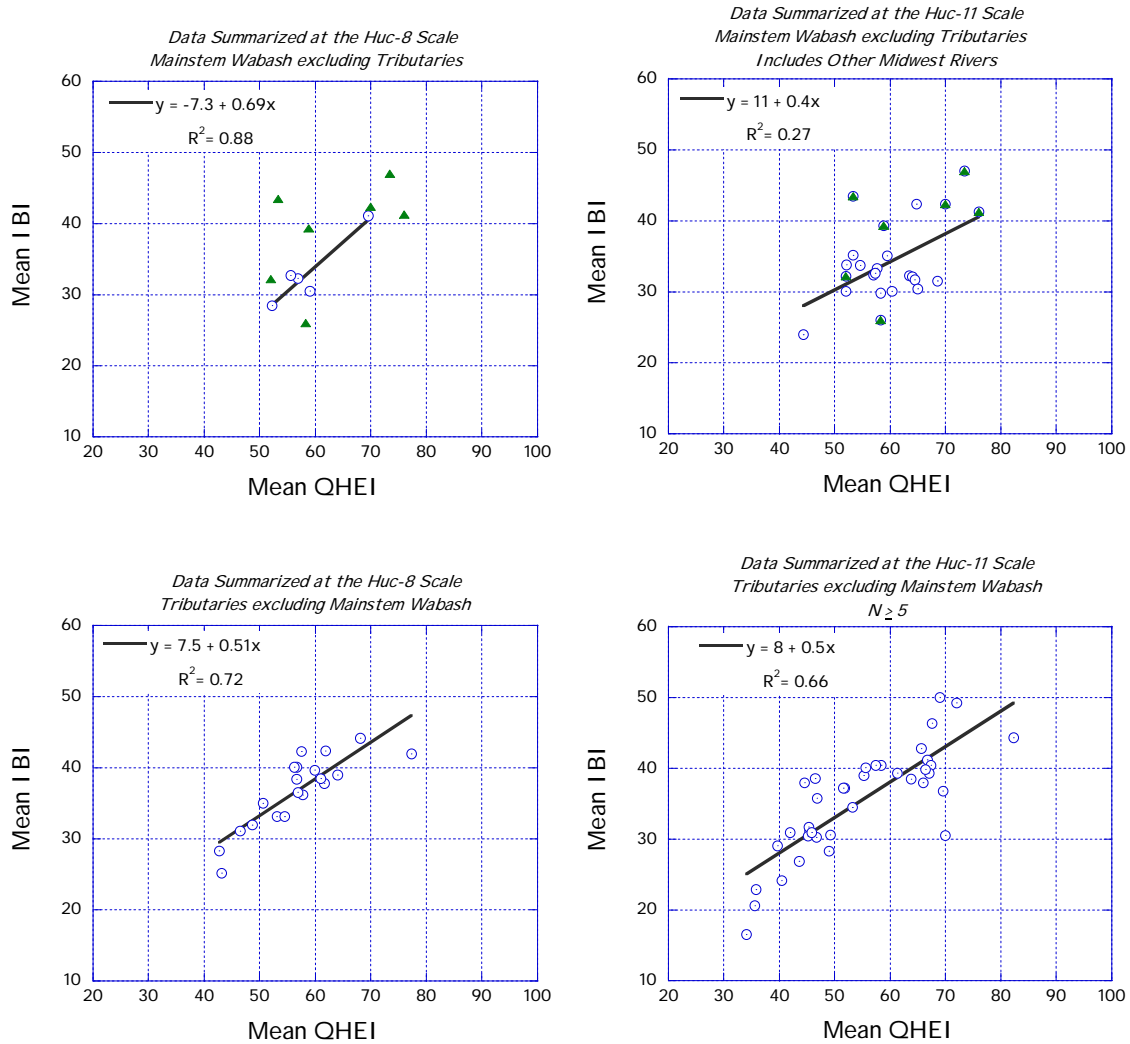
Mean QHEI at the HUC-11 and HUC-8 scale for the mainstem are strongly correlated with the mean IBI scores at these same watershed scales (Figure 11, top). Similarly, mean QHEI scores at these scales



**Figure 9.** Plots of mean mainstem QHEI score by HUC-11 watershed segments of the Wabash River for all years. Data extended back into the 1980s in the Ohio portion of the river (most upstream site), but otherwise dates from late 1990s to 2006.



**Figure 10.** Plots of mean mainstem QHEI metrics by HUC-11 watershed segments of the Wabash River for all years. Data extended back into the 1980s in the Ohio portion of the river (most upstream site), but otherwise dates from late 1990s to 2006.



**Figure 11.** Plots of mean QHEI vs. mean IBI for the Wabash River mainstem at the HUC-8 watershed scale (top, left) and HUC-11 watershed scale (top, right) and for Wabash River tributaries (excluding mainstems data) at the HUC-8 watershed scale (bottom, left) and HUC-11 watershed scale (bottom, right). Green triangles on top graphs represent some other Midwest data (Wisconsin River, St Croix River, Illinois River, Scioto River, Minnesota River and Muskingum River). Data included in HUC-11 regression analysis.

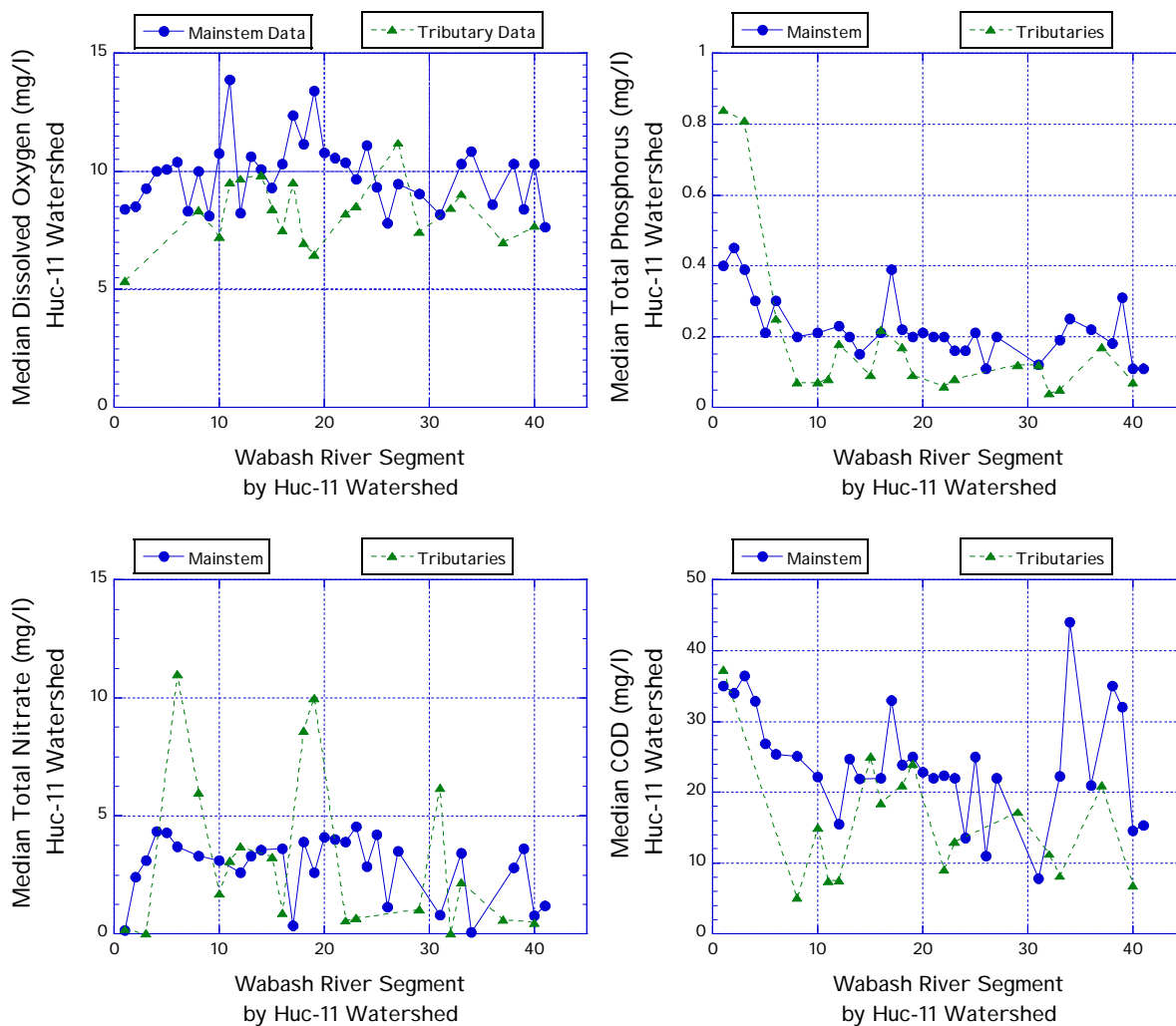
from tributaries (excluding mainstem sites) are also highly correlated (Figure 11, bottom). These are very strong correlations for field-derived data underscoring the importance of habitat conditions being an important determinant for biological performance and diversity.

### Chemical Stressors

We derived narrative ranges for each chemical parameter that incorporate median values, but also deviations compared to various percentile values found at reference sites or sites meeting the Ohio WWH habitat aquatic life use for wadeable (tributary data) or boatable rivers (mainstem Wabash River) (Ohio EPA 1999). This is not designed to take the place of the

water quality criteria, but is rather a risk-based assessment of values compared to deviation to “reference” or background. The greater the deviation from these values the greater the possibility of effect. These can be useful in a weight-of-evidence approach to help explain biological impairment.

For most of the chemical stressors in the mainstem of the Wabash River there is a general pattern of high stressor levels in the upper reaches of the Wabash River in Ohio and Indiana and a reduction or a “leveling off” of stressor levels in downstream reaches (Figures 12-15). Each of the graphs in Figures 12-15 has median chemical concentrations by HUC-11 watershed for both the mainstem (solid

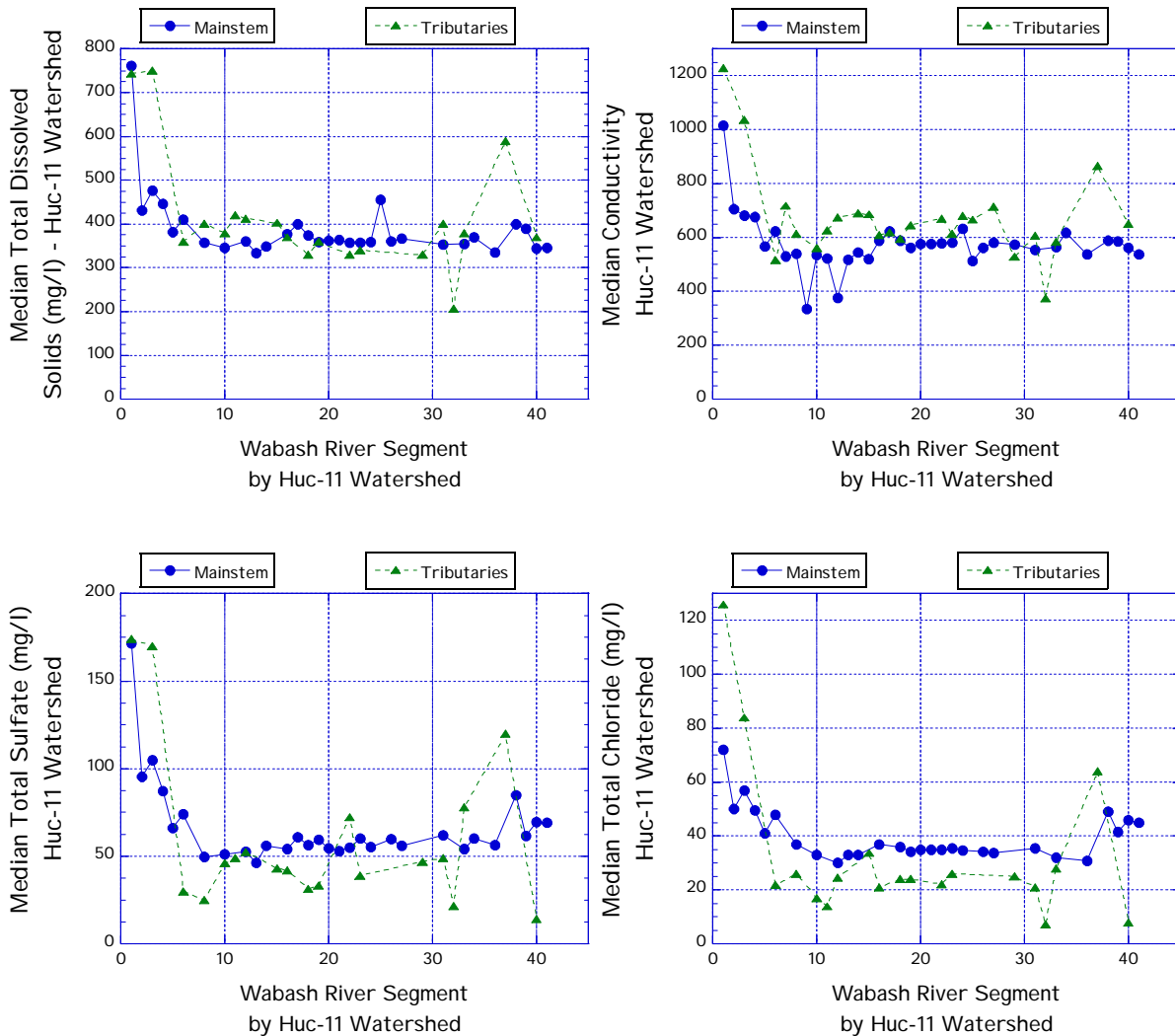


**Figure 12.** Plots of median water chemistry values vs. Wabash River mainstem HUC-11 watershed segment for mainstem (solid circles) and tributaries (green triangles) including dissolved oxygen (top, left), total phosphorus (top, right), total nitrate (bottom, left) and COD (bottom, right). Data obtained from IDEM and collected from 1996 to 2006.

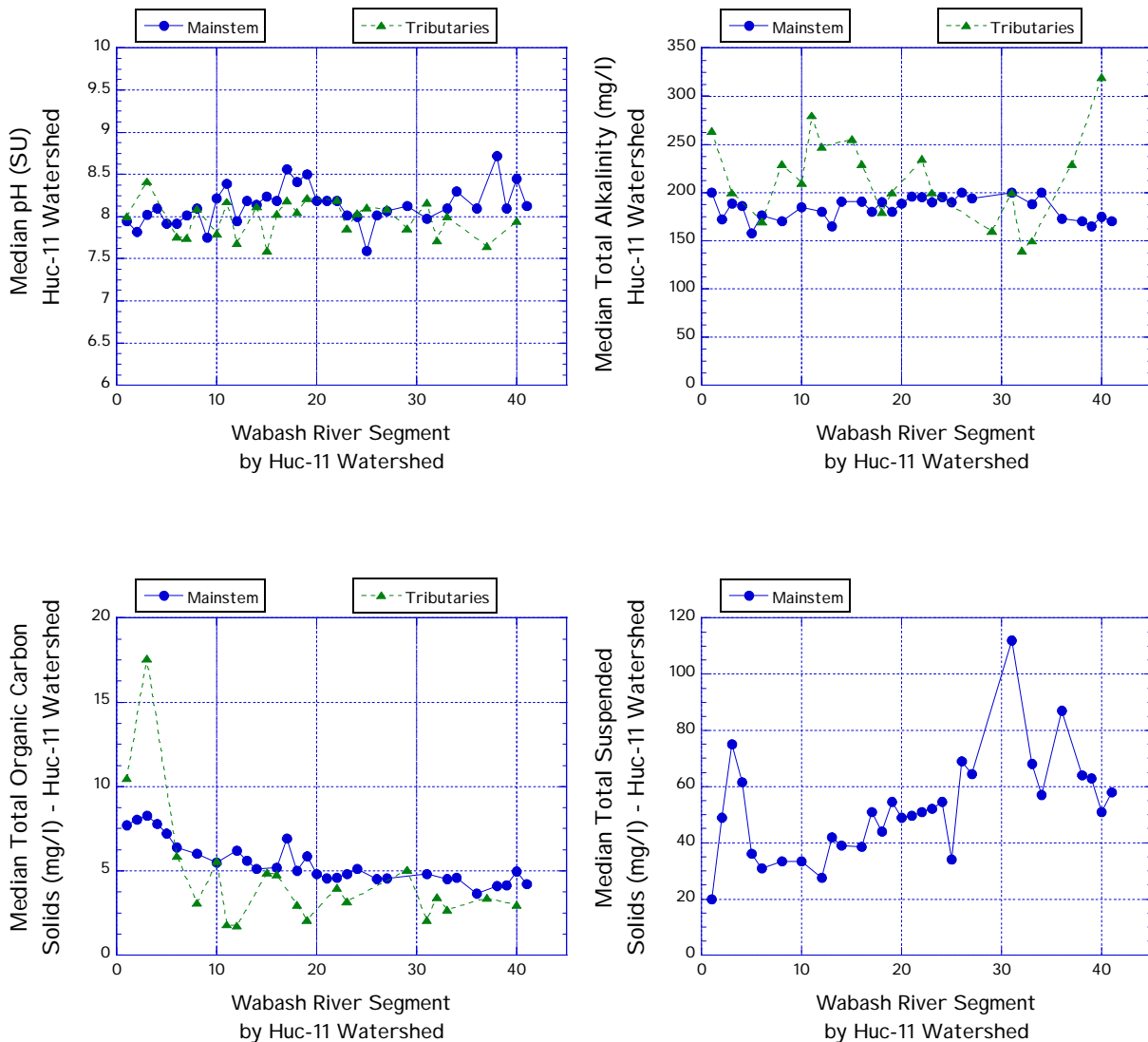
blue dots) and for the tributaries in that watershed (green triangles). The strong enrichment effect of the upper watershed is evident in each of the graphs in Figure 12: for dissolved oxygen, total phosphorus, nitrate and COD. Figures 12-15 represent median values within each HUC-11 watershed. The elevated nutrient conditions in many of the Upper Wabash River watersheds agreed with a USGS study, which concluded that nutrient values they measured would exceed proposed U.S. EPA criteria based on nutrient ecoregions (Leer et al. 2007).

Figure 13 represents parameters that measure various dissolved constituents in water: total dissolved solids (upper, left), conductivity (upper, right), total sulfate (upper, left), and total chloride (upper, right). These parameters show a similar pattern of high values in the upper Wabash and a leveling off for most of the rest of the river. There is an increase at a tributary reach in the lower river; however this HUC-11 has a small sample size.

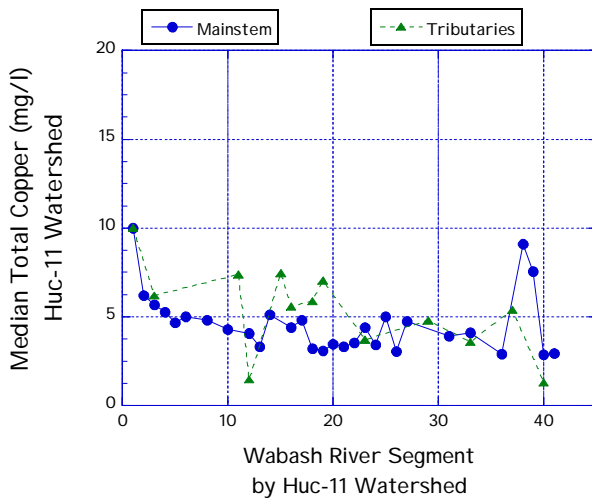
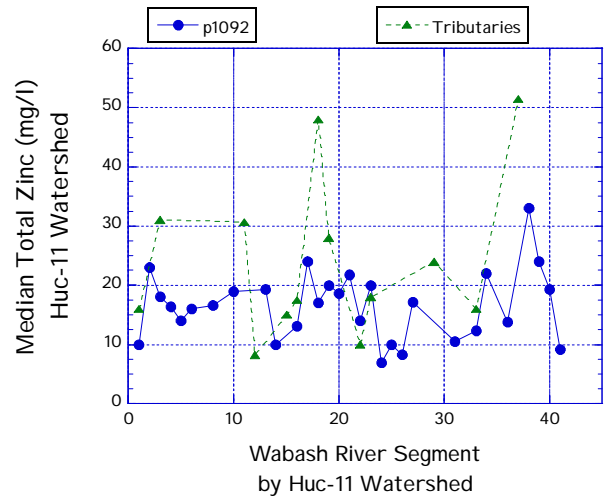
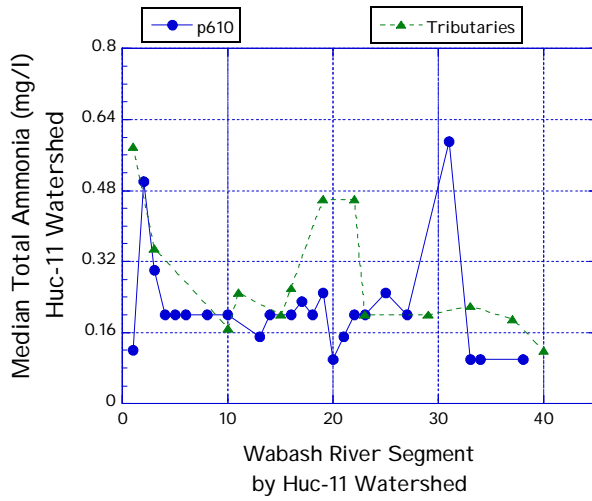
Total organic carbon (TOC) shows a steady decline along the river from upstream to downstream (Figure 14, lower, left) while total suspended solids show a gradual increase from upstream to downstream (Figure 14, lower, right). This matches the pattern observed by Gammon (1998) that he attributed to increasing algal production with downstream distance in the Wabash River mainstem.



**Figure 13.** Plots of median water chemistry values vs. Wabash River mainstem HUC-11 watershed segments for mainstem (solid circles) and tributaries (green triangles) including TDS (top, left), conductivity (top, right), total sulfate (bottom, left) and total chloride (bottom, right). Data obtained from IDEM and collected from 1996 to 2006.



**Figure 14.** Plots of median water chemistry values vs. Wabash River mainstem HUC-11 watershed segments for mainstem (solid circles) and tributaries (green triangles) including pH (top, left), alkalinity (top, right), total organic carbon (bottom, left) and total suspended solids (bottom, right). Data obtained from IDEM and collected from 1996 to 2006.



**Figure 15.** Plots of median water chemistry values vs. Wabash River mainstem HUC-11 watershed segments for yr mainstem (solid circles) and tributaries (green triangles) including total ammonia (top, left), total zinc (top, right), and total copper (bottom, left). Data obtained from IDEM and collected from 1996 to 2006.

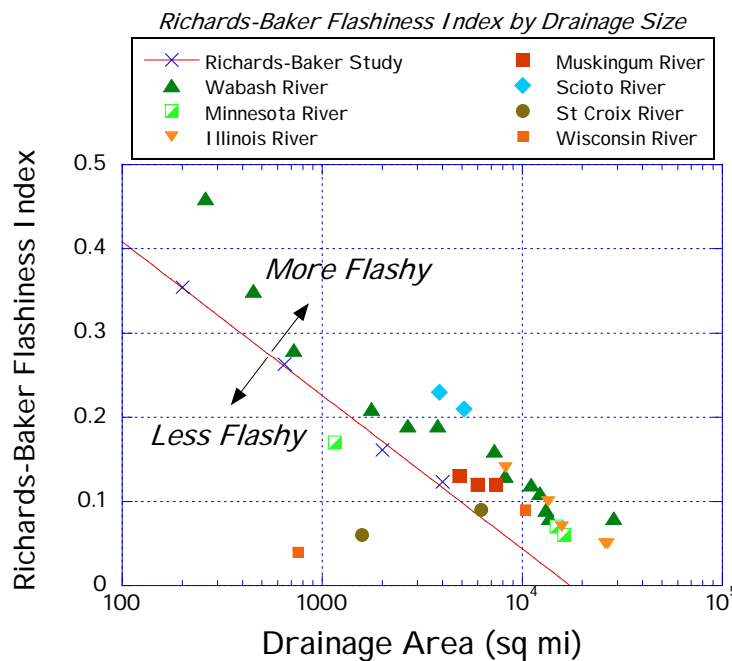
### Flow Stressors

We were not able to analyze the flow data for the entire Wabash River watershed in as much detail as we would have liked. We calculated the Richards-Baker flashiness index (R-B Index) for USGS gage sites on the mainstem of the Wabash River and a series of other Midwest Rivers for which we had fish and QHEI data: Wisconsin River, St. Croix River, Minnesota River, Illinois River, Scioto River and the Muskingum River. We also calculated a subset of flow indicators known as the Indicators of Hydrological Alteration (Richter et al. 1996) that are thought to be of importance aquatic communities. The term flashy refers to streams where flow quickly increases after rainfall events and then falls quickly as well. The R-B Index is influenced by stream size with larger rivers being naturally less flashy than small streams, so values of the R-B Index need to be considered relative to drainage size.

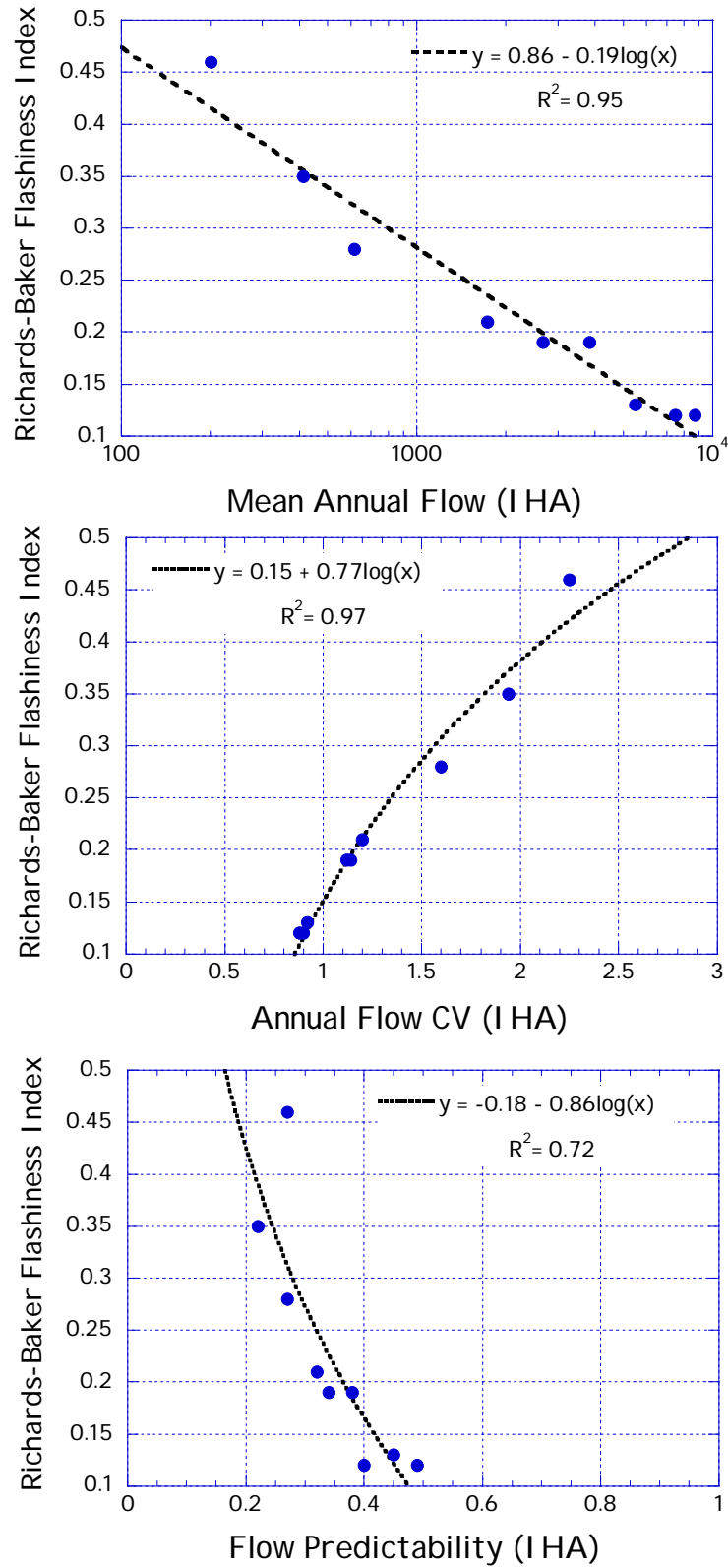
Figure 16 is a plot of the average R-B Index for mainstem Wabash River gages vs. drainage area along with median values for Midwest Rivers from a study of Baker et al. (2004). Sites above this median line are considered flashier and sites below less flashy.

