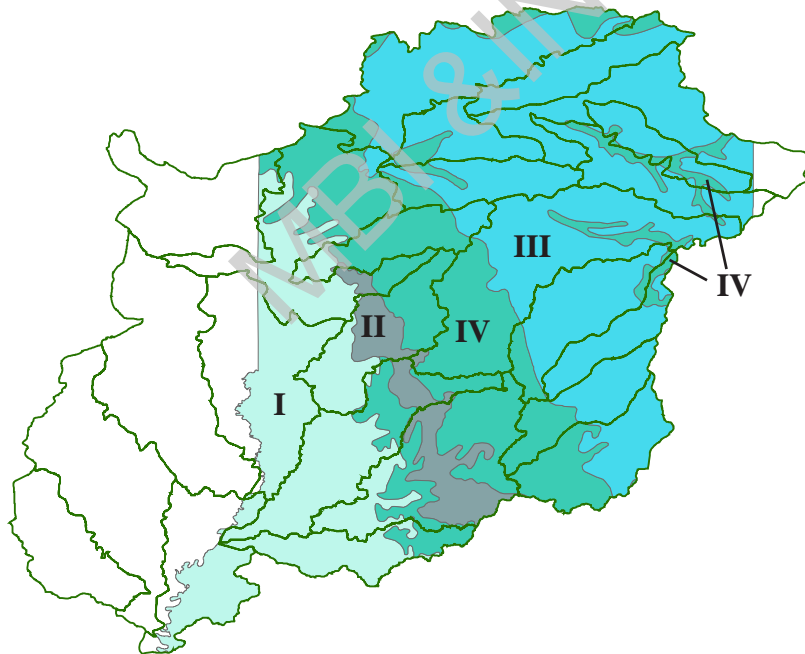


**Wabash Hydrogeologic Terrains**

- I. Bottomlands
- II. Central Till Plain
- III. Lake Michigan Rim
- IV. Maumee Subbasin
- V. Plymouth-Bremen-Nappanee Subbasin
- VI. Rochester-Warsaw-Topeka Subbasin
- VII. Settings Common To Multiple Subbasins
- VIII. South-Central Driftless Area
- IX. Southeastern Glaciated Region
- X. Southwestern Glaciated Region
- XI. Steuben-Huntertown-Wawasee Subbasin
- XII. Terrain-Fringing Outwash Plains And Sluiceways

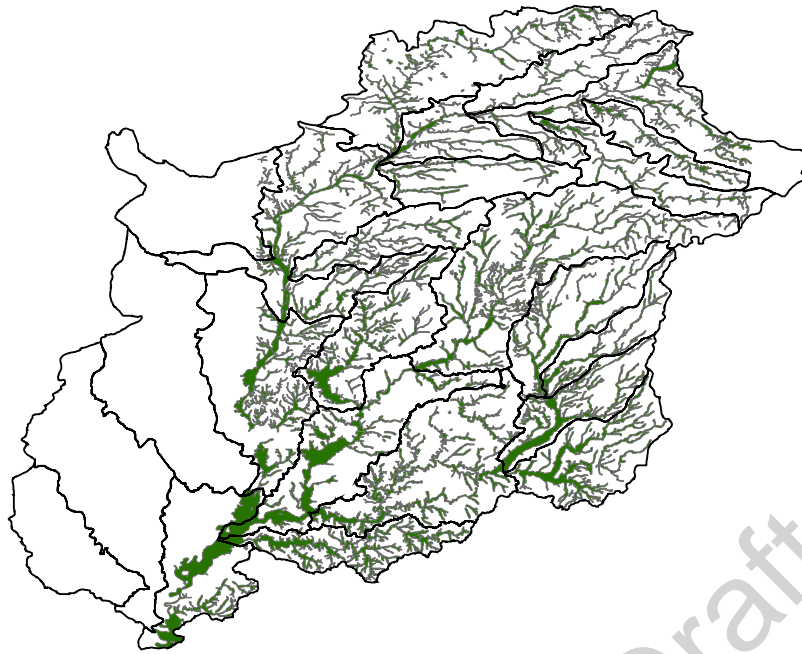
**Map 11. Wabash River Hydrogeologic Terrains.** A hydrogeological terrain is a mappable region with common hydrogeological characteristics. Pertinent primarily to groundwater, parameters such as depth to water table, net recharge, aquifer media, soil media, bedrock topography (particularly in relation to slope), and hydraulic conductivity, among others, are important. Color-figured above are the 12 hydrogeologic terrains found in the Wabash River Watershed. A HUC-8 subbasin overlay is provided with white borders.



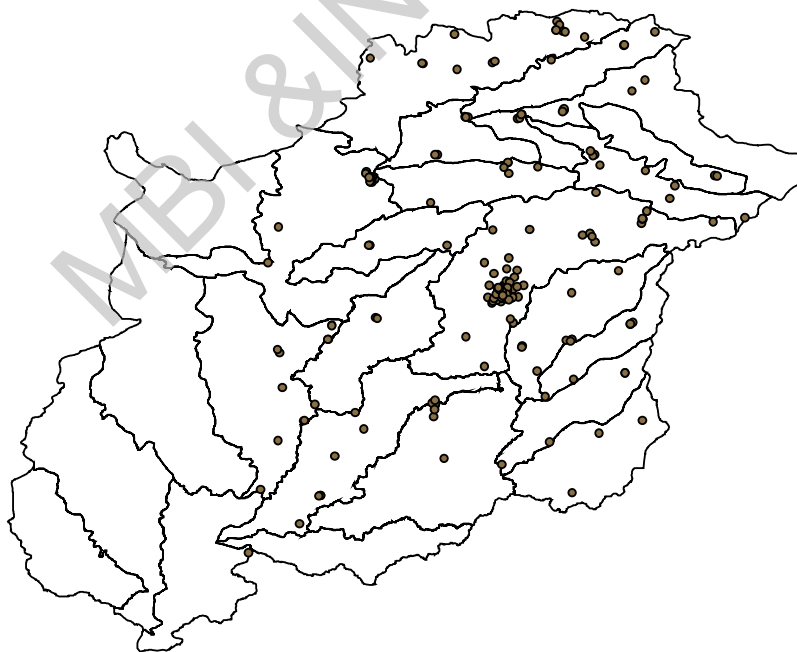
**Wabash Aquifers**

- I. Sandstone aquifers (Pennsylvanian)
- II. Sandstone and carbonate rock aquifers (Mississippian)
- III. Carbonate rock aquifers (Silurian-Devonian)
- IV. undefined aquifers

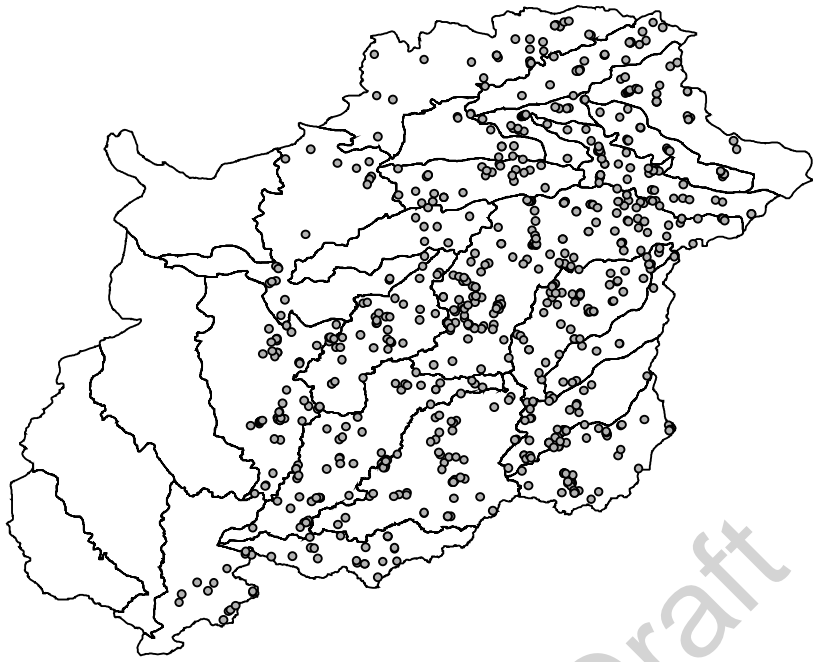
**Map 12. Wabash River Aquifers.** Ground water in Indiana is found in unconfined (near the surface) and confined (deeper between bedrock layers) aquifers. Ground water availability is greatest in the northern two-thirds of the state and in bottomlands of the Wabash and White rivers. The Wabash River Watershed in Indiana includes portions of three defined and two undefined aquifers (confined), color-figured above. A HUC-8 subbasin overlay is provided with green borders.



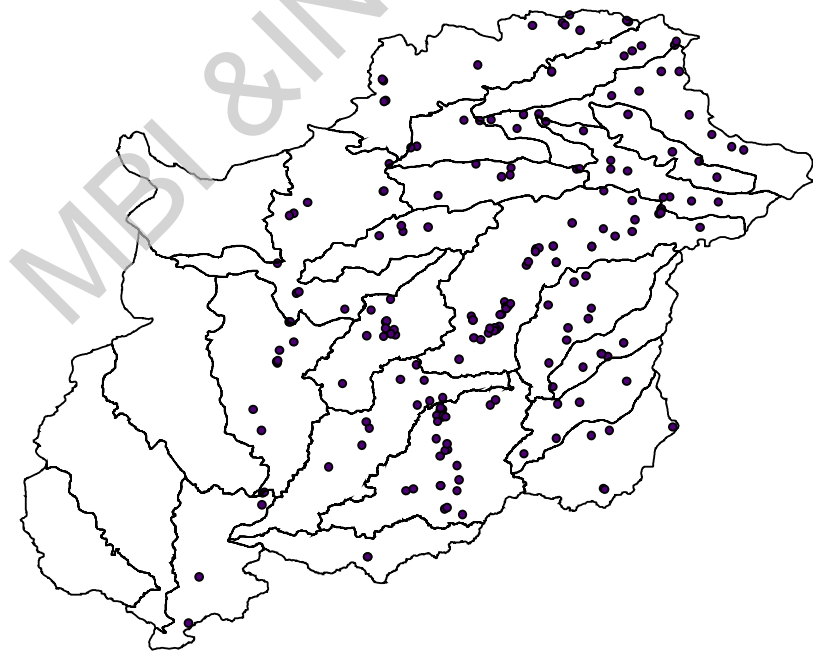
**Map 13. Wabsh River Floodplains.** Floodplains in Indiana are flat areas bordering a stream which become flooded when precipitation and upstream input exceeds the ability of the stream channel to discharge water normally. The extent of floodplains is constrained by the land topography around the stream, which in turn is determined, in part, by tectonic and orogenic events, by past glacial action, and by the meanderings of the stream itself. The Wabash River Watershed in Indiana has its widest floodplains along the mainstems of the Wabash and White rivers, particularly in the lower parts of the watershed. A HUC-8 subbasin overlay is provided with black borders.



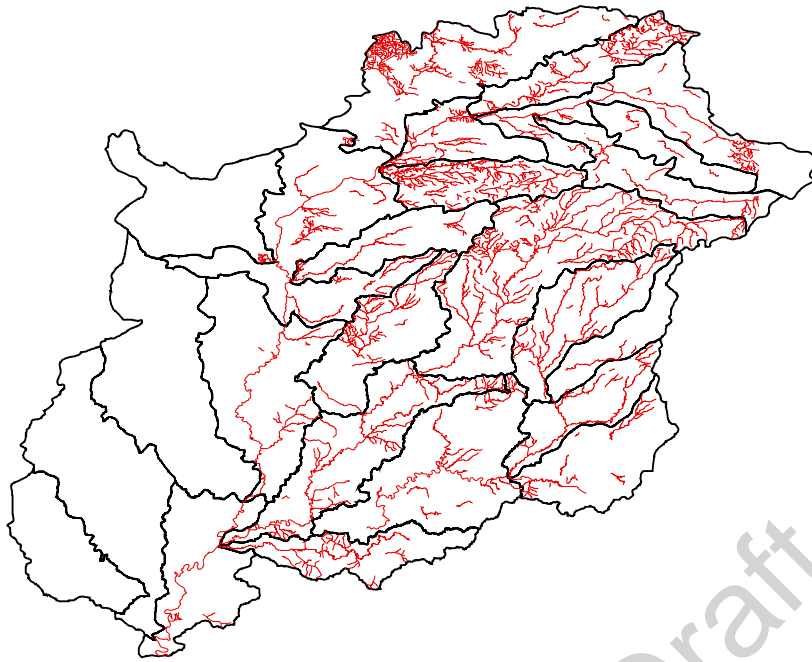
**Map 14. Wabsh River Brownfields .** Brownfields are land areas characterized by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Cleaning up and reinvesting in brownfields takes development pressures off of undeveloped, open land, and both improves and protects the environment. The Wabash River Watershed in Indiana has a number of brownfield sites in almost every subbasin (brown circles above), with a concentration around Indianapolis. A HUC-8 subbasin overlay is provided with black borders.



**Map 15. Wabash NPDES Point Sources.** The National Pollution Discharge Elimination System (NPDES) Compliance and Enforcement Program of the Clean Water Act, regulates point source discharges to the nation's waters. NPDES permits are issued to individual dischargers or can be issued for a group of dischargers (i.e., general permits). Both individual and general permits contain requirements for controlling pollutant dischargers, monitoring discharges, reporting compliance. The Wabash River Watershed in Indiana includes a large number of permit sites (gray circles above). A HUC-8 subbasin overlay is provided with black borders.



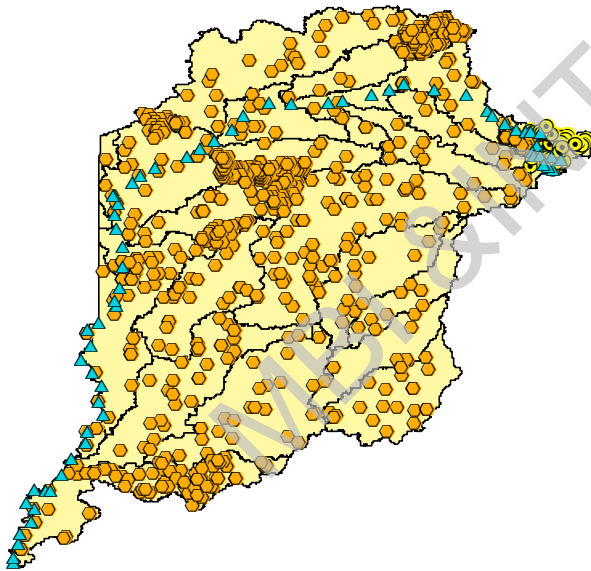
**Map 16. Wabash Industrial Mineral Sites.** Industrial mineral and fuel mining activities in Indiana include ball clay, common clay and shale, limestone and dolomite, construction sand and gravel, industrial sand, sandstone, gypsum, peat, and coal. The Wabash River Watershed in Indiana includes a number of industrial mineral sites (purple circles above). The largest number of sites produced sand and gravel (53.5% ) and crushed stone (31.1%). A HUC-8 subbasin overlay is provided with black borders.



