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Development of a Biological Condition Gradient for Fish Assemblages of the Upper Mississippi River and Development of a "Synthetic" Historical Fish Community

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Improving Water Quality Standards and Assessment Approaches for the Upper Mississippi River: Development of a Biological Condition Gradient for Fish Assemblages of the Upper Mississippi River and Development of a "Synthetic" Historical Fish Community

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Introduction

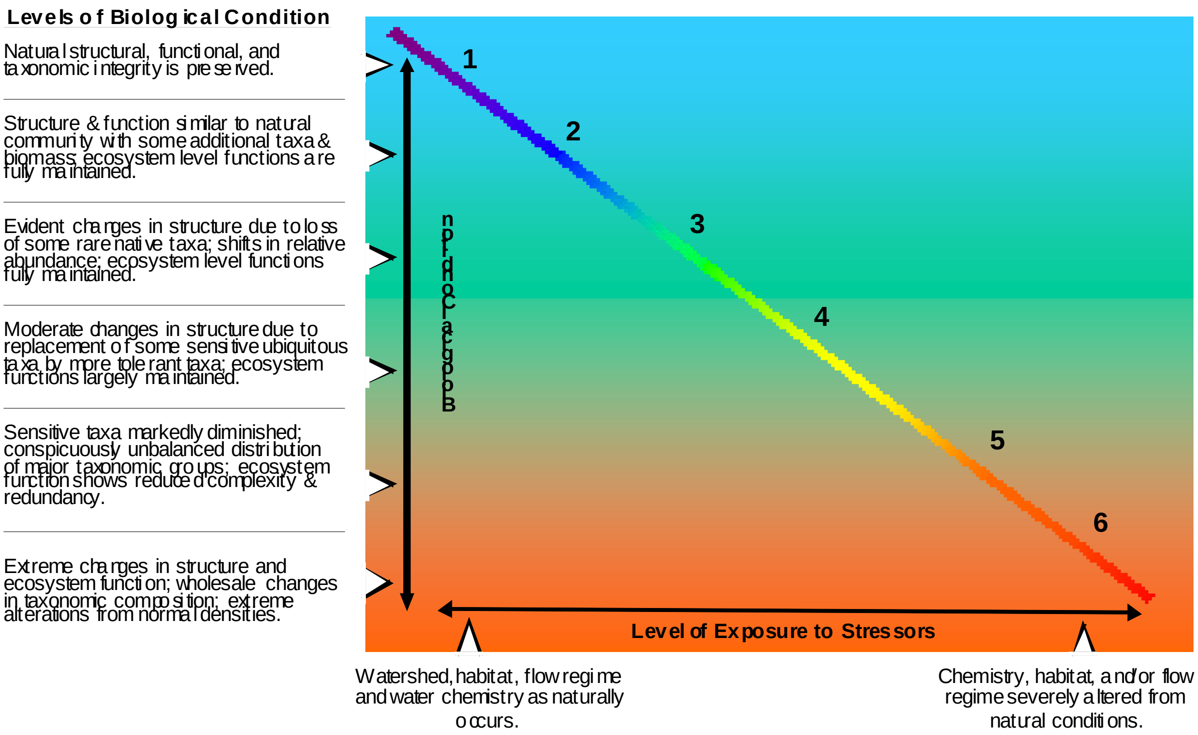
Development of the Biological Condition Gradient

Difficulty in communicating effectively about the ecological meaning and management relevance of different quantitative measures of ecological condition spurred an attempt to articulate the conceptual underpinnings that are common to all biological assessment methods. To help address this issue, Davies and Jackson (2006) proposed a scientific model of biological response to the increased effects of stressors, the ''Biological Condition Gradient'' (BCG; Figure 1). The BCG encompasses the complete range, or gradient, of aquatic resource condition from "as naturally occurs", e.g., undisturbed or minimally disturbed conditions, through increasing levels of alteration to severely degraded conditions. It describes changes in 10 ecological attributes along the BCG that respond to increasing levels of stressors. The BCG is divided into six condition levels, with level 1 representing natural, or undisturbed conditions, level 6 representing severely degraded conditions, and the other levels representing conditions in between. The ecological attributes for each BCG level are characterized by how each is expected to change as biological condition transitions to successively stressed levels. The intent was to tailor the make-up and response of the ecological attributes to the system in question.

The ecological condition to support an aquatic life use for a waterbody can be described in terms of the BCG levels. For example, the ecological condition needed to support a high quality pristine waterbody will be at level 1 or 2. Whereas the support of a sustainable assemblage in a historically altered waterbody may span levels 2-4. The ecological attributes that correspond to the BCG levels are measurable with common biological assessment methodologies and the resultant expression of quality via indices or other tools can be directly linked to an aquatic life use. As such the BCG is used here as an independent method for evaluating the ecological meaning of quantitative thresholds derived by empirical means (Miltner et al. 2011). As such the BCG provides a rational and consistent means for helping determine appropriate aquatic life uses for the purpose of setting biological impairment thresholds.

Application of a BCG to the Upper Mississippi River

The primary goal of the project is the development of a Clean Water Act (CWA) Biological Assessment Guidance for the Upper Mississippi River (UMR). An important component of this process is to develop a biological condition gradient (BCG) for the UMR study area. Natural conditions are the conceptual upper end "anchor" of any BCG process even where such conditions no longer exist due to human caused legacy alterations of the landscape and river system. Setting reasonably protective and attainable CWA attainment thresholds depends on being able to quantify both the biological and stressor gradients that exist across a region. A current major area of work on the project is to identify "potential impairment thresholds for the UMR main channel in determining the attainment of aquatic life uses," as identified in the project work plan (MBI 2010a). Herein we suggest that understanding the historical "anchor" or "as naturally occurs" condition is a fundamental component of this goal.



The Biological Condition Gradient: Biological Response to Increasing Levels of Stress

Figure 1. The Biological Condition Gradient (BCG) conceptual model that depicts six levels of change in key biological attributes in response to the increasing effect of stressors (modified from Davies and Jackson (2006).

Oftentimes a sufficiently broad disturbance gradient exists that helps to define and visualize the biological responses observed along one or more stressor gradients. Reference sites are typically used to empirically derive attainable goals for smaller streams and rivers (i.e., the regional reference condition approach). However, for large and great rivers, the widespread alterations of these waters makes the regional reference condition approach difficult at best due to a dearth of actual reference analogs (Angradi et al. 2009). Large and great rivers are frequently and directly modified by dams, other hydrological modifications, and chemical impacts (e.g., effluents, runoff). A good description of the historical changes that have occurred in the UMR is available in Pitlo and Rasmussen (2004). Both the impounded and unimpounded reaches represent highly modified conditions with the unimpounded reaches largely cutoff from their historical floodplains (Barko et al. 2003, 2004). Minimally disturbed reference sites typically do not exist for large and great rivers in which the integration of the effects of human disturbance in upstream watersheds and identification of attainable goals has relied on the use of “internal” reference sites (Emery et al. 2003; Angradi et al. 2009). As a supplementary approach, the development of a historical anchor can broaden the environmental gradient along which to measure biological performance and better understand the influence of stressor gradients.

Although there are few temperate great rivers that have not been substantially altered by anthropogenic impacts, there often exists historical information about fish assemblages from the accounts of pioneering naturalists, settlers, or from early fisheries accounts on these systems. Native American middens have also added to knowledge of species occurrences and distributions in these systems. Fish often show a species-specific response to the stressors that exist on the landscape. Many monitoring data sets in the Midwest now have a 20-25+ year accumulation of fish assemblage data matched with chemical stressors and habitat data. For many species a gradient of ecological sensitivity can be extracted from these datasets by examining probabilities of occurrence along both biological and stressor gradients. The comparative absence of rare species, once common or at least more commonly occurring in the past can be used to characterize the conditions that probably existed during more environmentally natural or benign time periods in a river’s history. The combination of recent data on species distributions along biological gradients can be combined with anecdotal or historical accounts of rare, extirpated, or extinct species to reconstruct “theoretical” or “synthetic” historic fish assemblages during historical time periods (Armitage et al. 2009). Based on this information, measured (for extant species) or extrapolated (for rare or extirpated species) data can be used to construct assemblage condition-stressor relationships which can be used to inform goal setting for a river system.