The upstream site on the Wabash River deviates the most from this line and reflects the extensive agricultural drainage upstream of this site. Lower Wabash River sites are still flashier than the median values of Baker et al. (2004) even with regulation of flow by dams on some of the tributaries to the Wabash (Salamonia, Mississinewa, etc.).

In a study on the Middle Wabash River, Pyron and Lauer (2004) used a multivariate correspondence analyses (CA) and found that river location, average daily discharge, or CV of daily discharge was correlated with the ordination axis that explained much of the variation in the fish assemblages. We were not able to generate all of these statistics because of time constraints; however we did generate these statistics for a subset of gages and found strong correlations between the R-B Index and the same IHA variables that Pyron and Lauer found to be important. Because we had insufficient data to add to the multivariate analyses we will use this data, along with the patterns found by Pyron and Lauer (2004) in our weight of evidence stressor identification process for the entire watershed and for individual HUC-11 watersheds.



**Figure 16.** Plot of the R-B index for gage sites on the Wabash River and other Midwest Rivers vs. drainage area in sq mi. The line on the graph reflects a relationship between median values from Midwest Rivers from a study of the Richards et al. (2004).



**Figure 17.** Plots of the R-B index for gage sites on the Wabash River and other Midwest Rivers vs. three variables generated as part of the Indicators of Hydrologic Alteration (IHA) : Mean Annual Flow (top); Coefficient of Variation of Annual Flow (middle) and Flow Predictability (bottom).

*Stressor Identification Using Multivariate Analyses*  
 As discussed in the methods we generally followed the steps of the WERF-published Integrated Impact Analysis (IIA) as outlined by Paulson et al. (2001) to discriminate among key stressor values in the Wabash River mainstem. Because we had so many stressor values we conducted a series of PCA analyses to reduce the number of variables to consider. We first conducted PCAs by stressor category, and then combined significant variables into a combined PCA to further reduce key variables. Where variables were highly correlated

we selected ones considered to be most biologically meaningful.

*Water Chemistry Variables*

We conducted a PCA on water chemistry variables summarized at the HUC-11 scale (mainstream data) or HUC-8 scale (upstream data) that was log transformed. Some HUC-11 watersheds had insufficient data collected within them and were dropped. The PCA identified three significant vectors that explained 76.9% on the variance in the water chemistry.

**Table 6.** PCA analyses of water chemistry data for the mainstem Wabash River at the HUC-11 scale and as Huc-11 data representing upstream, tributary data. Variables included with coefficients > 0.75.

Variable	Eigenvector		
	1	2	3
Mainstem Huc-8 Data			
COD	-0.81		
TP	-0.97		
Conductivity	-0.88		
TKN	-0.97		
Chloride	-0.84		
Sulfate	-0.90		
Nitrate		0.91	
TA		0.94	
DO		0.97	
TSS	-0.96		
Upstream Huc-8 Data			
TP	-0.92		
Conductivity	-0.84		
TKN	-0.91		
Sulfate			0.91
Zinc		-0.82	
DO		0.81	
Hardness	-0.82		
Mainstem Huc-11 Data			
Sulfate	-0.76		
TOC	-0.78		

**Table 7.** PCA analyses habitat data for the mainstem Wabash River at the HUC-11 scale and Huc-8 scale and as Huc-8 data representing upstream, tributary data. Variables included with coefficients > 0.75.

Variable	Eigenvector		
	1	2	3
Mainstem Huc-8 Data			
QHEI	0.89		
Pool	0.82		
Channel	0.93		
Gradient (ft/mi)	-0.88		
Riffle		-0.91	
Gradient Score			-0.89
Upstream Huc-8 Data			
QHEI	0.98		
Substrate	0.87		
Cover	0.96		
Pool	0.91		0.91
Riffle	0.88	-0.82	
Riparian	0.81	0.81	
Channel	0.99		
Mainstem Huc-11 Data			
Riffle		-0.79	

**Table 8.** PCA analyses habitat data for the mainstem Wabash River at the HUC-11 scale and Huc-8 scale and as Huc-8 data representing upstream, tributary data. Variables included with coefficients > 0.75.

Variable	Eigenvector		
	1	2	ns
Huc-11 Scale Data			
Percent Ag.	-0.77		
Percent Wetland		-0.76	
Huc-8 Scale Data			
Percent Ag	-0.93		
Percent Forest	0.89		
Percent Drained	-0.72		

**Table 9.** PCA analyses for all stressor data for the mainstem Wabash River at the HUC-11 scale and HUC-8 scale and as HUC-8 data representing upstream, tributary data. Variables included with coefficients > 0.75.

Variable	Eigenvector		
	1	2	3
Mainstem Huc-8 Data			
QHEI	0.73		
Pool	0.98		
Channel	0.98		
Gradient (ft/mi)	-0.99		
Riffle		-0.83	
Sulfate	-0.97		
Chloride	-0.99		
TKN	-0.97		
TP	-0.90		
COD	-0.97		
Gradient Score			-0.89
Upstream Huc-8 Data			
DO		-0.92	
TSS	-0.93		
Chloride	-0.90		
TKN	-0.90		
TP	-0.93		
QHEI	0.78		
Cover	0.75		
Pool	0.87		
Riffle		-0.82	
Riparian	0.93	0.81	
Channel	0.89		
Gradient Score			-0.99
Mainstem Huc-11 Data			
Riffle		-0.79	

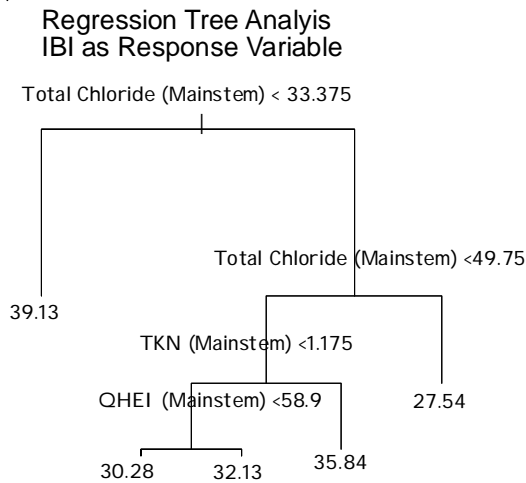
*Regression Tree Analysis*

We performed regression tree analyses on stressors that were important on the basis of PCA analyses and obtained several regression trees using mainstem IBI scores and mainstem sensitive fish species as dependent variables. A regression tree identified the best splits to maximize the explanatory power of the response variables (by creating homogeneous subsets). Results include the variables and values of these variables on which nodes split and the end of the nodes show the mean value for that node.

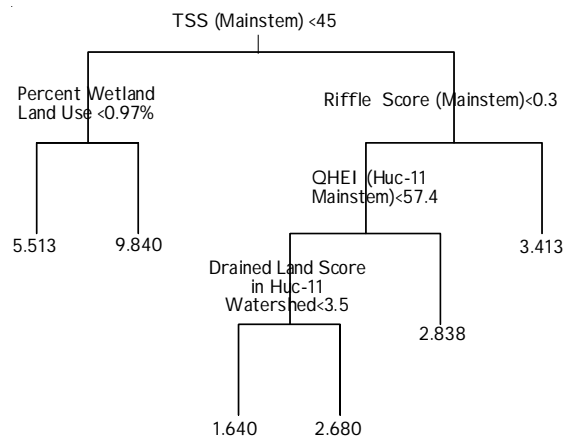
The first node in the IBI regression tree split on total chloride (Figure 18). Sites with lower average total chloride at the Huc-8 level in the mainstem had higher IBI scores. Subsequent splits in explaining IBI scores occurred again with total chloride in the mainstem, TKN nitrogen, and then overall QHEI scores. The lowest IBI

scores occurred where total chloride was > 49.75 and the highest where total chloride was < 33.375. There is a high degree of colinearity in some of these variables, but they are generally reflecting a gradient of chemical concentration from upstream to downstream and then habitat quality within the river which is highest in Huc-8 watershed 05120105.

Regression tree analyses using sensitive fish species as the dependent variable resulted in an ecologically similar tree, even though the specific variables changed. In this tree the first split occurred with TSS which increases from upstream to downstream in the mainstem Wabash River (see Figure 16, lower, right). This is, except for the Ohio portion of the Wabash River, the opposite pattern for sensitive species which are highest in the upper Wabash (again, excluding the headwater reaches) and generally decline with downstream distance.



**Figure 18.** Regression tree results using the mainstem average HUC-11 IBI scores and the stressor variables identified as useful from the PCA analyses.



**Figure 19.** Regression tree results using the mainstem average HUC-11 sensitive fish species and the stressor variables identified as useful from the PCA analyses.

## Conclusions and Recommendations

Both simple correlation analyses and more complex multivariate analyses point to habitat mediated export of suspended and dissolved materials and direct habitat losses in the mainstem Wabash River as key stressors limiting aquatic life in the Wabash River watershed. Habitat effects are generally very strong indicating that various mechanisms that limit habitat diversity, both direct and indirect are key stressor to prioritize for rehabilitation. Part 2 of this document focuses on more site and watershed-specific data to identify which habitat, chemical, or other indicator (e.g., land use) is limiting aquatic conditions in the various reaches of the Wabash and lower White Rivers.

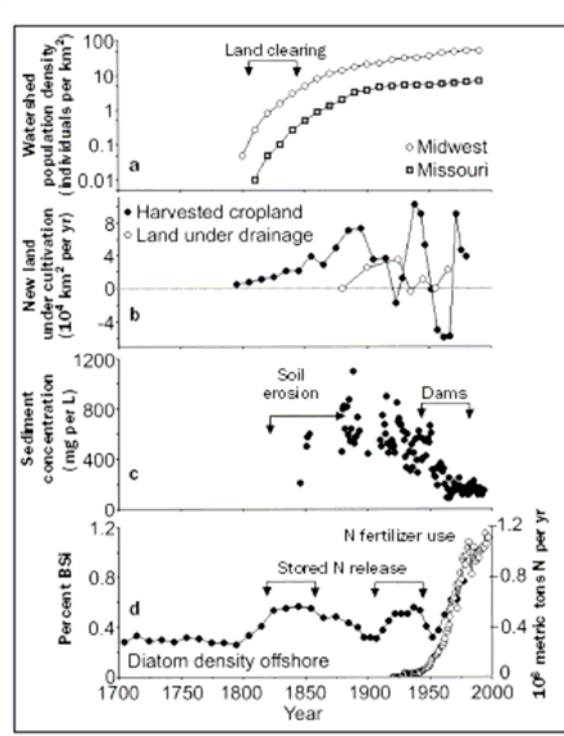
Large river systems in the agricultural Midwest have changed substantially since pre-settlement conditions. Land cover throughout the Midwest was primary natural vegetation with small pockets of subsistence agriculture. Land cover changes at that time were most likely related to natural events (e.g., fires from lightning strikes) or localized human activities. In any case, the land cover was dominated by natural vegetation and that resulted in very low rates of soil erosion and relatively “natural” export levels of nutrients related to natural decomposition and export from highly vegetated forest, prairie, and wetland landscapes (Turner and Rabalais 2003). Tuner and Rabalais present a number of summary graphs (Figure 20) that document changes in population, cropland, and land under drainage, sedimentation, and nitrogen patterns over the last 300 years in the Mississippi River basin. These data clearly implicate increased nutrients, increases sedimentation, and increased flow variability as important in the Mississippi River basin as we have found for the Wabash River. Our challenge is to determine what the solutions may be to moderating some of these effects while enhancing, not inhibiting, the economic engine that the agricultural Midwest represents.

### *Local vs. Upstream Watershed Influence on the Wabash River Ecosystem*

Our data suggests that both local habitat issues and upstream management of our agricultural systems, which are intensely drained and heavily fertilized, are major stressors to biological condition in the Wabash River watershed. The upper watershed in Ohio and Indiana is responsible

for significant chemical loadings to the Wabash River that result in high phosphorus and nitrate levels compared to what would be expected under more natural conditions.

Degraded, mediocre big river habitats can partially explain the losses of biodiversity (e.g., sensitive fish species) and biological conditions (mediocre IBI scores) in most reaches of the Wabash River. We will provide more site-specific detail in part 2 of this report. Time and resource constraints have limited some of the exploratory analyses we could perform. Part II of this report uses weight-of-evidence to identify the impacts of instream habitat limitations and upstream habitat limitations which are closely linked (e.g., via drainage) to increased export of sediments, nutrients and other dissolved materials (e.g., chloride, sulfate, etc.). Examination of the QHEI metrics identified low cover scores, low riparian scores and lack of riffles as being key habitat features lacking in the lower Wabash River. Each of these metrics can be influence directly though removal of mature wood riparian vegetation and shrinkage of mature bottomland forests to narrow strips of often early successional tree species that possess lower root strength and less habitat forming features than more climax species.



**Figure 20.** Figure from Tuner and Rabalais (2003) summarizing trends in watershed population, cultivated land, sediment concentrations and a measure of nutrient enrichment for the Mississippi River over the past 300 years.

Historical descriptions of the Wabash River identified extensive islands, backwaters, sloughs and adjacent wetlands that would flood frequently during storm events. Many of the species rare or extirpated in the lower river are associated in some way with the loss of these habitats. The connection with the floodprone areas and these features undoubtedly reduced the frequency of destructive flows that scour stream bottoms and erode denuded or under-protected banks.

This study as well as that of Gammon (1998) identified problems with narrow riparian areas or eroding banks. A more complete census of the banks and the riparian zones of the Wabash would be a relatively inexpensive way to document areas with the worst erosion and could help target areas for rehabilitation. There are a variety of visual or more quantitative methods that could be used including a digital photographic record of each bank.

The broadscale changes that have occurred in the Wabash River related to agricultural drainage are more challenging issues. While the acreage of drained land has not changed substantial in the past decade the intensity of drainage has continued to increase with more systematic drainage improvements taking place that add additional tile drains between existing drains, extend drains, etc. (Madramootoo et al. 2007). Compared to historical drainage patterns, drainage changes in the upper Mississippi have been responsible to an unknown degree for substantial changes in hydrology with upwards of a 6-fold increase in peak floods during the 20<sup>th</sup> century (Knox 1999, 2001).

Upland nutrient controls can have some influence on nutrient export to the Wabash River with Gammon (1998) attributing some of the improvement in fish assemblages in the 1980s to a "Payment-in-Kind" (PIK) program which paid farmers to not plant crops during certain years with a concomitant reduction in nutrient application. Although much of the phosphorus exported to streams is in particulate form, recent work has identified that drainage tiles can contribute substantial dissolved phosphorus to streams.

The strong correlations between aquatic life and in-stream habitat conditions suggest that habitat rehabilitation of one kind or another will be critical to long term progress in the Wabash River. The effect

of habitat changes to promote drainage controls the export of flow, sediment and nutrients to downstream reaches. Enhancing in-stream habitat without considering hydrological controls will not result in stable solutions to habitat issues. Upland controls on erosion alone can influence nutrient export, but will not likely reduce nutrients to more natural levels. Novel approaches to drainage management and stream naturalization that enhance habitat features, move toward natural flow regimes and control nutrient and sediment export need to be tested. There are a number of stream rehabilitation frameworks that are being tested (Frothingham et al. 2002, Powell et al. 2006), but much research is needed to engineer stream channels that will deal with the impact identified in this study and still be compatible with economically sustainable agricultural needs (Shields et al. 2003).



## Wabash River Study - Part II. HUC-11 Watershed-Specific Data and Analyses

### Introduction

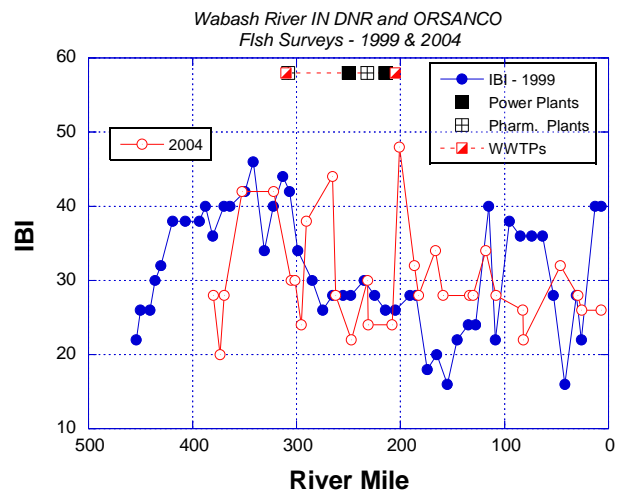
This document provides more details on the biological condition, biodiversity and stressors in each of the HUC-11 watersheds through which flows the mainstem of the Wabash River. Where data in any one HUC-11 was too sparse it was combined with a neighboring HUC-11 watershed. These watersheds are also grouped by HUC-8 watershed, the next larger hydrologic scale.

The goal here was not to focus on a very small spatial scale or to duplicate work of IDEM or others, but to focus on the major broadscale, upstream sources of impacts as well as the influence of important local in-river stressors that appear to limit biological performance and biodiversity. The goal is to provide a scientific basis of support for potential rehabilitation strategies. In some cases it is not possible to discriminate the relative effects of each stressor on the biota largely because the stressors themselves are highly correlated.

While this study was done to identify key stressors limiting biological condition and biodiversity, it was based on a limited number of assessment points along the mainstem Wabash River and largely a random sampling of tributary sites from IDEM's probabilistic sampling program. Thus while it should give a pretty sound indication of important problems and stressors, the sampling sites themselves should not be considered the universe of targets sites for enhancement or rehabilitation. This study and others (e.g., Gammon 1998) for example have identified loss of woody riparian areas as being strongly associated with increased bank erosion and lack of instream cover in the Wabash River. Selection of specific areas to target for rehabilitation, however, either needs to be made on a finer scale or needs to become a generalized strategy for enhancing these areas along the entire length of the mainstem. Similarly with regard to the condition of tributaries, most of these sites were random samples and a focus only on sampling station rehabilitation would leave likely leave may "unsampled" areas as sources of pollutants and other stressors (e.g., sediment). Any identified problems related to tributaries would likely be a call for alternative ways to manage such areas.

### Results and Discussion

**Point Source Stressors on the Wabash River –** Some of the earlier biological monitoring work on the Wabash River was done to assess the effects of major point sources of pollutants or thermal loading to the river (Gammon 1998). In the 1950s and 1960s in particular, loadings of pollutants to major rivers from WWTPs and industrial dischargers were often obvious limiting factors for losses in biological condition and biodiversity, and were responsible for poor diversity and occasional large fish kills on the Wabash River (Gammon 1998). Gammon (summarized in 1998) conducted numerous studies of thermal impacts of power plants on the Wabash River and the effects of other facilities (e.g., WWTPs). Overall the trend during the time period of his work (1960s to 1990s) was one of improvement in the river, especially when examined at the reach level (Pyron et al. 2006).



**Figure 1.** IBI vs. river mile for the Wabash River surveys from 1999 (IN DNR) and Ohio EPA (in Ohio) and 2004 (ORSANCO). Location of key point sources noted.

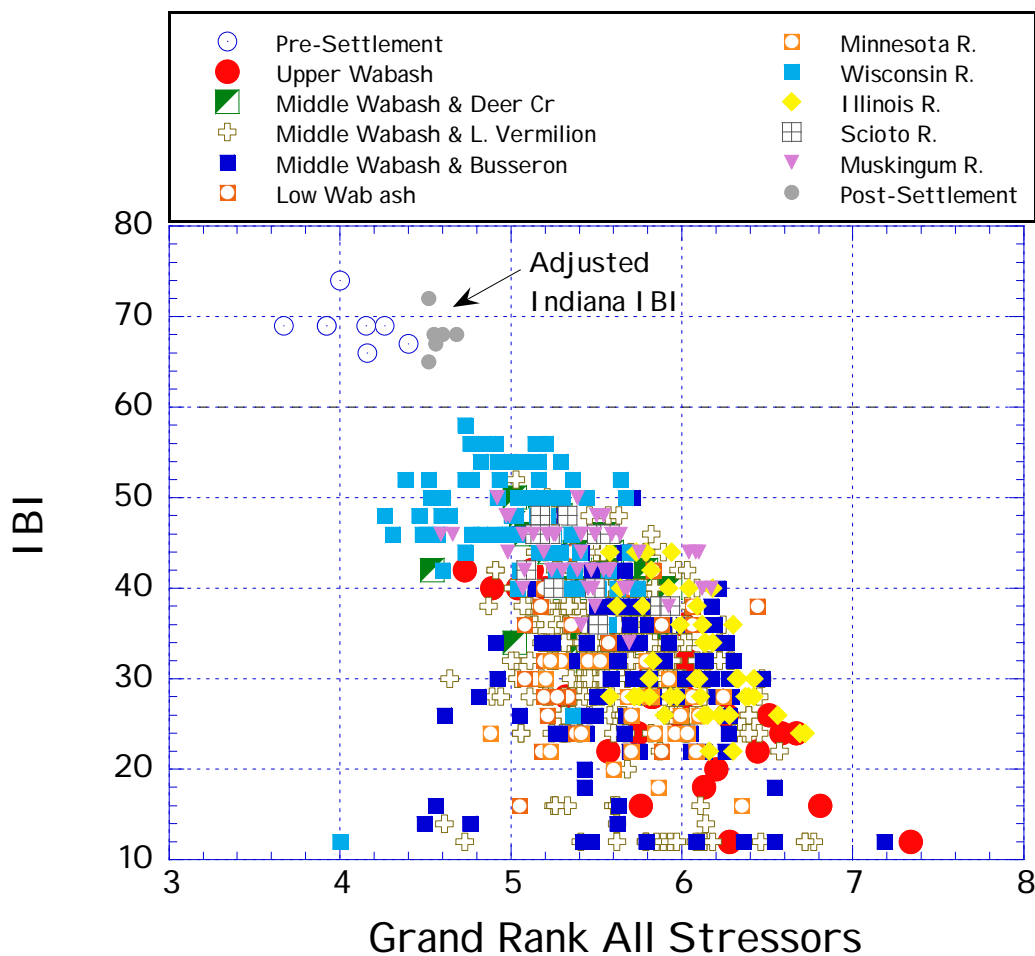
Fish assemblage data used in this study showed no clear impacts from thermal, wastewater, or industrial discharges in the Wabash River and variation in fish assemblages were consistent with nonpoint stressors including nutrient enrichment, sedimentation, habitat limitations and altered flow regimes. Figure 1 illustrates the patterns in IBI scores from Indiana DNR's survey in 1999 and the ORSANCO survey

in 2004. These surveys, however were not specifically designed to measure effects from point sources. The 1999 survey was conducted with fish management objectives and the 2004 survey used a probabilistic design to select sites. Local impacts from point sources could be underestimated with this survey design. Point source impacts could also be masked by the general level of impact from nonpoint pollution and habitat impacts in the river.

The ORSANCO effort in 2004-2006 employed a “regional” large river IBI called the FAQI (Fish Assessment Quality Index) (Emery et al. 2007). In addition, they used a multivariate approach to quantify abiotic stressor levels (water chemistry and habitat) using Principal Components Analysis (PCA). Their results indicated a significant correlation between the FAQI and their estimate of a stressor gradient in the river ( $R = 0.65$ , Spearman,

$p < 0.02$ , Emery et al. 2007). This matched our conclusions and an examination of their plot of the FAQI vs. RM from the length of the Wabash River did not find any responses in the vicinity of known point sources (Emery et al. 2007). As mentioned above, impacts such as combined sewer overflows may be important in localized areas, especially near population centers, however the predominant influence on the current biota of the Wabash is largely related to habitat loss, sedimentation, altered flow regimes, and nutrient enrichment associated with agriculture especially in drained landscapes or where agriculture is not buffered from aquatic systems

**Non-Point Source Stressors on the Wabash River** – The preceding technical summary (Part I of this report) took a broad spatial view of the factors influencing the Wabash River mainstem using



**Figure 2.** Plot of the grand rank of all stressor categories generated for individual fish sampling sites in the Wabash River, other Midwest Rivers and from a hypothetical, modeled fish assemblage for the Wabash River represent pre-settlement (circa 1800) and immediate post-settlement (circa 1860s) conditions. Ranking based on TIV values for multiple stressor categories generated for large rivers.

statistic tools such as regression tree analysis. These analyses used variation in stressor distribution from the entire Wabash River watershed including data from the Wabash mainstem (by HUC-11 watershed) and from upstream sources (as measured by average HUC-8 conditions) to explain patterns in fish assemblages in the Wabash River mainstem.

This part of the study is a more specific stressor identification exercise that builds on the patterns extracted from the entire watershed and focuses on multiple lines of evidence to identify key stressors within the mainstem itself or in upstream HUC-11 watersheds. This is a weight of evidence approach where we array important stressors for each HUC-11 watershed and compare them to reference values, water quality criteria or other targets. At this level of detail the individual biological responses can be used to “coarse focus” in on categories of impairment which we try to

confirm by examining stressor levels. Where there is specific data from Indiana’s TMDL assessments they are included here as well as the results of other site specific studies that we have found.

There are several novel approaches we have used to help support the assignment of causes and sources of impairment and to place the condition of the Wabash River in a broader ecological perspective along a standardized “Biological Condition Gradient” or BCG. Detail on a BCG for the Wabash River is found in Appendix 6 the technical summary. The essence of this exercise is to anchor a gradient of biological response in a “natural” or near pristine condition. This does not suggest that “pristine” is the ultimate goal for the Wabash, but rather it provides a trajectory from existing conditions and allows better founded discussion of reasonable and feasible goals for aquatic ecosystems and a way to develop quantitative targets.

**Table 1.** Some example sampling sites from the Wabash River, other Midwest Rivers and hypothetical historical pre-settlement sites on the Wabash River with back-calculated stressor ranks based on fish species TIV values weighted by relative abundance of each species at a site. TIV data based on boatable samples from Ohio and several other Midwest Rivers.