**Map 17. Wabash River Impaired Streams.** Every two years, the Indiana Department of Environmental Management develops a 303(d) list of impaired waters in the state to meet compliance with the Clean Water Act (CWA). The CWA Section 305(b) requires states to make water quality assessments and provide water quality reports to the U.S. EPA, and CWA Section 303(d) requires states to identify waters, through their Section 305(b) water quality assessments, that do not or are not expected to meet applicable water quality standards with federal technology based standards alone. The Wabash River Watershed in Indiana includes numerous reaches, color-figured in red above, that are included in the current report. A HUC-8 subbasin overlay is provided with black borders.

## Part II, Wabash and Lower White Rivers HUC-8 Watershed Summaries

This section of the report provides a general summary of the condition and potential causes and sources of impact to the mainstem Wabash River and to streams within each HUC-8 watershed through which the Wabash River flows. The Indiana Department of Environmental Management (IDEM) provides more detailed assessments of specific streams and watersheds within each of these HUC-8 watersheds (illustrated in Map 1) and summaries are provided here at the HUC-8 scale and in the technical report at the HUC-11 scale of watershed. Our focus is on the mainstem of the Wabash River and lower White River and on identification of the broad scale factors that appear to be statistically associated with degraded aquatic life and loss of biodiversity. In this effort we are attempting to discriminate among factors that originate within each Wabash River segment from stressors that are exported from upstream in the HUC-11 watersheds that drain to each Wabash River reach.



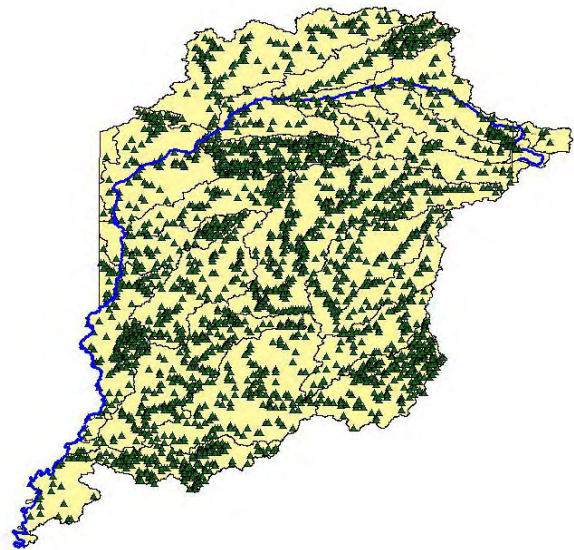
**Map 1.** Map of the HUC-8 Wabash River watersheds in Indiana with locations of Indiana DEM fish data (orange circles), IN DNR mainstem fish data (blue triangles) and Ohio EPA fish data (yellow circles) used in this study.

**Data** – The biological GIS layers available for this analyses are fairly extensive. However, the fish data set was the largest and the most uniform in both coverage of the Wabash mainstem (1999 IN DNR and Ohio EPA data; 2004 ORSANCO data, IDEM data; Gammon/Pyron data) and of the upstream watersheds (IDEM). Map 1 illustrates the coverage across the

Wabash River watershed from IDEM's probabilistic and intensive watershed sampling efforts, Ohio EPA surveys in Ohio, and the 1999 mainstem river data collected by IN DNR (and in Ohio by Ohio EPA).

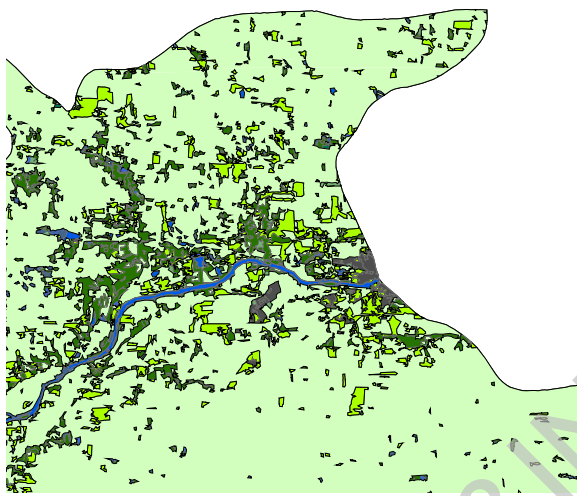
We used the Indiana Index of Biotic Integrity (IBI) cutoffs for determining use-attainment based on IBI to rate condition of the reaches and watersheds. Generally, sites  $\geq 36$  are considered attaining an aquatic life use and sites with IBIs less than 36 are considered impaired. We also used narrative ranges of the IBI and selected IBI metrics to illustrate changes in condition in the Wabash River.

**Stressor Data** – We used water chemistry data collected by IDEM (Map 2) from 1990 to 2006. We selected key stressors that reflect nutrient enrichment, dissolved oxygen stress, common toxicants (e.g., metals, ammonia) and suspended and dissolved chemical constituents (e.g., total suspended solids and total dissolved solids). We also used the Qualitative Habitat Evaluation Index (QHEI) collected by IDEM and others in Indiana and Ohio. The QHEI ranges from about 10-100 and reflects the diversity of stream habitat features important to aquatic life such as substrate condition, channel condition, structure, etc. We also calculated several versions of a water quality index (with and without habitat data) as an overall stressor measure which was calibrated using the response of each variable to the IBI.

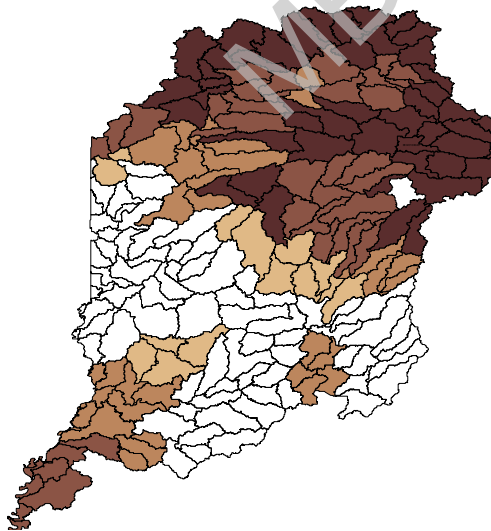


**Map 2.** Map of IDEM water chemistry sampling sites in the Wabash River drainage from 1990 to 2006.

**Land Use and Agriculture Drainage** – In 1800, Indiana was populated by Native Americans and less than 6,000 white settlers (Gammon 1998). The Wabash River is strongly influenced by the changes that have occurred to the landscape over the past 200 years, particularly land use (Map 3) and agriculture drainage (Map 4). The effects of agricultural drainage are of interest because stream channels were often modified (entrenched and deepened to promote drainage – i.e., the physical effects of drainage) and the purpose for drainage resulted in a greatly altered flow regime locally and in downstream reaches. Some estimates indicate that peak flows in the Mississippi River basin have increased six-fold over the past 200 years (Knox 2001).

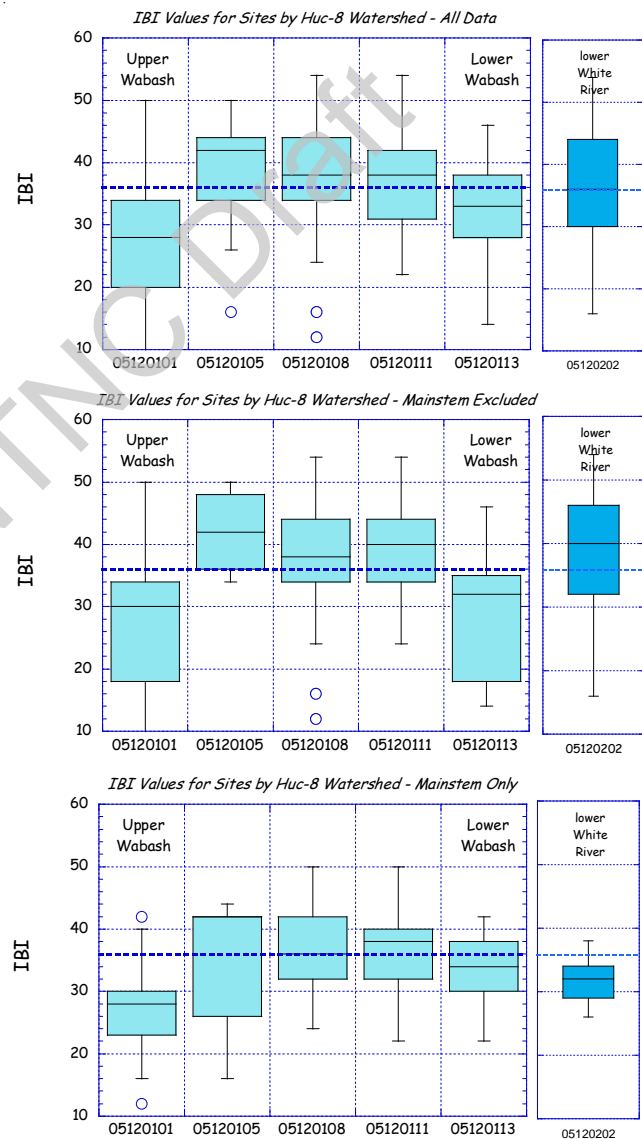


**Map 3.** Land use (2002) in the upstream portion of HUC-8: 05120105, dominated by agriculture (light greens). Most would have been forested (dark green) before 1700.



**Map 4.** Percentage of HUC-11 watersheds subject to agricultural drainage activities range from < 20% drainage (white) to > 80% drainage (darkest).

**Overall Results** - Figure 1 summarizes IBI values for the five HUC-8 segments that contain the Wabash River mainstem. The top panel contains data from the mainstem only, the middle panel contains all data, and the lower panel excludes the mainstem data. Overall it is clear the upper mainstem reaches of the Wabash River and its watershed in general have the greatest impacts for reaches in Indiana. Stressor data for each of these five HUC-8 watersheds is summarized in Table 1 and color coded by risk level (Rankin and Miltner 1999) to ease interpretation.



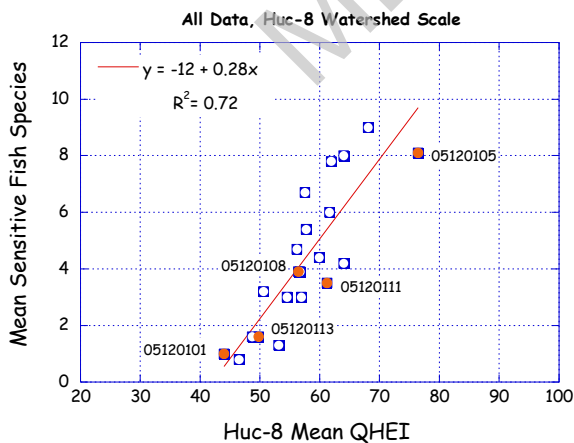
**Figure 1.** Box and whisker plots of IBI from the Wabash River by HUC-8 watershed from Indiana and Ohio. Top panel is mainstem data only, middle panel has mainstem data and data from other, upstream sites in that watershed, and the lower panel excludes mainstem data.

**Table 1.** Summary of selected biological condition measures and stressor measures by mainstem Wabash HUC-11 watershed. Colors represent either condition or stress risk based on mean values in the mainstem only or in the upstream reaches of the immediate HUC-11 watershed. “Risk” levels for stressors 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)

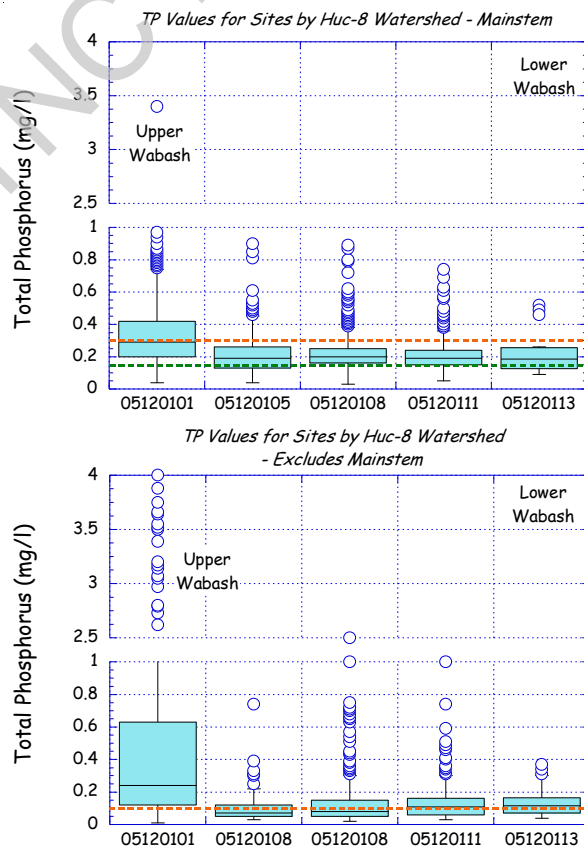
The second HUC-8 watershed (05120105, Middle Wabash River and Deer Creek) has the best average biological condition of any of the mainstem HUC-8 watersheds on the Wabash. More than half of the sites in this watershed achieved the attainment cutoff of 36. The next two HUC-8 watersheds also had more than half their sites in both the mainstem and watershed achieving the 36 cut-off. Scores declined in the lowest most mainstem HUC-8 watershed. Lower White River mainstem sites were generally below the IBI cutoff, however, IBIs in tributaries were generally of higher quality, with 50% of the sites above the 36 IBI cutoff.

**Other Biological Indicators** – In the technical report prepared for this project, we examine a number of the biological indicators, including key metrics of the IBI. Sensitive fish species (species that decline in the presence of elevated chemical stressors and habitat loss) are one of the best measures of biological condition. The variation in sensitive fish species in HUC-8 watersheds is very strongly related to the habitat quality of these watersheds ( $r^2 = 0.72$ ; Figure 2). This is a similar pattern to that observed in Ohio streams. The lower most HUC-8 watershed and the upper-most watershed have very few sensitive species, which tends to be strongly associated with limited in-stream habitat in these waters. Note that in Map 3, the upper portions of the Wabash and the lower most reaches are where agricultural drainage is the most intense.