Background

The Upper Mississippi River is a historically diverse system with 163 fish species recorded based on a report by Steuck et al. (2010). The list was compiled from a variety of current and historical sources and was used herein as our primary source for the historical occurrence of fish species in the UMR. Expected fish distributions and abundances change with stream size and location so we are following the demarcation of (UMRBA 2011) which divided the UMR into the following three reaches:

<u>Upper Impounded Reach</u>: This reach starts upstream on the UMR at St. Croix River and goes downstream to Lock and Dam 13. This includes CWA assessment reaches 1-6 and encompasses river miles 812-523.

<u>Lower Impounded Reach</u>: This reach starts upstream on the UMR at Pool 14 and goes downstream to the Missouri River. This includes CWA assessment reaches 7-11 and encompasses river miles 523-196.

Un-impounded Reach ("Open River"): This reach starts upstream on the UMR at the confluence with the Missouri River and goes downstream to the confluence with the Ohio River. This includes CWA assessment reaches 12-13 and encompasses river miles 196-0.

Methods

We used the distributional information in Steuck et al. (2010) as our "universe" of historical species distributions in the UMR. Steuck et al. (2010) reported, by UMR reach, the presence and relative abundance of each fish species recently or historically collected in the UMR. Presence and abundance codes include:

Table 1. Key to species status codes for the UMR reported by Steuck et al. (2010).

O	Occasionally collected, not generally distributed, but local concentrations may occur.
C	Commonly taken in most sample collections; can make up a large portion of some samples.
A	Abundantly taken in all river surveys.
X	Probably occurs only as a stray from a tributary or inland stocking.
H	Records of occurrence are available, but no collections have been documented in the last ten years.
R	Considered to be rare. Some species in this category may be on the verge of extirpation.
U	Uncommon, does not usually appear in sample collections, populations are small, but the species in this category do not appear to be on the verge of extirpation.

Creating a "Synthetic" Data Set

To extrapolate fish species and abundances during a historical pre-disturbance[1] time period we used existing large river data from throughout the Midwest (more heavily weighted by Ohio and Indiana databases) to estimate; 1) the frequency of occurrence of a species by biological condition range based on the Ohio IBI; and, 2) the relative catch rates using boat electrofishing methods of each species by biological condition range (i.e., numbers per km). This information was combined with the historical fish distribution information (e.g., historical and present occurrence of species in the upper impounded reach, lower impounded reach and unimpounded reach) of Steuck et al. (2010), knowledge of life history information, and descriptions of fish populations from historical snippets (e.g., Carlander 1954) to derive extrapolated potential catch frequencies and abundances that likely occurred during historical periods (e.g., pre-impoundment). We used these frequencies and average estimates of abundances to create a "pool" of fish to "sample" using a random selection process without

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[1] We recognize that Native Americans did exert some level of impact to streams and rivers by early farming practices and our "pre-disturbance" conditions would reflect pre-impounded conditions during which early fish distribution patterns were recorded by naturalists, settlers, etc.

replacement. We did this for 10 iterations for each of the three UMR reaches and then calculated the FACI index, the GRFIn indices for the impounded and open river reaches of the Mississippi River, and the new Ohio Continuous IBI for boatable rivers for this data. The process is summarized in Table 2. In addition to the modeling of pre-settlement conditions we also used early fish data from large rivers of Ohio that had very poor conditions to model a "very poor" fish assemblage that might have occurred during the 1960s-1980s prior to CWA point source pollution control mandates. For the calculation of the GRFIn we used the current and historical data to recalculate metric ceiling and floor values (95th and 5th percentiles).

Table 2. Steps in the creation of a synthetic fish assemblage approximating pre-settlement conditions in the UMR.

Step	Activity
1	Compile historical fish assemblage list for reaches of the Mississippi River (i.e., upper impounded, lower impounded, open river)
2	Use existing data to determine response in abundance and probability of occurrence of each species at biological condition ranges (Very Poor, Poor, Fair, Good, Excellent; used Ohio and Indiana large river data and Ohio IBI).
3	Estimate typical relative abundance in catch when trend is extrapolated to pre-settlement conditions (use trends from step 2 along with life history information, historical descriptions of occurrence, abundances recorded elsewhere, etc.,). Do separately for upper impounded, lower impounded, open river.
4	For rare, extirpated or extinct species estimate abundance during pre-settlement periods using historical descriptions, life history information, abundances recorded elsewhere, etc. .,). Do separately for upper impounded, lower impounded, open river.
5	Create "population" of > 100,00 fish for "sampling" by multiplying for each species the probability of occurrence x the average estimated abundance x 1000
6	Begin random selection process for "fishing" historical "synthetic" pool of fish – 10 iterations for each reach of UMR.
7	Randomly select among best large rivers in Ohio/Indiana data to define maximum abundance and species richness for each iteration; cap richness at randomly selected site +5 and abundance at relative number/km + 500
8	For each iteration randomly select, without replacement, individuals until species and abundance caps reached
9	For each iteration a "sampled" assemblage is created which is scored with appropriate GRFIn, FACI, and Ohio continuous IBI

Inferring Stressor Levels from Species Assemblages

For the UMR, multivariate and correlative measures using GRFIn and GRMIn, the FACI and other measures to identify limiting stressors is one way to understand stressor impacts - this is a "top-down" approach (Miltner et al. 2011). An alternative, but complementary, approach is to use information about individual species responses to stressors gained from broad-scale studies of species sensitivities to infer: 1) which stressors are most limiting; 2) understanding the limiting nature of stressors; and, 3) predict species occurrence and distribution under various stressor reduction scenarios – this is a "bottom-up" approach.

In the past decade using weighted average tolerance values has become more widespread as a way to infer stressor conditions from aquatic assemblage data (e.g., Meador et al. 2008). In employing the bottom-up, broad scale approach we used Weighted Stressor Values (WSVs) for each species in our fish assemblage database for boat electrofishing sites and generated Tolerance Indicator Values (TIVs) which are ranked on a scale of 1 (least stress) to 10 (most stress) for each species (Meador & Carlisle 2007). To calculate WSVs for each stressor (e.g., DO, pH, etc.) the average (or maximum) ambient co-occurring stressor value was calculated at each site where a species was found and weighted by the abundance of the species at each site. These values were then summed across all sites and divided by the total abundance at all sites to arrive at a WSV. TIVs are simply the ordinal ranks (1-10) for each species and stressor. Calculating TIV scores standardizes WSVs measured on different scales and allows averaging the TIVs to create a cumulative grand stressor rank across major stressor categories. Since this data was generated largely from data in Indiana and Ohio there are gaps for some species in the UMR and the analyses we conducted herein could be refined with data from other large Midwest Rivers and excluding data from small rivers. In addition, these analyses do not include a measure of hydrological stress and the habitat measures may include some factors deemed less important in the UMR (Taylor et al. 2011). Nevertheless, the approach may be a useful demonstration of a concept for understanding how stressors may be limiting fish assemblages in the UMR.

A key use of the TIVs was to infer the stressor level at a site based on the biological assemblage data that was collected, for example, where we did not have complete stressor data or to extrapolate to the historical simulated sites where no stressor data existed. We calculated grand mean TIV values by creating a mean across all species weighted by the abundance of that species at a site. If no TIV data existed for a species it was not used in the calculation. The lack of WSV data for some UMR species may have contributed some variation to our analyses. A goal of such an analysis is to estimate how different stressor conditions are between current and historical time periods.