Date	RM	Type	Grand Stressor Rank	Habitat Stressor Rank	Nutrient Stressor Rank	BOD Stressor Rank	Metals Stressor Rank	Ionic Stressor Rank	IBI
<b>IN: Upper Wabash River (05120101)</b>									
<b>HUC-11:</b>	<b>05120101-040</b>								
07/15/1999	454.0	A	6.8	7.1	7.7	7.9	6.0	4.8	22
<b>HUC11:</b>	<b>05120101-070</b>								
07/15/1999	419.3	A	5.9	4.7	7.2	6.1	6.0	4.3	38
<b>IN: Middle Wabash-Busseron (05120111)</b>									
<b>HUC11:</b>	<b>05120111-040</b>								
08/29/2006	205.8	A	6.1	5.4	6.8	6.6	5.9	4.2	34
<b>IN: Historical - Pre-settlement Period (05120113)</b>									
07/15/1807	7.1	A	4.1	3.2	4.4	3.6	4.6	2.9	54
07/15/1807	6.1	A	4.1	3.0	4.6	3.7	4.6	2.7	54
<b>IL: Illinois River Mainstem</b>									
07/28/2006	298.3	A	6.6	6.4	6.5	6.3	6.5	5.2	28
<b>OH Scioto River Mainstem</b>									
07/10/2006	99.7	A	5.6	4.9	6.2	6.4	5.7	4.2	40
<b>WI: St. Croix River Mainstem</b>									
08/12/2004	91.8	A	4.2	3.7	4.8	5.7	4.3	3.3	4.8
<b>Summary of Narrative Ranges:</b>			-Ref.	-Low	-Med.	-High	-V.High	-Extreme	

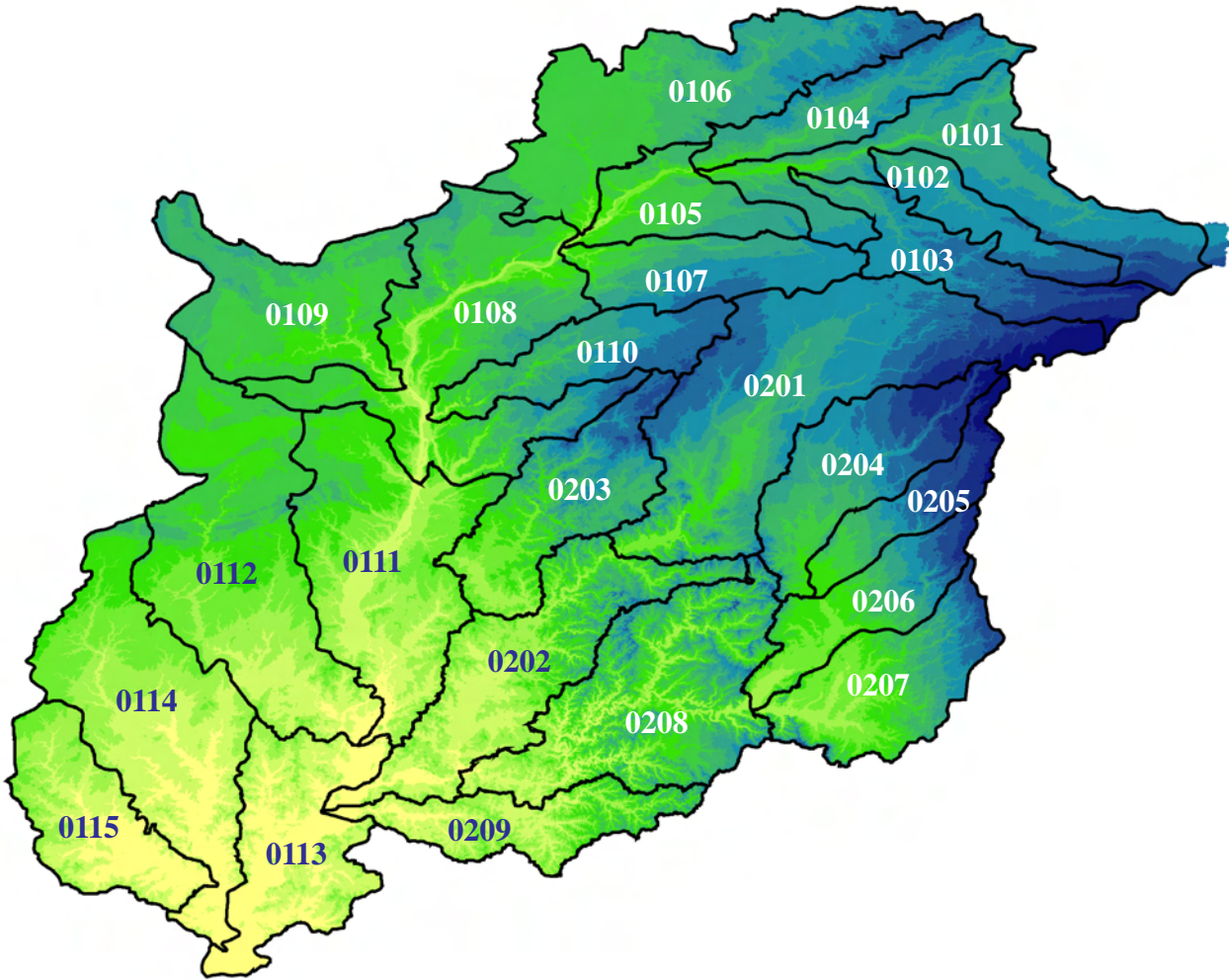
Another method we used was to estimate or infer the “stressor load” at a site from the assemblage data we collected. This was done by taking individual species based “Taxa Intolerance Values” (TIVs) that have been derived from ambient data where data was available (or estimated from life history descriptions where species are rare or have been extirpated) and then calculating weighted average ranks for stressor categories based on the fish species and abundances collected at a site. If a site was dominated by habitat sensitive species it would have a low habitat stressor ranking at a site. The scale is 1-10 with one being most sensitive and a 10 being most tolerant. Details on deriving TIVs are summarized in Part I of this report and in Appendix 6 and species TIVs in Appendices 5 and 6. These analyses were paired with our extrapolation of what a pre-settlement (circa 1800) and an immediate post-settlement (circa 1860s) fish fauna may have looked like based on extrapolations of existing data and historical descriptions of conditions at these times. This was supplemented with data from some other large rivers in the Midwest that current have ranges of stressor approximating the Wabash River (e.g., Illinois, Minnesota, Scioto) or with less stress (Wisconsin and Muskingum Rivers). The goal is to place stressors in a gradient of possible conditions and to help support the stressor identification process to provide a basis for data interpretation. The graph of the “grand” or cumulative stressor ranks across stressor categories generated by species catches at sites vs. IBIs at sites is presented in Figure 2.

Table 1 presents some inferred site average TIVs for a cross section of sites that are listed in Appendix Table 8. Each rank is color coded with red indicating species skewed towards very tolerant species and dark blue indicating a prevalence of species and individuals that are sensitive for that stressor category. Comparing relative rankings between stressor categories can be useful for stressor identification. For example, in the historical data, the assemblage was skewed towards species intolerant to all stressor categories (Table 1). In the upper-most Wabash River sites (05120101-040) the assemblages were tolerant across all stressor categories; this matches the mix of habitat degradation, nutrient enrichment and high dissolved pollutants documented in this reach. Further down in this reach (05120101-070) and further downstream (05120111-040), habitat improved substantially in

the mainstem Wabash, but nutrients, and oxygen demanding substances remained high (as they do for most of the Wabash). At these sites species were still nutrient tolerant, but more habitat specialists were present (Table 1). Example sites from other Midwest watersheds allow the patterns in Wabash segments to be compared to other Midwest rivers that reflect an actual gradient of anthropogenic stress.

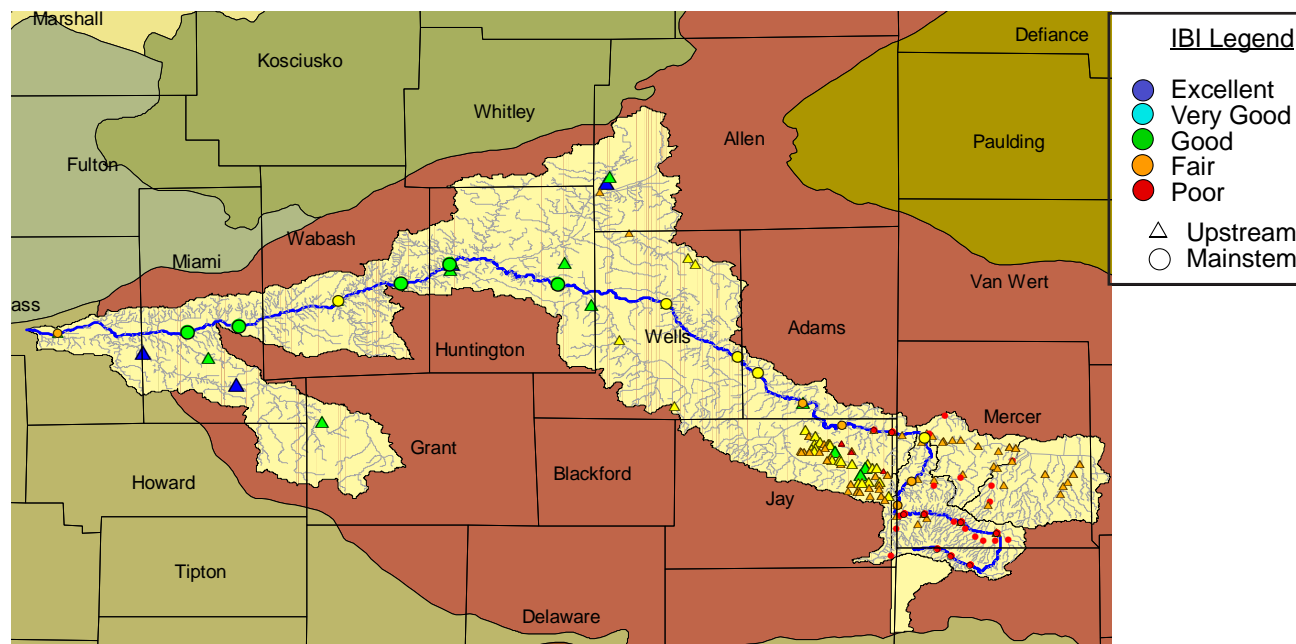
In the technical summary report we developed several ways of looking at the biota to help us determine how to set reasonable goals for the Wabash River and how to use species-specific responses to various stressors over a broad Midwest gradient to provide more evidence for what are key limiting stressors. Details of the methodology are in the technical summary report, but we will use some of the results to support are identification of key stressors.

The following results and discussion for individual watersheds are organized by HUC-8 watersheds (Map 1). In this study, we concentrated on the mainstem HUC-8s for the Wabash River (05120101, 05120105, 05120108, 0520111, and 05120113) and the Lower White River (05120202). For each HUC-8, we discuss the available data and environmental setting, and then provide brief summaries. This is followed by additional discussion of factors distributed at the HUC-11 watershed scale.



**Map 1.** HUC 8 subbasins overlaying an elevation raster file for the Wabash River Watershed in Illinois, Indiana, and Ohio. All labels have the precursor 0512 (Wabash River Watershed). Only the last four digits of the HUC-8 code, beginning 0512, are shown. Color differences in labels for contrast only.

## Upper Wabash River (HUC-8 05120101)



**Map 2.** IBI values from the mainstem (circles) or upstream tributaries within the upper Wabash River HUC-8 watershed (05120101). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana and Ohio from 1999; other data collected between 1990 and 2006 by IN DEM (IN) or Ohio EPA (OH). Shaded areas are Level IV ecoregions; the upper Wabash is primarily in the the Clayey, High Lime Till Plains subecoregion and ends in the the Loamy, High Lime Till Plains subecoregion.

### Data and Background - 05120101

As the name implies this is the uppermost HUC-8 watershed through which the mainstem flows. To visually array the stressors we have compiled a number of data tables that include summary statistics for mainstem sites and separately for tributaries for habitat, water chemistry, land use data, and mainstem flow regime flashiness. We will include tables for the specific Wabash River HUC-8 or HUC-11 in the text and present tables for the entire watershed in the Appendix.

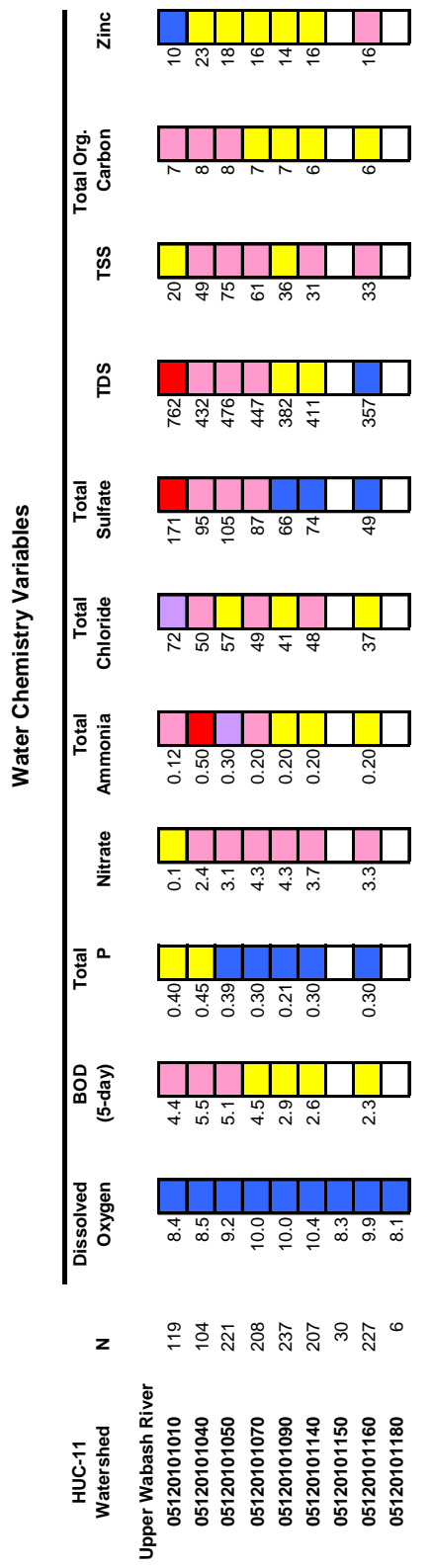
For water chemistry data (Tables 2-4) we provide median values as well a color coding of values that represent deviations from “reference” background conditions based on medians and more extreme statistics (e.g., 75<sup>th</sup>, 90<sup>th</sup> percentiles, etc., see main text). These do not necessarily represent water quality criteria violations, although for parameters with water quality criteria (DO, ammonia) there is a general correlation. The rationale for using these ranges is to identify watersheds where runoff and export of stressors is elevated compared to

“reference” conditions or conditions where aquatic life normally attains aquatic life use goals. These reference or background conditions are not “pristine” background, but rather conditions associated with sites that routinely have good-excellent biological assemblages. More explanation on the methodologies is found in the body of the overall technical summary.

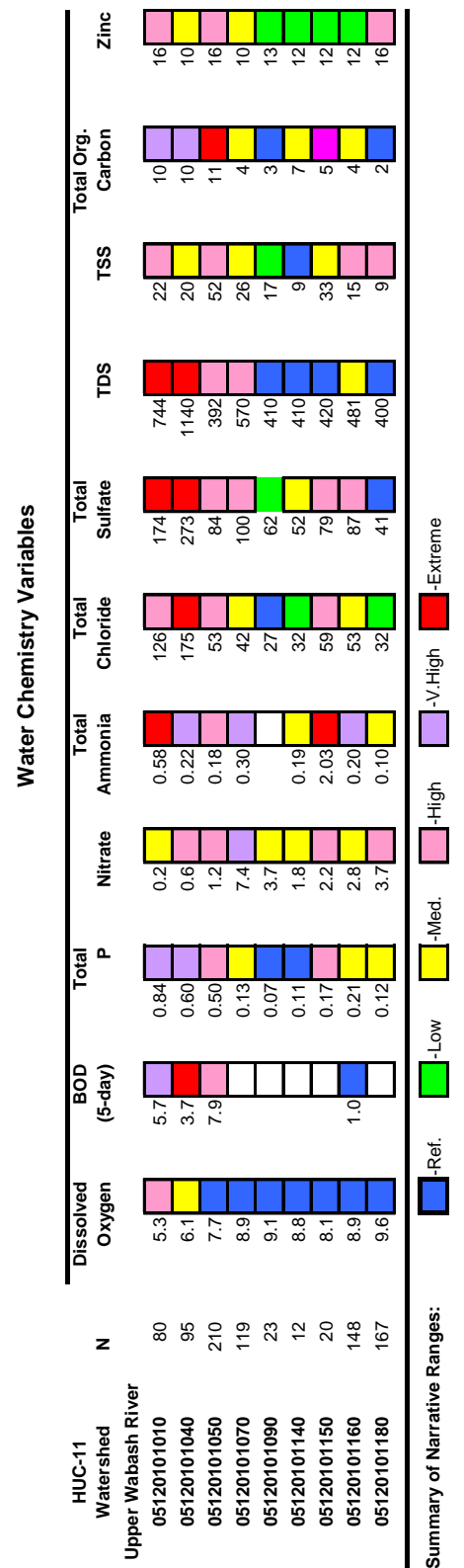
**Biological Assemblages** – The data we used to assess biological condition was collected by Indiana DNR in 1999 and ORSANCO in 2004-2006 and in Ohio waters by Ohio EPA from 1984-2006 with most of the data from 1999. Because of the completeness of the 1999 sampling much of the assessment focuses on this information.

**Biological Condition Gradient (BCG)** – The BCG developed for the lower mainstem of the Wabash River does not directly apply to the upper Wabash River, especially in the HUC11 watersheds below 1,000 square miles, although the conceptual basis for such a BCG would be similar. BCGs for the upper Wabash would need to reflect the range of stream

**Table 2.** Selected median water quality values for HUC-11 watersheds from the upper Wabash River HUC-8 watershed (05120101); mainstream data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.



**Table 3.** Selected median water quality values for HUC-11 watersheds from the upper Wabash River HUC-8 watershed (05120101); tributary data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.



**Table 4.** Water Quality Index values for HUC-11 watersheds from the upper Wabash River HUC-8 watershed (05120101); tributary and mainstem data combined. N reflects number of stations. Mean WQI does not include QHEI component. Colors represent increasing risk of aquatic life impairment.

Water Chemistry Variables											
HUC-11 Watershed	N	Dissolved Oxygen	Total P	QHEI	TSS	Min. WQI	Mean WQI				
Upper Wabash River											
05120101040	8	97.4	30.0	31.1	40.7	47.2	61.3				
05120101050	58	94.0	87.2	71.0	90.8	67.0	89.2				
05120101060	20	90.0	47.0	57.0	35.9	23.8	60.0				
05120101070	22	92.8	58.0	35.8	56.2	45.7	70.6				
05120101080	9	100.0	97.1	86.1	100.0	96.0	99.5				
05120101090	25	96.0	78.9	43.9	86.5	68.5	86.8				
05120101100	4	100.0	94.7	88.1	100.0	83.8	95.2				
05120101110	6	99.8	90.9	78.5	64.3	88.4	94.4				
05120101120	17	98.4	66.9	48.0	51.7	60.1	82.0				
05120101140	19	95.4	53.7	88.7	62.5	40.3	78.3				
05120101150	6					89.4					
05120101160	23	97.0	64.2	44.1	73.7	56.3	82.3				
05120101170	23	98.2	75.5	56.4	82.1	81.8	91.7				
05120101180	4					100.0					

**Summary of Narrative Ranges:**

■ -Ref.   
 ■ -Low   
 ■ -Med.   
 ■ -High   
 ■ -V.High   
 ■ -Extreme

sizes which includes headwater (< 20 square miles), wadeable streams (20-200 square miles) as well as streams considered small rivers (~200-1,000 sq mi). Our focus for the BCG analyses for these reports is on the lower river and its characteristic large river fauna, much of which has been lost or is now rare. The biota in the extreme headwaters of the Wabash River has also been greatly altered and the loss of species in these watersheds is symptomatic of the loss of habitat and increase runoff of sediment, nutrients,

and other substances. In terms of BCG tiers, many upstream reaches would reflect Tier 5 and 6 conditions, with best conditions in Tier 4.

**Identification of Stressors** – We used a “weight-of-evidence” stressor identification approach to assign likely causes of biological impairment. For example, we compared stressor levels in the mainstem and at upstream sites to ranges of values considered to be “least impacted” to rank stressor levels and to identify stressor that could be

**Table 5.** Reconstructed historical estimation of habitat conditions in the headwaters and further downstream reaches of HUC-8 05120101 (Upper Wabash River). The reconstruction of this QHEI assumes conditions during early settlement of the Wabash River Valley in the 1800s and is provided as an “anchor” for interpreting habitat conditions. Feasible goals for habitat rehabilitation would likely be somewhere between these values and existing values shown in later tables.

QHEI Metrics									
HUC-8 Watershed	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	Narrative
0520101-HW*	84.0	17.0	20.0	18.0	10.0	9.0	0.0	1.4 (10)	Excellent
0520101-DST*	99.0	20.0	21.0	19.5	10.0	12.0	7.5	5.0 (10)	Excellent

\* Year = 1800; HW = headwaters; DST = downstream

responsible for limiting biological conditions and biodiversity.

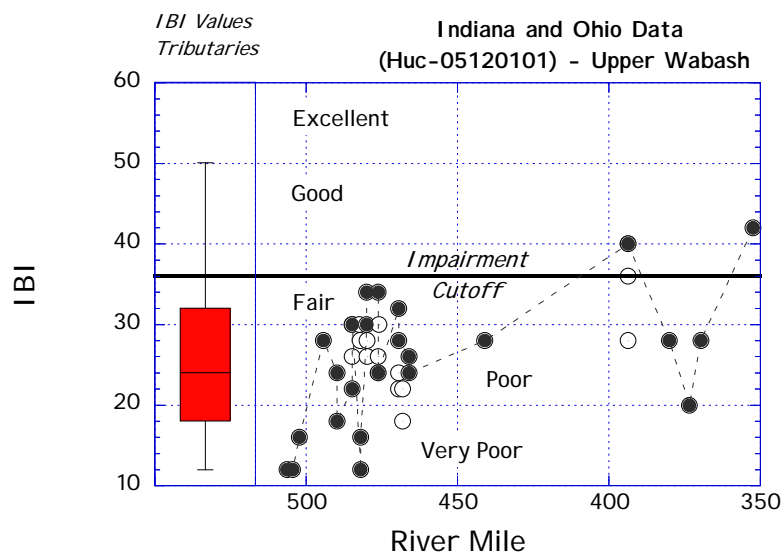
**Historical Habitat Condition** – Table 1 represents a “reconstruction” of what the habitat in wadeable and headwater sections of the Wabash River in Ohio may have looked like based on descriptions of the area by early settlers and later biologists. These areas were undoubtedly predominated by prairies, forest and wetland habitats prior to settlement (Gammon 1998, Burke Engineering 2007). Where stream channels were present, they likely had extensive aquatic plant growth, clean gravel and sand substrates or wetland type bottom materials. Erosion was likely minimal off the heavily vegetated landscape. Early investigators often describe the water as clear, even after rainfall. Depending on the location of a site, riffles were likely uncommon and many streams would be classified as wetland stream channels. Even without riffles, habitat conditions in such streams would be considered excellent by today’s standards with clean substrates, dense cover provided by aquatic plants and woody material, intact riparian areas with little erosion and deep pool habitats.

**Results and Summary -05120101**

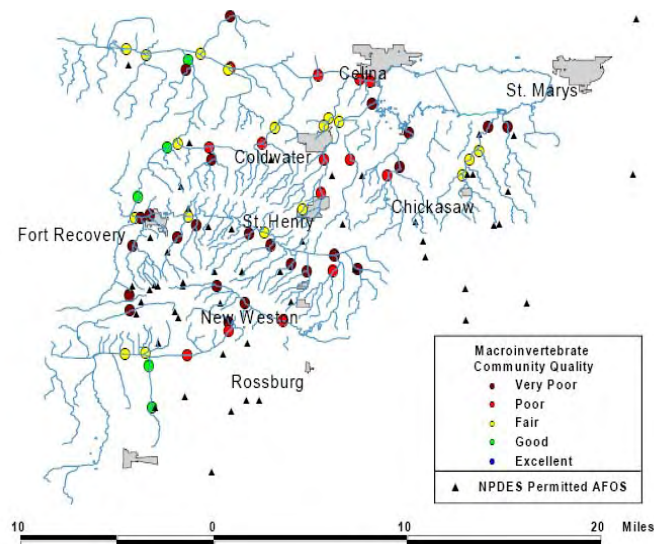
**Biological Condition** – Fish sites sampled in the upper-most reaches of the Wabash River, especially

in Ohio were mostly impaired as can be observed in Map 2 and Figure 3. The IBI was in poor condition at most sites in Ohio and assemblage condition improved in Indiana on the mainstem, but was still considered impaired until it reached the Indiana DEM attainment cutoff score of 36 in Wells County and remained in good shape in the mainstem for the rest of watershed. Indiana DEM analyzed all of their probabilistic data in the Wabash River hydrologic unit and estimated that 53% of the river miles in the entire Wabash unit meet the biological condition target (reference). Their data did not include data from the Ohio portion of the Wabash which is in poor condition, considered one the most polluted watersheds in Ohio (US EPA 2004, Ohio EPA 2002) and a major source of stressors exported to Indiana. Thus, this watershed underperforms the average for Wabash River watersheds.

Although extensive and detailed macro-invertebrate data was not available for much of the Wabash River, Ohio EPA (2002) collected such data during their 1999 survey of the Ohio portion of the upper Wabash River watershed. Map 3 from their watershed report summarized the mostly poor condition of this assemblage which is similar to the condition of the fish. The attached Ohio EPA “infographic” (Appendix 1) provides a stark illustration of the condition of this portion of the river.



**Figure 3.** Plot of IBI by river mile in the upper Wabash River HUC-11 watershed. Mainstream sites are black and connected by a dashed line. Data from IN DEM and Ohio EPA and primarily collected during 1999.



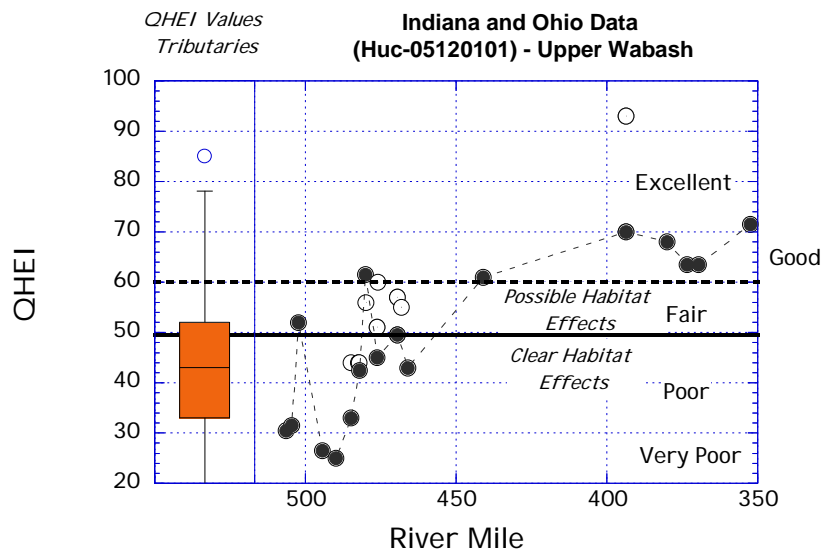
**Map 3.** Map illustrating narrative condition ratings of the Ohio EPA macroinvertebrate data collected the Ohio portion of the Wabash River during 1999. Taken from Ohio EPA 2002.