**Figure 2.** Plot of mean HUC-8 watershed QHEI scores vs. the mean numbers of sensitive species collected in these watersheds. Mainstem HUC-8 segments are highlighted in red.

**Key Stressors in HUC-8 Watersheds** – Stressors from both within the mainstem and those exported from upstream tributary watersheds influence the biological condition of the mainstem Wabash River. Suspended sediments, nutrients (phosphorus and nitrogen compounds) and dissolved materials (e.g., total dissolved solids) all exert an influence on the mainstem (Table 1, Figure 3). The highest concentrations of these are contributed from the upper watersheds of the Wabash River (Table 1, Figure 3) where agriculture is the most intense and the drainage characteristics rapidly deliver these compounds during rain events. Table 1 is a summary of key biological and stressor conditions in the five primary or mainstem HUC-8 watersheds of the Wabash and lower White Rivers. Most of these statistics represent mean values in these watersheds, and data is largely from the last 10 years (1999-2008). We used an analysis developed for similar watersheds in Ohio that rates the levels of water chemistry or habitat



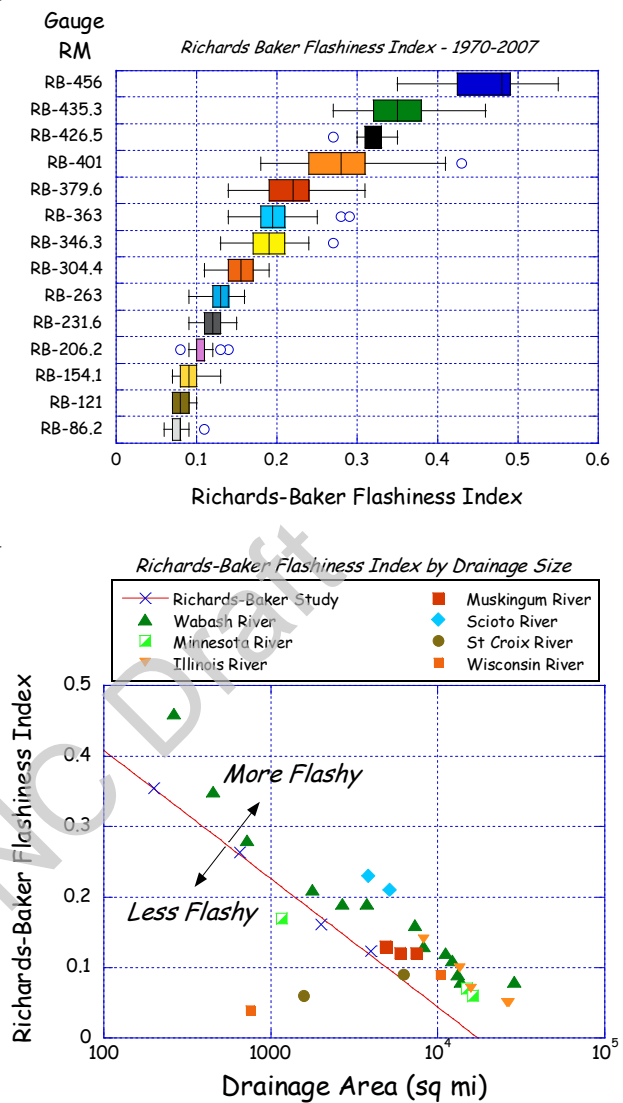
**Figure 3.** Box and whisker plots for total phosphorus by HUC-8 watershed with mainstem sites only (top) or mainstem sites eliminated (bottom). Orange line represents Ohio EPA's large river mean TP target for WWH streams; green line similar target for EWH.

values in relation to the risk of biological impairment. This was done by examining reference waters in the East Corn Belt Plain ecoregion of Ohio, and was done separately for large river data (e.g., mainstem rivers) vs. upstream data (largely wadeable streams).

Recent research has shown that the greatest ability to remove nutrients and similar chemical stressors is in small headwaters streams and that ability declines as river size increases. Thus, the nutrients and other compounds exported from the headwater areas, especially in the drained subwatersheds continue to leave a footprint along the length of the Wabash River even though the concentrations are diluted somewhat by higher quality (but not pristine) tributaries further down the Wabash River (Figure 3). The orange lines on Figure 3 represent lines associated with Clean Water Act (CWA) fishable goals, and expectations differ with stream size. Note that although total phosphorus levels are lower in downstream HUC-11 watersheds (lower plot that excludes mainstem data) there are still many values greater than would be expected at reference sites. This indicates these lower watersheds are still exporting “excess” nutrients.

### Flow Regimes in the Wabash River

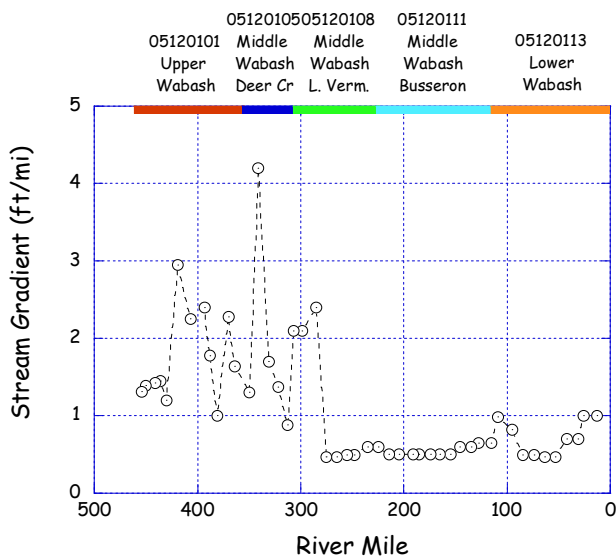
As mentioned earlier, flow regimes (e.g., peak flows, flood frequencies, low flow frequencies) have been greatly altered by agriculture, especially where drainage has been extensive. Compared to pre-agricultural conditions peak flows are up to six times greater (Knox 2001) and flashiness has increased in Midwest rivers (Baker et al. 2004). Flashiness as measured by the Richards-Baker flashiness index essentially compares the rise in flows compared to average conditions between storms. Flashiness is naturally lower in large vs. small rivers so a plot within a river would show a pattern similar to what we see in the top panel of Figure 4. Any increase or decrease in flashiness needs to be compared with other rivers of a similar size. The bottom panel compares the Wabash River to other Midwest Rivers and data from the Baker et al. (2004) study. The Wabash is clearly a flashy river especially compared to rivers in Wisconsin where natural vegetation and wetlands are still widespread and drainage less intense. The Wabash is similar in flashiness to other large Midwest river watersheds (e.g., Illinois and Scioto Rivers) that also have extensive agriculture and drainage. This flashiness can have direct effects on



**Figure 4.** Plots of the Richards-Baker flashiness index by river location in the Wabash River (top panel) and by drainage area in relation to other Midwest rivers (bottom).

biota (hydraulic shear stress), delivers more nutrients and sediments to downstream reaches, and can have severe scouring effects on habitats removing natural substrates or making them unstable, associated with eroding banks and altered habitat features.

**Mainstem Habitat** – The habitat conditions in the Wabash River are relatively mediocre outside of the a reach including the lower portion of the upstream-most HUC-8 watershed (05120101) and the second most upstream watershed (05120105). This area of the mainstem is located where the gradient is relatively high (Figure 5) and where some naturally coarse substrate materials are dominant. In this reach QHEI scores are either good or excellent with a

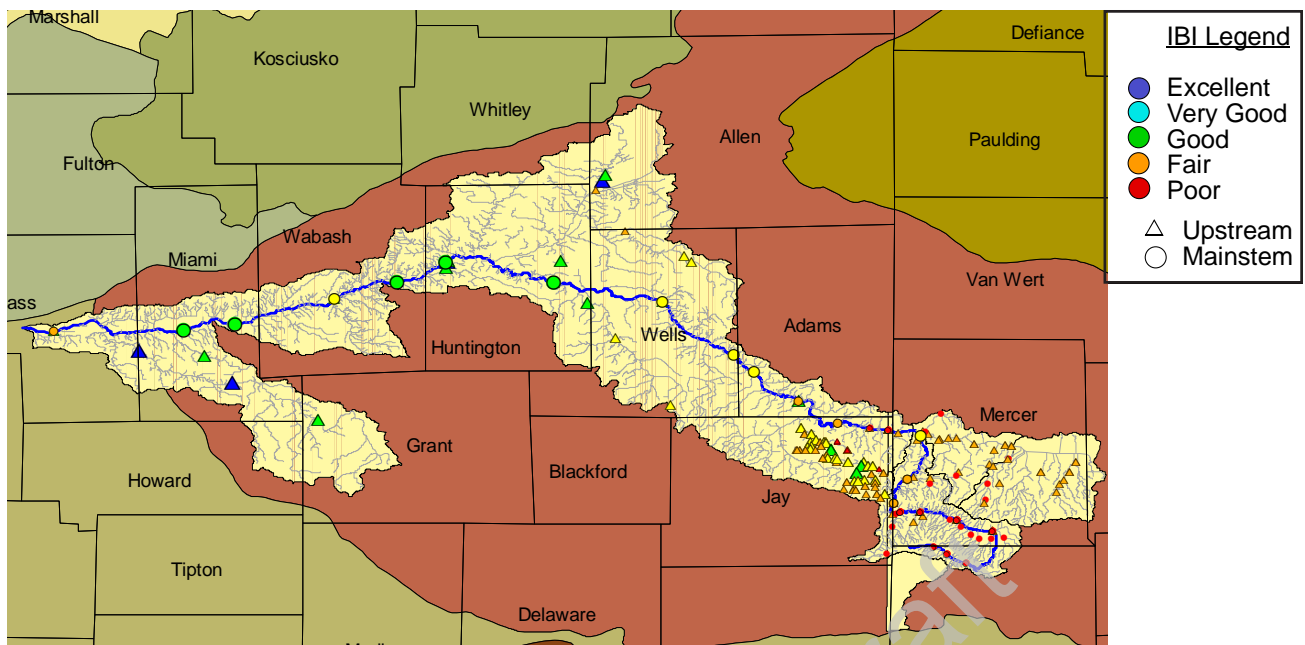


**Figure 5.** Stream gradient (feet/mile) for sites sampled along the Wabash River mainstem during 1999 by IN DNR and Ohio EPA (Ohio portion).

maximum score of 93. Historically the mainstem Wabash was characterized by extensive backwater oxbow swamps and sloughs and likely much more extensive instream habitat structure, better substrates and lush aquatic plant growth (Gammon 2001). More detail on habitat conditions will be provided under each HUC-8 summary sections. However, an examination of key species that are now extirpated, rare, or in low abundance (alligator gar, Ohio River muskellunge, bantam sunfish, etc.) depended on these habitats for all or part of their life cycle (e.g., spawning, feeding, etc.).

An examination of how the QHEI habitat attributes change along the mainstem (Table 2) indicate that instream cover, low sinuosity, poor riparian condition, and substrate embeddedness in the pools and riffles are the most consistent problems along the mainstem. The loss of backwater areas, sloughs etc., is responsible for much of the loss in functional sinuosity along the Wabash River. Similarly, loss of riparian forests directly influences the riparian metric and reduces scores for instream cover. Gammon (2001) found that 10-14% of the riparian zones in the middle Wabash River had no trees or 1-2 rows and was associated with accelerated bank erosion. The data we examined here confirms that there are still frequent areas with insufficient woody riparian zones. Lack of riparian areas and adjacent wetlands increases stress on bank areas increasing erosion, made worse by flashier (peak) flows from upstream drainage.

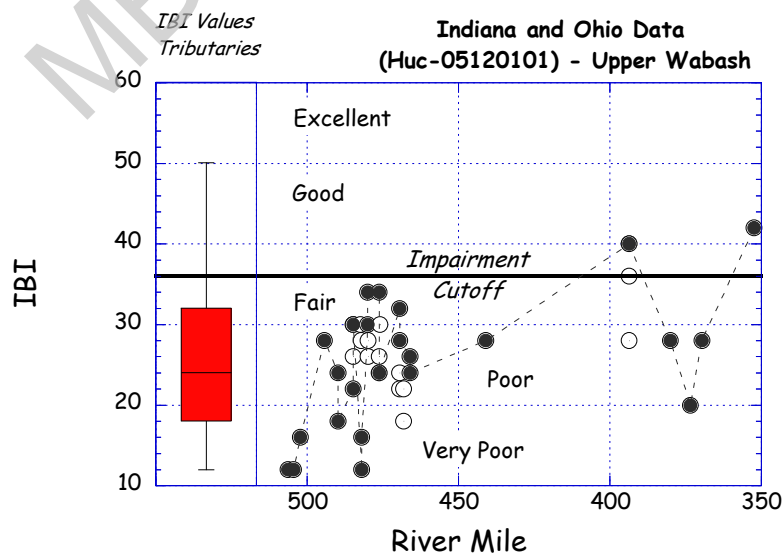
Historical data on Wabash bottomland forests documented extensive stands of large trees with American Sycamores, common close to the river, attaining heights of up to 200 feet and girth of 15 or more feet (Jackson 2006). Such large trees would occasionally fall into the river. These have been documented as being key features for stabilizing banks, improving diversity, and providing channel cover for fish and other aquatic animals.



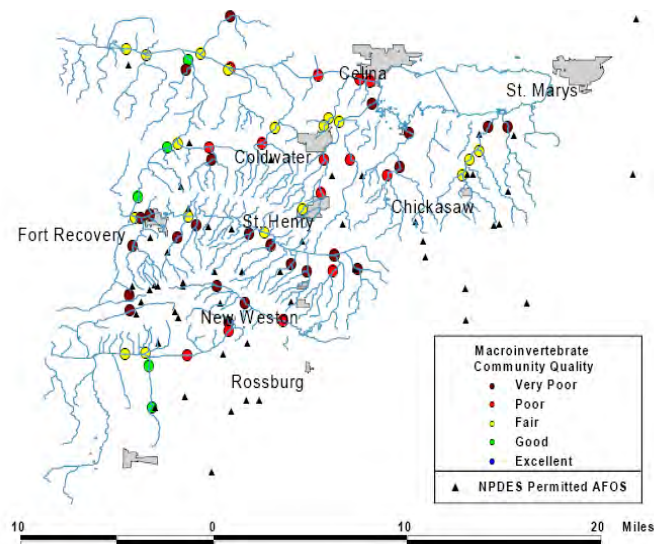
**Map 5.** IBI values from the mainstem (circles) or upstream tributaries within the upper Wabash River HUC-8 watershed (05120101). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana and Ohio from 1999; other data collected between 1990 and 2006 by 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 subcoregion and ends in the the Loamy, High Lime Till Plains subcoregion.