Assumptions

We assumed that if habitat conditions were close to "as naturally occurs" that sampling would occur along the main channel border and would reflect the availability of historical species from backwater and side channel habitats, many of which [species] are now rare or extirpated. This assumption has been made by others sampling the main channel and they concluded that such sampling was typically representative of the conditions in the backwaters and secondary channels (Angradi 2006; Thorp 1992). Most of the connections to the floodplain and backwaters have been substantially altered as follows:

> "By the late 1930 the river and its valley had been vastly transformed by agricultural and flood control levees, fragmented by navigational locks and dams,

> and disturbed by navigational channel maintenance, impoundment and levees (Weigel et al. 2006)."

It may well be that the conditions that occurred during the historical period are not attainable because of habitat limitations related to the impounded and disconnected nature of the Upper Mississippi River. **What these extrapolated indices do is provide an anchor point along a continuum of change that "reaches down" to current conditions. It allows us to consider or develop hypotheses about the amount of restorability that might be possible.** That could vary within an impounded pool where the upper portions may be more amenable to restoration compared to lower reaches that are more permanently inundated. In any case the extrapolated data can be used to develop a continuum along one or more disturbance axes.

Results

Biological Condition Gradient (BCG)

A complete BCG process depends on input from a panel of regional or system-wide experts on biological assemblages. What is presented here is a modification of an initial BCG exercise conducted on the Wabash River in Indiana (Armitage et al. 2009) modified to fit conditions in the Upper Mississippi River. **It is presented as a starting point, not a final BCG product.** As with the synthetic community exercise it is designed to help anchor the biological assemblages of the UMR in a historical natural condition and to understand how these assemblages have changed and might change in response to changes along various stressor gradients in the system, thus it is complementary with the stressor analyses done in the other parts of this study.

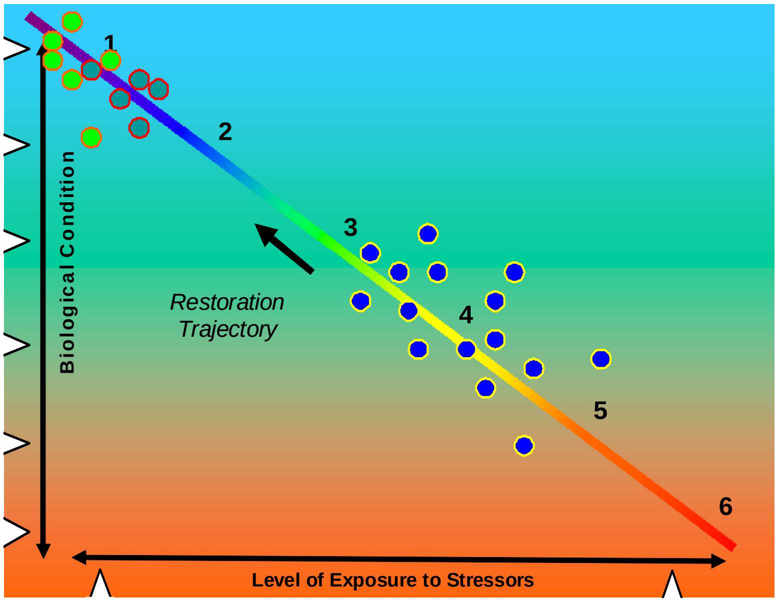


Figure 2. *U.S. EPA hypothetical plot of biological condition (y-axis) vs. a stressor gradient (x-axis) (Modified from U.S. EPA 2005). On this graph we have superimposed points presenting existing conditions in the UMR mainstem (blue points) and two groups of points representing pre-settlement (green points) and post-settlement conditions (grey points).*

Two recent papers (Davies and Jackson 2006 and Stoddard et al. 2006) summarize efforts over the past three decades to identify and define regional reference conditions. The Davies and Jackson (2006) paper summarizes the work of a U.S. EPA National Workgroup to develop a nationally applicable model that allows biological condition to be interpreted independently of assessment methods – this is the BCG.

Reference Sites in the UMR

Stoddard et al. (2006) summarized the stages of reference conditions that can be used in the management of flowing waters (Table 1). For all of the major Midwestern rivers it is unlikely that any, or even reaches of these rivers, could be classified as having Minimally Disturbed Conditions (MDC). Existing conditions, depending on the river and setting, would likely be described as in a Least Disturbed Condition (LDC) at best and more typically as Best Available Condition (BAC). For the UMR this has been discussed in the efforts to derive the multimetric fish and invertebrate indices (GRFIn and GRMIn; Angradi et al. 2009). Describing the Historical Condition (HC) and extrapolating from historical descriptions to an approximate MDC can be used to determine the potential to shift river fish assemblages towards these conditions. We used the BCG exercise described below, based on historical data from the UMR (Steuck et al. 2010), to guide in establishing and quantifying what historical conditions may have approximated in terms of the fish assemblages that existed. The goal of this exercise is not to set a pristine or natural goal for aquatic life impairment in the UMR, but rather to create a dataset to derive a *trajectory* between existing and historical conditions. By projecting what would be feasible in terms of stressor reduction we can be at least partially predictive in terms of what biological goals are attainable for the UMR.

Extrapolation of Fish Assemblages to Pristine and Pre-Settlement Historical Conditions in the UMR System

One of our goals was to be able to understand the historical fish assemblage condition and biodiversity in the UMR to provide an endpoint or anchor point for extrapolating between existing conditions. This concept is illustrated in Figure 2 - the dark blue points represent the existing conditions in the UMR along a generalized “stressor gradient” along the x-axis (e.g., the stressor gradient of Angradi et al 2009). This stressor gradient represents the cumulative stressor “load” that influences the biota of the UMR. The green and grey points reflect hypothetical pre-settlement and immediate post-settlement conditions in the UMR. Because of the magnitude of landscape changes and impoundment of much of the UMR that has occurred, these conditions may not be realistic or even desirable societal goals. Hence the expectations for biological assemblages will change in accordance with either.

A principal goal of a BCG is to establish 6-7 categories or levels that represent a biological gradient from pristine or MDC along one or more stressor gradients either specific (e.g., chemical, habitat) or along a more “generalized” stressor gradient that combines various measures of anthropogenic stress that typically include landscape measures, population measures (e.g., actual population, housing density, impervious surface, road density, etc.). Table 3 provides descriptions of how each of the attributes of the BCG is expected to change with increased stress in the UMR.

Table 3. Summary Tiers of BCG matrix for aquatic assemblages in the UMR (modified from Gerritsen and Leppo (2005) and summary of expected changes in attributes with increasing stress.

Ecological Attributes	**1 Natural Condition**	**2 Minimal Loss**	**3 Some Replacement; Function Maintained**	**4 Notable Replacement Function Largely Maintained**	**5 Tolerants Dominant, Loss of Function**	**6 Severely Altered Structure and Function**
I *Historically documented, sensitive, long-lived or regionally endemic taxa*	As predicted for natural occurrence except for global extinctions	As predicted natural occurrence except for global extinctions	Some may be absent due to global extinction or local extirpation	Some may be absent due to global, regional or local extirpation	Usually absent	Absent
II *Highly sensitive taxa*	As predicted for natural occurrence, with at most minor changes from natural densities	Virtually all are maintained and well represented (both taxa and abundance)	May be markedly diminished (in either taxa or abundance), with replacement by functionally equivalent *Sensitive and common* taxa	Significantly diminished (taxa and abundance)	Usually absent	Absent
III *Sensitive & common taxa*	As predicted for natural occurrence, with at most minor changes from natural densities	Present and may be increasingly abundant.	Common and abundant; relative abundance greater than *Highly Sensitive* taxa. Similar to good taxa (sensitive & common taxa).	Present with reproducing populations maintained; replacement functionally equivalent *taxa intermediate tolerance.*	Frequently absent or significantly diminished (if present incidental)	Absent
IV *Taxa of intermediate tolerance*	As predicted for natural occurrence, with at most minor changes from natural densities	As naturally present at low abundances	Often evident increases in abundance	Common and often abundant; relative abundance greater than *Sensitive and common* taxa	Often exhibit excessive dominance	Richness of all taxa is low
V *Tolerant taxa*	As naturally occur, with at most minor changes from natural densities. If present, at very low abundance.	As naturally present at low abundances. May have several taxa at low abundances.	May be increases in abundance of functionally diverse tolerant taxa	May be common but do not exhibit significant dominance	Often occur in high densities and may be dominant	Usually comprise the majority of the assemblage; often either very low or very high densities.