**Biodiversity** – The fish species collected in the upper Wabash were characterized by extreme tolerance to habitat, low dissolved oxygen, and degraded habitat. Four of the six most common species collected are considered very tolerant (Table 6) and the other two species (Gizzard Shad and Central Stoneroller) are opportunistic, insensitive to habitat and associated with nutrient enriched conditions. This HUC-8 watershed has records for endangered fish (Tippecanoe Darter-1980) and freshwater mussels (Clubshell-2000), although most locations are in tributaries and in the lower reaches. Live mussel species richness ranged from 2-20 (live+dead: 17-29) in this watershed (see Appendix 10).

**Habitat** – Historically, the upper reaches of the Wabash were quite different in character from what they are like today. The landscape was covered with permanent forest, prairie and wetland vegetation. Stream habitat was natural and likely consisted of flowing wetlands and where channels were obvious, water was clear, habitat was diverse and aquatic vegetation was likely abundant. QHEI scores would have ranged from the 70s to 90s. Today, in contrast most of the small channels have been altered to enhance agriculture drainage and habitat is predominantly poor and very poor, with many scores less than 50 (Figure 4). In reaches in Ohio, tributaries and the mainstem have been largely channelized. As

**Table 6.** Five most dominant fish species by number collected in fish samples in the upper Wabash River watershed (Huc 05120101) collected in Indiana and Ohio. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

Five Most Dominant Fish Species by Number		
All Data	Mainstem	Excluding Mainstem
Central Stoneroller - (19,357)	Central Stoneroller - (16,409)	Bluntnose Minnow [T] – (2,328)
Bluntnose Minnow [T] – (17,696)	Bluntnose Minnow [T] – (8,874)	Fathead Minnow [T] – (4,404)
Creek Chub [T] – (8,627)	Creek Chub [T] – (4,827)	Creek Chub [T] – (3,800)
Fathead Minnow [T] – (5,476)	Suckermouth Minnow [T] – (4,626)	Central Stoneroller - (2,948)
Suckermouth Minnow [T] – (5,206)	White Sucker [T] – (2,961)	Gizzard Shad – (2,762)



**Figure 4.** Plot of QHEI by river mile in the upper Wabash River HUC-8 watershed. Mainstream sites from 1999-2006 are black and connected by a dashed line. Data from IN DEM and Ohio EPA and collected during 1999. Tributary sites are presented on the box and whisker plot on left (data from all available years).

is illustrated in Figure 4, positive habitat attributes in the Ohio portion of the Wabash are largely absent and it is dominated by high and moderate influence negative metrics. These habitat features of the Wabash River and its tributaries contribute to the export of nutrients, sediments, and dissolved materials. Near universal agricultural drainage and channelization are responsible for the flashy flows, including high peak flows and longer duration, low flows.

**Pollutant Stressors in the Watershed** – Much of the immediate source of the chemical impacts in the upper Wabash River HUC-11 are related to the severe nutrient enrichment and sediment export from confined animal feeding operations (CAFOs) in the watershed. This condition is made worse by severely degraded habitat as a result of extensive and maintained channelization for agricultural drainage. In turn, this drainage results in extreme flashiness in the flow regime which exports nutrients, solids, and sediments downstream.

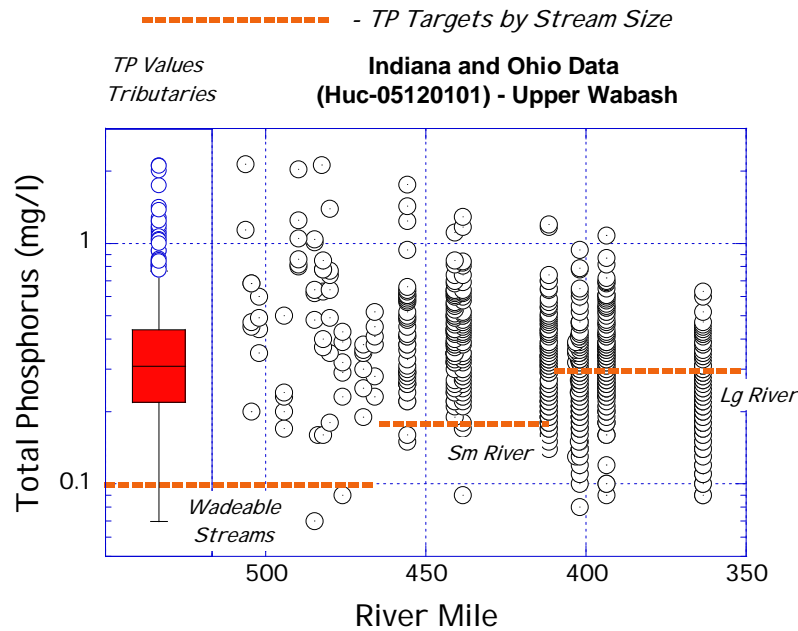
Figure 5 summarizes the total phosphorus (TP) concentration changes with river mile in the mainstem of the Wabash and the distribution of values in the upstream tributaries, reflecting data collected after 1998 (1999-2006). These values are higher than Gammon (2001) quoted for similar areas of the Wabash River from 1977-1987 (~ 0.20 mg/l). This may be attributable to the increase in CAFOs in the upper watershed.

The orange dashed lines represent nutrients targets that have been developed in Ohio for wadeable streams, small rivers and large rivers. It is clear that nearly all of the wadeable and small stream values in the Wabash River mainstem are well above the targets set for these size streams, as are most of the sites in the tributaries to the Wabash River. As the Wabash River takes on major tributaries with lower total phosphorus, the dilution lowers some of the values relative to the targets for large rivers; however the majority of the values are still above the large river target.

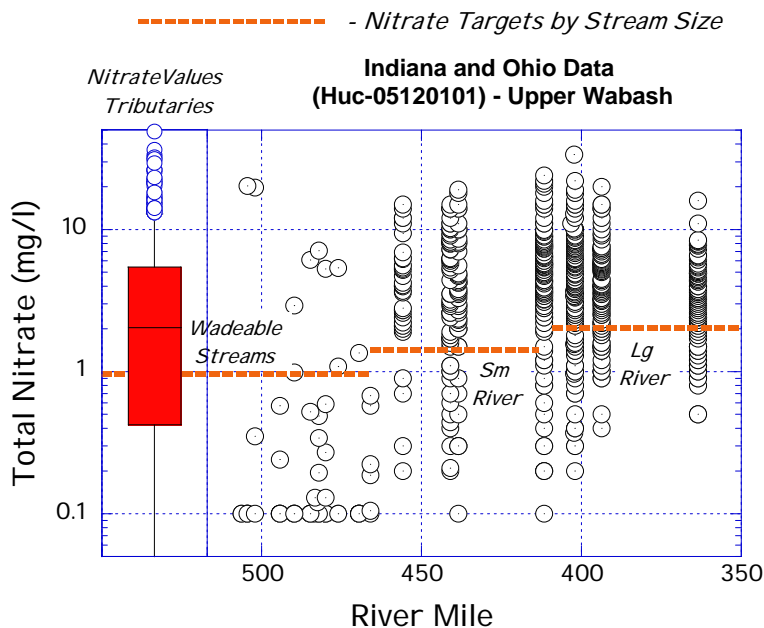
The tributaries and mainstem are nitrate enriched as well (Figure 6). The pattern is somewhat different with nitrate as it increases with distance downstream as the river passes from Ohio into Indiana. This is related to additions of nitrate from tributaries and the conversion of ammonia (from CAFOs and other sources in Ohio and Indiana streams) to nitrate as the river proceeds downstream. The pattern with the nutrients is repeated with other materials that erode off the landscape (e.g., total suspended solids (TSS) and dissolved materials such as chlorides). The upper reaches of Wabash River in this HUC-8 are some of the most impaired waters in Ohio. Ohio completed a watershed survey (Ohio EPA 2002) and is currently completing a TMDL to begin to deal with these impairments (TetraTech 2004).

Recent research on nutrient dynamics in small streams indicates that small headwater streams are the location where most nutrients enter the aquatic system. Failure to limit nutrient runoff in headwaters, or alteration of

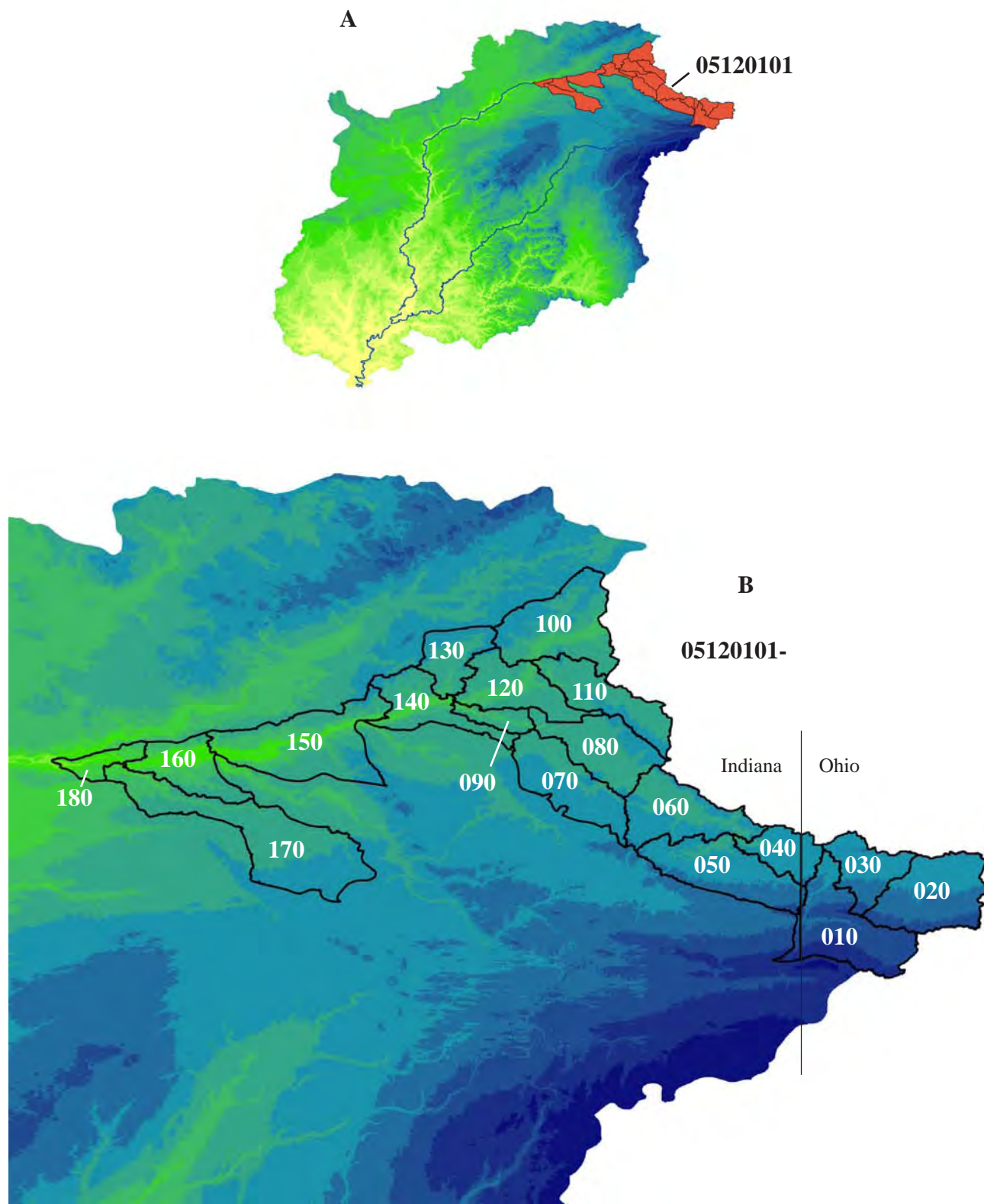
habitat that inhibits assimilation, makes it difficult or impossible to control nutrients in larger waters. Elevated pollutants from non-point sources need to be controlled in the headwaters.



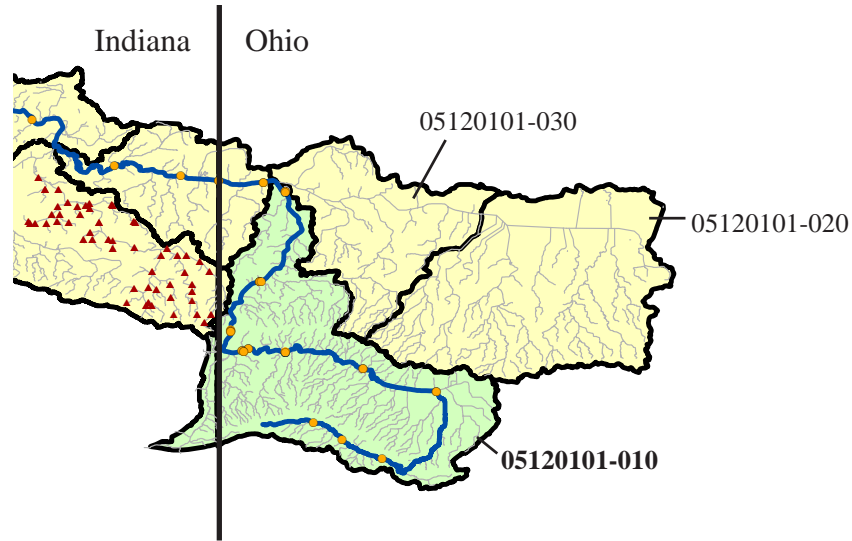
**Figure 5.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within the upper Wabash River HUC-8 watershed (05120101). Box and whisker plots represent data from tributaries from within this HUC-8. Orange dash lines represent total phosphorus targets for wadeable streams, small rivers or large rivers based on work done in Ohio (Ohio EPA 1999).



**Figure 6.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within the upper Wabash River HUC-8 watershed (05120101). Box and whisker plots represent data from tributaries from within this HUC-8. Orange dash lines represent total phosphorus targets for wadeable streams, small rivers or large rivers based on work done in Ohio (Ohio EPA 1999).



**Map 4.** Maps of the Wabash River HUC-8 watershed, 05120101, showing its position in the Wabash River Watershed (A) and the HUC-11 catchments within it (B). Elevation (0-255 meters; color-coded - 15 levels) serves as the background of each map. Only the last three digits of each HUC-11 are shown.



**Map 5.** Map of HUC-11 watershed 05120101-010, Upper Wabash River (Headwaters in Ohio). Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Much of the impact in the HUC-8 upper Wabash River mainstem (05120101) originates with impacts to the habitat in the headwaters and smaller wadeable streams that originate in Ohio (Table 4) and from runoff from agriculture operations and confined animal feeding operations (U.S. EPA 2004, Ohio EPA 2008). An examination of levels of chemical pollutants in the mainstem (Table 2) identified that levels of most parameters from moderate to extreme and data from the tributaries (Table 3) ranged from high to extreme. Ohio EPA rated the average basin health as “POOR” (Ohio EPA 2008). Ohio EPA



**Photo 2.** View of a typical modified and heavily enriched headwater stream in the upper Wabash River watershed in Ohio. Photo: Brian Alsdorf, Ohio EPA.



**Photo 1.** View of a typical modified headwater stream in the upper Wabash River watershed in Ohio. Photo: Ohio EPA.

documented numerous violations and exceedances of water quality parameters particularly for DO, ammonia and fecal coliform bacteria (Ohio EPA 2008). This watershed is impaired by multiple stressors (habitat and nutrients) and the extensive agriculture drainage has altered the hydrology of these streams so that peak flows are high and much more frequent than natural. Another consequence of

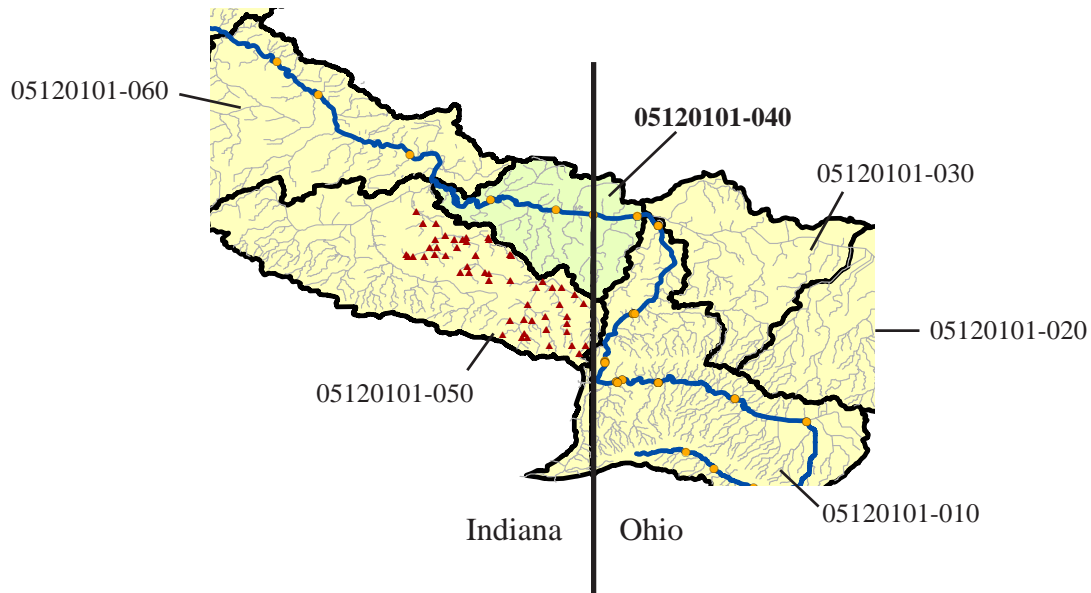
**Table 7.** QHEI scores and metrics with narrative ratings for stream sites on the mainstem Wabash River in watershed 05120101-010. Data collected by Ohio EPA.

05120101-010		QHEI Metrics								
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	Narrative	
Year: 1984										
<b>469.5</b>	57.0	15.0	9.0	12.0	4.0	5.0	4.0	3.94 - (8)	<b>Fair</b>	
Year: 1985										
<b>476.2</b>	51.0	15.0	6.0	10.0	5.0	3.0	4.0	5.65 - (8)	<b>Fair</b>	
<b>479.9</b>	56.0	17.0	6.0	10.0	6.0	5.0	4.0	5.65 - (8)	<b>Fair</b>	
<b>482.1</b>	44.0	16.0	5.0	4.0	4.0	4.0	3.0	5.59 - (8)	<b>Poor</b>	
<b>482.4</b>	44.0	16.0	5.0	4.0	4.0	6.0	3.0	4.93 - (6)	<b>Poor</b>	
<b>484.8</b>	44.0	15.0	5.0	8.0	5.0	3.0	2.0	4.85 - (6)	<b>Poor</b>	
Year: 1999										
<b>469.5</b>	49.5	10.0	8.0	9.5	4.0	10.0	0.0	3.94 - (8)	<b>Fair</b>	
<b>476.2</b>	45.0	15.0	5.0	8.0	4.0	5.0	0.0	5.65 - (8)	<b>Fair</b>	
<b>480.0</b>	61.5	16.0	10.0	13.0	5.5	6.0	3.0	5.65 - (8)	<b>Good</b>	
<b>482.0</b>	42.5	13.0	5.0	7.0	4.5	5.0	0.0	5.59 - (8)	<b>Poor</b>	
<b>484.8</b>	33.0	12.0	4.0	4.0	3.0	4.0	0.0	4.85 - (6)	<b>Poor</b>	
<b>489.9</b>	25.0	10.0	2.0	4.0	3.0	2.0	0.0	1.85 - (4)	<b>Very Poor</b>	
<b>494.3</b>	26.5	9.0	3.0	5.0	2.5	4.0	-1.0	1.25 - (4)	<b>Very Poor</b>	
<b>502.2</b>	52.0	13.0	6.0	12.0	7.0	5.0	-1.0	6.67 - (10)	<b>Fair</b>	
<b>504.5</b>	31.5	10.5	5.0	5.0	3.0	2.0	0.0	5.68 - (6)	<b>Poor</b>	
<b>506.4</b>	30.5	11.0	5.0	5.0	3.0	1.0	-0.5	6.33 - (6)	<b>Poor</b>	
Year: 2005										
<b>476.0</b>	60.0	14.0	14.0	4.0	4.0	7.5	3.0	5.65 - (8)	<b>Good</b>	

this flashy hydrology is that many of the small tributaries (< 5 sq mi) experience drought conditions during parts of most years. As is evident in the Figures 12-15 in Part I of this report, the high levels of these pollutants are exported downstream in the mainstem of the Wabash River. Photo 2 taken in a small Wabash River tributary in Ohio illustrates the degree of enrichment common to many streams in this region.

**Table 8.** Fish species captured in HUC-11 watershed 05120101-010 from 1999-2006. BI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
43-043	Bluntnose Minnow	Pimephales notatus	T	3485
43-044	Central Stoneroller	Campostoma anomalum		2297
43-015	Suckermouth Minnow	Phenacobius mirabilis		2006
43-034	Sand Shiner	Notropis stramineus	M	1075
43-042	Fathead Minnow	Pimephales promelas	T	914
43-013	Creek Chub	Semotilus atromaculatus	T	613
54-002	Blackstripe Topminnow	Fundulus notatus		575
43-039	Silverjaw Minnow	Notropis buccatus		501
40-005	Quillback Carpsucker	Carpoides cyprinus		305
77-008	Green Sunfish	Lepomis cyanellus	T	289
40-016	White Sucker	Catostomus commersoni	T	273
43-001	Common Carp	Cyprinus carpio	T	265
47-004	Yellow Bullhead	Ameiurus natalis	T	234
43-032	Spotfin Shiner	Cyprinella spiloptera		150
80-015	Greenside Darter	Etheostoma blennioides	M	145
80-014	Johnny Darter	Etheostoma nigrum		108
47-002	Channel Catfish	Ictalurus punctatus		92
77-011	Longear Sunfish	Lepomis megalotis	M	72
20-003	Gizzard Shad	Dorosoma cepedianum		45
77-001	White Crappie	Pomoxis annularis		19
85-001	Freshwater Drum	Aplodinotus grunniens	P	18
43-002	Goldfish	Carassius auratus	T	15
40-010	Golden Redhorse	Moxostoma erythrurum	M	11
77-009	Bluegill Sunfish	Lepomis macrochirus	P	11
77-002	Black Crappie	Pomoxis nigromaculatus		9
43-025	Striped Shiner	Luxilus chrysocephalus		7
47-008	Stonecat Madtom	Noturus flavus	I	7
77-006	Largemouth Bass	Micropterus salmoides		7
47-006	Black Bullhead	Ameiurus melas	P	6
47-013	Tadpole Madtom	Noturus gyrinus		3
40-015	Northern Hog Sucker	Hypentelium nigricans	M	2
40-018	Spotted Sucker	Minytrema melanops		1
77-010	Orangespotted Sunfish	Lepomis humilis		1
99-999	No fish	No fish		0



**Map 6.** Map of HUC-11 watershed 05120101-040, Upper Wabash River with Hickory Branch and Brewster Ditch. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

IBI scores in the mainstem (data from 1999) were in the fair range. Fish species in the mainstem were dominated by tolerant species (Table 10). Few sites exist in the tributaries within HUC-11 05120101-040, but IDEMs Integrated Water Quality Report identified nutrients as a cause of impairment in the Wabash and in Brewster Ditch a tributary in this HUC-11 watershed. Upstream watersheds in Ohio and adjacent watersheds (Limberlost Creek) are highly impaired and likely contribute to high levels of nutrients and other chemicals in this watershed.

QHEI scores in the mainstem were fair-to-poor condition (Table 9) with the “poor” site having been channelized, with inadequate substrates, a degraded

channel and scant instream cover. Other QHEI data collected at several tributaries (Simison Creek and Loblolly Creek) and on the Wabash River itself were in fair to poor condition on the tributaries and fair-good condition on the mainstem (Burke Engineering 2007).

Water chemistry values in the Mainstem reaches of this watershed range from normal for dissolved oxygen, high for BOD, nitrate, total chloride, total sulfate, TDS, TSS, and TOC and extreme for total ammonia (Table 2). There was no historical data available from tributaries in the watershed, however data recently collected at several tributaries (Simison

**Table 9.** QHEI, QHEI metrics, and narrative rating for mainstem Wabash River sites sampled in HUC-11 watershed 051201010-040.

05120101-040	QHEI Metrics								Narrative	
	River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle		Gradient (Score)
Year: 1984	<b>468.1</b>	55.0	15.0	10.0	14.0	5.0	5.0	0.0	1.12 - (6)	<b>Fair</b>
Year: 1999	<b>466.1</b>	43.0	5.0	9.0	8.0	5.0	10.0	0.0	1.12 - (6)	<b>Poor</b>

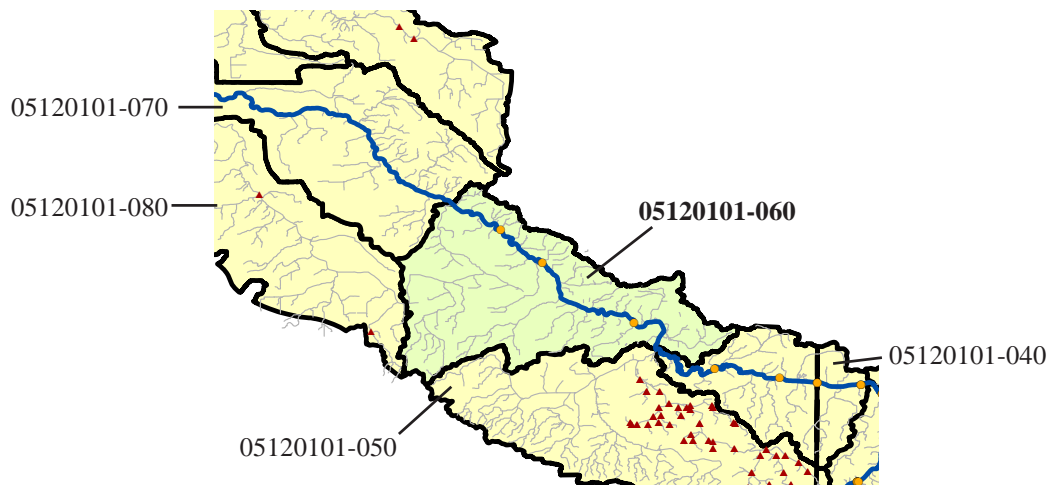
Creek and Loblolly Creek) as part of the upper Wabash River management plan had TP levels of > 1 mg/l (very high) and nitrates of 5 and 8 mg/l (also very high) (Burke Engineering 2007).

**Summary**—This segment of the Wabash is influenced by degraded habitat on the mainstem and in the

tributaries and agricultural and drainage practices that export nutrients and other materials (e.g., dissolved solids) into the mainstem. The drainage activities result in flashy and higher peak flows that worsen erosion of banks and export of materials from banks and dissolved materials (e.g., nitrates and soluble forms of phosphorus) through drainage systems.