05120101 – Upper Wabash River Watershed (including Ohio). Fish sites sampled in the upper-most reaches of the Wabash River, especially in Ohio were mostly impaired as can be observed in Map 5 and Figure 6. 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



**Figure 6.** 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 6.** 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.

data from the Ohio portion of the Wabash which is in poor condition, considered one of 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 macroinvertebrate 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 6 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.

**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 3) 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. 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

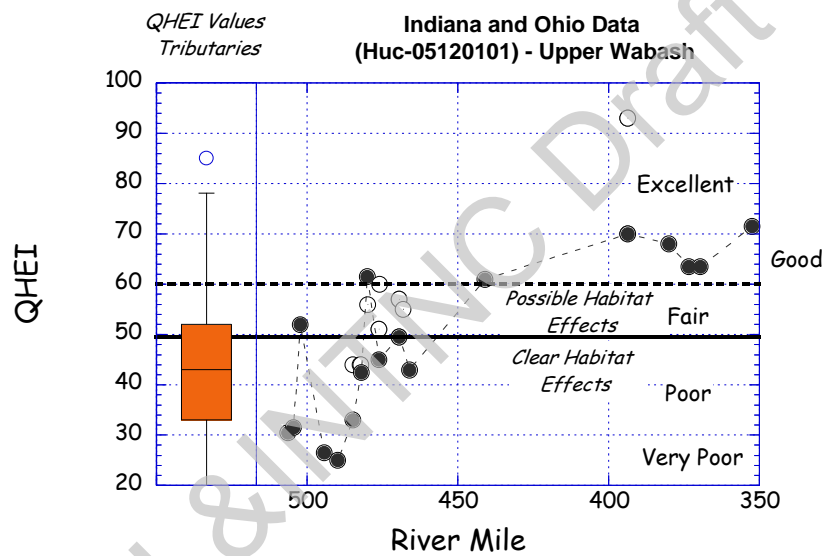
**Table 3.** Five most dominant fish species by number collected in fish samples in the upper Wabash River watershed (Huc 05120101) collected in Indiana and Ohio. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

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)

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 7). In reaches in Ohio, tributaries and the mainstem have been largely channelized. As is illustrated in Table 2, 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 and for its flashy flows.

**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 7.** 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).

Figure 8 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.

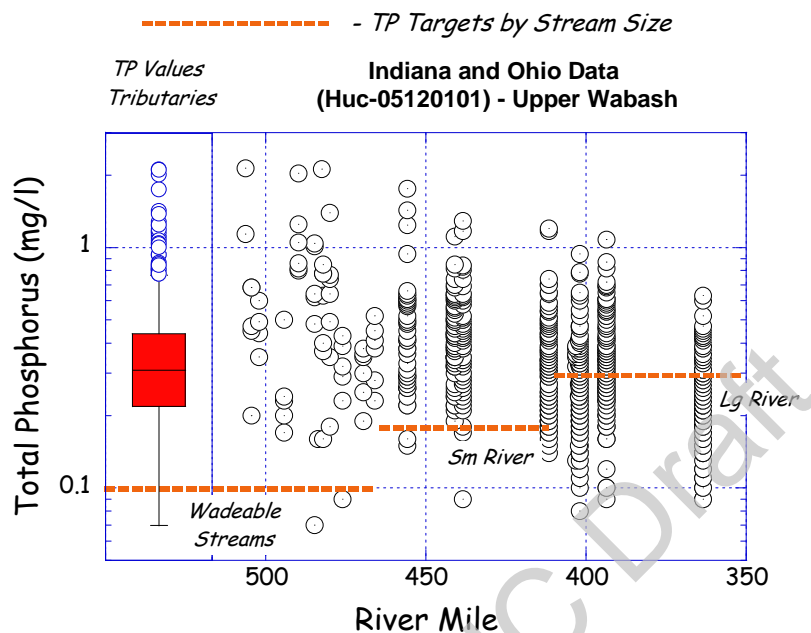
sites in the tributaries to the Wabash River. As the Wabash River takes on major tributaries with lower total phosphorus, the dilution lowers some of the values relative to the targets for large rivers; however the majority of the values are still above the large river target.

The 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

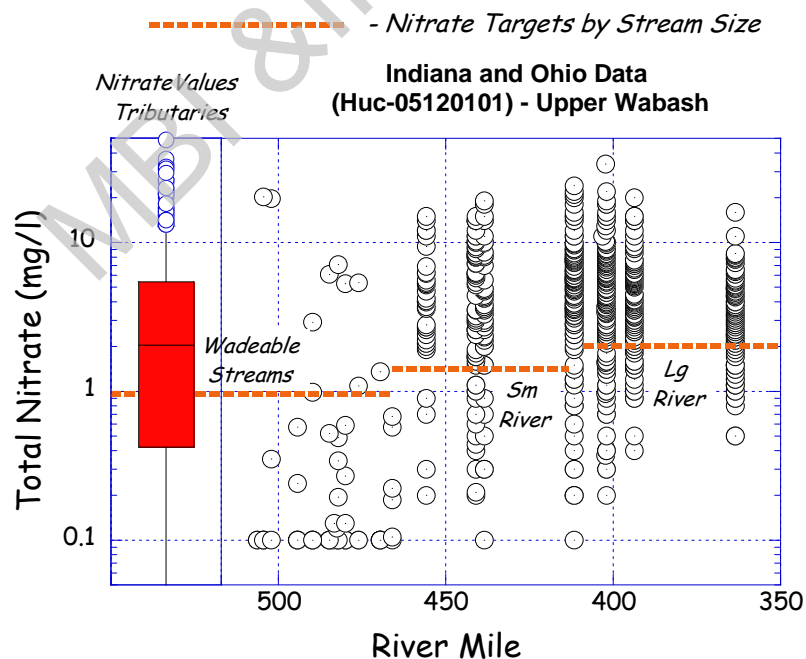
The tributaries and mainstem are nitrate enriched as well (Figure 9). The pattern is somewhat different with nitrate as it increases with distance downstream as the river passes from Ohio into Indiana. This is related to additions of nitrate from tributaries and the conversion of ammonia (from CAFOs 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 see Table 1). The upper reaches of Wabash River in this HUC-8 are some of the most

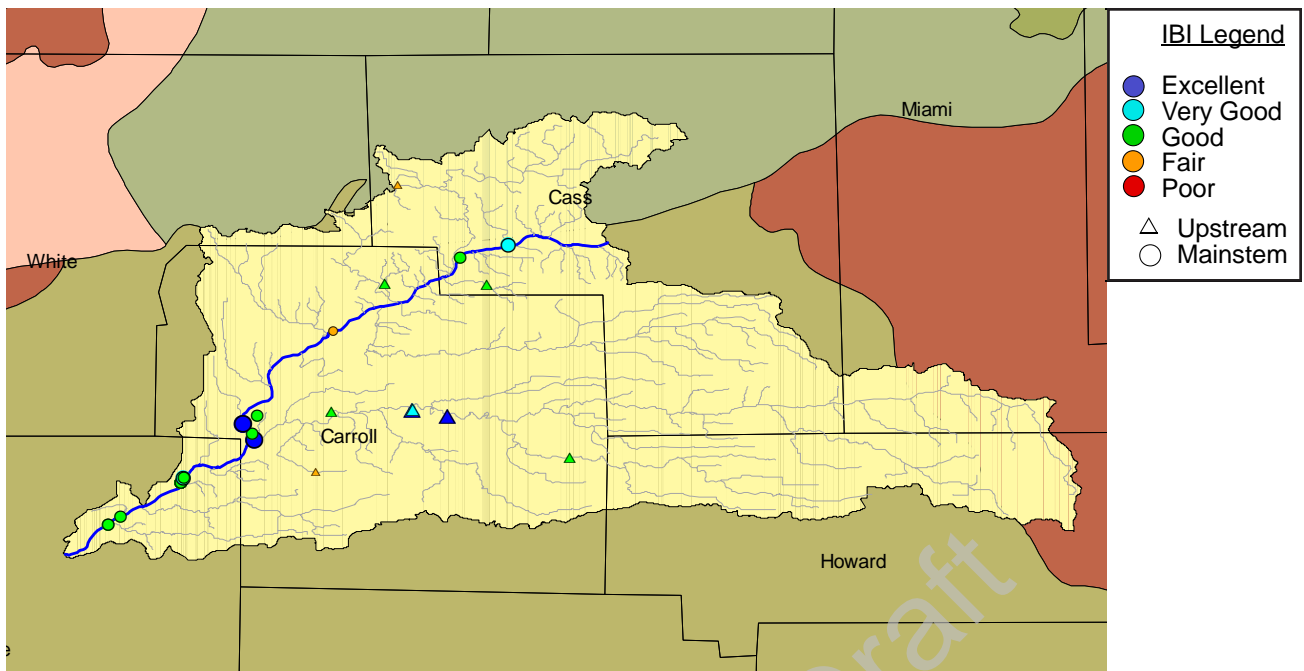
impaired waters in Ohio. Ohio completed a watershed survey (Ohio EPA 2002) and is currently completing a TMDL to begin to deal with these impairments (TetraTech 2004).



**Figure 8.** 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).



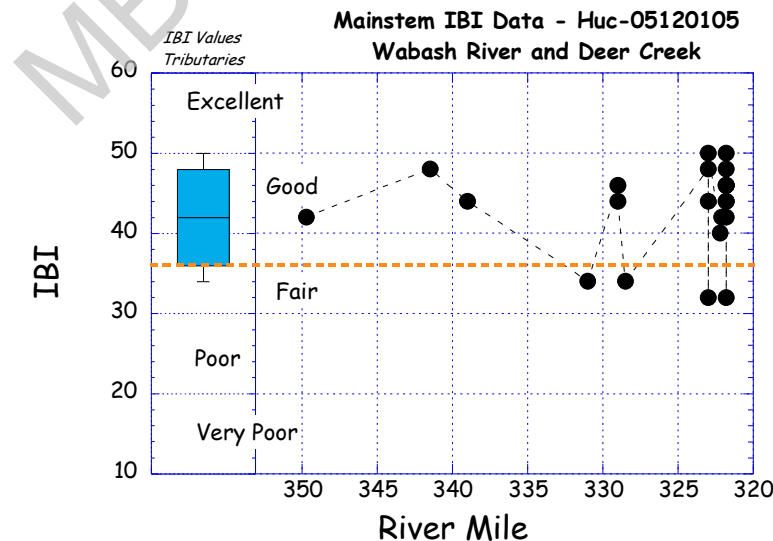
**Figure 9.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within the upper Wabash River HUC-8 watershed (05120101). Box and whisker plots represent data from tributaries from within this HUC-8. Orange dash lines represent total phosphorus targets for wadeable streams, small rivers or large rivers based on work done in Ohio (Ohio EPA 1999).



**Map 7.** 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 subecoregion with a northern portion in the Lake Country subecoregion and the eastern most portion in the Clayey, High Lime Till Plains subecoregion.

*05120105 – Middle Wabash River and Deer Creek.* 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. Fish sites sampled in this second reach of the Wabash River were mostly in good shape as can be observed in Map 7 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, Little Deer Creek and some other tributaries (N=9). Most IBI scores in this reach of the mainstem met the biological condition target (reference). The results from this HUC-8 are better than for entire watershed in general.



**Figure 10.** Plot of IBI by river mile in the middle Wabash River and Deer Creek HUC-8 watershed. Mainstem sites are black and connected by a dashed line. Box and whisker plot represents IDEM tributary QHEI data from this watershed.

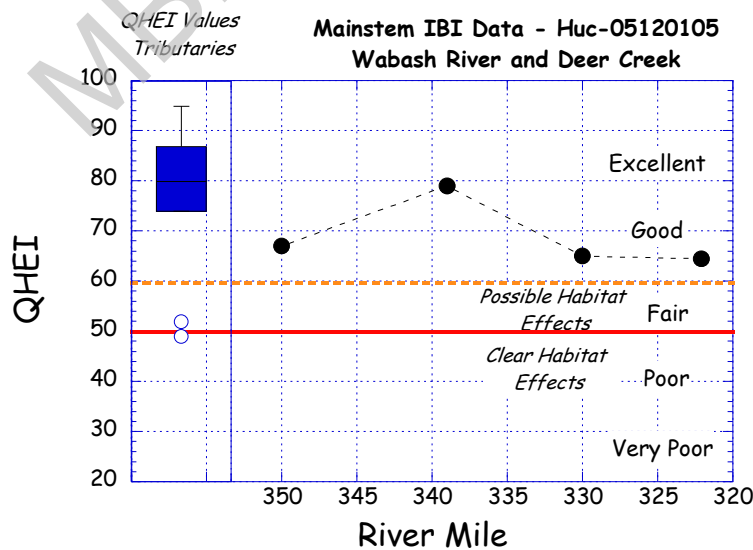
**Table 4.** Five most dominant fish species by number collected in fish samples in the middle Wabash River and Deer Creek watershed (Huc 05120105) collected in Indiana. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

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)

**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 4) 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 4). 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.