Table 3. Summary Tiers of BCG matrix for aquatic assemblages in the UMR (modified from Gerritsen and Leppo (2005) and summary of expected changes in attributes with increasing stress.

VI *Non-native or intentionally introduced taxa*	Non-native taxa, if present, do not displace native taxa or alter native structural or functional integrity	Non-native taxa may be present, but occurrence has a non-detrimental effect on native taxa	Sensitive or intentionally introduced nonnative taxa may dominate some assemblages (e.g. fish or macrophytes)	Some replacement of sensitive nonnative taxa with functionally diverse assemblage of nonnative taxa of intermediate tolerance	Some assemblages (e.g., fish or macrophytes) are dominated by tolerant non-native taxa	Often dominant; may be the only representative of some assemblages (e.g., plants, fish, bivalves)
VII *Organism Condition*	Anomalies very rare with lesions, etc., arising from natural sources of mortality or the natural result of spawning, age, etc.		Anomalies not common with lesions, etc., arising from natural sources of mortality or the natural result of spawning, age, or perhaps from some enrichment that is not acute.		Anomalies may be elevated and common where effluents incompletely treated or other stressors elevated	Anomalies can be extremely elevated if causes of impairment stress fish immune systems, cause reproductive issues or directly cause injury or damage to skin or other organs
VIII *Ecosystem Functions*	***Not Currently Measured***					
IX *Spatial and temporal extent of detrimental effects*	NA	Spatial and temporal extent of anthropogenic stress limited	Stress limited to scattered reaches and/or occasional time periods	Cumulative effects of stress becoming evident, especially in sensitive species	Spatial and temporal areas of stress more common than intact reaches resulting in obvious effects or extirpations of species	Widespread and frequent or continuous stress leads to extensive effects and loss of species
X *Ecosystem connectance*	All areas of watershed connected in space and time as naturally occurred	Watershed connections intact enough to show little/no influence on biodiversity and condition.	Loss of connections (e.g., small dams, etc.) show little-no cumulative influence – adequate alternate recolonization sources	Reduction in connectance results in some reduce recolonization at least in a temporal sense of for species traveling long distances (e.g., eel)	Significant loss of connectance (either by barriers or expanses of avoided poor habitat areas results in local extirpations of some species	Widespread loss of connectance (either by barriers or expanses of avoided poor habitat areas) results in local extirpations of many species

Attribute I. Historically documented, sensitive, long-lived, or regionally endemic taxa

This attribute of the BCG is perhaps among the most influential in defining the characteristics of the Upper Mississippi River as it naturally occurred. We envision that this attribute should contain information on species occurrence, but also on age/size distributions of the large, long lived species such as paddlefish, sturgeons, muskellunge, etc. Appendix Table 1 lists the candidates for BCG species attributes 1-6, along with the endangered, threatened, and special concern (ETS) status in Wisconsin, Iowa, Illinois, Minnesota and Missouri. Appendix Table 2 lists the probability of capture and average relative abundance of each species by increasing ranges of the Ohio boatable IBI and extrapolating to historical conditions. In Appendix Table 1 we gave a single designation to each species BCG attribute for the entire UMR, but this should eventually be adjusted by the designated reaches of the UMR (e.g. , upper impounded, lower impounded and unimpounded reaches). The BCG designations in Appendix Table 1 contain two groups of species. The first group consists of primarily main channel species and these would be the primary core of the fish assemblage – these are designated with an "X" under this attribute. The second group includes species that originate primarily in upstream watersheds or which are found primarily in backwaters, side channel, or other "connected" habitats and these are occasionally collected in the mainstem. These are important species because the more stable environmental conditions are in the main channel and in upstream reaches the greater the probability of capture in the main channel (i.e., higher population size = greater capture probability). This second group is termed "occasional species" and these are designated by an "O" under the attribute.

Nearly all of the species in BCG attribute 1 are sensitive to pollutants, habitat loss, and other alterations. Some species, such as American eel, are tolerant of pollutants, but were included because of their importance in reflecting ecological connectance. Because of their great migration distances an abundance of this species would reflect that the UMR was well connected downstream into the Gulf of Mexico. Again, the exercise of making the attribute assignments is best done by a panel of UMR experts who can bring their insights into the life history characteristics of these species and their respective attribute assignments; we consider these attributes as draft and subject to input by UMR experts.

Attribute II. Rare, Sensitive Taxa

The rare, sensitive attribute reflects a general sensitivity to stressors influencing large Midwest rivers such as the UMR (Appendix Table 1). Many of these species are still extant in the UMR, but are presently rare and would likely be more common in samples as the UMR is closer to "natural" with regard to stressors (e.g., less nutrient enrichment, unimpounded, or better connected to backwater and side-channel habitats). This group especially reflects sensitivity to habitat degradation and loss of connectivity.

Attribute III. Sensitive, Ubiquitous Taxa

The sensitive and ubiquitous taxa represent those species considered sensitive, and generally numerically predominant in natural assemblages (Appendix Table 1). Although they may not be as sensitive as the rare and endemic species and may be able to persist though the initial stages of increasing levels of stress, they are generally at their highest abundances when such stress is the lowest. Because they can persist at lower numbers with an intermediate level of stress and they have been shown to increase with reductions in stress, they provide useful contemporary information as stressor levels are changed in rivers.

Attribute IV. Species of Intermediate Tolerance

These are fish species that are not especially sensitive to most stressors and will be predominant if stressors reduce populations of attribute 1-3 species and reduced competition and/or predation of intermediately tolerant species. Their presence, by themselves, suggests less about stressor levels; however, combined with the absence or reduction of attribute 1-3 species they can be indicative of increased stress levels.

Attribute V. Tolerant Species

These are fish species that are especially tolerant to most stressors and will be predominant at stresses that are increasing above intermediate levels. At the very highest stressor levels, however, even most of these species will be reduced in numbers and/or biomass. Some of the "occasional (O)" mainstem tolerant species would normally be rare in large rivers; however, where extreme stress exists some of these species (e.g., yellow bullhead and creek chub) can persist or become more numerous in large rivers.

Attribute VI: Nonnative or intentionally introduced taxa

These are fish species that have either been introduced (intentionally or otherwise) and some are now resident in the UMR. Some (e.g., silver and bighead carp) are potentially more deleterious than others. Many of these are moderately to highly tolerant of chemical and physical stressors.

Attribute VII. Changes in organism condition or increase in anomalies in response to pollution gradients

We suggest several commonly used biological metrics can gauge the condition of this attribute.

Table 4. Candidate measures of organism condition for fishes in the UMR system.

Name	*Description*
Anomalies	*Rate of disease, deformities, eroded fins and tumors noted on fish species during data collection*
Multiple Year Classes	*Populations of all expected year classes should exist for all species in Attribute groups 1-3*
High diversity based on numbers and weight	*MIwb and subcomponents based on numbers and weight*

Many states have successful used fish anomalies to measure exposure to toxic conditions and severe pollution (Table 4). For the UMR one would expect multiple year classes for species and a good distribution of large, older year classes. This would also translate to a high diversity by numbers and weights and high indices that reflects these characteristics, such as the MIwb.