**Table 10.** Fish species captured in HUC-11 watershed 05120101-040 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-001	Common Carp	Cyprinus carpio	T	191
43-002	Goldfish	Carassius auratus	T	55
85-001	Freshwater Drum	Aplodinotus grunniens	P	40
77-011	Longear Sunfish	Lepomis megalotis	M	33
77-009	Bluegill Sunfish	Lepomis macrochirus	P	29
20-003	Gizzard Shad	Dorosoma cepedianum		27
47-002	Channel Catfish	Ictalurus punctatus		27
40-016	White Sucker	Catostomus commersoni	T	20
77-001	White Crappie	Pomoxis annularis		18
40-005	Quillback Carpsucker	Carpionodes cyprinus		17
43-031	Steelcolor Shiner	Cyprinella whipplei	P	15
40-010	Golden Redhorse	Moxostoma erythrurum	M	10
80-011	Logperch	Percina caprodes	M	9
77-002	Black Crappie	Pomoxis nigromaculatus		6
43-026	Common Shiner	Luxilus cornutus		5
77-008	Green Sunfish	Lepomis cyanellus	T	4
40-018	Spotted Sucker	Minytrema melanops		3
43-015	Suckermouth Minnow	Phenacobius mirabilis		3
43-043	Bluntnose Minnow	Pimephales notatus	T	2
47-004	Yellow Bullhead	Ameiurus natalis	T	1
47-008	Stonecat Madtom	Noturus flavus	I	1
77-006	Largemouth Bass	Micropterus salmoides		1



**Map 7.** Map of HUC-11 watershed 05120101-060, Upper Wabash River with Sixmile and Threemile Creeks. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Mainstem sites in this watershed were in the poor range. Fish species were dominated by tolerant species such as Common Carp and White Sucker and only two intolerant species were captured in low numbers (Stonecat Madtom and Slenderhead Darter) in low numbers.

There was no data available from the tributaries within 05120101-060, however, extensive data exists in Limberlost Creek and tributaries (05120101-050), which drains into watershed - 060 at the upper end. Sites in this heavily sampled watershed have very high-to-extreme levels of TP and nitrates at some sites and likely contributed to impairment in the Wabash along with 05120101-010.

In addition, many tributary sites throughout HUC-8 05120101, but especially in 05120101-050, were in fair, poor and very poor condition. Indiana is

preparing a TMDL for watersheds 05120101-050 and segments throughout this watershed area are listed for nutrients and TSS.

The QHEI score at the available mainstem site in 05120101-060 was rated as good (marginally), however, substrate and cover scores were lower than what might be expected at natural sites (see Table 1). Six Wabash River sites were recently sampled as part of the upper Wabash River management plan and scores ranged from 44 (poor) to 66 (most fair-to-good); three tributaries had QHEI scores of 21-43 (poor-to-very poor).

**Summary**—This segment of the Wabash is influenced by degraded habitat on the mainstem and in the tributaries and agricultural and drainage practices that export nutrients and other materials (e.g., dissolved solids) into the mainstem. The drainage activities result in flashy and higher peak flows that worsen erosion of

**Table 11.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in HUC-11 watershed 051201010-060.

05120101-060		QHEI Metrics								Narrative
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)		
Year: 1998										
441.0	61	12	12	14	7	10	0	1.30 - (6)	Good	

banks and export sediments from banks and nutrients through the drainage systems. As with other watersheds in the Upper Wabash, long-term solutions need to address in-stream habitat and hydrology (flashy flows), as well as nutrients, TSS, and other sediments.

**Table 12.** Fish species captured in HUC-11 watershed 05120101-060 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-001	Common Carp	Cyprinus carpio	T	184
40-016	White Sucker	Catostomus commersoni	T	152
40-010	Golden Redhorse	Moxostoma erythrurum	M	144
43-031	Steelcolor Shiner	Cyprinella whipplei	P	118
77-011	Longear Sunfish	Lepomis megalotis	M	93
47-002	Channel Catfish	Ictalurus punctatus		63
85-001	Freshwater Drum	Aplodinotus grunniens	P	43
43-002	Goldfish	Carassius auratus	T	41
77-009	Bluegill Sunfish	Lepomis macrochirus	P	40
40-005	Quillback Carpsucker	Carpodes cyprinus		29
20-003	Gizzard Shad	Dorosoma cepedianum		28
43-026	Common Shiner	Luxilus cornutus		26
80-011	Logperch	Percina caprodes	M	25
43-043	Bluntnose Minnow	Pimephales notatus	T	20
43-032	Spotfin Shiner	Cyprinella spiloptera		18
77-008	Green Sunfish	Lepomis cyanellus	T	17
77-001	White Crappie	Pomoxis annularis		12
47-004	Yellow Bullhead	Ameiurus natalis	T	10
40-015	Northern Hog Sucker	Hypentelium nigricans	M	9
40-018	Spotted Sucker	Minytrema melanops		9
77-002	Black Crappie	Pomoxis nigromaculatus		6
47-008	Stonecat Madtom	Noturus flavus	I	5
77-004	Smallmouth Bass	Micropterus dolomieu	M	5
77-006	Largemouth Bass	Micropterus salmoides		5
43-015	Suckermouth Minnow	Phenacobius mirabilis		4
80-007	Slenderhead Darter	Percina phoxocephala	I	4
77-003	Rock Bass	Ambloplites rupestris		1



**Map 8.** Map of HUC-11 watershed 05120101-070, Upper Wabash River with Sixmile, Halls, and Johns Creeks. Data points reflect fish sampling sites on the mainstem (circles).

The fish assemblage condition in this watershed has improved to a fair condition. The fish are still predominated by tolerant species (carp, drum) and species of intermediate tolerance, however there are more sensitive species (Longear Sunfish, Smallmouth Bass, Northern Hogsucker).

No QHEI was available for this Wabash River segment, but sites were likely similar to upstream sites.

Water quality parameters in this reach were near background (DO, TP), moderate (TOC, BOD, Zn), and high (nitrate, TA, chloride, sulfate, TDS and TSS), but none were very high or extreme. IDEM has listed the mainstem in this area as impaired for nutrients and TDS.

**Summary**—Data within this watershed was relatively sparse, however the fish assemblage in the Wabash was still likely influenced by degraded habitat on the mainstem and in the tributaries. In addition, agricultural runoff from upstream and nearby tributaries export nutrients and other materials (e.g., dissolved solids that influence this portion of the mainstem Wabash River. The drainage activities upstream result in flashy and higher peak flows that worsen erosion of banks and export sediments from banks and nutrients that are readily exported through the drainage systems.

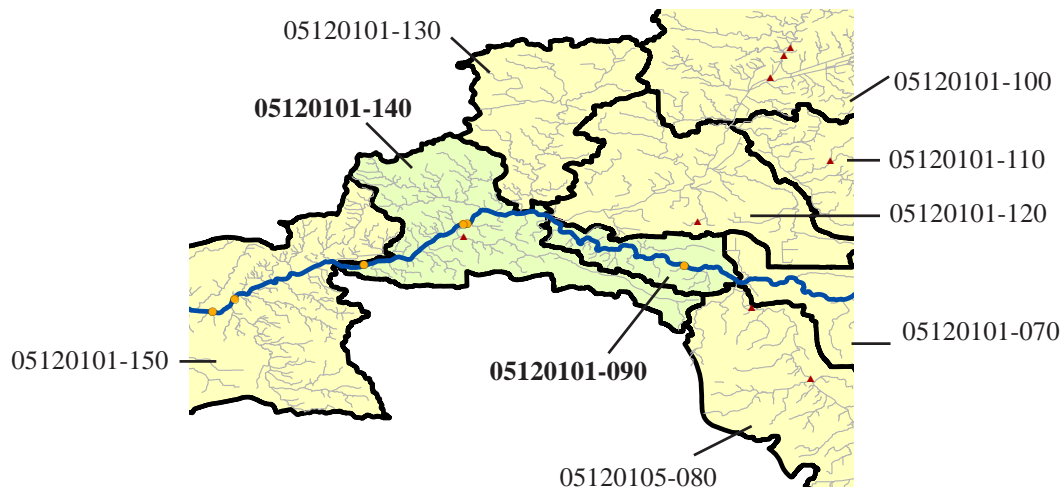
As with other HUC-11 watersheds, agricultural activities that result in these stressors are widespread. Management responses to reduce these stressors would need to be broadscale. As discussed in Part I of this report, small headwaters have the greatest capacity, through restoration, to assimilate and transform nutrients because of the high surface to volume ratios in these streams. The challenge will be to identify the location and extent of channel restoration that would be the most effective at the least cost.

**Table 13.** Fish species captured in HUC-11 watershed 05120101-070 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
43-031	Steelcolor Shiner	Cyprinella whipplei	P	81
20-003	Gizzard Shad	Dorosoma cepedianum		37
47-002	Channel Catfish	Ictalurus punctatus		37
43-001	Common Carp	Cyprinus carpio	T	34
77-011	Longear Sunfish	Lepomis megalotis	M	19
85-001	Freshwater Drum	Aplodinotus grunniens	P	19
80-011	Logperch	Percina caprodes	M	10
43-015	Suckermouth Minnow	Phenacobius mirabilis		9
40-015	Northern Hog Sucker	Hypentelium nigricans	M	8
77-004	Smallmouth Bass	Micropterus dolomieu	M	5
47-004	Yellow Bullhead	Ameiurus natalis	T	4
77-009	Bluegill Sunfish	Lepomis macrochirus	P	4
74-001	White Bass	Morone chrysops		3
77-001	White Crappie	Pomoxis annularis		3
40-018	Spotted Sucker	Minytrema melanops		2
43-044	Central Stoneroller	Campostoma anomalum		2
47-008	Stonecat Madtom	Noturus flavus	I	2
77-006	Largemouth Bass	Micropterus salmoides		2
77-008	Green Sunfish	Lepomis cyanellus	T	2
40-010	Golden Redhorse	Moxostoma erythrurum	M	1
40-016	White Sucker	Catostomus commersoni	T	1
80-002	Walleye	Stizostedion vitreum		1

**Wabash River including Loon Creek, Silver Creek,  
and the Little River**

**HUC-11: 05120101-090 &  
05120101-140**



**Map 9.** Map of HUC-11 watersheds 05120101-090 and -140, Upper Wabash River with Loon and Silver Creeks, and the Little River. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Biological communities show substantial improvement in these HUC-11s as the enriched water from the very upper watershed is diluted or assimilated to a degree. Although tolerant species such as carp still predominate, sensitive fish species (Slenderhead Darter and redhorse species) are increasing in abundance.

Habitat in the mainstem of the Wabash River improves substantially in these watersheds as stream gradient increases and the two locations sampled were rated as good and excellent (Table 14). Substrates were of high quality at these sites and cover and channel quality were better than at upstream sites.

Water quality parameters in these mainstem segments were near background (DO, TP), moderate (TOC, BOD, Zn, TA, chloride (in -090), sulfate, TDS and TSS (in -

090)), and high (nitrate, chloride and TSS in -140), but none were very high or extreme. IDEM has listed the mainstem Wabash in this area as impaired for nutrients and TDS.

**Summary**—Biological condition improved in these reaches of the Wabash River as the gradient and habitat condition increased. The fish assemblage still has substantial populations of tolerant species although sensitive species increased as did overall species richness. The fish assemblage in the Wabash mainstem was still influenced by degraded habitat on the mainstem and in the tributaries. In addition agricultural runoff from upstream and nearby tributaries export nutrients and other materials (e.g., dissolved solids) that influence this portion of the mainstem

**Table 14.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in HUC-11 watershed 051201010-140.

05120101-140		QHEI Metrics							Gradient (Score)	Narrative
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle			
Year: 1998	<b>393.7</b>	70.0	16.0	13.0	14.0	6.0	7.0	4.0	2.20 - (10)	<b>Good</b>
Year: 2003	<b>393.7</b>	93.0	20.0	20.0	16.0	8.0	12.0	7.0	2.20 - (10)	<b>Excellent</b>

Wabash River; however the high gradients and better habitat moderate and assimilate some of these influences. The drainage activities upstream result in flashy and higher peak flows that worsen erosion of banks and export sediments from banks and nutrients are readily exported through the drainage systems.

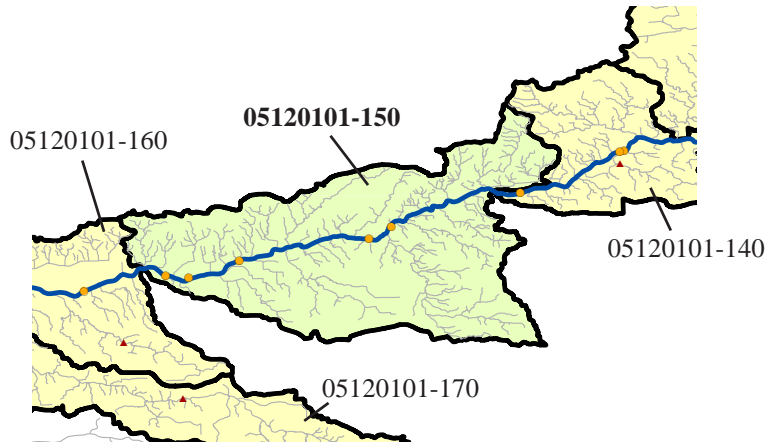
As upstream watersheds are improved or enhanced, we expect this watershed and other downstream reaches would respond strongly because of good in-stream habitat conditions.

**Table 15a.** Fish species captured in HUC-11 watershed 05120101-090 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
77-009	Bluegill Sunfish	Lepomis macrochirus	P	30
43-001	Common Carp	Cyprinus carpio	T	29
77-011	Longear Sunfish	Lepomis megalotis	M	21
77-008	Green Sunfish	Lepomis cyanellus	T	20
80-007	Slenderhead Darter	Percina phoxocephala	I	9
40-010	Golden Redhorse	Moxostoma erythrurum	M	6
85-001	Freshwater Drum	Aplodinotus grunniens	P	5
47-007	Flathead Catfish	Pylodictis olivaris		4
77-001	White Crappie	Pomoxis annularis		4
77-005	Spotted Bass	Micropterus punctulatus		4
80-011	Logperch	Percina caprodes	M	4
43-041	Bullhead Minnow	Pimephales vigilax		3
20-003	Gizzard Shad	Dorosoma cepedianum		2
40-005	Quillback Carpsucker	Carpionodes cyprinus		2
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	2
43-031	Steelcolor Shiner	Cyprinella whipplei	P	2
43-032	Spotfin Shiner	Cyprinella spiloptera		2
47-008	Stonecat Madtom	Noturus flavus	I	2
80-001	Sauger	Stizostedion canadense		2
80-002	Walleye	Stizostedion vitreum		2
80-015	Greenside Darter	Etheostoma blennioides	M	2
40-008	Silver Redhorse	Moxostoma anisurum	M	1
40-015	Northern Hog Sucker	Hypentelium nigricans	M	1
43-002	Goldfish	Carassius auratus	T	1
47-002	Channel Catfish	Ictalurus punctatus		1
74-001	White Bass	Morone chrysops		1
77-002	Black Crappie	Pomoxis nigromaculatus		1
77-006	Largemouth Bass	Micropterus salmoides		1
80-026	Sauger X Walleye	Stizostedion canadense X vitreum		1

**Table 15b.** Fish species captured in HUC-11 watershed 05120101140 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-001	Common Carp	Cyprinus carpio	T	99
40-005	Quillback Carpsucker	Carpiodes cyprinus		74
43-032	Spotfin Shiner	Cyprinella spiloptera		58
20-003	Gizzard Shad	Dorosoma cepedianum		57
77-011	Longear Sunfish	Lepomis megalotis	M	55
85-001	Freshwater Drum	Aplodinotus grunniens	P	47
47-002	Channel Catfish	Ictalurus punctatus		41
43-031	Steelcolor Shiner	Cyprinella whipplei	P	29
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	27
77-009	Bluegill Sunfish	Lepomis macrochirus	P	25
77-001	White Crappie	Pomoxis annularis		23
80-007	Slenderhead Darter	Percina phoxocephala	I	21
40-008	Silver Redhorse	Moxostoma anisurum	M	20
80-011	Logperch	Percina caprodes	M	18
40-010	Golden Redhorse	Moxostoma erythrurum	M	17
43-020	Emerald Shiner	Notropis atherinoides		17
43-006	Silver Chub	Macrhybopsis storeriana		15
43-041	Bullhead Minnow	Pimephales vigilax		14
77-008	Green Sunfish	Lepomis cyanellus	T	9
10-004	Longnose Gar	Lepisosteus osseus		8
80-002	Walleye	Stizostedion vitreum		8
80-001	Sauger	Stizostedion canadense		7
08-002	Shovelnose Sturgeon	Scaphirhynchus platyrhynchus		6
40-015	Northern Hog Sucker	Hypentelium nigricans	M	6
43-034	Sand Shiner	Notropis stramineus	M	6
47-007	Flathead Catfish	Pylodictis olivaris		5
77-005	Spotted Bass	Micropterus punctulatus		4
80-015	Greenside Darter	Etheostoma blennioides	M	4
40-007	Highfin Carpsucker	Carpiodes velifer		3
77-004	Smallmouth Bass	Micropterus dolomieu	M	3
10-002	Shortnose Gar	Lepisosteus platostomus		2
74-001	White Bass	Morone chrysops		2
40-002	Bigmouth Buffalo	Ictiobus cyprinellus		1
40-013	River Redhorse	Moxostoma carinatum	I	1
40-016	White Sucker	Catostomus commersoni	T	1
43-035	Mimic Shiner	Notropis volucellus	I	1
43-040	Miss. Silvery Minnow	Hybognathus nuchalis		1
47-008	Stonecat Madtom	Noturus flavus	I	1
47-012	Brindled Madtom	Noturus miurus	I	1
77-002	Black Crappie	Pomoxis nigromaculatus		1
80-022	Rainbow Darter	Etheostoma caeruleum	M	1



**Map 10.** Map of HUC-11 watershed 05120101-150, Upper Wabash River with Mill, Kentner, and Lagro Creeks. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Fish condition based on IBI in 1999 was in good condition although IBIs in 2004 indicated some impact (Appendix 1a). Fish species were still predominated by carp, however, redhorse and other sensitive species were a larger proportion of the community.

Habitat conditions were good throughout the Wabash River (Table 16), but still well below what might be expected under more natural conditions (Table 1).

There was insufficient chemical data collected in this reach, however, upstream and downstream trends indicate nitrate, TDS, and TSS would still be high due to export from upstream agricultural areas.

tributaries and sedimentation from upstream land uses and stream banks. The assemblage is still influenced by agricultural runoff from upstream and nearby tributaries that are contributing nutrients and other materials (e.g., dissolved solids). Higher gradient and better habitat moderate and assimilate some of these influences and allow populations of more sensitive species to exist. Higher gradient reaches tend to maintain better DO, flush silts, export material before their effects are strongly exerted. The drainage activities in this part of the state result in flashy and higher peak flows that worsen erosion of banks and export sediments from banks and nutrients are readily exported through the drainage systems.

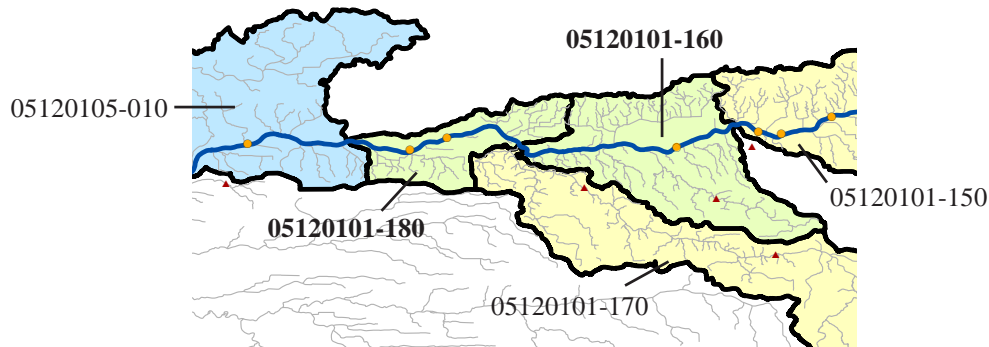
**Summary**—Biological condition improved in these reaches of the Wabash River as the gradient and habitat condition increased. The fish assemblage still has substantial populations of tolerant species although sensitive species increased as did overall species richness. The fish assemblage in the Wabash mainstem was still influenced by degraded habitat in the

**Table 16.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in HUC-11 watershed 051201010-150.

05120101-150		QHEI Metrics							Narrative
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	
Year: 2004									
369.6	63.5	14.0	14.0	14.0	4.5	7.0	0.0	3.00 - (10)	Good
373.4	63.5	14.0	15.0	13.0	4.5	7.0	0.0	2.00 - (10)	Good
380.0	68.0	15.5	13.0	14.0	4.5	7.0	6.0	1.00 - (8)	Good

**Table 17.** Fish species captured in HUC-11 watershed 05120101150 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-001	Common Carp	Cyprinus carpio	T	72
40-005	Quillback Carpsucker	Carpiodes cyprinus		69
85-001	Freshwater Drum	Aplodinotus grunniens	P	61
20-003	Gizzard Shad	Dorosoma cepedianum		59
47-002	Channel Catfish	Ictalurus punctatus		30
40-010	Golden Redhorse	Moxostoma erythrum	M	26
77-011	Longear Sunfish	Lepomis megalotis	M	23
47-007	Flathead Catfish	Pylodictis olivaris		19
43-006	Silver Chub	Macrhybopsis storeriana		17
40-006	River Carpsucker	Carpiodes carpio carpio		15
40-008	Silver Redhorse	Moxostoma anisurum	M	15
08-002	Shovelnose Sturgeon	Scaphirhynchus platyrhynchus		14
43-020	Emerald Shiner	Notropis atherinoides		14
43-032	Spotfin Shiner	Cyprinella spiloptera		12
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	10
43-031	Steelcolor Shiner	Cyprinella whipplei	P	8
10-002	Shortnose Gar	Lepisosteus platostomus		5
77-001	White Crappie	Pomoxis annularis		5
77-009	Bluegill Sunfish	Lepomis macrochirus	P	5
10-004	Longnose Gar	Lepisosteus osseus		4
40-015	Northern Hog Sucker	Hypentelium nigricans	M	4
43-043	Bluntnose Minnow	Pimephales notatus	T	4
77-004	Smallmouth Bass	Micropterus dolomieu	M	4
77-008	Green Sunfish	Lepomis cyanellus	T	4
80-001	Sauger	Stizostedion canadense		4
77-005	Spotted Bass	Micropterus punctulatus		3
77-028	Bluegill Sunfish X Redear Sunfish	Lepomis macrochirus X macrolophus		3
80-007	Slenderhead Darter	Percina phoxocephala	I	3
80-011	Logperch	Percina caprodes	M	3
18-001	Goldeye	Hiodon alosoides	I	2
40-002	Bigmouth Buffalo	Ictiobus cyprinellus		2
40-023	Smallmouth Redhorse	Moxostoma breviceps	M	2
77-003	Rock Bass	Ambloplites rupestris		2
77-006	Largemouth Bass	Micropterus salmoides		2
80-002	Walleye	Stizostedion vitreum		2
80-005	Blackside Darter	Percina maculata		2
40-003	Black Buffalo	Ictiobus niger		1
40-013	River Redhorse	Moxostoma carinatum	I	1
43-034	Sand Shiner	Notropis stramineus	M	1
43-040	Miss. Silvery Minnow	Hybognathus nuchalis		1
43-041	Bullhead Minnow	Pimephales vigilax		1
43-042	Fathead Minnow	Pimephales promelas	T	1
47-009	Mountain Madtom	Noturus eleutherus	I	1
74-001	White Bass	Morone chrysops		1
77-002	Black Crappie	Pomoxis nigromaculatus		1
80-008	River Darter	Percina shumardi		1
80-026	Sauger X Walleye	Stizostedion canadense X vitreum		1
90-002	Mottled Sculpin	Cottus bairdi		1



**Map 11.** Map of HUC-11 watersheds 05120101-160 and -180, Upper Wabash River with Pipe Creek, Little Pipe Creek, and Prairie Ditch. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

IBI scores in this reach of the Wabash were in the good range and scored in the 40s. Although some tolerant species were abundant, sensitive species were predominant (e.g., Shorthead Redhorse) and good populations of intolerant species including Slenderhead Darter, River Redhorse, and Streamline Chub were present. The Streamline Chub itself is especially associated with high quality habitat. In our calculation of weighted stressor values, it has the highest weighted mean channel score (17.5) of all fish examined and the second highest weighted mean for substrate (17.9).

Habitat quality at the site sampled in these reaches were both rated as good (Table 18) and were among the higher scores obtained on the Wabash River. Substrate and cover scores were a bit low, but riffle scores were good at these sites.

Water chemistry concentration in the mainstem were near background for DO, TP, sulfate and TDS, moderate for BOD, TA, chloride and TSS and high

for nitrate, TSS and zinc. No parameters were considered very high or extreme. There was no substantial data available for tributaries in the immediate HUC-11s watersheds, however the Mississinewa River confluences at the upstream border of these HUCs. The lower Mississinewa HUC had low concentrations of sulfate and TDS, but moderate to high concentrations of TP, nitrate, TSS, zinc, TOC and BOD indicating a strong enrichment signature in the data.

**Summary**—Biological condition continued to improve in these reaches of the Wabash River as the gradient and habitat quality increased. The fish assemblage was characterized by more sensitive species although tolerant species remained abundant. The fish assemblage in the Wabash mainstem was again influenced by agricultural runoff from upstream and nearby tributaries (e.g., Mississinewa River) that are contributing nutrients and sediment. Higher gradient and better habitat moderate and assimilate some of these influences and allowed

**Table 18.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in HUC-11 watersheds 051201010-160 and 051201010-180.

05120101-180		QHEI Metrics							Narrative
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	
Year: 2004									
350.0	67.0	13.5	13.0	14.0	4.5	7.0	7.0	1.00 - (8)	Good
352.4	71.5	18.0	12.0	14.0	6.5	7.0	6.0	1.00 - (8)	Good

populations of more sensitive species to increase. Higher gradient reaches tend to maintain better DO, flush silts, export material before their effects are strongly exerted. Because of the magnitude of the loads of nutrients that move past these reaches the

nutrients are likely mostly 'passed through' rather than assimilated. The opportunities to assimilate nutrients is largely a characteristic of headwater reaches with high surface (bioactive substrates) to water volume ratios.