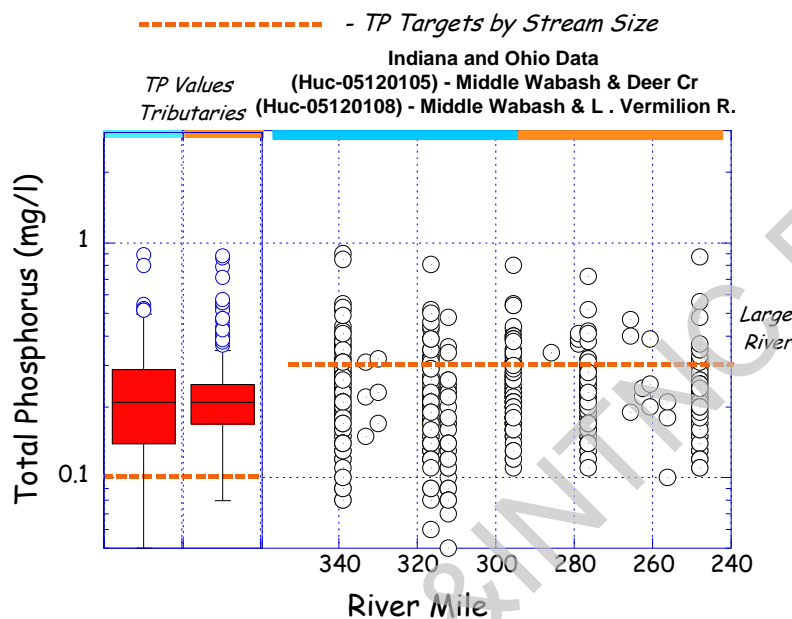
**Habitat** – Historically, the upper and middle reaches of the Wabash were quite different in character from what they are like today. The landscape was covered with permanent forest, prairie and wetland vegetation. Stream habitat was natural and likely consisted of a mix of higher gradient streams and flowing wetlands. In these streams, water was clear, habitat was likely diverse and aquatic vegetation was



**Figure 11.** 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.

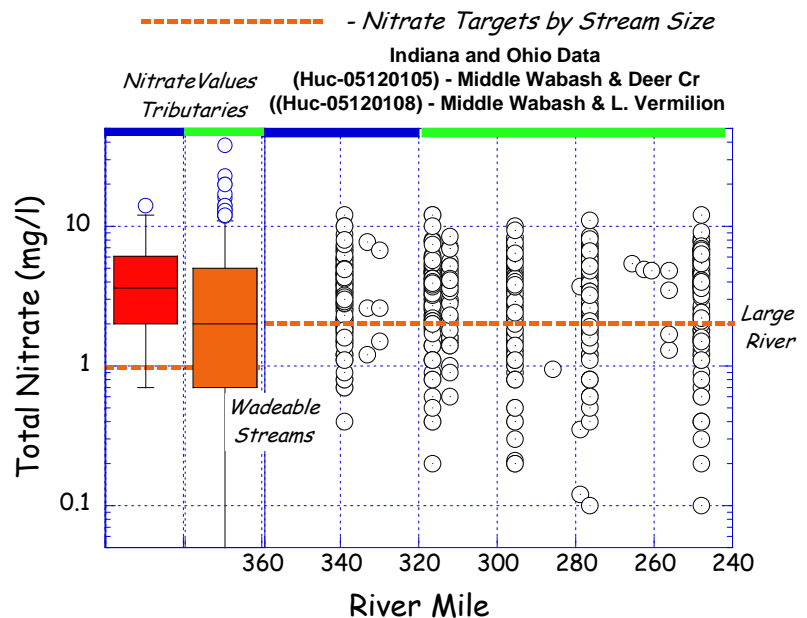
likely abundant. QHEI scores would have ranged from the 70s to 90s. This reach of the Wabash River mainstem has the best quality habitat of any of the reaches (Figure 11), likely related to the higher gradient and more natural cover and channel features. As summarized in Table 2, sites in this reach 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).

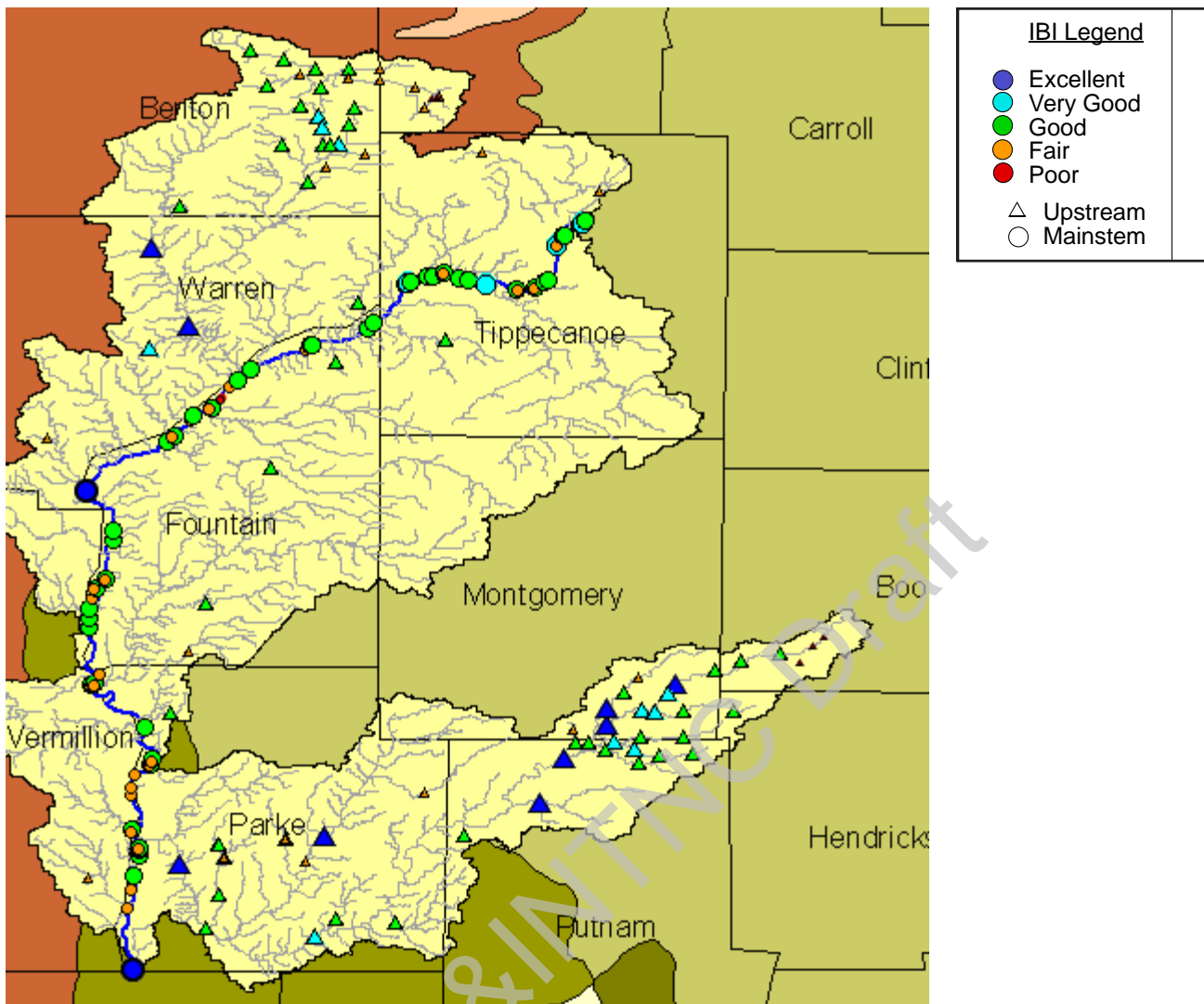
**Stressors in the Watershed** – While this reach of the Wabash performs much better biologically, the nutrient enrichment from the upper Wabash River is still evident in the mainstem (Figures 12 and 13). The tributaries in this HUC-8 are also enriched with TP even though habitat is generally better 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.



**Figure 12.** 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 13.** 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).

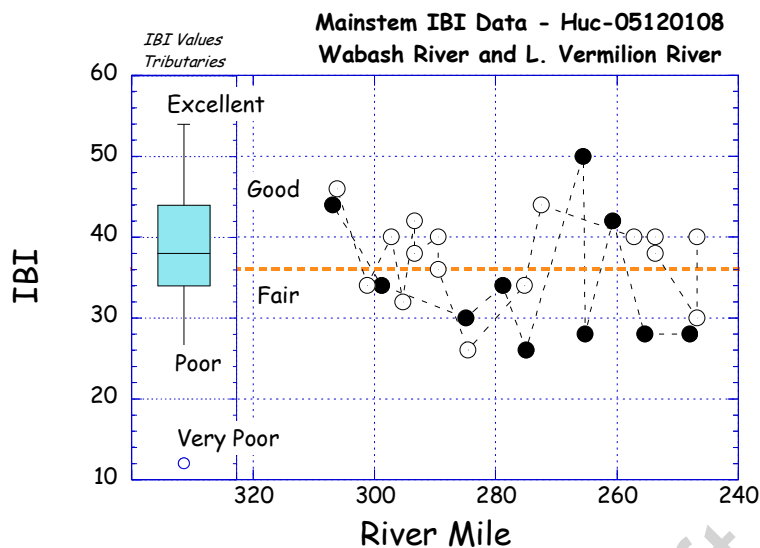




**Map 8.** IBI values from the mainstem (circles) or upstream tributaries within the Middle Wabash River - Little Vermilion River HUC-8 watershed (05120108). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana from 1999 and 2005/6; other data collected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

05120108 – Middle Wabash River and Little Vermilion R.. 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. 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 8 and Figure 14. 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 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 mussle species richness which drops sharply from the upstream to downstream borders of this HUC-8 watershed, again matching decline stream gradients. High gradient tends to buffer reaches from the effects of fine sediments and nutrients by transporting them downstream instead of letting them settle within the river.



**Figure 14.** 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.

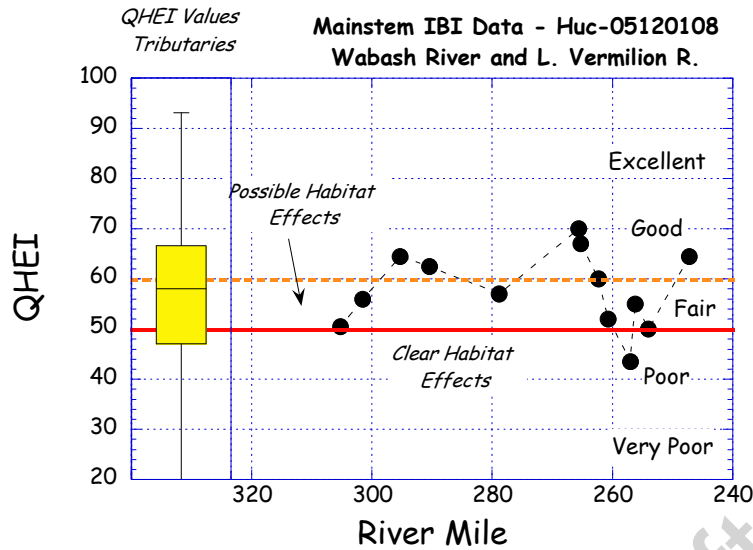
**Biodiversity** – The most common fish species in the Middle Wabash and Little Vermilion River reach were much more tolerant than in the previous upstream reach (05120105). The only sensitive species in the top ten was longear sunfish and the rest was dominated by two tolerant species (carp and freshwater drum) or species considered on the tolerant edge of intermediate tolerant. These species include emerald shiner, river carpsucker and gizzard shad, all of which thrive in nutrient enriched habitats.

**Habitat** – Figure 15 illustrates the longitudinal trend of QHEI through this reach. Values varied, 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

**Table 5.** Five 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)

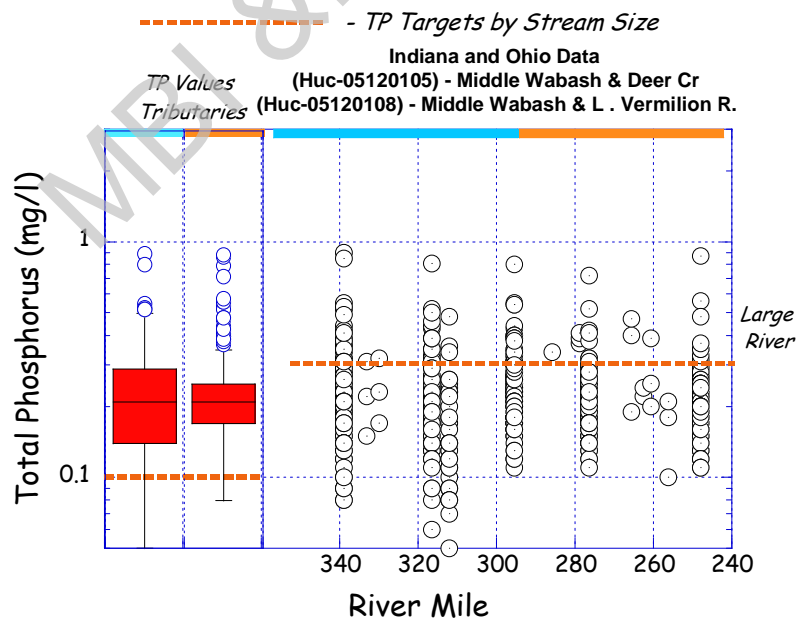


**Figure 15.** Plot of QHEI by river mile in the middle Wabash River and L. Vermilion River HUC-11 watershed (05010108). Mainstream sites are black and connected by a dashed line. Box and whisker plot data from IDEM.

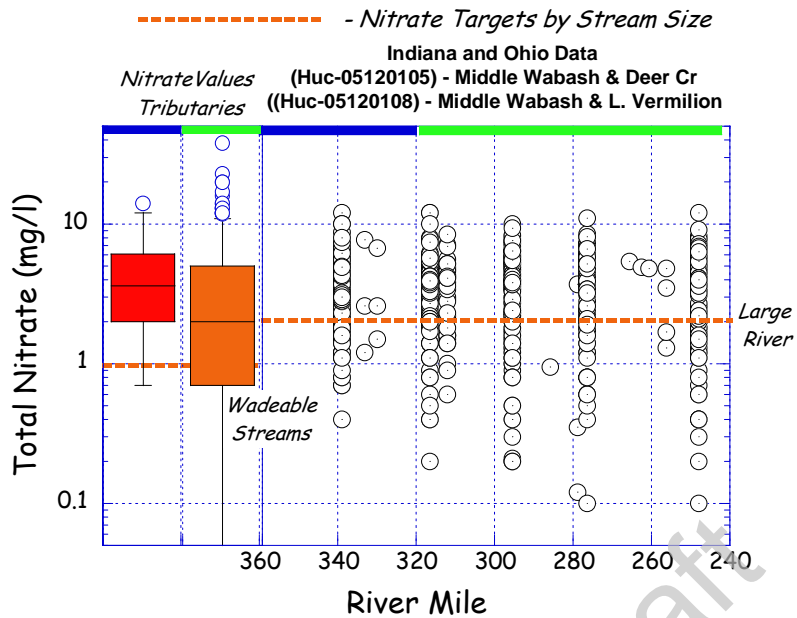
of individual habitat metrics indicates suggest that the biota is likely limited by poor instream structure, lack of riffles, narrow riparian vegetation lack of fast current flows. Loss of stream-edge wetlands and sloughs combined with increased flashiness and peak flows has undoubted increased pressure on river banks and increase erosion. Increased flow stresses may have increased pressure of bottom substrates.

Tributary streams show great variety in habitat scores (< 20 to > 90), however median scores were less than 60 indicating a majority of tributary streams may have habitat impacts.