Attribute VIII. Disruptions of function at the ecosystem level

Major rivers systems can have very complex ecosystem functions that result in high diversity and abundance of various trophic guilds. We suggest these structural measures can be used as surrogates to infer healthy ecosystem function (Table 5).

Table 5. Candidate measures of to infer ecosystem functioning is intact for fishes in the UMR.

Name	*Description*
Invertivores	*The UMR and other large rivers were characterized by large numbers of specialized invertivores that fed on the high diversity and production of aquatic invertebrates in multiple habitat types*
Top Carnivores	*The UMR and other large rivers supported a high diversity and production of top carnivores that fed on abundant forage fish and other organisms supported by energy movement through this system.*
Omnivores	*Omnivores were likely not predominant in the mainstem UMR river given the abundant insects and mussel assemblages that occurred in the river*

Attribute IX. Influence of spatial and temporal scale of disturbance on biological response and recovery potential

This is an especially important attribute for the UMR and Midwest large floodplain rivers in general. Data from Indiana and Ohio suggests that widespread habitat loss is associated with intensive agricultural drainage and stream alterations which in turn limit fish assemblage condition. This has resulted in watershed level extirpations of sensitive species of fish, mussels, and invertebrates. The stressors associated with these extreme habitat alterations include increased nutrients and sedimentation, altered stream hydrology (increases in flashiness and desiccation) and losses of biological diversity to downstream reaches. At the Huc11 watershed scale we have documented the decline of sensitive species with the scale of habitat damage in these

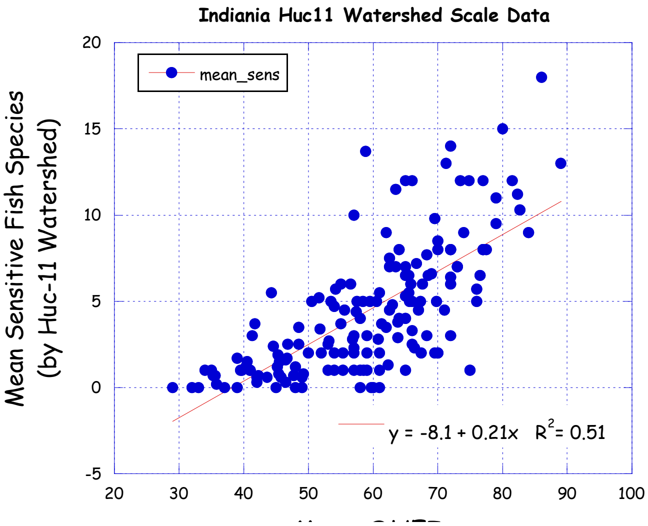


Figure 3. *Plot of mean QHEI in Huc-11 watersheds with mean IBI scores in these watersheds for sites collected in Indiana by IDEM from 2001-2006.*

watersheds (Figure 3). We hypothesize here that the alterations to the UMR especially with tributary watersheds is likely to have had similar results.

Attribute X. Ecosystem connectance

This is related somewhat to the previous attribute, but it focuses on more direct effects on movements of fish species in the main channel due to dams and the loss of connectance with floodplains, sloughs, and oxbows that were once characteristic of the UMR and the annual inundation of the floodplain to which many attribute 1-3 species are adapted. Many of the intolerant species that are now rare or extirpated were associated with these connected, but off-main channel habitats.

Synthetic Assemblage Results

The basis for deriving a "synthetic" historical fish assemblage is the observation that the probability of capture and average abundance of a species is related to the array of stressors present in a reach and is reflected in the biological indices used as response indicators (e.g., GRFIn, IBI, FACI). We used this information to derive probabilities of capture and extrapolated abundances during historical periods prior to much anthropogenic disturbance as well as a time period (e.g., 1960s) with poor-very poor conditions related to inadequate effluent controls. Figure 4 illustrates changes in the probability of capture, relative abundance, and abundance by capture rate with Ohio IBI for three riverine species in the UMR, the blue sucker, river darter, and black buffalo. The extrapolation to historical data used to derive the pool of potential fish for our historical IBI was developed using the trend of actual data, the historical reports of occurrence and distribution from Steuck et al. (2010), and life history information and other historical sources that discussed the occurrence of fish species in large Midwest rivers prior to the anthropogenic impacts of the past two centuries. The extrapolation (Appendix Table 2) was done separately for each of the three reaches of the UMR (upper impounded, lower impounded, and unimpounded; Table 1).

For this analysis we calculated the GRFIn indices for the impounded and open river portions of the Mississippi River, the Regional FACI score and the new "continuous" Ohio boatable IBI (CIBI). We ran the Ohio IBI because it was calibrated to allow scoring above existing LDC reference sites although it was originally developed for rivers smaller than the UMR. We modified the GRFIn indices by dropping biomass-based metrics because we did not extrapolate biomass for this exercise. We also recalibrated the scoring expectations by including the historical data (both pre-settlement and 1960s). As expected the synthetic data resulted in higher GRFIn, FACI and CIBI scores than the sampled data (Figure 5). Two metrics of the FACI "under-performed" compared to what might have been expected in a "historical" assemblage; the proportion of deep-bodied suckers and round-bodied suckers. Our estimates of abundance were based on abundances of each species at the best existing sites and for rare species extrapolations based on species life histories and anecdotal descriptions of abundances where available. The FACI was calibrated based on existing data in the Midwest and generally on somewhat smaller rivers.