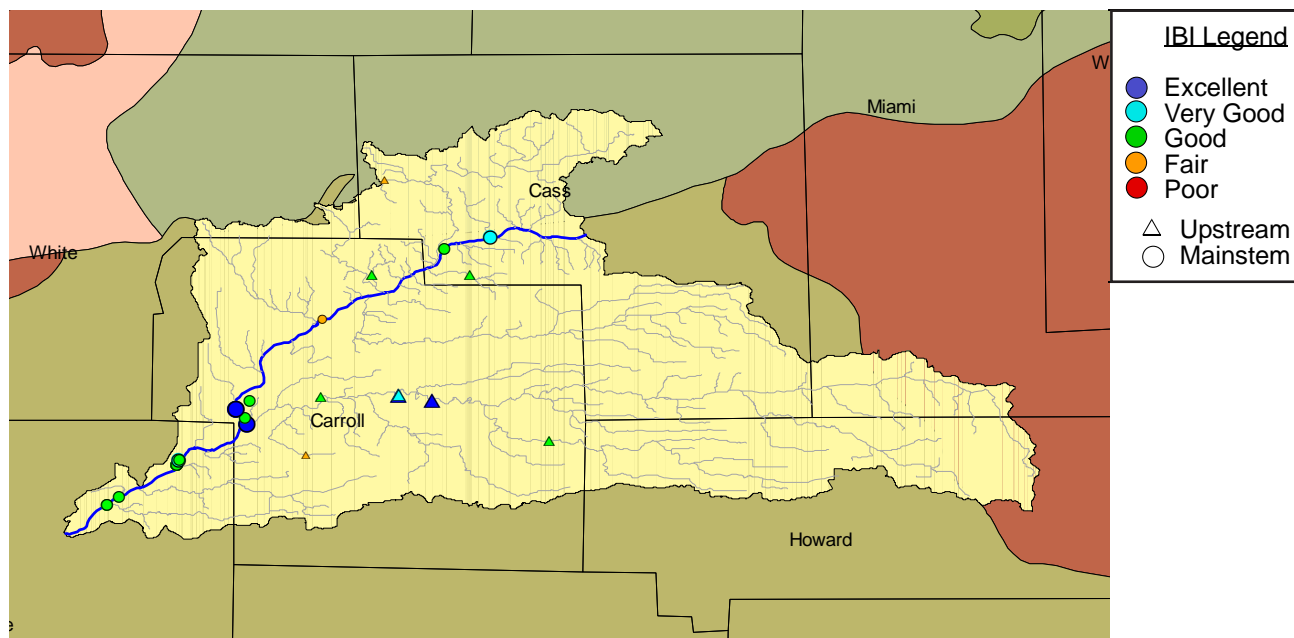
**Table 19a.** Fish species captured in HUC-11 watershed 05120101160 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
40-005	Quillback Carpsucker	<i>Carpiodes cyprinus</i>		52
20-003	Gizzard Shad	<i>Dorosoma cepedianum</i>		20
43-001	Common Carp	<i>Cyprinus carpio</i>	T	19
40-011	Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>	M	17
40-013	River Redhorse	<i>Moxostoma carinatum</i>	I	15
43-031	Steelcolor Shiner	<i>Cyprinella whipplei</i>	P	15
43-032	Spotfin Shiner	<i>Cyprinella spiloptera</i>		15
85-001	Freshwater Drum	<i>Aplodinotus grunniens</i>	P	15
40-008	Silver Redhorse	<i>Moxostoma anisurum</i>	M	8
47-002	Channel Catfish	<i>Ictalurus punctatus</i>		8
10-004	Longnose Gar	<i>Lepisosteus osseus</i>		5
77-011	Longear Sunfish	<i>Lepomis megalotis</i>	M	4
40-004	Smallmouth Buffalo	<i>Ictiobus bubalus</i>		3
40-015	Northern Hog Sucker	<i>Hypentelium nigricans</i>	M	3
43-020	Emerald Shiner	<i>Notropis atherinoides</i>		3
43-034	Sand Shiner	<i>Notropis stramineus</i>	M	2
08-002	Shovelnose Sturgeon	<i>Scaphirhynchus platyrhynchus</i>		1
10-002	Shortnose Gar	<i>Lepisosteus platostomus</i>		1
10-003	Spotted Gar	<i>Lepisosteus oculatus</i>		1
18-001	Goldeye	<i>Hiodon alosoides</i>	I	1
40-007	Highfin Carpsucker	<i>Carpiodes velifer</i>		1
43-041	Bullhead Minnow	<i>Pimephales vigilax</i>		1
77-001	White Crappie	<i>Pomoxis annularis</i>		1
77-004	Smallmouth Bass	<i>Micropterus dolomieu</i>	M	1
77-005	Spotted Bass	<i>Micropterus punctulatus</i>		1
77-006	Largemouth Bass	<i>Micropterus salmoides</i>		1
80-001	Sauger	<i>Stizostedion canadense</i>		1
80-002	Walleye	<i>Stizostedion vitreum</i>		1
80-015	Greenside Darter	<i>Etheostoma blennioides</i>	M	1

**Table 19b.** Fish species captured in HUC-11 watershed 05120101180 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	34
40-006	River Carpsucker	Carpiodes carpio carpio		17
80-007	Slenderhead Darter	Percina phoxocephala	I	12
77-011	Longear Sunfish	Lepomis megalotis	M	11
85-001	Freshwater Drum	Aplodinotus grunniens	P	10
20-003	Gizzard Shad	Dorosoma cepedianum		6
43-008	Streamline Chub	Erimystax dissimilis	I	6
43-043	Bluntnose Minnow	Pimephales notatus	T	6
47-002	Channel Catfish	Ictalurus punctatus		6
43-032	Spotfin Shiner	Cyprinella spiloptera		5
77-028	Bluegill Sunfish X Redear Sunfish	Lepomis macrochirus X macrolophus		5
43-006	Silver Chub	Macrhybopsis storeriana		4
40-004	Smallmouth Buffalo	Ictiobus bubalus		3
10-004	Longnose Gar	Lepisosteus osseus		2
40-003	Black Buffalo	Ictiobus niger		2
40-010	Golden Redhorse	Moxostoma erythrurum	M	2
43-031	Steelcolor Shiner	Cyprinella whipplei	P	2
47-009	Mountain Madtom	Noturus eleutherus	I	2
80-008	River Darter	Percina shumardi		2
80-011	Logperch	Percina caprodes	M	2
08-002	Shovelnose Sturgeon	Scaphirhynchus platyrhynchus		1
40-005	Quillback Carpsucker	Carpiodes cyprinus		1
40-007	Highfin Carpsucker	Carpiodes velifer		1
40-013	River Redhorse	Moxostoma carinatum	I	1
43-001	Common Carp	Cyprinus carpio	T	1
43-010	Shoal Chub	Macrhybopsis hystoma	I	1
43-041	Bullhead Minnow	Pimephales vigilax		1
47-008	Stonecat Madtom	Noturus flavus	I	1
77-003	Rock Bass	Ambloplites rupestris		1
77-004	Smallmouth Bass	Micropterus dolomieu	M	1
77-006	Largemouth Bass	Micropterus salmoides		1
77-010	Orangespotted Sunfish	Lepomis humilis		1
80-015	Greenside Darter	Etheostoma blennioides	M	1
80-023	Orangethroat Darter	Etheostoma spectabile		1

## Middle Wabash River and Deer Creek (HUC-8 05120105)



**Map 12.** IBI values from the mainstem (circles) or upstream tributaries within the middle Wabash River and Deer Creek HUC-8 watershed (05120105). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana from 1999 and 2005/6; other data collected between 1990 and 2006 by IDEM). Shaded areas are Level IV ecoregions; this watershed is primarily in the Loamy, High Lime Till Plains subcoregion with a northern portion in the Lake Country subcoregion and the eastern most portion in the Clayey, High Lime Till Plains subcoregion.

### Data and Background - 05120105

This is the shortest of the five mainstream HUC-8 watersheds and includes only about thirty-seven miles (RMs 346.7 – 309.4) of the Wabash River. Data for this HUC-8 watershed was somewhat sparse compared to data available in the upstream watershed (05120101). Fish assemblage data is primarily from the 1999 survey by the Indiana DNR and some later ORSANCO data from 2004-2006.

**Biological Condition Gradient** – The BCG that we developed for the mainstem Wabash River starts to have some applicability in this reach, especially for some of the species associated with higher gradient reaches. Many of the backwater and Great River species were probably less prevalent in this reach. As discussed in the next section, the biodiversity indicates existing conditions would at best approximate “Tier 3” conditions for a large river.

**Table 20.** Reconstructed historical estimation of habitat conditions in the HUC-8 05120105 watershed (Wabash River with Deer Creek). The reconstruction of this QHEI assumes conditions during early settlement of the Wabash River Valley in the 1800s and is provided as an “anchor” for interpreting habitat conditions. Feasible goals for habitat rehabilitation would likely be somewhere between these values and existing values shown in later tables.

05120105		QHEI Metrics							
HUC-11 Watershed	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	Narrative
0520105*	98.5	21.0	22.0	19.0	10.0	12.0	7.5	3.0 (10)	Excellent

\* Year = 1800

**Table 21.** Selected median water quality values for HUC-11 watersheds from the Middle Wabash River and Deer Creek HUC-8 watershed (05120105); mainstem data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.

Water Chemistry Variables												
HUC-11 Watershed	N	Dissolved Oxygen	BOD (5-day)	Total P	Nitrate	Ammonia	Total Chloride	Total Sulfate	TDS	TSS	Total Org. Carbon	Zinc
Upper Wabash River												
05120105010	229	10.7	2.2	0.21	3.1	0.20	33	51	345	33	5.5	18
05120105030	19	8.2		0.23	2.6		30	52	360	27	6.2	
05120105050	93	10.6	2.5	0.20	3.3	0.15	33	46	334	42	5.6	19
05120105070	112	10.1	2.6	0.15	3.5	0.20	33	56	348	39	5.1	10

Summary of Narrative Ranges: -Ref. -Low -Med. -High -V.High -Extreme

**Table 22.** Selected median water quality values for HUC-11 watersheds from the Middle Wabash River and Deer Creek HUC-8 watershed (05120105); tributary data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.

Water Chemistry Variables												
HUC-11 Watershed	N	Dissolved Oxygen	BOD (5-day)	Total P	Nitrate	Ammonia	Total Chloride	Total Sulfate	TDS	TSS	Total Org. Carbon	Zinc
05120105010	7	7.2		0.07	1.7	0.17	17	46	380	6	5	
05120105020	13	9.5		0.08	3.1	0.25	14	49	420	35	1	30
05120105030	10	9.7		0.18	3.7		24	52	413	13	1	8
05120105040	8	9.5										
05120105050	195	10.1	3.1	0.08	3.9	0.20	34	52	418	11	3	16
05120105070	11	9.8										

Summary of Narrative Ranges: -Ref. -Low -Med. -High -V.High -Extreme

**Table 23.** Water Quality Index values for HUC-11 watersheds from the upper Wabash River Huc-8 watershed (05120105); tributary and mainstem data combined. N reflects number of stations. Mean WQI does not include QHEI component. Colors represent increasing risk of aquatic life impairment.

HUC-11 Watershed	N	Water Chemistry Variables										
		Dissolved Oxygen	Total P	QHEI	TSS	Min. WQI	Mean WQI					
05120105010	22	93.0	53.2	86.9	63.0	46.4	76.5					
05120105020	8	69.4	95.4	72.1	16.0	62.0	86.5					
05120105030	15	57.9	43.8	49.8	50.0	71.8	88.1					
05120105040	37	96.0	91.6	63.2	72.3	83.1	94.4					
05120105050	7	95.0	83.2	41.6	81.6	27.5	82.3					
05120105070	16	90.0	85.6	41.0	81.3	56.7	81.2					

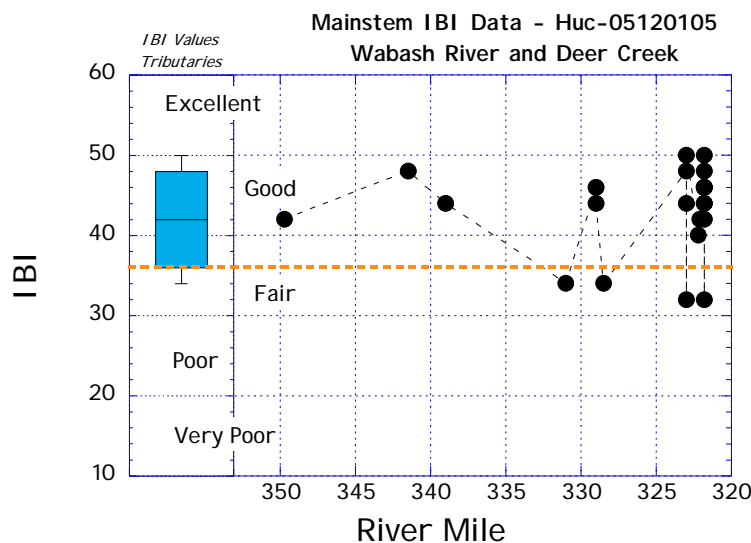
<span style="color: blue;">■</span> -Ref.	<span style="color: green;">■</span> -Low	<span style="color: yellow;">■</span> -Med.	<span style="color: pink;">■</span> -High	<span style="color: purple;">■</span> -V.High	<span style="color: red;">■</span> -Extreme
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**Identification of Stressors** – We used a “weight-of-evidence” stressor identification approach to assign likely causes of biological impairment. For example, we compared stressor levels in the mainstem and at upstream sites to ranges of values considered to be “least impacted” to rank stressor levels and to identify stressor that could be responsible for limiting biological conditions and biodiversity.

are relatively high for this size of river and substrate materials are conducive to good habitat and biota. Table 20 presents a hypothetical reconstruction of what Wabash River stream habitat might have looked like prior to settlement. Habitat then would have been classified as excellent with maximum or near maximum scores for most metrics.

**Historical Habitat Conditions** – This HUC-8 watershed contains the best reaches of habitat that still occur in the Wabash River. Stream gradients

**Pollutant Stressors in the Watershed** – Tables 21 and 22 summarize chemical concentrations for these HUC-11 watersheds in the mainstem Wabash (Table



**Figure 7.** Plot of IBI by river mile in the middle Wabash River and Deer Creek HUC-8 watershed. Mainstream sites are black and connected by a dashed line. Box and whisker plot represents IDEM tributary QHEI data from this watershed.

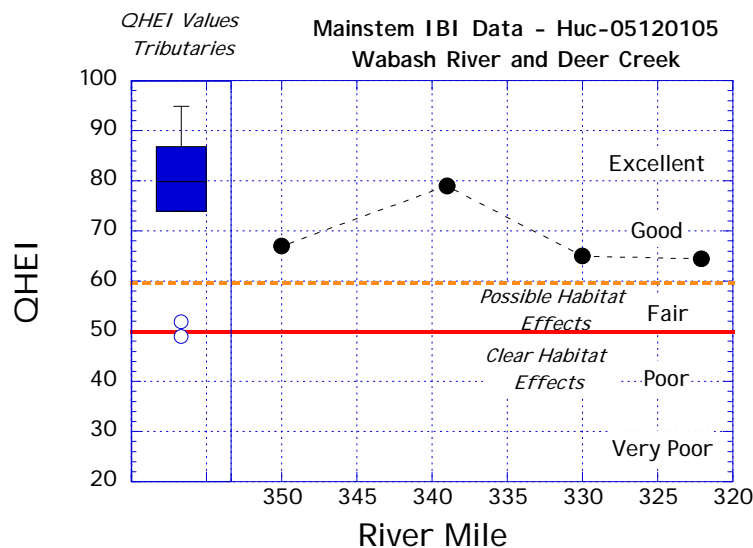
**Table 24.** Ten most dominant fish species by number collected in fish samples in the middle Wabash River and Deer Creek watershed (Huc 05120105) collected in Indiana. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

Ten Most Dominant Fish Species by Relative Abundance	
Mainstem	Tributaries (Excluding Mainstem)
Emerald Shiner - (350)	Western Blacknose Dace [T] - (297)
River Shiner - (337)	Bluntnose Minnow [T] - (296)
Freshwater Drum [P] - (286)	Longear Sunfish [M] - (283)
Gizzard Shad - (311)	Spotfin Shiner - 282
Sand Shiner [M] - (212)	Creek Chub [T] - (145)
Longear Sunfish [M] - (183)	Central Stoneroller - (2,948)
Spotfin Shiner - (190)	Greenside Darter [M] - (105)
Shorthead Redhorse [M] - (129)	Black Redhorse [I] - (92)
Mimic Shiner [I] - (114)	Golden Redhorse [M] - (80)
Northern Hogsucker [M] - (89)	Northern Hogsucker [M] - (65)

21) and in the tributaries of these HUC-11s (Table 22), as described in the technical summary. Table 23 provides a different way of looking at water chemistry results using a Water Quality Index (WQI) that was calibrated by linking chemical concentrations to threshold responses of IBI scores at samples sites. None of these tables are replacements for water quality criteria, but are simply a way to consider risks to aquatic life from increased concentrations based on ambient stressor response relationships.

### Results and Summary -05120105

Fish sites sampled in this second reach of the Wabash River were mostly in good shape as can be observed in Map 12 and Figure 10. The IBI was generally good in the tributaries of the Wabash in this HUC-8 watershed which includes samples in Deer Creek and Little Deer Creek (N=9). Most IBI scores in this reach of the mainstem met the biological condition target of IDEM (IBI=36). Compared to the probability



**Figure 8.** Plot of QHEI by river mile in the middle Wabash River and Deer Creek HUC-8 watershed. Mainstream sites are black and connected by a dashed line. Box and whisker plot represents tributary QHEI data from this watershed.

based results from the entire Wabash Watershed, the results from this HUC-8 are better.

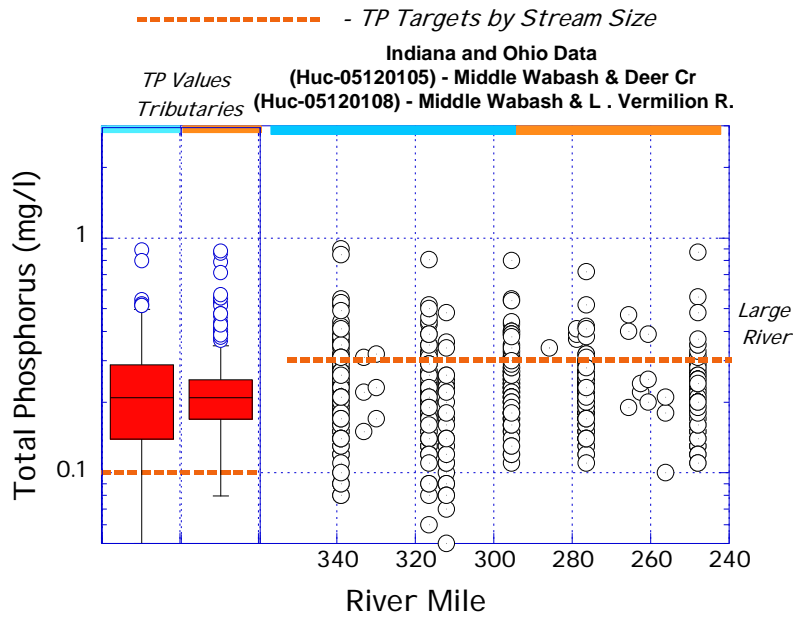
**Biodiversity** – The fish species collected in the Middle Wabash and Deer Creek were characterized by more sensitive species than those in the upper Wabash River HUC-11. Five of the ten most common species collected in the mainstem are considered sensitive or intolerant (Table 24) and only one is considered pollution tolerant (Freshwater Drum, moderately tolerant). The tributaries in this watershed also have five sensitive and intolerant species among the top ten (Table 24). Some of the tolerant species are expected in small tributaries and the mix with sensitive species is typical of good quality wadeable streams. Live freshwater mussel species in the mainstem of this HUC-8 watershed ranged from 20-23 species (live+dead; 30-36 species). This represents one of the most diverse reaches in the Wabash River for freshwater mussels.

**Habitat** – Historically, the upper and middle reaches of the Wabash were quite different in character from what they are like today. The landscape was covered with permanent forest, prairie and wetland vegetation. Stream habitat was natural and likely consisted of a mix of higher gradient streams and flowing wetlands. In these streams, water was clear, habitat was likely diverse and aquatic vegetation was likely abundant. QHEI scores would have ranged from the 70s to 90s. This reach of the Wabash River mainstem has the best quality habitat of any of the reaches (Figure 8), likely related to the higher gradient and more natural cover and channel features. As summarized in Table 20, sites in this reach have most of the positive warmwater habitat features expected in a medium-large river. Tributaries also have high quality habitat features with scores ranging from the 70s to the 90s (excellent quality habitat).

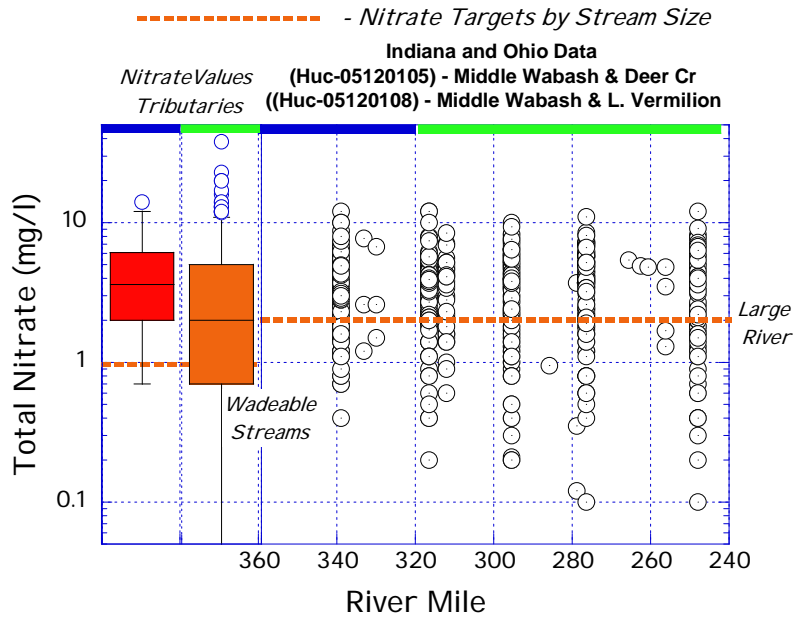
**Pollutant Stressors in the Watershed** – While this reach of the Wabash performs much better biologically, the nutrient enrichment from the upper Wabash River is still evident in the mainstream (Figures 9 and 10). The tributaries in this HUC-8 are also enriched with TP even though habitat is generally better at sampled sites. Chemistry sites may not be all the same as the biological stations. Nitrates were also high in streams that are tributaries in this HUC-8 watershed. Nitrates

typically originate from tile drainage common in agricultural landscapes.

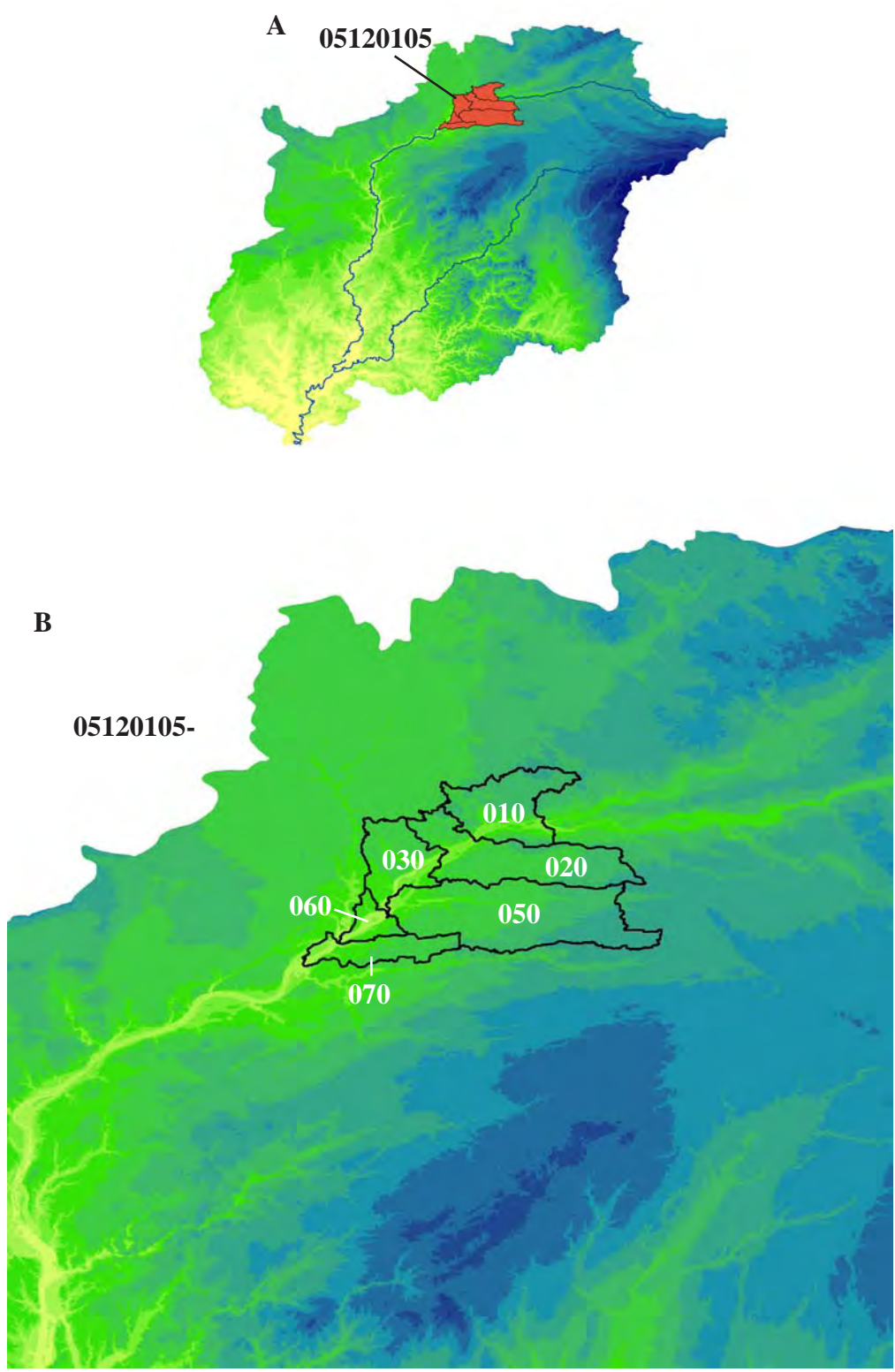
**Pollutant Stressors in the Watershed** – Nutrients, including TP (Figure 9) and Nitrate (Figure 10), remain elevated in the mainstem. This reflects the upstream contributions from 05120101 and the lack of dilution (i.e., elevated nutrients from HUC-11 watersheds within 05120105). As discussed under the Upper Wabash section, control of nutrients is dependent on dynamics in the headwaters. As in 05120101, many streams in 05120105 are also channelized and do little to dilute or convert high nutrients.



**Figure 9.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within two of the middle Wabash River HUC-8 watersheds (05120105-blue and 05120108-orange). Box and whisker plots represents data from tributaries from within each these HUC-8 watersheds. Orange dash lines represent total phosphorus targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



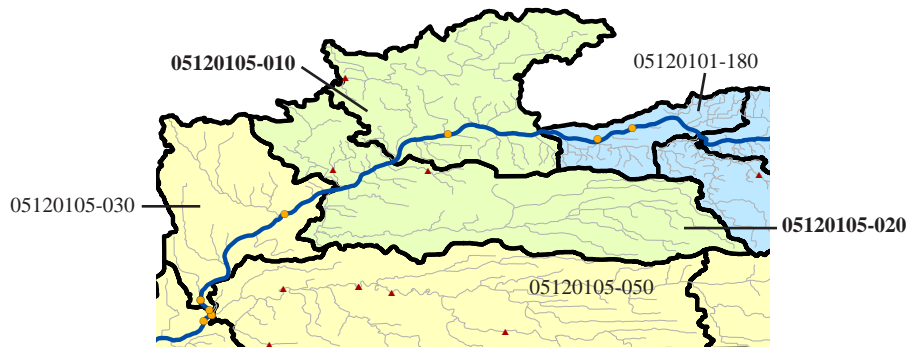
**Figure 10.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within two of the middle Wabash River HUC-8 watersheds (05120105-purple and 05120108-green). Box and whisker plots represents data from tributaries from within each these HUC-8 watersheds. Orange dash lines represent total phosphorus targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



**Map 13.** Maps of the Wabash River HUC-8 watershed, 05120105, showing its position in the Wabash River Watershed (A) and the HUC-11 catchments within it (B). Elevation (0-255 meters; color-coded - 15 levels) serves as the background of each map. Only the last three digits of each HUC-11 are shown.