**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

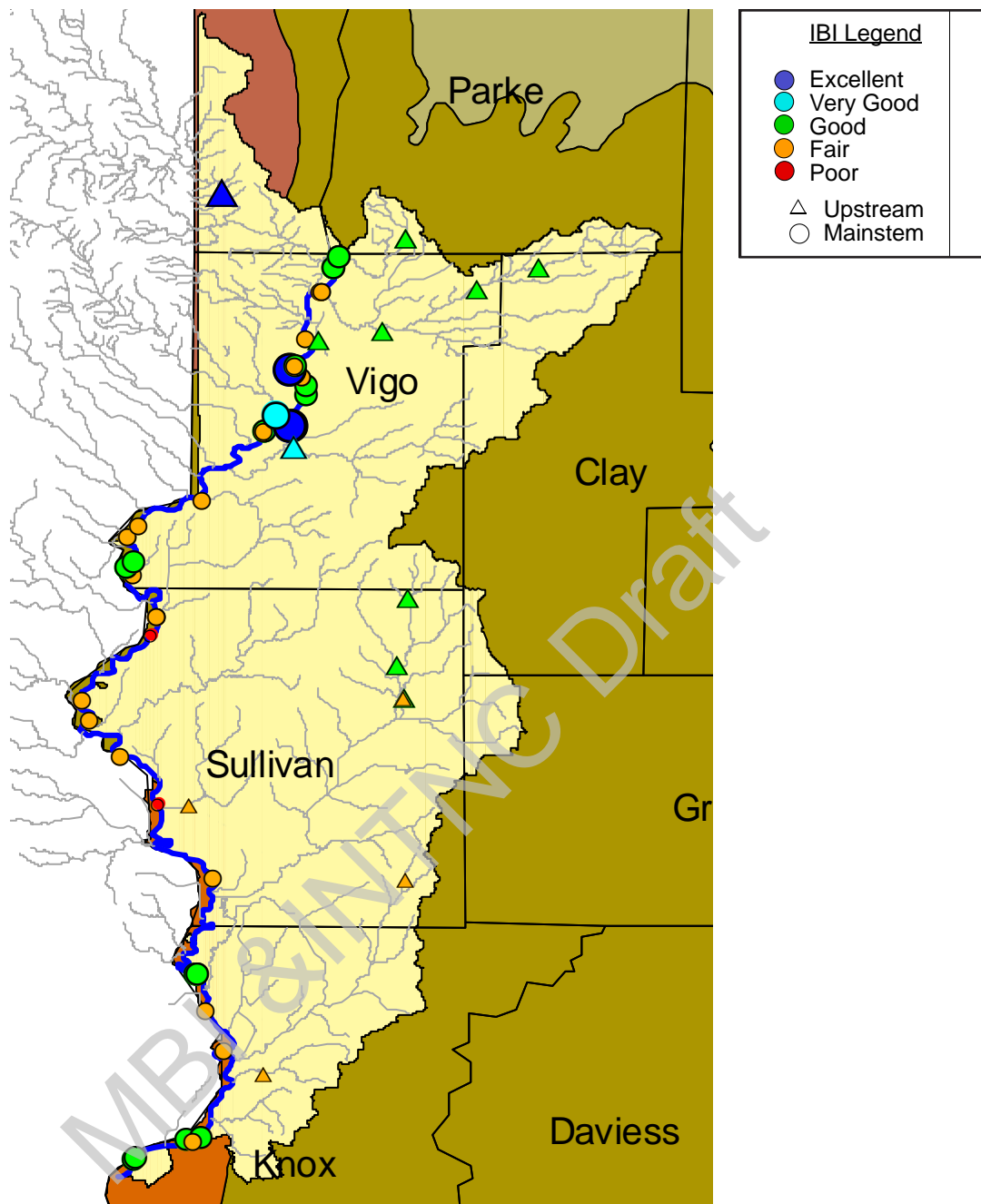


**Figure 16.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within two of the middle Wabash River HUC-8 watersheds (05120105-blue and 05120108-orange). Box and whisker plots represents data from tributaries from within each of these HUC-8 watersheds. Orange dash lines represent total phosphorus targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



**Figure 17.** 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).

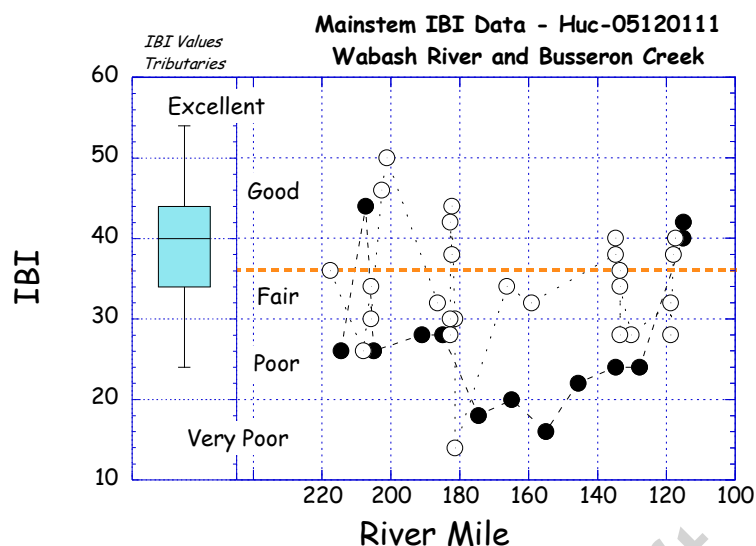
are still elevated above this target (Figure 16). In addition the tributaries in this watershed are highly elevated and likely contribute to the maintenance of high TP values in the mainstem of the Wabash River (Figure 16). Nitrate levels remain high in the mainstem, with most well above the targets for nitrate for large rivers (Table 17). 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 17).



**Map 9.** IBI values from the mainstem (circles) or upstream tributaries within the middle Wabash River HUC-8 watershed (05120111). 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.

*05120111 – Middle Wabash River and Busseron Creek.* This mainstream Wabash River HUC-8 watershed (RMs 309.4 – 236.5) is about seventy-three miles in length. Fish sites sampled in this fourth reach of the Wabash River were variable with some sites in the upstream and downstream sections in the good range and sites in the middle portion fair-poor

as can be observed in Map 9 and Figure 18. The IBI was generally good in the majority of the tributaries to the Wabash in this HUC-8 watershed which includes samples in Busseron Creek and Spring Creek and other tributaries (N=15). Tributaries were in a bit better condition than the basinwide average for the Wabash River as calculated by



**Figure 18.** Plot of IBI by river mile in the middle Wabash River & Busseron Creek HUC-8 watershed. Mainstream sites sampled in 1999 by IN DNR are black and connected by a dashed line; sites sampled in 2004/6 by ORSANCO are open circles. Data from tributaries sampled by IDEM are summarized in the box plot.

IDEM, but the Wabash River mainstem was generally in worse condition (see Figure 18). Mussel species richness generally follows the same pattern with fewer mussel species, in general, in the middle portion of this reach (see Appendix 10).

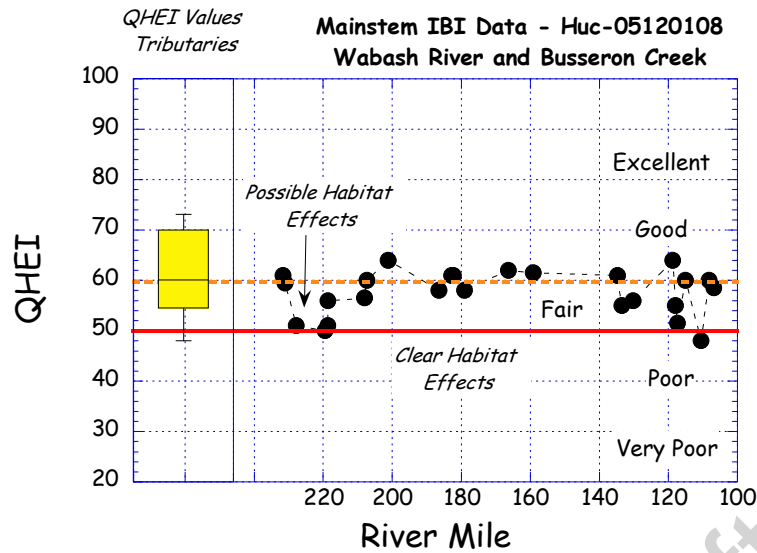
**Biodiversity** – The fish species collected in the middle Wabash and Busseron Creek HUC-8 reach of the Wabash River mainstem (Table 6) were characterized by a lack of sensitive species and more species of intermediate tolerance and several tolerant species (Freshwater Drum and carp) than the

previous two HUCs. These intermediate species would also be rated as being towards the tolerant range of intermediate tolerance.

The tributary streams to this HUC-8 watershed that were sampled are predominantly composed of intermediate and tolerant fish species and one sensitive species (Longear Sunfish). Distribution of IBI scores between 34 and 44 identifies that many of these sites meet the CWA cutoff, but do not contain many of the most sensitive fish species.

**Table 6.** Five most dominant fish species by number collected in fish samples in the middle Wabash River and Busseron Creek watershed (Huc 05120111) 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 - (1,773)	Creek Chub [T] - (596)
Gizzard Shad - (1,997)	Central Stoneroller - (578)
Freshwater Drum [P] - (1,446)	Longear Sunfish [M] - (524)
Spotfin Shiner - (1,065)	Bluntnose Minnow [T] - (406)
Common Carp [T] - (1,022)	Silverjaw Minnow - (284)
Channel Catfish - (919)	Johnny Darter - (257)
River Shiner - (338)	Green Sunfish [T] - (174)
River Carpsucker - (450)	Bluegill Sunfish - (126)
Flathead Catfish - (353)	White Sucker (104)
Spotted Bass - (232)	Orangethroat Darter - (92)



**Figure 19.** Plot of QHEI by river mile in the middle Wabash River and Busseron Creek HUC-8 watershed (05120111). Mainstem sites are black and connected by a dashed line. Data from tributaries sampled by IDEM are summarized in the box plot.

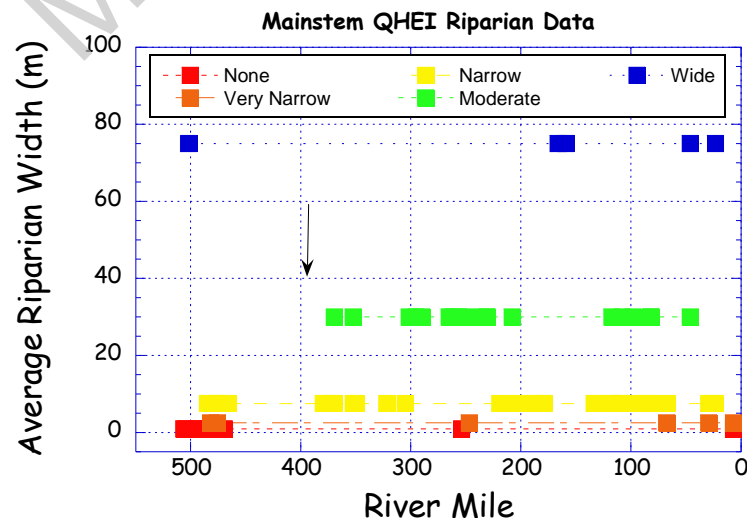
**Habitat** – Historically, the lower reaches of the Wabash were quite different in character from what they are like today. The mainstem had extensive backwaters, oxbows, and sloughs. Water was clear and did not rise rapidly during flooding (non-flashy) and habitat was likely diverse and aquatic vegetation was likely abundant. QHEI scores would have ranged from the 70s to 90s.

The mainstem habitat today in this reach is in fair to marginal-good condition. The habitat in fact was very similar along most of the reach (Figure 19). Long stretches of mediocre habitat can cause some cumulative effects of not interspersed with areas of high quality

habitat. It is missing well developed riffles and instream structure is poor (see Table 2). Historical riparian forests and wetlands were undoubtedly vast; riparian zones today (Figure 20) are very narrow in some reaches, even on such a larger river, which has led to bank erosion.

The tributary sites that were sampled in this HUC-8 had fair to good habitat (Figure 19), but sample size was rather small to make broad comparisons

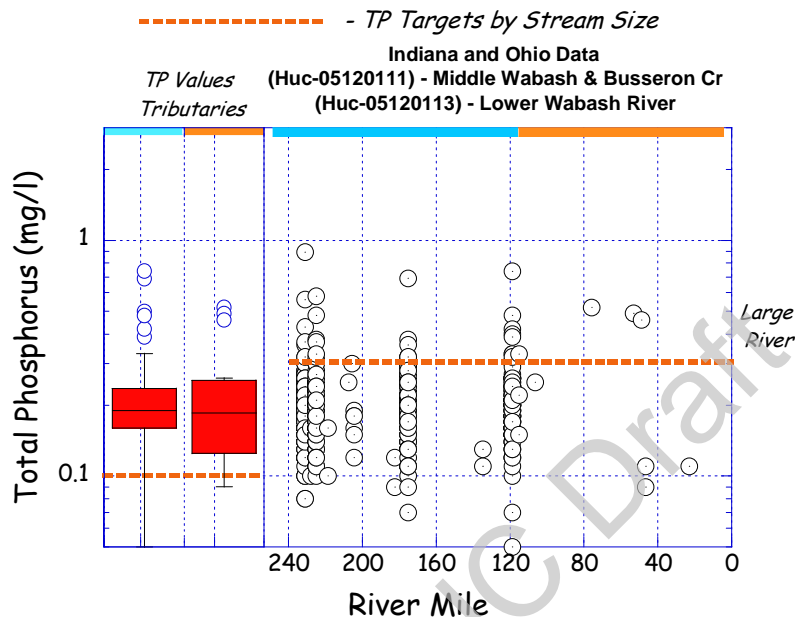
**Stressors in the Watershed** – Mean total phosphorus concentrations at stations were not substantially different among the lower four mainstem reaches



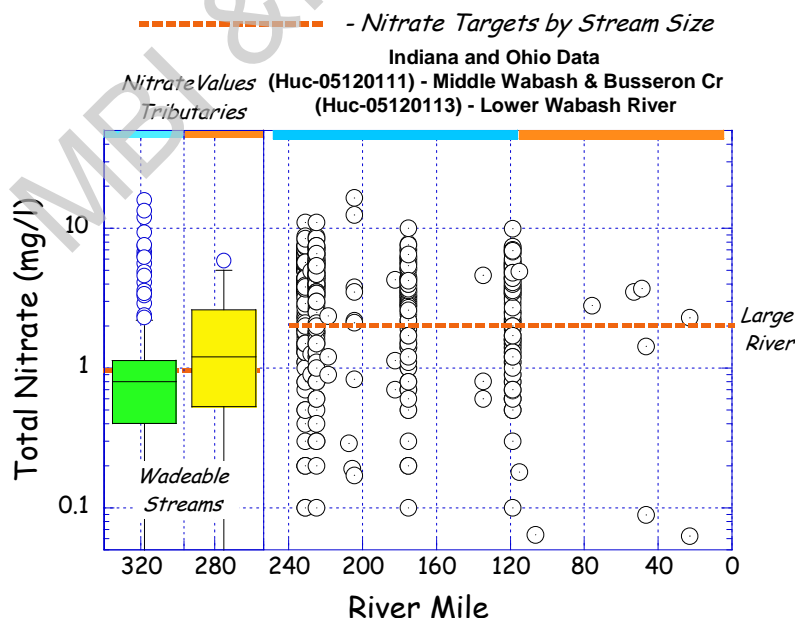
**Figure 20.** Plot of QHEI Mean Riparian Width by river mile in the entire Wabash mainstem. Data IDEM, ORSANCO, and Ohio EPA (Ohio reaches).