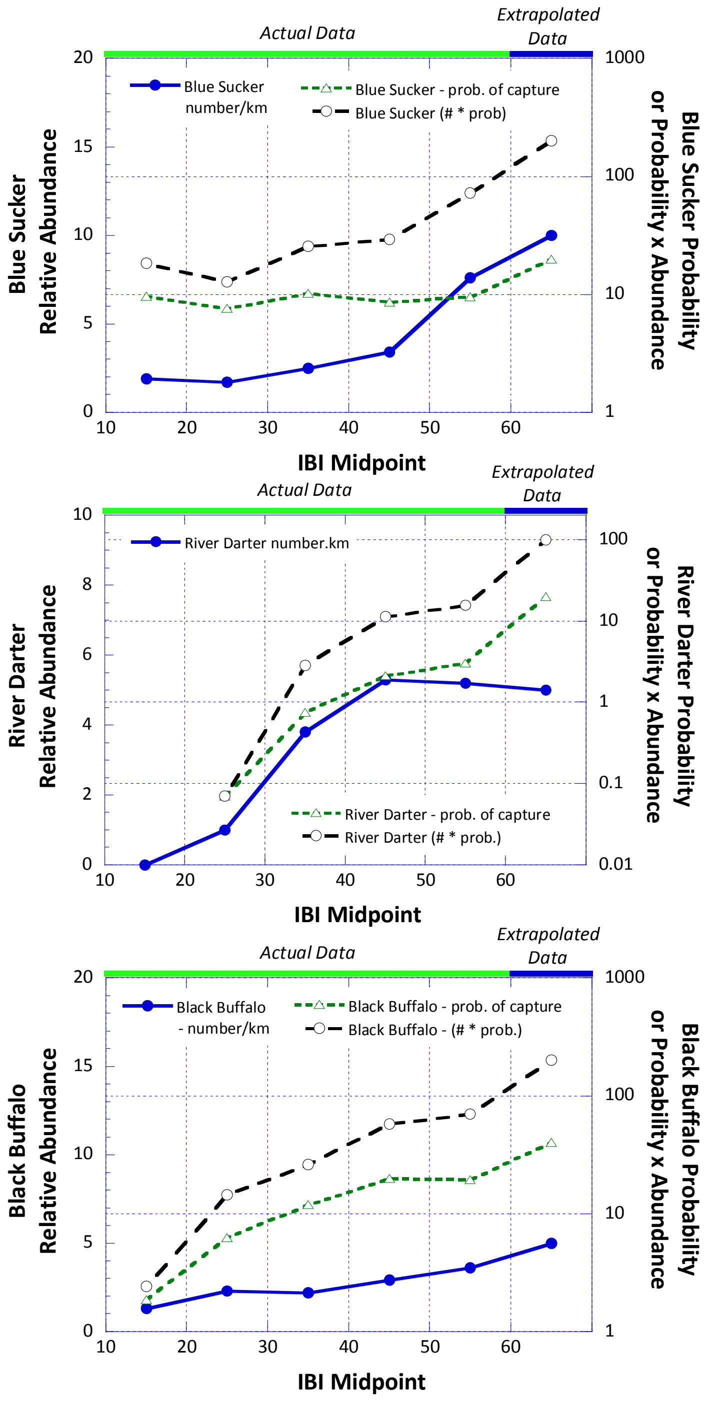
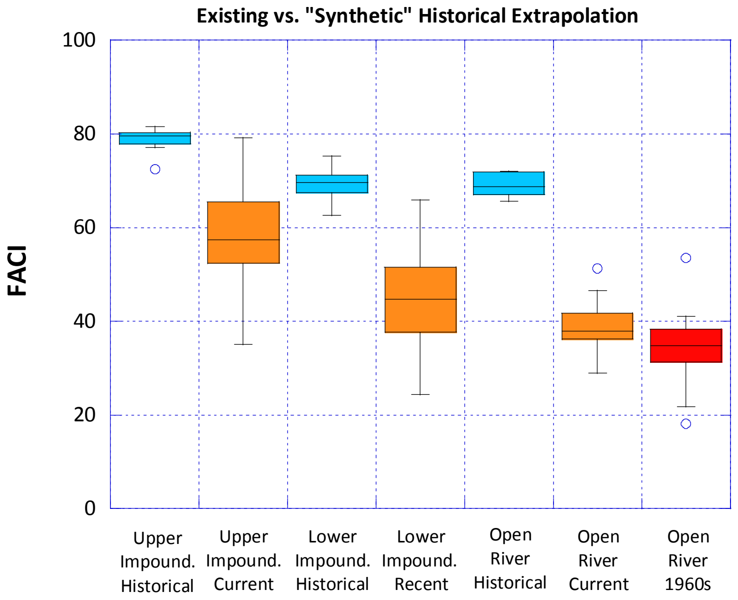


Figure 4. *Plots of relative abundance, probability of capture, and abundance x probability vs. IBI midpoint for three riverine fish species: blue sucker, river darter, and black buffalo. Actual abundance data and probability of capture data generated from data on boatable sites from Ohio and Indiana; extrapolated data estimated using BPJ based on trends in actual data, data on historical distributions in the UMR (Steuck et al. 2010) and life history information and other historical information.*



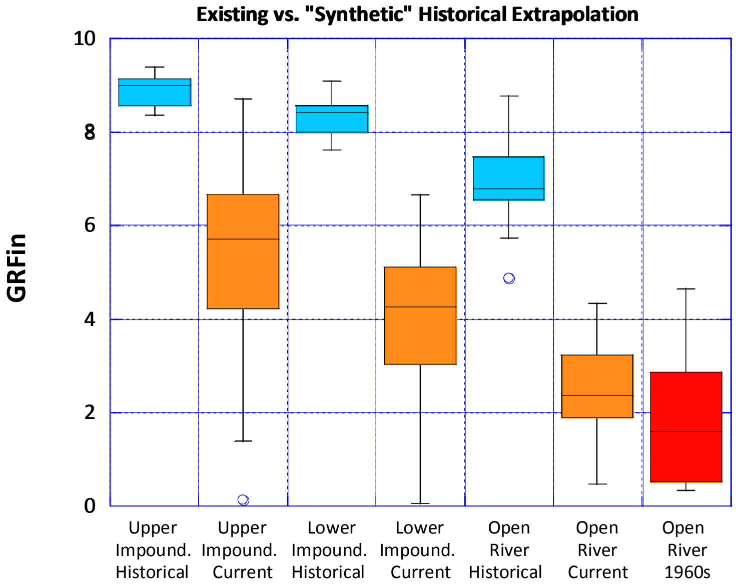


Figure 5. *Box and whisker plot of FACI scores (top) and GRFIn scores (bottom) for historical “synthetically” derived fish assemblages (blue) and recent data (orange) for the upper impounded reaches, lower impounded reaches, and the open river reaches of the UMR. Red box is synthetic data estimating score in the open river during the 1960s prior to CWA point source controls.*

While deep-bodied suckers and round-bodied suckers were abundant in our synthetic results, other species, particularly rare species, were likely higher in abundance in our synthetic assemblage and round-bodied and deep-bodies suckers thus had lower proportional abundances which depressed these metrics. Whether this is a reasonable assumption is not completely certain, but calibration of the FACI from a historical perspective would have captured this difference and these metrics would have scored higher (FACIs in high 80s and 90s). The CIBI has a similar problem with both the proportion of round-bodied sucker metric and simple lithophilic spawners "underperforming" compared to the species composition extrapolated from the model. The scoring of these metrics would have been adjusted or calibrated differently if this data was used in the original calibration of FACI or the CIBI. In any case, the synthetic assemblages scored substantially higher than the present-day data, as might be expected. An understanding of which stressors are limiting to species common in the historical data, but rare or uncommon the recent data would be the basis for understanding whether and where restoration may be feasible.

Human Disturbance Gradients

The extrapolation of QHEI scores as a measure of habitat conditions during pre-disturbance that we did for the Wabash River (Armitage et al. 2009) might not be representative of the upper UMR because of the potential decrease in importance of the substrate, riparian, riffle and pool metrics in as limiting habitat attributes in the UMR. According to Taylor et al. (2011):

> "Physical habitat attributes used to assess habitat quality in streams and small rivers (e.g., Kaufmann et al., 1999) may be irrelevant for assessing habitat quality in great rivers, or they may be impractical to apply due to sampling effort, including cost (Edsall et al., 1997; Stoddard et al., 2005). For example, riffle and pool sequences create valuable and varied fish habitat in wadeable streams, but are largely non-existent in great rivers (Fitzpatrick et al., 1998). Unlike in smaller streams and rivers, it is unlikely that the immediately adjacent riparian zone, such as the first 30 m inland from the bankfull line, strongly influences in-channel habitat because great river channels can be >1000 m wide (Allen, 2004; Vannote et al., 1980). The substrate in the Upper Mississippi, Missouri, and much of the Ohio River is dominated by sand and finer particles, and mapping these fine bottom substrates may be impractical due to the size of the river channel (but see Jacobson and Gallat 2006). Even some of the metrics found useful in fifth to seventh order non-wadeable rivers, such as bank stability and aquatic vegetation cover may not effectively characterize habitat in mainstem channels of the Mississippi, Missouri, and Ohio Rivers (Wilhelm et al., 2005). In contrast, some habitat types rarely found or measured in wadeable streams assume considerable importance in low gradient large and great rivers, including the presence of backwaters and islands, and the degree of connectivity with the rivers' floodplain (Petts, 1996; Shaeffer and Nickum, 1986; Thorp, 1992)."

The work of Taylor et al. (2011) suggests that key habitat characteristics in the UMR would relate to the natural flow regime of these big rivers and to channel complexity. The occurrence of high channel complexity and natural hydrological variability undoubtedly results in patches of local habitat being present to which fish are dependent for completing various parts of their life histories such as spawning, nursery areas, feeding, migration pathways, etc. The analyses performed below used stressors that were important in the Wabash River, but these may need to be changed for the UMR, even though several are in common to each river. Nevertheless, we present the results herein to demonstrate a conceptual approach that may be used in modified form on the UMR.