**Middle Wabash River, including Eel River, Rock Creek, Burnetts Creek, and Crooked Creek**

**HUC-11: 05120105-010  
& 05120105-020**



**Map 14.** Map of HUC-11 watersheds 05120105-010 and -020, Middle Wabash River with Eel River, Rock Creek, Burnetts Creek and Crooked Creek. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Biological condition was very good in this reach of the Wabash River. The sampling site in 05120105-010 had the highest IBI and the most species (37) of any site sampled in the Wabash River (Appendix Table 1a). It was dominated by sensitive and intolerant fish species, including Streamline Chub, Rosyface Shiner, Black Redhorse, River Chub, and Hornyhead Chub, species that would be expected with excellent habitat and generally good water quality (Table 23). The back-calculated stressor signal from this site indicate good habitat and elevated nutrients (Appendix 8), which is consistent with the actual chemical stressor data. Mussel species richness was also good in this reach, related to the good in-stream habitat conditions (Appendix 10).

Habitat as measured by the QHEI was excellent with near maximum score on substrate, pool and riffle (Table 25). Even with excellent habitat, natural historical habitat quality would have been about 10 points higher with more extensive cover and more diverse channel characteristics.

DO, TP, and dissolved constituents approximated background conditions for this size river, but BOD,

TA, Zn and TOC were moderately elevated and nitrate and TSS were high; no variables were considered very high or extremely elevated (Table 19). The good habitat conditions and high gradient buffer this reach from the high nutrients which are probably quickly transported through the reach.

**Summary**—Biological condition was good in these reaches of the Wabash River related to the good gradient and excellent habitat quality. The fish assemblage was predominated by sensitive and intolerant species and the reach was among the most species rich in the river. The intolerant species in this reach are generally associated with clean substrates and good channel and habitat diversity which was present at the sample sites. River Chub, Hornyhead Chub, Rosyface Shiner and Streamline Chub are among the most sensitive to habitat and to chemical stressors (see Appendix 5a and 5b).

Tolerant fishes in the Wabash mainstem were still not rare and were likely influence by agricultural runoff from upstream and nearby tributaries (e.g., Eel River) that are contributing high nutrients and

**Table 25.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in HUC-11 watershed 051205010-010.

05120105-010		QHEI Metrics							Narrative
River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	
Year: 1998									
339.0	79.0	19.0	14.0	13.0	6.0	10.0	7.0	1.3 - (10)	Excellent

sediment (see Appendix 7). Higher gradient and better habitat moderate and assimilate some of these influences and allowed populations of more sensitive species to increase. Higher gradient reaches tend to maintain better DO, flush silts, export material before their effects are strongly exerted. Because of the magnitude of the loads of nutrients that move past

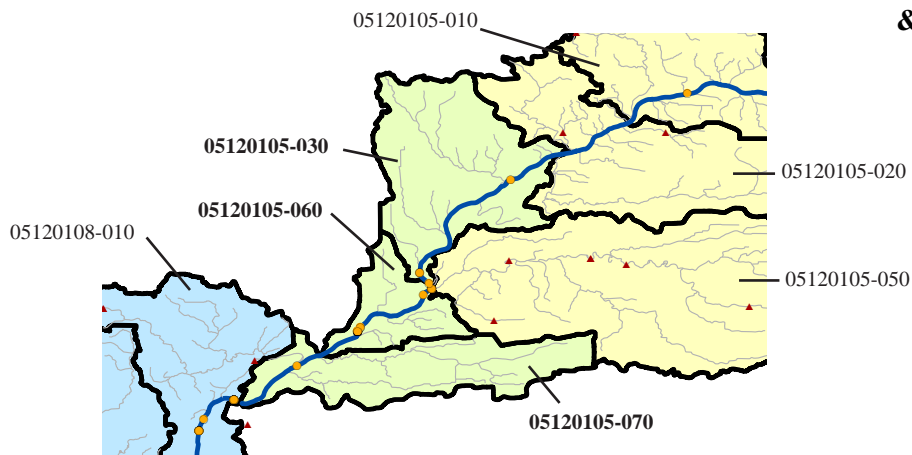
these reaches the nutrients are likely mostly ‘passed through rather than assimilated. The opportunities to assimilate nutrients are largely a characteristic of headwater reaches with high surface (bioactive substrates) to water volume ratios.

**Table 26.** Fish species captured in HUC-11 watershed 05120105-010 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
20-003	Gizzard Shad	Dorosoma cepedianum		30
43-034	Sand Shiner	Notropis stramineus	M	30
43-044	Central Stoneroller	Campostoma anomalum		25
43-032	Spotfin Shiner	Cyprinella spiloptera		23
40-010	Golden Redhorse	Moxostoma erythrurum	M	15
43-001	Common Carp	Cyprinus carpio	T	11
40-015	Northern Hog Sucker	Hypentelium nigricans	M	10
85-001	Freshwater Drum	Aplodinotus grunniens	P	7
43-020	Emerald Shiner	Notropis atherinoides		6
43-025	Striped Shiner	Luxilus chrysocephalus		6
43-039	Silverjaw Minnow	Notropis buccatus		6
80-015	Greenside Darter	Etheostoma blennioides	M	6
40-009	Black Redhorse	Moxostoma duquesnei	I	5
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	5
43-027	River Shiner	Notropis blennius		5
77-011	Longear Sunfish	Lepomis megalotis	M	5
47-002	Channel Catfish	Ictalurus punctatus		4
77-006	Largemouth Bass	Micropterus salmoides		4
40-005	Quillback Carpsucker	Carpiodes cyprinus		3
40-006	River Carpsucker	Carpiodes carpio carpio		3
43-015	Suckermouth Minnow	Phenacobius mirabilis		3
80-007	Slenderhead Darter	Percina phoxocephala	I	3
40-008	Silver Redhorse	Moxostoma anisurum	M	2
43-043	Bluntnose Minnow	Pimephales notatus	T	2
77-004	Smallmouth Bass	Micropterus dolomieu	M	2
80-014	Johnny Darter	Etheostoma nigrum		2
40-013	River Redhorse	Moxostoma carinatum	I	1
43-004	Hornyhead Chub	Nocomis biguttatus	I	1
43-005	River Chub	Nocomis micropogon	I	1
43-008	Streamline Chub	Erimystax dissimilis	I	1
43-022	Rosyface Shiner	Notropis rubellus	I	1
47-007	Flathead Catfish	Pylodictis olivaris		1
47-008	Stonecat Madtom	Noturus flavus	I	1
77-003	Rock Bass	Ambloplites rupestris		1
77-008	Green Sunfish	Lepomis cyanellus	T	1
77-009	Bluegill Sunfish	Lepomis macrochirus	P	1
80-001	Sauger	Stizostedion canadense		1
80-022	Rainbow Darter	Etheostoma caeruleum	M	1

**Middle Wabash River – Deer Creek, Sugar Creek,  
and Rattlesnake Creek**

**HUC-11: 05120105-030  
05120105-060  
& 05120105070**



**Map 15.** Map of HUC-11 watersheds 05120105-030, -060 and -070, Middle Wabash River with Deer Creek, Sugar Creek, and Rattlesnake Creeks. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

These reaches have been relatively well sampled (see Appendix 1a and fish assemblages are generally in good shape. There are good populations of sensitive and intolerant species, but there are also good populations of some relatively tolerant species that favor high nutrients (drum, carp, bluegill) (Table 25). The Tippecanoe River with its diverse fauna, confluences with the Wabash River at the junction of HUC-11 watersheds -060 and -070 and likely contributes to the high biodiversity of the Wabash River mainstem in these HUC-11 watersheds. The back-calculated stressor signals matched the good habitat conditions, but variable and often high nutrient signal (Appendix 8). These reaches also support a high species richness of freshwater mussels (Appendix 10), likely related to the gradient and habitat characteristics.

Habitat conditions are good in these reaches with generally good substrate conditions, especially where riffles are present (Table 27). Cover, channel

and riparian scores are a bit low and are evidence of encroachment on riparian areas which probably keeps habitat from reaching the excellent range.

DO, TP, and dissolved constituents approximated background conditions for this size river, but BOD, TA, TOC were moderately elevated and nitrate and TSS were high; no variables were considered very high or extremely elevated (Table 21).

**Summary**–Biological condition was good in these reaches of the Wabash River related to the good gradient and good habitat quality. The fish assemblage was predominated by mostly sensitive and intolerant. The intolerant species in this reach are generally associated with clean substrates and good channel and habitat diversity which were present at the sample sites. Some of the sensitive larger river species were beginning to show up in these reaches, specifically the Shoal Chub, Paddlefish, and Shovelnose Sturgeon.

**Table 27.** QHEI, QHEI metrics, and narrative rating for mainstream Wabash River sites sampled in Huc-11 watersheds 05120105-030.

05120105-030	QHEI Metrics								Narrative	
	River Mile	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle		Gradient (Score)
Year: 2003	<b>330.0</b>	65.0	13.0	10.0	14.0	9.0	9.0	0.0	1.26 - (10)	<b>Good</b>
Year: 2004	<b>322.1</b>	64.5	18.5	9.0	12.0	4.0	7.0	6.0	1.00 - (8)	<b>Good</b>

Tolerant fishes in the Wabash mainstem were still not rare and were likely influenced by agricultural runoff from upstream and nearby tributaries (e.g., Deer Creek) that are contributing high nitrate and TSS (see Appendix 7). Higher gradient and better habitat moderate and assimilate some of these influences and allowed populations of more sensitive

species to increase. Downstream of the Wabash River and Deer Creek HUC-8 watershed, river gradient decreases and the river habitat is less diverse. Invasive alien species (e.g., silver carp and bighead carp) were collected in these reaches, and are likely more abundant today.

**Table 28a.** Fish species captured in HUC-11 watershed 05120105-030 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-020	Emerald Shiner	Notropis atherinoides		428
43-027	River Shiner	Notropis blennioides		375
85-001	Freshwater Drum	Aplodinotus grunniens	P	326
20-003	Gizzard Shad	Dorosoma cepedianum		313
43-032	Spotfin Shiner	Cyprinella spiloptera		218
43-034	Sand Shiner	Notropis stramineus	M	200
77-011	Longear Sunfish	Lepomis megalotis	M	156
43-035	Mimic Shiner	Notropis volucellus	I	140
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	132
43-041	Bullhead Minnow	Pimephales vigilax		94
47-002	Channel Catfish	Ictalurus punctatus		87
40-015	Northern Hog Sucker	Hypentelium nigricans	M	83
40-006	River Carpsucker	Carpionodes carpio carpio		79
43-031	Steelcolor Shiner	Cyprinella whipplei	P	77
40-008	Silver Redhorse	Moxostoma anisurum	M	68
77-009	Bluegill Sunfish	Lepomis macrochirus	P	65
43-001	Common Carp	Cyprinus carpio	T	54
43-022	Rosyface Shiner	Notropis rubellus	I	52
43-063	Channel Shiner	Notropis wickliffi	I	43
43-043	Bluntnose Minnow	Pimephales notatus	T	37
77-004	Smallmouth Bass	Micropterus dolomieu	M	32
40-010	Golden Redhorse	Moxostoma erythrurum	M	31
43-006	Silver Chub	Macrhybopsis storeriana		27
80-001	Sauger	Stizostedion canadense		26
77-005	Spotted Bass	Micropterus punctulatus		21
43-010	Shoal Chub	Macrhybopsis hystoma	I	16
10-004	Longnose Gar	Lepisosteus osseus		15
47-007	Flathead Catfish	Pylodictis olivaris		15
40-009	Black Redhorse	Moxostoma duquesnei	I	13
43-009	Gravel Chub	Erimystax x-punctata	M	13
74-001	White Bass	Morone chrysops		12
10-002	Shortnose Gar	Lepisosteus platostomus		11
40-001	Blue Sucker	Cycleptus elongatus	I	10
43-040	Miss. Silvery Minnow	Hybognathus nuchalis		10
43-015	Suckermouth Minnow	Phenacobius mirabilis		9
43-044	Central Stoneroller	Campostoma anomalum		9
80-002	Walleye	Stizostedion vitreum		9
08-002	Shovelnose Sturgeon	Scaphirhynchus platyrhynchus		7

**Table 28a.** Fish species captured in HUC-11 watershed 05120105-030, continued.

40-007	Highfin Carpsucker	<i>Carpiodes velifer</i>		7
40-002	Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>		6
77-006	Largemouth Bass	<i>Micropterus salmoides</i>		6
18-002	Mooneye	<i>Hiodon tergisus</i>	I	5
80-007	Slenderhead Darter	<i>Percina phoxocephala</i>	I	5
40-004	Smallmouth Buffalo	<i>Ictiobus bubalus</i>		4
43-007	Bigeye Chub	<i>Notropis amblops</i>	I	4
77-001	White Crappie	<i>Pomoxis annularis</i>		4
77-002	Black Crappie	<i>Pomoxis nigromaculatus</i>		4
77-008	Green Sunfish	<i>Lepomis cyanellus</i>	T	4
77-013	Pumpkinseed Sunfish	<i>Lepomis gibbosus</i>	P	4
80-011	Logperch	<i>Percina caprodes</i>	M	4
43-047	Grass Carp	<i>Ctenopharyngodon idella</i>		3
47-009	Mountain Madtom	<i>Noturus eleutherus</i>	I	3
80-005	Blackside Darter	<i>Percina maculata</i>		3
43-028	Spottail Shiner	<i>Notropis hudsonius</i>	P	2
80-014	Johnny Darter	<i>Etheostoma nigrum</i>		2
99-040	unspecified sucker	unspecified sucker		2
01-001	Silver Lamprey	<i>Ichthyomyzon unicuspis</i>		1
20-001	Skipjack Herring	<i>Alosa chrysochloris</i>		1
40-005	Quillback Carpsucker	<i>Carpiodes cyprinus</i>		1
40-013	River Redhorse	<i>Moxostoma carinatum</i>	I	1
40-023	Smallmouth Redhorse	<i>Moxostoma breviceps</i>	M	1
43-003	Golden Shiner	<i>Notemigonus crysoleucas</i>	T	1
43-113	Bighead Carp	<i>Hypophthalmichthys nobilis</i>		1
47-003	White Catfish	<i>Ictalurus catus</i>		1
80-004	Dusky Darter	<i>Percina sciera sciera</i>	M	1
80-015	Greenside Darter	<i>Etheostoma blennioides</i>	M	1

**Table 29b.** Fish species captured in HUC-11 watershed 05120105-060 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species Code	Species Name	Latin Name	Species Tolerance	Number Collected
43-032	Spotfin Shiner	<i>Cyprinella spiloptera</i>		350
85-001	Freshwater Drum	<i>Aplodinotus grunniens</i>	P	315
43-027	River Shiner	<i>Notropis blennioides</i>		191
43-020	Emerald Shiner	<i>Notropis atherinoides</i>		142
40-006	River Carpsucker	<i>Carpiodes carpio carpio</i>		136
43-041	Bullhead Minnow	<i>Pimephales vigilax</i>		128
77-011	Longear Sunfish	<i>Lepomis megalotis</i>	M	117
43-034	Sand Shiner	<i>Notropis stramineus</i>	M	108
20-003	Gizzard Shad	<i>Dorosoma cepedianum</i>		99
43-001	Common Carp	<i>Cyprinus carpio</i>	T	84
40-011	Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>	M	82
40-004	Smallmouth Buffalo	<i>Ictiobus bubalus</i>		57
43-031	Steelcolor Shiner	<i>Cyprinella whipplei</i>	P	55
47-002	Channel Catfish	<i>Ictalurus punctatus</i>		42
40-008	Silver Redhorse	<i>Moxostoma anisurum</i>	M	40
77-004	Smallmouth Bass	<i>Micropterus dolomieu</i>	M	36

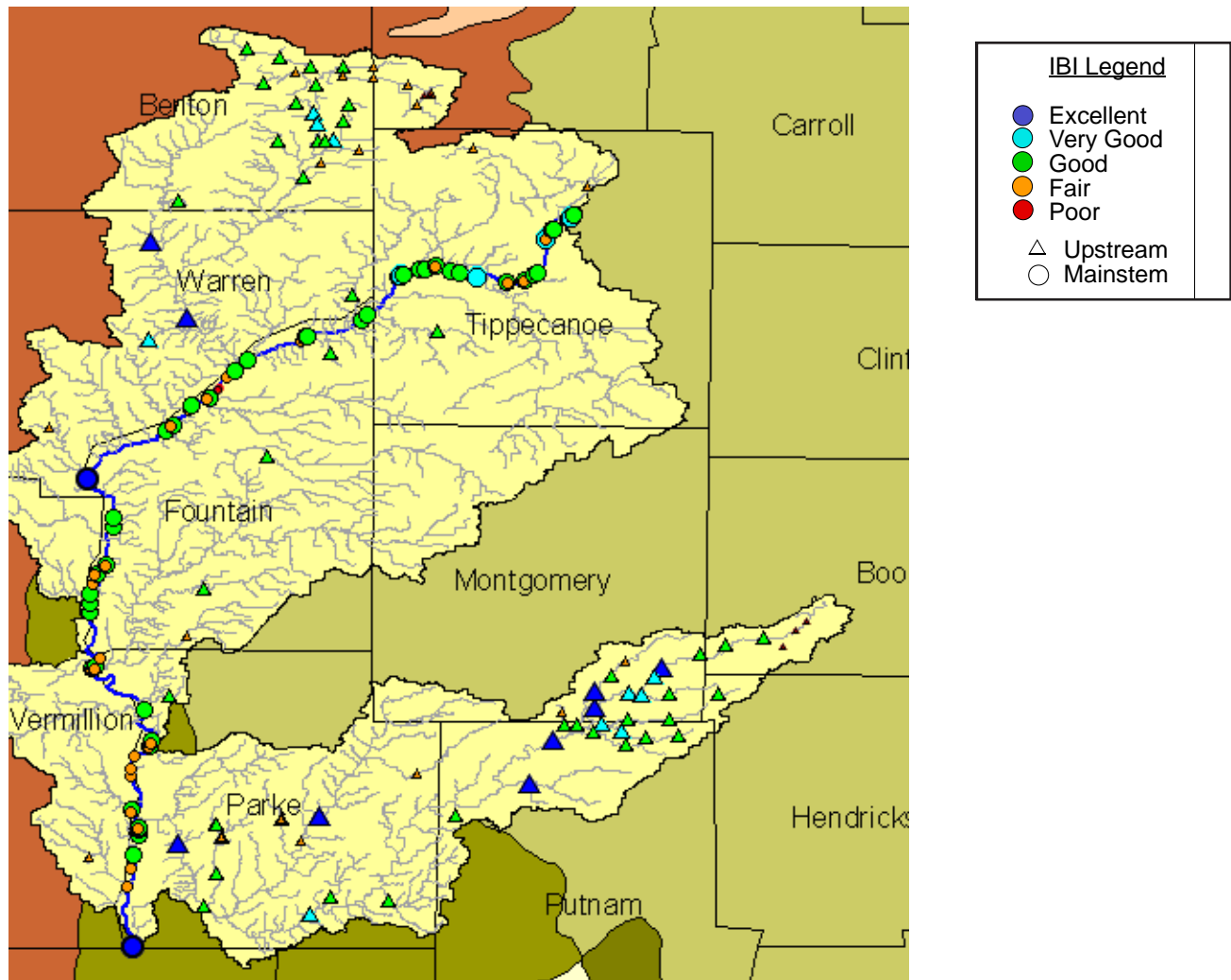
**Table 29b.** Fish species captured in HUC-11 watershed 05120105-060, continued.

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
77-004	Smallmouth Bass	<i>Micropterus dolomieu</i>	M	36
77-009	Bluegill Sunfish	<i>Lepomis macrochirus</i>	P	29
99-040	unspecified sucker	unspecified sucker		28
43-035	Mimic Shiner	<i>Notropis volucellus</i>	I	26
77-005	Spotted Bass	<i>Micropterus punctulatus</i>		23
40-003	Black Buffalo	<i>Ictiobus niger</i>		21
77-008	Green Sunfish	<i>Lepomis cyanellus</i>	T	15
74-001	White Bass	<i>Morone chrysops</i>		14
40-010	Golden Redhorse	<i>Moxostoma erythrurum</i>	M	13
47-007	Flathead Catfish	<i>Pylodictis olivaris</i>		12
40-001	Blue Sucker	<i>Cycleptus elongatus</i>	I	11
77-001	White Crappie	<i>Pomoxis annularis</i>		11
77-013	Pumpkinseed Sunfish	<i>Lepomis gibbosus</i>	P	10
10-004	Longnose Gar	<i>Lepisosteus osseus</i>		9
40-005	Quillback Carpsucker	<i>Carpiodes cyprinus</i>		8
40-007	Highfin Carpsucker	<i>Carpiodes velifer</i>		8
40-002	Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>		6
40-009	Black Redhorse	<i>Moxostoma duquesnei</i>	I	6
20-001	Skipjack Herring	<i>Alosa chrysochloris</i>		5
43-022	Rosyface Shiner	<i>Notropis rubellus</i>	I	5
43-043	Bluntnose Minnow	<i>Pimephales notatus</i>	T	5
80-001	Sauger	<i>Stizostedion canadense</i>		5
08-002	Shovelnose Sturgeon	<i>Scaphirhynchus platyrhynchus</i>		3
40-015	Northern Hog Sucker	<i>Hypentelium nigricans</i>	M	3
43-006	Silver Chub	<i>Macrhybopsis storeriana</i>		3
43-113	Bighead Carp	<i>Hypophthalmichthys nobilis</i>		3
10-002	Shortnose Gar	<i>Lepisosteus platostomus</i>		2
18-002	Mooneye	<i>Hiodon tergisus</i>	I	2
43-047	Grass Carp	<i>Ctenopharyngodon idella</i>		2
43-079	Silver Carp	<i>Hypophthalmichthys molitrix</i>		2
77-006	Largemouth Bass	<i>Micropterus salmoides</i>		2
80-007	Slenderhead Darter	<i>Percina phoxocephala</i>	I	2
43-003	Golden Shiner	<i>Notemigonus crysoleucas</i>	T	1
43-039	Silverjaw Minnow	<i>Notropis buccatus</i>		1
77-012	Redear Sunfish	<i>Lepomis microlophus</i>		1
80-004	Dusky Darter	<i>Percina sciera sciera</i>	M	1
80-011	Logperch	<i>Percina caprodes</i>	M	1

**Table 29c.** Fish species captured in HUC-11 watershed 05120105-070 from 1999-2006. IBI tolerances are color coded: I – Intolerant (blue); M – Sensitive (green); P – Moderately Tolerant (pink); T – Tolerant (red).

Species			Species	Number
Code	Species Name	Latin Name	Tolerance	Collected
20-003	Gizzard Shad	Dorosoma cepedianum		68
85-001	Freshwater Drum	Aplodinotus grunniens	P	50
43-020	Emerald Shiner	Notropis atherinoides		40
43-032	Spotfin Shiner	Cyprinella spiloptera		40
08-002	Shovelnose Sturgeon	Scaphirhynchus platyrhynchus		27
43-027	River Shiner	Notropis blennioides		21
40-006	River Carpsucker	Carpododes carpio carpio		17
43-001	Common Carp	Cyprinus carpio	T	16
47-002	Channel Catfish	Ictalurus punctatus		16
40-011	Shorthead Redhorse	Moxostoma macrolepidotum	M	12
43-006	Silver Chub	Macrhybopsis storeriana		11
77-005	Spotted Bass	Micropterus punctulatus		9
80-001	Sauger	Stizostedion canadense		8
40-008	Silver Redhorse	Moxostoma anisurum	M	7
43-031	Steelcolor Shiner	Cyprinella whipplei	P	7
43-041	Bullhead Minnow	Pimephales vigilax		7
77-009	Bluegill Sunfish	Lepomis macrochirus	P	7
77-006	Largemouth Bass	Micropterus salmoides		5
77-011	Longear Sunfish	Lepomis megalotis	M	5
43-034	Sand Shiner	Notropis stramineus	M	4
77-004	Smallmouth Bass	Micropterus dolomieu	M	4
40-003	Black Buffalo	Ictiobus niger		3
77-001	White Crappie	Pomoxis annularis		3
10-004	Longnose Gar	Lepisosteus osseus		2
40-001	Blue Sucker	Cycleptus elongatus	I	2
40-010	Golden Redhorse	Moxostoma erythrurum	M	2
47-007	Flathead Catfish	Pylodictis olivaris		2
80-002	Walleye	Stizostedion vitreum		2
80-011	Logperch	Percina caprodes	M	2
04-001	Paddlefish	Polyodon spathula	I	1
10-002	Shortnose Gar	Lepisosteus platostomus		1
18-001	Goldeye	Hiodon alosoides	I	1
40-004	Smallmouth Buffalo	Ictiobus bubalus		1
40-007	Highfin Carpsucker	Carpododes velifer		1
40-018	Spotted Sucker	Minytrema melanops		1
43-015	Suckermouth Minnow	Phenacobius mirabilis		1
43-035	Mimic Shiner	Notropis volucellus	I	1
43-043	Bluntnose Minnow	Pimephales notatus	T	1
74-001	White Bass	Morone chrysops		1
74-002	Striped Bass	Morone saxatilis		1
77-008	Green Sunfish	Lepomis cyanellus	T	1

## Middle Wabash River and Little Vermilion River (HUC-8 05120108)



**Map 16.** IBI values from the mainstem (circles) or upstream tributaries within the Middle Wabash River - Little Vermilion River HUC-8 watershed (05120108). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana from 1999 and 2005/6; other data collected between 1990 and 2006 by IDEM (IN). Shaded areas are Level IV ecoregions; this watershed is primarily in the Loamy, High Lime Till Plains subcoregion with a northern and western portion in the Illinois/Indiana Prairies subcoregion and the southern portion in the Glaciated Wabash Lowlands subcoregion.

### Data and Background - 05120108

This is one of the longest of the five mainstream HUC-8 watersheds and includes about (RMs 309.4 – 236.5) seventy-three miles of the Wabash River. Biological data was relatively abundant for this HUC-8, and the tributary data includes two densely sampled HUC-11 watersheds (Map 16). Mainstem data contains historical sites sampled by Jim Gammon and Mark Pyron, although we primarily focused on more recent fish data collected by Indiana DNR in 1999 or by ORSANCO and Mark Pyron in 2004-2006.

**Identification of Stressors** – We used a “weight-of-evidence” stressor identification approach to assign likely causes of biological impairment. For example, we compared stressor levels in the mainstem and at upstream sites to ranges of values considered to be “least impacted” to rank stressor levels and to identify stressor that could be responsible for limiting biological conditions and biodiversity.

**Historical Habitat Conditions** – This HUC-8 watershed is where the Wabash River becomes a “Great River” and gains more big river

**Table 30.** Reconstructed historical estimation of habitat conditions in HUC-8 05120108 watershed (Wabash River and Little Vermilion River). The reconstruction of this QHEI assumes conditions during early settlement of the Wabash River Valley in the 1800s and is provided as an “anchor” for interpreting habitat conditions. Feasible goals for habitat rehabilitation would likely be somewhere between these values and existing values shown in later tables.