(Table 2), but the highest values declined (Figure 21) which may be due to the higher average volume of flow dampening extreme values. Tributaries still had elevated TP values that may have contributed to maintaining concentrations in the mainstem. Total

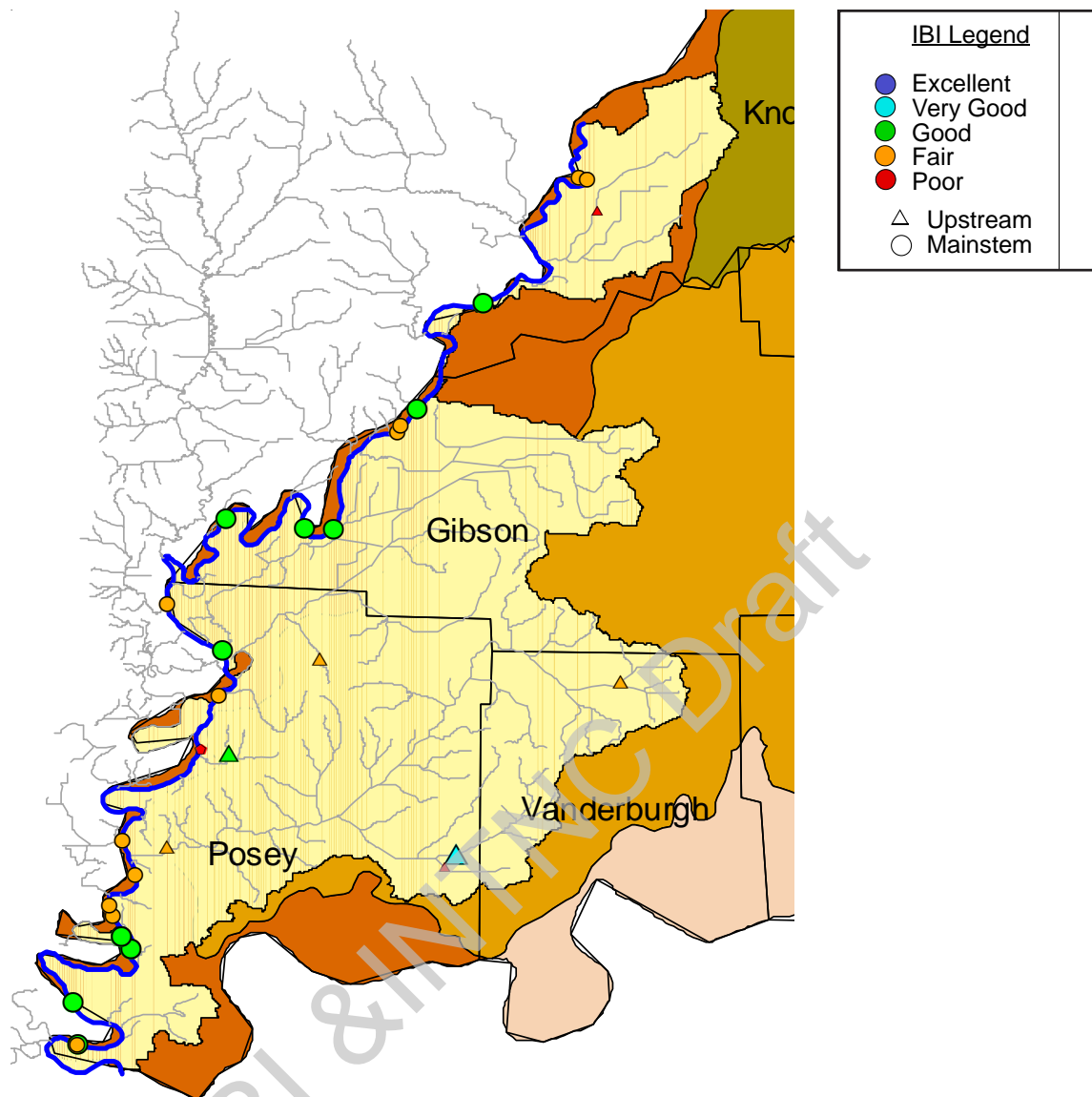
nitrate values were generally still high in the mainstem; however, tributaries in 05120111 had relatively lower nitrate concentrations compared to upstream HUC-8 watersheds (Figure 22).



**Figure 21.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within the two lower Wabash River HUC-8 watersheds (05120111-blue and 05120113-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 22.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within the two lower Wabash River HUC-8 watersheds (05120111-blue and 05120113-orange). Box and whisker plots represents data from tributaries from within each these HUC-8 watersheds. Orange dash lines represent total nitrate targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).

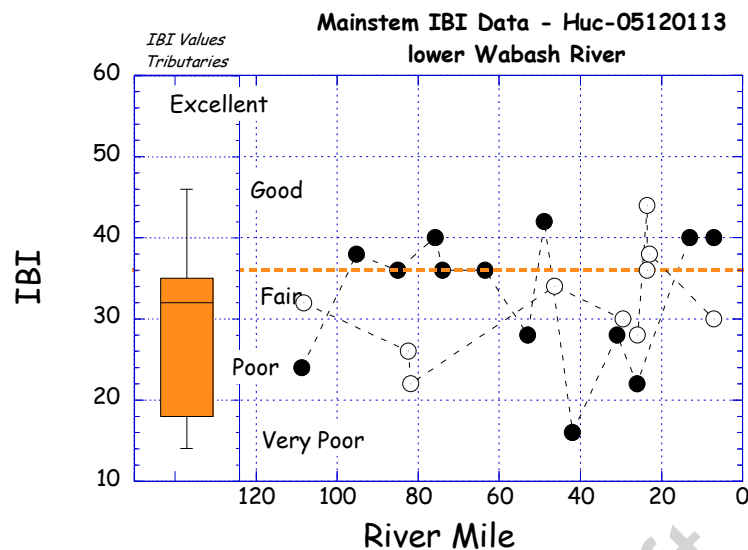


**Map 10.** IBI values from the mainstem (circles) or upstream tributaries within the Lower Wabash River HUC-8 watershed (05120113). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data in Indiana from 1999 and 2004-6; other data collected between 1990 and 2006 by IDEM (IN). Shaded areas are Level IV ecoregions; this watershed is primarily in the Wabash Bottomlands subcoregion with the western portion in the Southern Wabash Lowland subcoregion.

*05120113 Lower Wabash River.* This is one of the longest of the five mainstream HUC-8 watersheds and includes over one hundred and thirteen miles (RMs 113.41 – 0.0) of the Wabash River. Although IBI values were variable (Map 10 and Figure 23), a plot of sensitive fish species showed that they were very low in this lower reach, with generally less than 5 sensitive species in any sample. This matched a pattern in the mussel assemblages which showed a substantial depression in species richness in the lower river. The IBI also ranged from very poor to

good in the tributaries which included Big Creek and some other streams (N=7).

**Biodiversity** – The fish species collected in the Lower Wabash River were characterized by species of intermediate sensitivity or were tolerant. In an analysis of the relative tolerance of fish and macroinvertebrates to various individual stressors, most of the species in the mainstem are habitat generalists and associated with nutrient enriched conditions. Many of the fish species that are rare,



**Figure 23.** Plot of IBI by river mile in the lower Wabash River HUC-8 watershed. Mainstream sites sample in 1999 by IN DNR are black and connected by a dashed line; sites sampled in 2004/6 by ORSANCO are open circles. Data from tributaries sampled by IDEM are summarized in the box plot.

endangered, or extirpated in the Wabash River once inhabited this lower reach and were associated with the backwater swamps and aquatic vegetation that have been largely eliminated from the river.

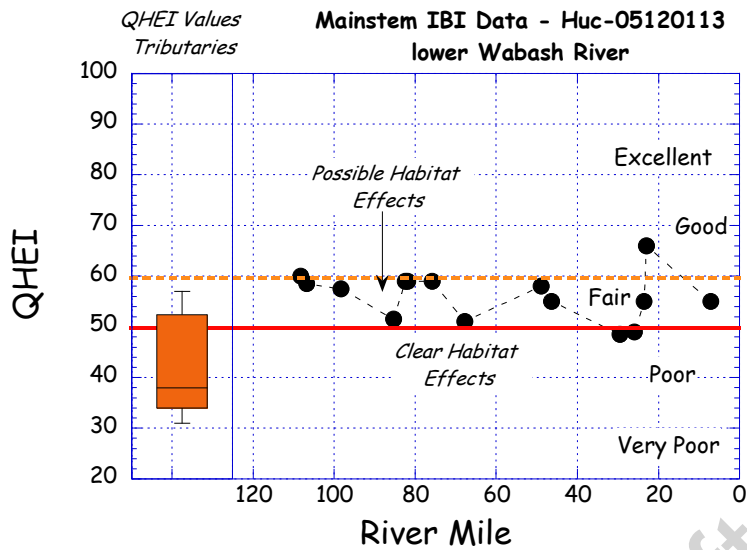
The species which are not rare or extirpated from the lower river fall into two groups. One group was associated with the oxbows, swamps and other wetland type features along the lower river. The other group are species that inhabited fast flowing areas of the river with stable substrates and but good flows but with relatively low shear stresses

during most storms. This would include many of the mussel species as well as certain darter (Harlequin Darter), chub (Shoal Chub), and madtom species.

One important stressor we have not discussed in detail is the recent invasion by the alien carp species (silver, bighead, and black) that have been introduced into the Mississippi River basin. These were already present (silver and bighead carp) in the data we examined for this report (up to 2006), but are likely more common now. Black carp would be a serious threat because they feed on snails and mussels which are already a

Table 7. Ten most dominant fish species by number collected in fish samples in the lower Wabash River HUC-8 watershed (Huc 05120113) 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)
Spotfin Shiner - (1,068)	Creek Chub [T] - (119)
Emerald Shiner - (916)	Blackstripe Topminnow - (115)
Freshwater Drum [P] - (954)	Bluntnose Minnow [T] - (115)
Gizzard Shad - (551)	Central Stoneroller - (79)
Mississippi Silvery Minnow (301)	Silverjaw Minnow - (50)
Common Carp [T] - (427)	Longear Sunfish [M] - (46)
Shortnose Gar - (285)	Spotfin Shiner - (34)
Bullhead Minnow - (191)	Green Sunfish [T] - (22)
River Carpsucker (182)	Yellow Bullhead [T] - (20)
Channel Catfish - (139)	Sand Shiner [M] - (18)

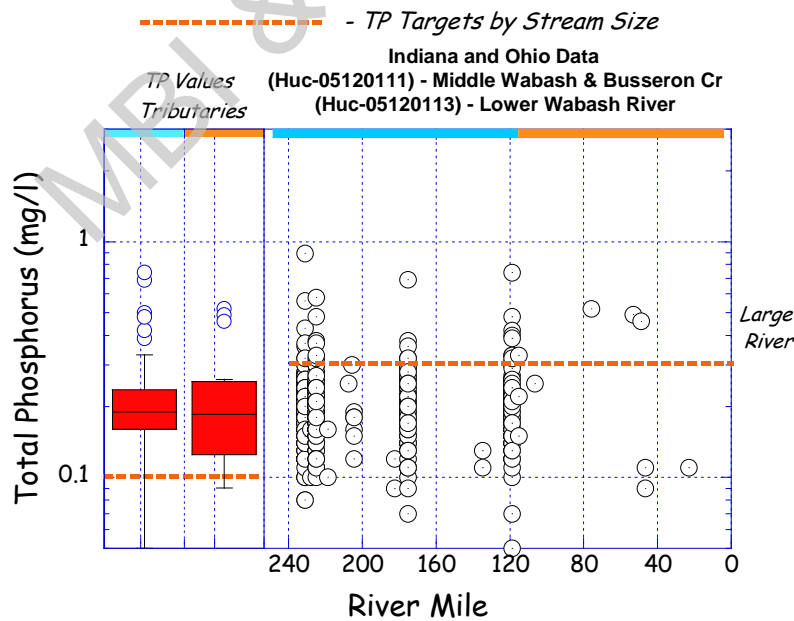


**Figure 24.** Plot of QHEI by river mile in the lower Wabash River HUC-8 watershed. Mainstream sites are black and connected by a dashed line. Box plot data is from IDEM.

threatened component of ecosystems in the Wabash and across the US.

**Habitat** – Historically, the lower reaches of the Wabash had extensive backwater swamps and bottomwood forests. These were largely removed or filled for agriculture in their rich soils. QHEI scores

would have ranged from the 80s to 90s. Habitat in the mainstem Wabash River was very mediocre for such a large river. QHEI values at sites in the lower river were clearly in range where impacts to minimal Clean Water Act biological goals would be impacted. QHEI Expectations for intolerant species would actually be much higher than illustrated on Figure 24. Some of these



**Figure 25.** Total phosphorus (mg/l) vs. river mile in the Wabash River mainstem within the two lower Wabash River HUC-8 watersheds (05120111-blue and 05120113-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).