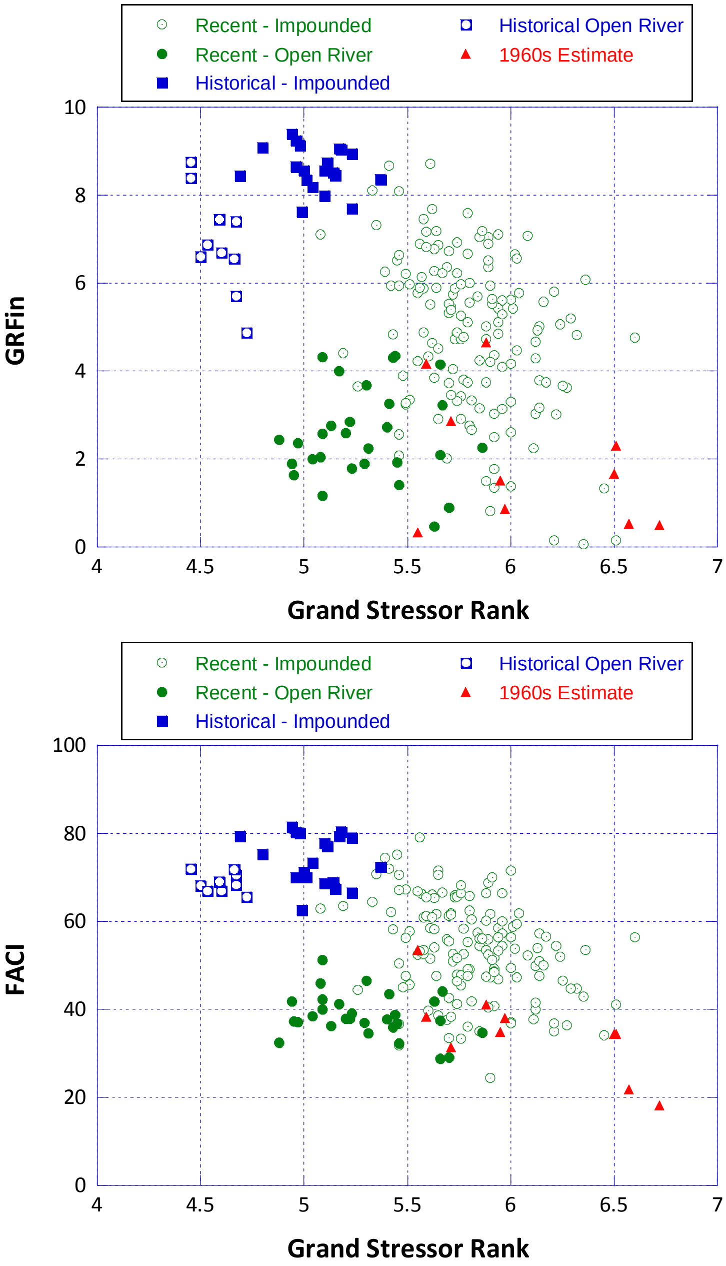


Figure 6. Plots of Grand Stressor Rank based on the average of TIV ranks for species collected at sites vs. the GRFIn (top) and FACI (bottom) for historical synthetic data (blue)recent actual data (green) and synthetic 1960s estimated data from the impounded and open river reaches of the UMR.

Initial Reconstruction of Environmental Conditions to Match BCG Tiers 1-2

The synthetic fish assemblages we created were designed to approximate Tiers 1-2 of the BCG described above during pre-settlement periods and prior to CWA point source controls in the 1960s. Although we did not have the resources to explore these patterns in depth and lacked data on hydrological stressors, we generated environmental conditions based on the grand ranking of TIV scores for the synthetic and existing data and plotted it versus the GRFIn indices and FACI for the impounded and open river segments (Figure 6). The Tier 1-2 synthetic data are near the top of the biological gradient as expected, but do overlap somewhat in terms of extrapolated stressor levels with some of the recent data, particularly from the unimpounded reaches of the UMR. This is at least partly related to the absence of TIV data for some of the great river species and the fact that the stressor gradient lacks direct hydrological measures and includes some other factors that might not be limiting to the obligate great river species found in the UMR. Even so there is a substantial degree of separation between the stressor levels approximating the historical assemblages and that reflected in the recent data. The synthesized data from the 1960s are among the lower FACI and GRFIn scores and the higher range of the extrapolated stressor rank.

Use of the BCG to Help Establish Reasonable Biological Thresholds

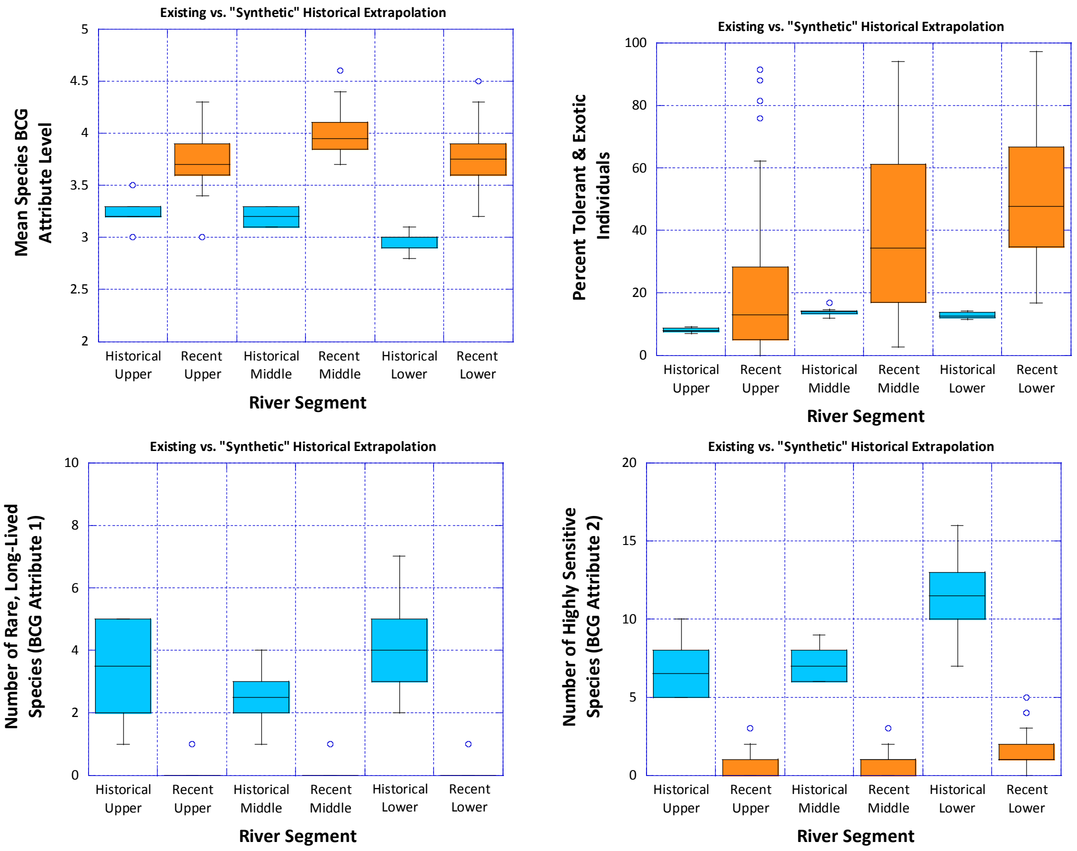
Our primary analyses of the existing EMAP GRE 2004-6 dataset focused on the statistical assumptions and consequences of using various methods to develop biological endpoints and assessment thresholds for assessing attainment CWA act goals (Miltner et al. 2011). We suggest that this statistical approach, while important, must be linked explicitly to biological inferences and narratives about the various biological thresholds. Nestler et al. (2010) identified difficulties related to restorability in the UMR:

> ". . . unimpacted conditions predate the systematic collection of ecosystem state and structure data, ecosystems dynamically respond to long-term hydrologic or climatic cycles making simple description difficult, future conditions desired by modern societies may differ substantially from historical conditions, irreversible fragmentation (Power-Bratton, 1992), external factors, such as watershed land use, demographic patterns and invasive species (Chick and Pegg 2001), and extensive existing infrastructure investments that cannot be easily divested."