QHEI Metrics									
Middle Wabash - Little Vermilion									
HUC-8 Watershed	QHEI	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient (Score)	Narrative
0520108*	93.5	19.0	21.0	19.0	10.0	12.0	7.5	0.50 - (6)	Excellent

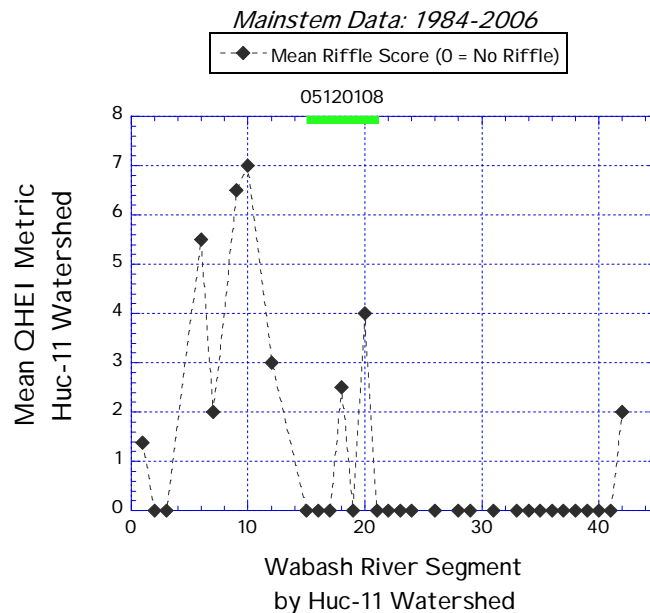
\* Year = 1800

characteristics. Most of the extensive bottomland forests, wetlands, and sloughs have been eliminated which has a substantial effect on the habitat in the Wabash River. Table 30 presents a hypothetical reconstruction of what Wabash River stream might have looked like prior to settlement. At that time, habitat would be rated as excellent with maximum or near maximum scores for most metrics. Back calculated stressor signals in the fish assemblage reflect the variable conditions of habitat, which general range from fair-to-marginally good in this HUC-8 watershed (Appendix 8).

**Riffles in HUC-11 Wabash Reaches** – This segment of the Wabash River was the last where riffle reaches commonly occurred in sampling reaches (Figure 10). Simon (2006) hypothesized that riffles may have been reduced by river meandering in the Wabash

River. Increasing flashiness and peak flows in the Wabash (see Part I of this report) has undoubtedly changed the hydrologic characteristics that influence riffle form and deposition.

**Water Chemistry Stressors** – Tables 31 and 32 summarize chemical concentrations for HUC-11 watersheds in the mainstem Wabash (Table 31) and in the tributaries within these Huc-11 watersheds (Table 32). Table 33 provides a different way of looking at water chemistry results using a Water Quality Index (WQI) that was calibrated by linking chemical concentrations to threshold responses of IBI scores at samples sites. None of these tables are replacements for water quality criteria, but are simply a way to consider risks to aquatic life from increased concentrations based on ambient stressor response relationships.



**Figure 11.** QHEI - Riffle metric scores averaged by HUC-11 watershed. Extent of HUC-8 subbasin 05120108 is noted in green on the top axis.

**Table 31.** Selected median water quality values for HUC-11 watersheds from within the Wabash River and Little Vermilion River (05120108) HUC-8 watershed; mainstem data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.

Water Chemistry Variables												
HUC-11 Watershed	N	Dissolved Oxygen	BOD (5-day)	Total P	Nitrate	Total Ammonia	Total Chloride	Total Sulfate	TDS	TSS	Total Org. Carbon	Zinc
Middle Wabash - Little Vermilion												
05120108010	34	9.3	2.4	0.21	3.6	0.20	37	54	378	38	5	13
05120108030	216	10.3	2.0	0.39	0.0	0.23	58	61	400	51	6	24
05120108070	3	12.3	2.0	0.22	3.9	0.20	36	56	375	44	5	17
05120108080	135	11.1	2.5	0.20	2.5	0.25	34	59	359	54	5	20
05120108090	20	13.4	2.5	0.21	4.1	0.10	35	54	362	49	4	18
05120108140	209	10.8	2.6	0.20	4.0	0.15	35	53	364	49	4	21
05120108150	227	10.5	2.7	0.20	3.9	0.20	35	55	358	51	4	14
05120108200	220	10.3	2.7	0.20	3.9	0.20	35	55	358	51	4	14

Summary of Narrative Ranges: -Ref. -Low -Med. -High -V.High -Extreme

**Table 32.** Selected median water quality values for HUC-11 watersheds from within the Wabash River and Little Vermilion River (05120108) HUC-8 watershed; tributary data ONLY. Narrative descriptions represent deviation from a reference background concentration and not a water quality criteria standard.

Water Chemistry Variables												
HUC-11 Watershed	N	Dissolved Oxygen	BOD (5-day)	Total P	Nitrate	Total Ammonia	Total Chloride	Total Sulfate	TDS	TSS	Total Org. Carbon	Zinc
05120108010	25	8.4		0.09	3.2	0.20	33	43	402	6	4	15
05120108020	12	9.9		0.06	2.9		30	53	530	9	1	13
05120108030	46	7.5		0.22	0.9	0.26	21	42	370	17	4	17
05120108040	203	9.4	1.3	0.09	6.0	0.20	22	52	400	21	3	14
05120108050	9	7.1		0.10	11.0		24	38	375	37	2	17
05120108060	29	9.3		0.10	4.3	0.20	18	38	352	14	2	12
05120108070	6	9.5										
05120108100	25	9.1		0.06	1.4	0.30	23	55	415	10	2	36
05120108110	21	8.6		0.06	0.7		37	44	408	7	3	
05120108120	14	8.5		0.14	1.6	0.10	14	45	370	17	2	21
05120108160	181	9.6		0.07	2.0	0.16	23	33	350	13	2	16
05120108170	40	8.8		0.06	1.2	0.19	18	31	265	22	2	16
05120108180	46	8.1		0.19	1.0	0.29	39	33	430	9	3	24
05120108190	162	8.8		0.07	1.7	0.11	17	31	300	21	2	12
05120108200	9	8.1		0.06	0.5	0.46	22	72	329	38	4	10

Summary of Narrative Ranges: -Ref. -Low -Med. -High -V.High -Extreme

**Table 33.** Water Quality Index values for HUC-11 watersheds from the upper Wabash River HUC-8 watershed (05120108); tributary and mainstem data combined. N reflects number of stations. Mean WQI does not include QHEI component. Colors represent increasing risk of aquatic life impairment.

05120108		Water Chemistry Variables									
HUC-11 Watershed	N	Dissolved Oxygen	Total P	QHEI	TSS	Min. WQI	Mean WQI				
<b>Middle Wabash - Little Vermilion</b>											
05120108010	11	93.7	92.8	74.8	100.0	81.4	92.5				
05120108020	7	94.5	100.0	48.8	100.0	80.7	96.7				
05120108030	38	89.7	83.2	47.4	59.0	58.5	85.1				
05120108040	53	68.1	85.0	59.0	57.6	60.2	87.7				
05120108060	10	89.4	99.3	93.0	100.0	84.2	95.2				
05120108080	15	97.7	83.6	50.9	73.9	61.0	86.3				
05120108100	9	83.2	96.1	69.0	86.2	81.1	91.3				
05120108140	18	91.8	72.0	37.6	61.5	27.3	74.2				
05120108150	18	94.6	67.5	67.6	64.1	28.2	74.3				
05120108160	50	86.4	80.0	69.2	92.5	70.9	92.0				
05120108170	8	100.0	100.0	69.5	91.9	85.3	96.8				
05120108180	24	96.9	64.7	51.4	91.6	58.3	83.5				
05120108190	23	99.1	92.6	53.3	76.0	73.8	92.6				
05120108200	21	93.3	67.4	43.2	55.9	33.6	75.2				

**Summary of Narrative Ranges:**

■ -Ref.   
 ■ -Low   
 ■ -Med.   
 ■ -High   
 ■ -V.High   
 ■ -Extreme

### Results and Summary - 05120108

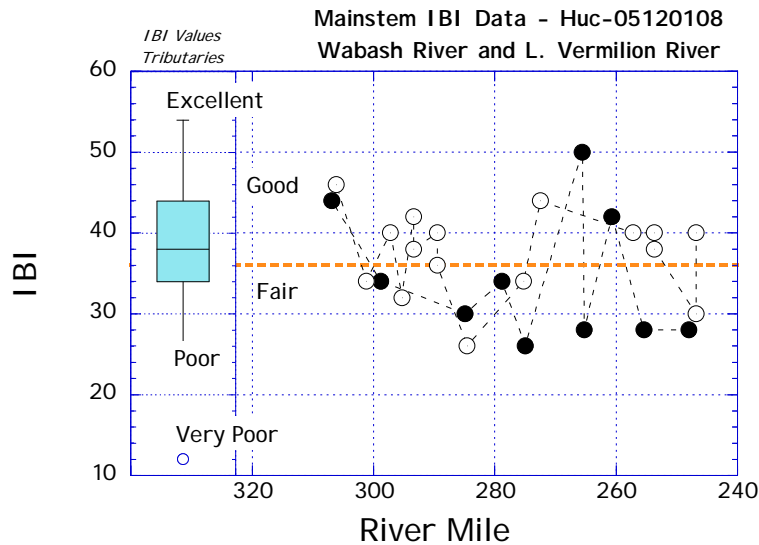
Fish sites sampled in this third reach of the Wabash River, especially in Ohio were mostly in fair-good shape as can be observed in Map 16 and Figure 12. The IBI was generally skewed toward the good range in the tributaries of the Wabash in this HUC-8 watershed which includes samples in Big and Little Pine Creeks and Big and Little Raccoon Creeks and other tributaries (N=95).

Fish assemblages in this reach are generally better than the average for entire Wabash watershed as calculated by IDEM. The upstream reaches tend to be in better condition than lower reaches where the gradient drops. This is especially obvious in mussel species richness which drops sharply from the upstream to downstream borders of this HUC-8 watershed, again matching declining stream gradients. High gradient tends to buffer reaches from the effects of fine sediments and nutrients by transporting fines downstream instead of permitting them to settle within the river.

**Biological Condition Gradient** – The BCG we developed applies primarily to this and downstream reaches of the mainstem Wabash and Lower White Rivers. The loss of rare species and generally low abundance of sensitive species suggests the Wabash here reflects Tier 4 to Tier 5 conditions, with the best remaining sites perhaps approximating Tier 3 conditions.

**Biodiversity** – The most common fish species in the Middle Wabash and Little Vermilion River reach were much more tolerant than in the previous upstream reach (05120105). The only sensitive species in the top ten was Longear Sunfish and the rest of the assemblage was dominated by two tolerant species (Common Carp and Freshwater Drum) or species considered on the tolerant edge of “intermediate” tolerance. These species include Emerald Shiner, River Carpsucker and Gizzard Shad, all of which are thrive in nutrient enriched habitats.

**Habitat** – Figure 11 illustrates the longitudinal trend of QHEI through this reach. Values varied,



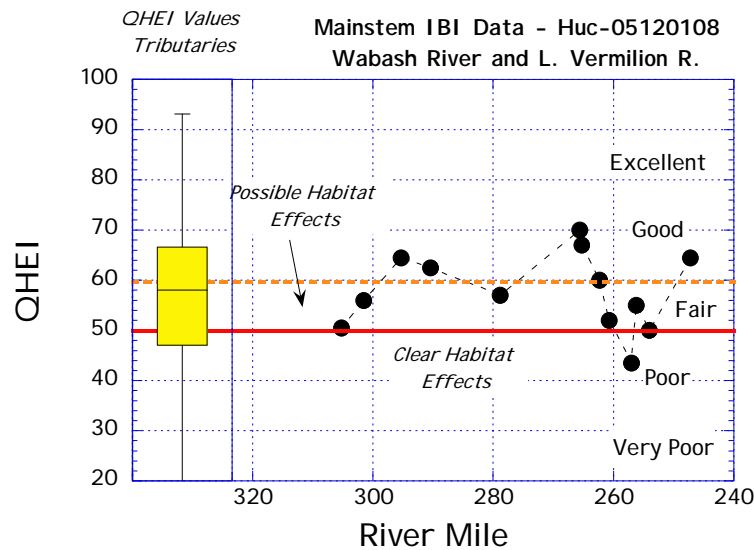
**Figure 12.** Plot of IBI by river mile in the middle Wabash River & L. Vermilion River HUC-8 watershed. Mainstream sites sampled in 1999 by IN DNR are black and connected by a dashed line; sites sampled in 2005/6 by ORSANCO are open circles. Data from tributaries sampled by IDEM are summarized in the box plot.

likely in response to local habitat modifications (riparian encroachment) or natural variation in substrate materials and gradient changes. Historically, the middle reaches of the Wabash were quite different in character from what they are like today. The landscape was covered with permanent forest, prairie and wetland vegetation. Descriptions of the mainstem Wabash River by early settlers indicated that habitat was likely diverse, wetlands and backwaters were common and aquatic vegetation was abundant. QHEI scores would have ranged from the 70s to 90s. QHEI scores in the mainstem largely ranged from fair to good in this reach. Examination of

individual habitat metrics indicates suggest that the biota is likely limited by poor instream structure, lack of riffles, narrow riparian vegetation lack of fast current flows. Loss of stream-edge wetlands and sloughs combined with increased flashiness and peak flows have undoubtedly increased pressure on river banks and increased erosion. Increased flow stresses may have increased pressure on bottom substrates, making them less stable. Tributary streams show great variety in habitat scores (QHEIs from < 20 to > 90), however median scores were less than 60 indicating a majority of tributary streams may have habitat impacts.

**Table 34.** Ten most dominant fish species by number collected in fish samples in the middle Wabash River and Little Vermilion River watershed (HUC 05120108) collected in Indiana. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

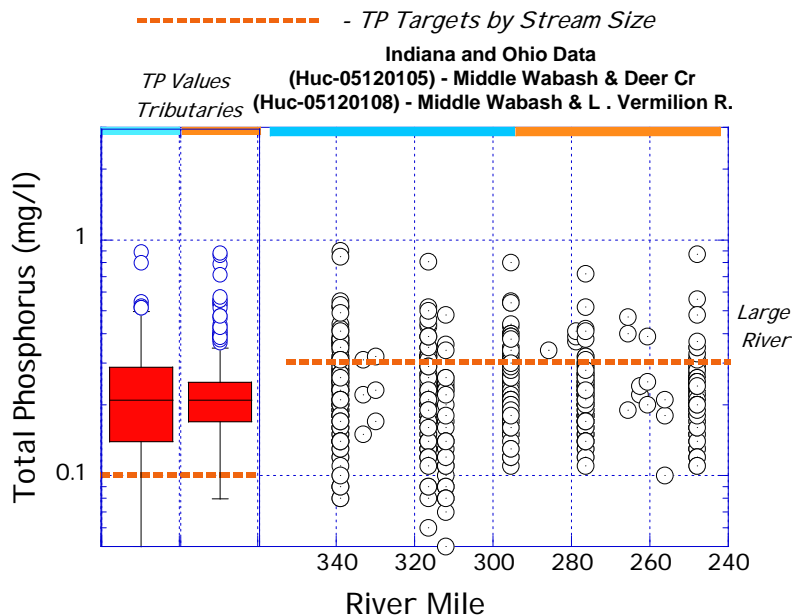
Ten Most Dominant Fish Species by Relative Abundance	
Mainstem	Tributaries (Excluding Mainstem)
Emerald Shiner - (6187)	Central Stoneroller - (6,584)
Gizzard Shad - (5258)	Creek Chub [T] - (3,790)
Spotfin Shiner - (4731)	Bluntnose Minnow [T] - (2,600)
Freshwater Drum [P] - (3774)	Western Blacknose Dace [T] - (1,714)
River Shiner - (3307)	Longear Sunfish [M] - (1,091)
River Carpsucker (1955)	Orangethroat Darter - (935)
Bullhead Minnow (1887)	Silverjaw Minnow - (788)
Common Carp [T] - 1196	Striped Shiner - (693)
Longear Sunfish [M] - (1007)	Green Sunfish [T] - (80)
Channel Catfish - (847)	Spotfin Shiner - (633)



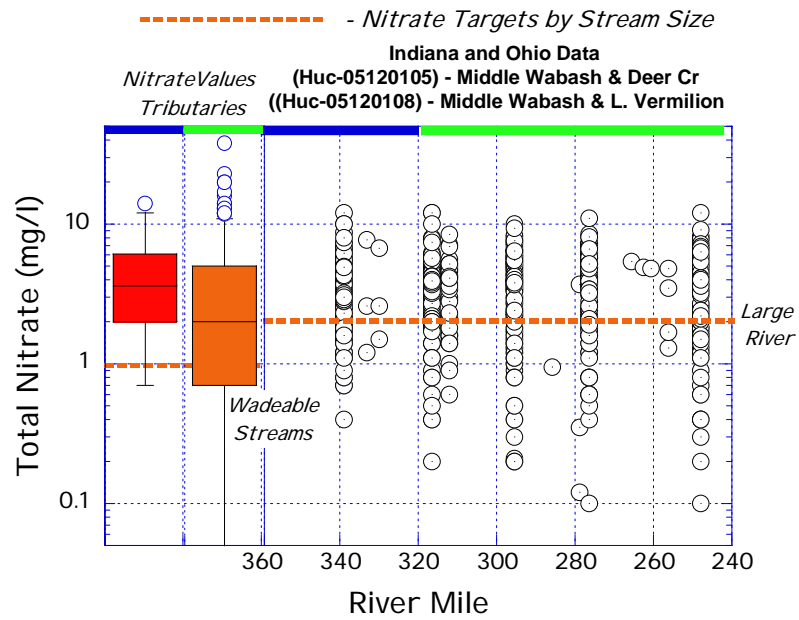
**Figure 13.** Plot of QHEI by river mile in the middle Wabash River and L. Vermillion River HUC-11 watershed (05010108). Mainstream sites are black and connected by a dashed line. Box and whisker plot data from IDEM.

**Pollutant Stressors in the Watershed** – Although median values of TP (Table 1) are less than the large river TP targets for the Wabash River mainstem, many individual values are still elevated above this target (Figure 14). In addition the tributaries in this watershed are highly elevated and likely contribute to the maintenance of high TP values in the mainstem of the Wabash River (Figure 14). Nitrate levels remain high in the mainstem, with most well above the targets for nitrate for large rivers (Table 15). The elevated nature of nutrients in tributaries and

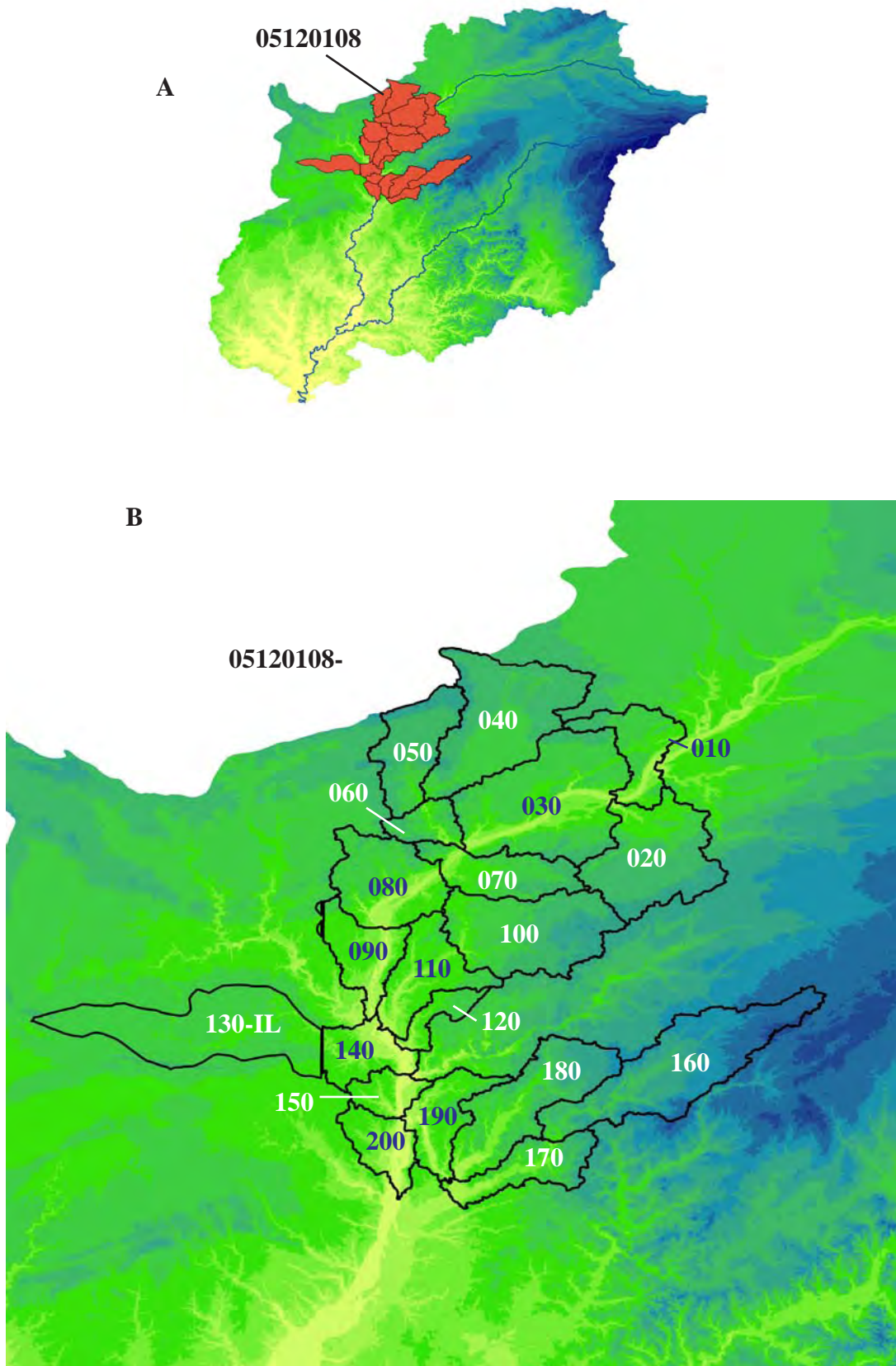
extended high values in the mainstem suggests the high values are not being diluted significantly by tributaries (Figure 15). As discussed earlier, control of nutrients takes place in small, headwater streams and is related to fertilizer applications. Other contributing factors include lack of buffers from agricultural land use, delivery of nutrients via drainage systems, and degradation of instream habitat that, in concert with altered hydrology, severely limits assimilation and transformation.



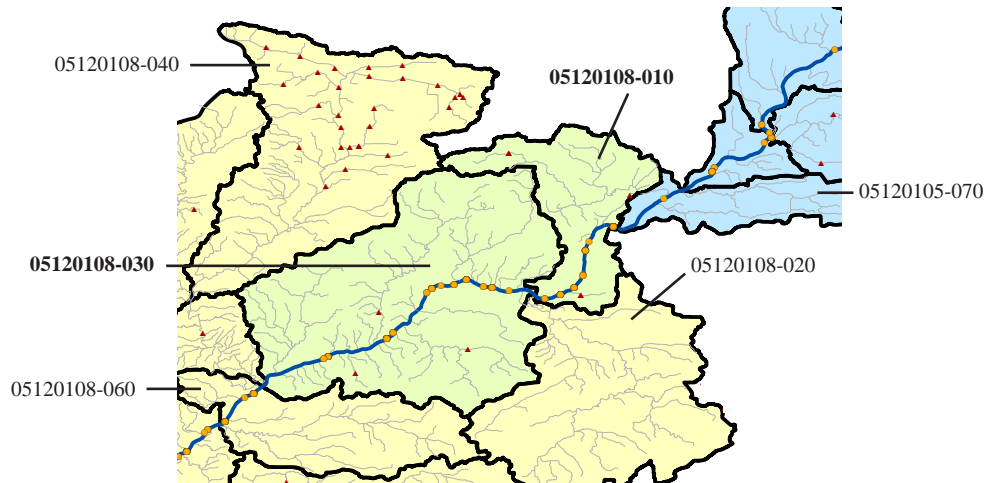
**Figure 14.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within two of the middle Wabash River HUC-8 watersheds (05120105-blue and 05120108-orange). Box and whisker plots represents data from tributaries from within each of these HUC-8 watersheds. Orange dash lines represent total phosphorus targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



**Figure 15.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within two of the middle Wabash River HUC-8 watersheds (05120105-purple and 05120108-green). Box and whisker plots represents data from tributaries from within each these HUC-8 watersheds. Orange dash lines represent total phosphorus targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



**Map 17.** Maps of the Wabash River HUC-8 watershed, 05120105, showing its position in the Wabash River Watershed (A) and the HUC-11 catchments within it (B). Elevation (0-255 meters; color-coded - 15 levels) serves as the background of each map. Only the last three digits of each HUC-11 are shown. Label color differences are for contrast.



**Map 18.** Map of HUC-11 watersheds 05120108-010, and -030, Middle Wabash River with Wea Creek, Indian Creek, Little Pine Creek, and Kickapoo Creek. Data points reflect fish sampling sites on the mainstem (circles) and tributaries (triangles).

Biological conditions as measured by the IBI are generally good in the mainstem Wabash River within these HUC-11 watersheds (Appendix Table 1a). There is some variability with sampling results that other researchers have related to the flow variation in the river (Gammon 1999, Pyron et al. 2004). These reaches (-010 and -030) still contain a diversity of intolerant (Blue Sucker, Rosyface and Mimic Shiners, and Mooneye) and sensitive species (Longear Sunfish, Smallmouth Bass, and redhorse spp.) (Table 36). Tolerant and moderately tolerant species are more abundant than they should be with large populations of Common Carp and Freshwater Drum (Table 36). Back-calculated stressor signals from fish in these reaches are consistent with general good habitat, but nutrient enriched conditions (Appendix Table 8).

Nitrate and TSS are still high in this reach as they are in most of the Wabash River mainstem. BOD, TA and zinc are at moderate concentrations, but DO, TP, dissolved parameters and TOC are at background for a large river (Table 31). Back-calculated stressor signals in fish assemblages for high nutrients are consistent with the actual sampled nitrates in the mainstem (Appendix Table 8). Tributaries in these HUC-11 watersheds generally have concentrations with moderate to very high concentrations of nutrient-related parameters (Table 32), helping to maintain enriched conditions in the Wabash River mainstem.

Habitat ranged from fair to the low range of “good” and is lower than expected in a natural condition. Back-calculated stressor signals in fish for habitat generally match the pattern in the QHEI data (Appendix 8). In particular the substrate, cover, channel, and riparian metrics are mediocre and are likely showing effects of direct manipulation of riparian vegetation, bank erosion and sedimentation from upstream reaches. No riffles were in the sampling sites where these QHEIs were collected (Table 35).

**Summary**—This reach is where the Wabash transforms from a large to a “great” river, and begins to maintain populations of Great River species. Biological conditions are good and the mainstem in these HUC-11s still have species characteristic of high gradient reaches. Nitrate and TSS are high in these reaches, as they are along most of the Wabash River. Tributaries in and upstream of these reaches contribute to this enriched condition. Mediocre habitat conditions, partly related to lack of mature and sufficiently wide riparian forest are an important local limiting factor. Flashy hydrology and high nutrient and sediment delivery from the drained agricultural landscape could be managed in a way to enhance biodiversity, in-stream habitat quality, and river function.