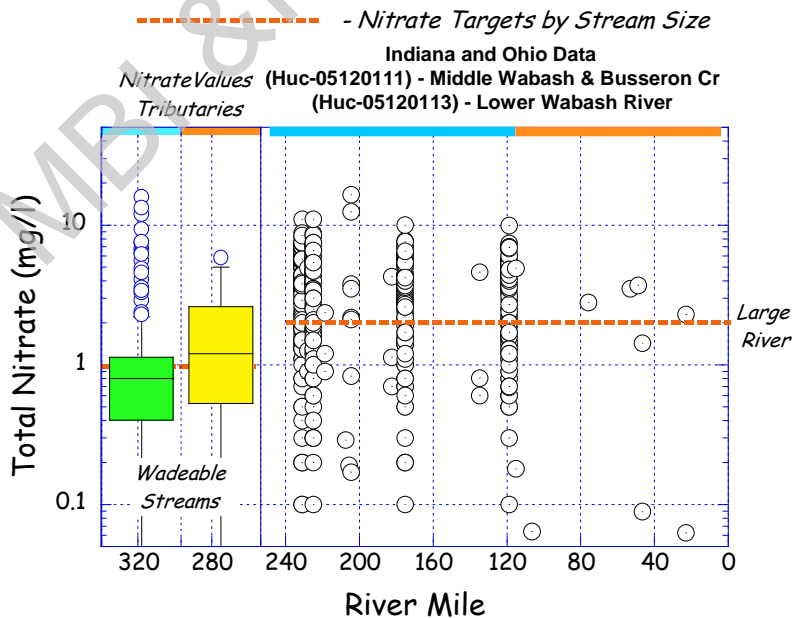
species would be lost after QHEI scores were lowered past 70. As in the upper most Wabash, the lower part of the watershed has many streams that have been subjected to agricultural drainage (see Figure 3). As a result of these small channels having been altered to enhance drainage, habitat is mostly poor with most QHEI scores less than 50 (Figure 24).

**Stressors in the Watershed** – Total phosphorus data in the mainstem was lowest in this reach of the Wabash with most values below the large river cutoff illustrated on Figure 25. The TP target was developed for “large” rivers smaller in size than this reach of the Wabash so it simply represents a “best guess” as what would be an expected level under current best agricultural land practices. Anecdotal information suggests that TP would have been much lower prior to current agricultural and drainage practices. Mean nitrate concentrations in the lower Wabash River are lower than the other mainstem HUC-8 reaches (Table 1) and there are fewer very high values (Figure 26), although our sample size was much lower. In any case, nutrient values in the lower reach are very dependent on

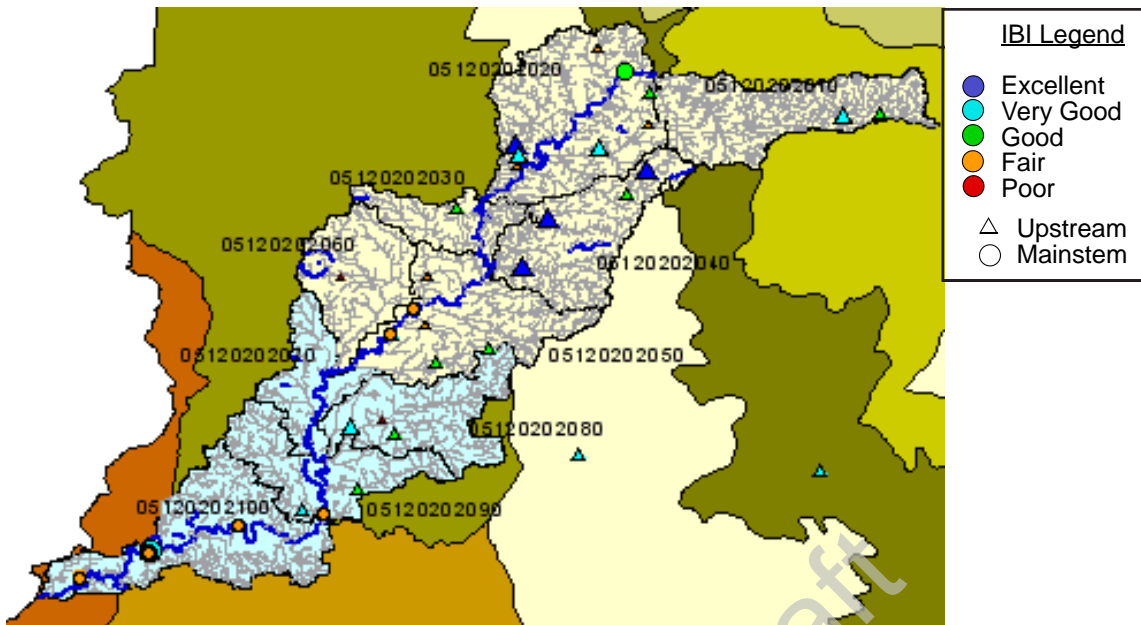
what happens in the upper watershed and small streams.

Another obvious pattern by examining chemical data is the gradual increase in TSS in downstream reaches. This, at least partially, reflects increase algal production in the large pools in the lower river.

Research on the basic nutrient dynamics in streams and rivers has identified small headwater streams as being of primary importance in assimilating and transforming nutrients in a watershed. The mediocre QHEI values in the lower Wabash identify instream habitat characteristics (bank erosion, lack of riparian habitats, and lack of instream cover) as key limiting factors to the biodiversity of this reach. Historically, backwater swamps, oxbows and other similar features provided habitats now rare along the river. The loss of these stream features and the “flood-proofing” of previous floodprone areas has undoubtedly increased problems associated with increased flashy flows compared to historical levels. Some estimates of hydrological changes to the Mississippi basin has estimated that peak flows are up to six times higher than prior to settlement.



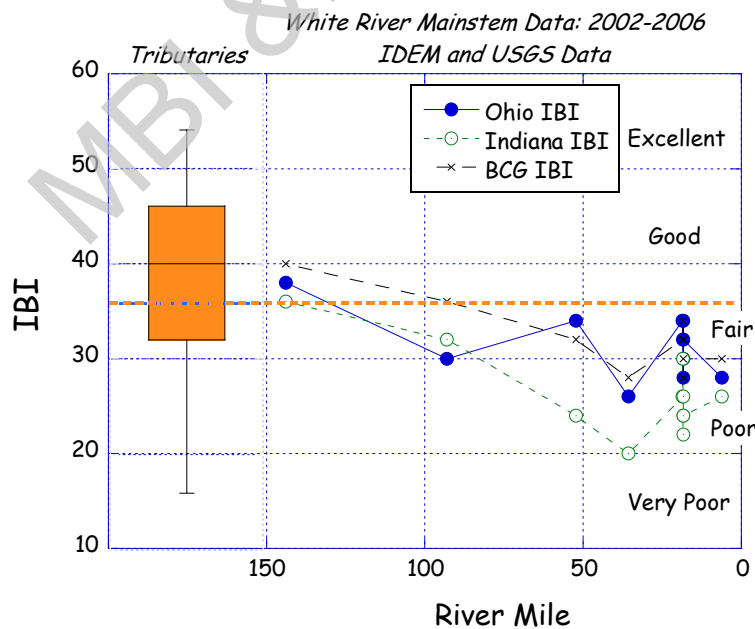
**Figure 26.** Total nitrate (mg/l) vs. river mile in the Wabash River mainstem within the two lower Wabash River HUC-8 watersheds (05120111-blue and 05120113-orange). Box and whisker plots represents data from tributaries from within each these HUC-8 watersheds. Orange dash lines represent total nitrate targets for wadeable streams or large rivers based on work done in Ohio (Ohio EPA 1999).



**Map 11.** IBI values from the mainstem (circles) or upstream tributaries within the lower White River Huc-8 watershed (05120202). Points are scaled by IBI values and colors reflect narrative ranges for scores. Mainstem data from IDEM and USGS collected between 2002 and 2006. Shaded areas are Level IV ecoregions; this watershed crosses five Level IV ecoregions (two Level III ecoregions: In the Level III Interior River Lowland - the Wabash Bottomlands, the Southern Wabash Lowland and the Glaciated Wabash Lowlands and in the Level III Interior Plateau: the Crawford Uplands and the Mitchell Plains

*05120202 Lower White River.* The lower White River HUC-8 is composed of 10 HUC-11 watersheds . IBIs for fish sites sampled in this lower White River were variable and ranged between poor to good as can be

observed in Map 11 and Figure 27. The IBI ranged from very poor to excellent in the tributaries of the lower White River (N=26) in this HUC-8 watershed. Stream that rated excellent included Plummer Creed



**Figure 27.** Plot of IBI by river mile in the lower White River HUC-8 watershed (05120202).. Mainstem sites sampled between 2002 and 2006 by IDEM and USGS.. Data from tributaries sampled by IDEM are summarized in the box plot.

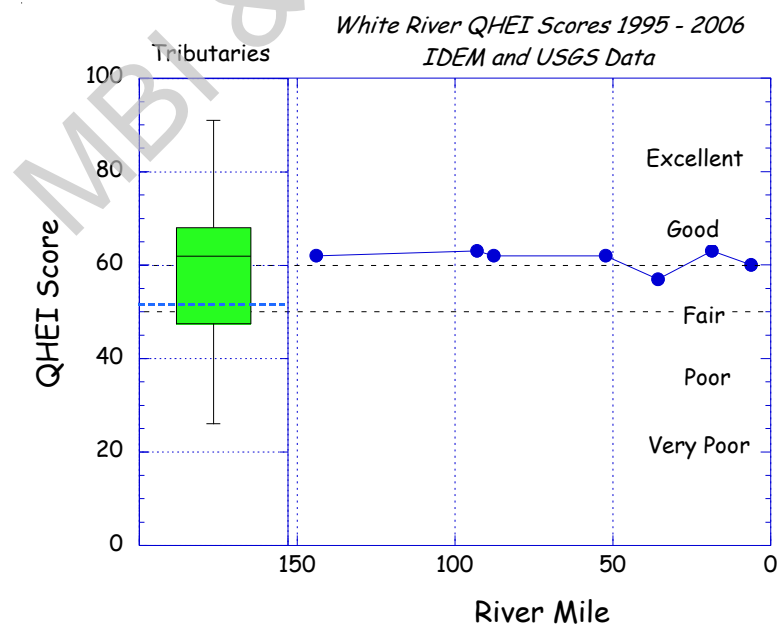
**Table 7.** Ten most dominant fish species by number collected in fish samples in the lower White River Huc-8 watershed (Huc 05120202) collected in Indiana. IBI tolerance category for each species is noted as is the total individuals counted during sampling.

Ten Most Dominant Fish Species by Relative Abundance	
Mainstem	Tributaries (Excluding Mainstem)
Mississippi Silvery Minnow - (435)	Longear Sunfish [M] - (519)
Gizzard Shad - (399)	Spotfin Shiner - (462)
Spotfin Shiner - (3294)	Creek Chub [T] - (399)
Bullhead Minnow - (184)	Bluntnose Minnow - (398)
Freshwater Drum [P] - (176)	Western Mosquitofish - (245)
River Carpsucker (147)	Bluegill [P] - (228)
Common Carp [T] - (119)	Green Sunfish [T] - (163)
Shortnose Gar - (105)	Central Stoneroller - (157)
Flathead Catfish (101)	Striped Shiner - (132)
Channel Catfish - (139)	Sand Shiner [M] - (18)

and Richland Creek; the North Fork of Prairie Creek was rated as very poor. IBI scores in the mainstem declined from upstream to downstream.

**Biodiversity** – The fish species collected in the lower White River were characterized by species of intermediate sensitivity or species are tolerant (common carp, freshwater drum) (Table 7). In an analysis of the relative tolerance of fish and macroinvertebrates to various individual stressors,

most of the species in the mainstem are habitat generalists and associated with nutrient enriched conditions. Many of the fish species that are rare, endangered, or extirpated in the White River once inhabited this lower reach and were associated with the backwater swamps and aquatic vegetation that have been largely eliminated from the river. USGS collected an alligator gar in the lower White in the 1990s which is a remnant associated with these habitats.



**Figure 28.** Plot of QHEI by river mile in the lower White River Huc-8 watershed (05120202). Mainstream sites are blue and connected by a solid line and were collected by USGS and IDEM. Box plot data is from IDEM.

**Habitat**– Historically, the lower reaches of the White River had extensive backwater swamps and bottomwood forests. These were largely removed or filled for agriculture in the rich soils. QHEI scores the lower White River would have ranged from the 80s to 90s. As in the upper most Wabash, the lower part of the watershed has many streams that have been subjected to agricultural drainage (see Figure 3). As a result of these small channels having been altered to enhance drainage, habitat is mostly poor with most QHEI scores less than 50 (Figure 28).

**Stressors in the Watershed** – Total phosphorus (TP) data in the mainstem White River was variable, but a high proportion of values were greater than the large river cutoff illustrated in Figure 29. Similarly a high proportion of tributary sites were above a wadeable river cutoff for TP as well. These patterns are typical for highly agricultural watersheds in the Midwest and reflect a substantial runoff of silt and sediments from these uses and some contribution from tile drainage sources. Work in Ohio has found that in small streams there is a strong correlation with intact stream habitat and low TP values indicating intact stream habitat, associated with intact riparian buffer zones would reduce TP in tributaries and mainstem reaches of rivers such as the White River.

Mean nitrate concentrations in the lower White River were also predominantly above a large river cutoff values for total nitrate (Figure 30). These are similar to high values observed in the Wabash River mainstem. A large proportion of nitrate is exported through tile drains. USGS conducted studies of nutrients in the White River basin in the 1990s (Fenelon 1998). With regard to aquatic life issues they found, as we did, high concentrations of nitrates in the river (Fenelon 1998), that are likely exported by agricultural drainage tiles in the Wabash River. Associated with the high nitrate levels from drain tiles are high pesticide levels (Fenelon 1998), although the precise affect of pesticides on aquatic life is unclear. In any case, nutrient values in the lower reach are very dependent on what happens in the upper watershed and small streams.

Research on the basic nutrient dynamics in streams and rivers has identified small headwater streams as being of primary importance in assimilating and transforming nutrients in a watershed. As with the

lower Wabash River, habitat in the Wabash River has some limitations which influence the biodiversity of these reaches. Key limiting habitat characteristics include bank erosion, lack of riparian habitats, and lack of instream cover. As with the lower Wabash River, backwater swamps, oxbows and other similar features provided habitats now rare along the river. The increase in levees, loss of connections with natural floodways and increase flashiness from agricultural drainage have all worked to greatly alter the flow regimes in the lower White River. For examples other studies in the Mississippi River basin have estimated that peak flows are up to six times higher than prior to settlement. High shear stress during storm events in particularly troublesome for species such as mussels that require areas of low shear stress during infrequent storm events. Given the long life span of these animals (decades to centuries) for frequent severe storms can prevent maintenance of large populations.



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