Our effort here to develop a synthetic historical fish assemblage attempts to provide a foundation for the selection of various biological endpoints and benchmarks, yet other factors need to be integrated into such decision making. Biological endpoints should be chosen to represent a condition that can be feasibly restorable for the interim CWA goal, but where it exists also offer a more protective threshold goal for higher quality reaches. In wadeable streams the identification of various reference conditions (LDC or MDC) can provide an empirical basis for quantifying these endpoints. For best attainable conditions, such as those that exist in various reaches of the UMR, it will be important to link existing conditions to a BCG analysis so that hypotheses about the restorability of reaches can be established. This assures that endpoints are not set too low when restorable conditions may actually be readily attainable. A correlate of this approach is the need to link biological condition explicitly to the various disturbance gradients to enable such attainability analyses to be performed. The statistical approaches conducted in the Thresholds Analysis (Miltner et al. 2011) were designed to offer an analysis of various ways of developing attainment thresholds and then evaluate their respective plausibility. Consideration of the attainability of a threshold also depends on the identification of factors that actually limit biological performance. There should not be an over-reliance on statistically derived thresholds that are not also linked to a process to understand the actual limitations to biological performance (as measured by the suite of tested indices) which could institutionalize thresholds that are either over or under-protective of tiers of aquatic life uses.

The selection of species to populate the BCG attributes is essentially an exercise in deriving a narrative description of what is to be expected along a gradient of disturbance. The occurrence and population size of the various attribute members is a “quantification” of what is expected with increases or decreases in disturbance and it can help describe whether statistically derived endpoints actually mesh with our conceptual ideas about the resource which is to be assessed by these statistically derived endpoints.

One way to look at whether thresholds are “ecologically reasonable” is to examine the data above and below various thresholds and look for the presence or absence of key species that should be present in reasonable numbers under various stressor remediation scenarios. The attributes of the BCG, for example, can serve as the key indicator of this for the UMR. Figure 7 illustrates some of the key BCG attributes for the upper and middle reaches (impounded) and the lower, unimpounded “open river” reach of the UMR using recent data and the “synthetic” historical data generated by our analyses. Historical “synthetic” data is clearly separated from recent data for each of these measures indicating that the current conditions are far removed from the more natural historic conditions. It is not too difficult to conclude that the accumulation of pollution, hydrological, and physical modifications of the UMR mainstem, attendant off channel habitats, and upstream watersheds have all been the culprits of the declines in these fish assemblage attributes.



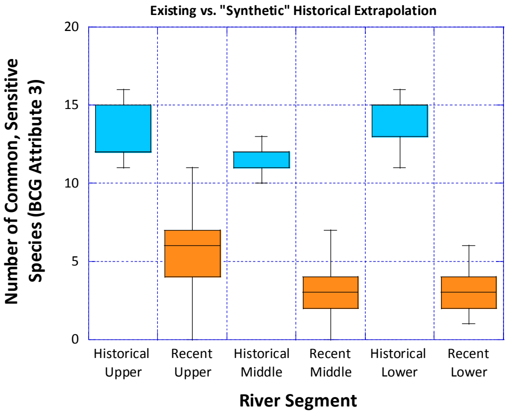


Figure 7. *Box and whisker plots of BCG attribute data for recent data (orange) and historical "synthetic" data for the "upper" impounded (RM 523-812), "middle" impounded (RM 523-196) and "lower" un-impounded (RM 196-0) UMR for BCG attribute measures: mean species BCG attribute (upper left), mean tolerant and exotic species (upper right), number of rare, long-live species (middle, left), highly sensitive species (middle, right) and sensitive common species (bottom, right).*

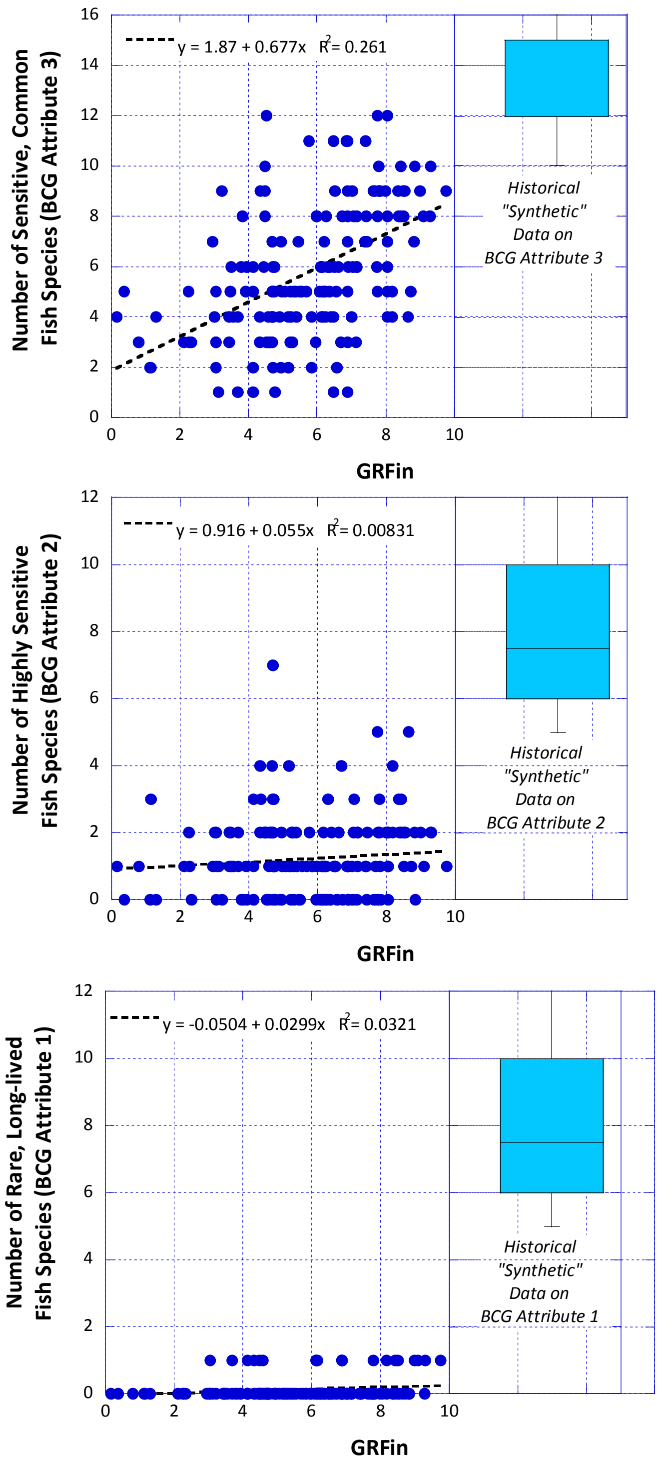


Figure 8. Scatter plots of the GRFIn index for existing data vs. BCG attributes 3 (top), 2 (middle) and 1 (bottom) from this data. Historical distribution of synthetic data for these attributes for the UMR is illustrated with a box plot to the right of each box.

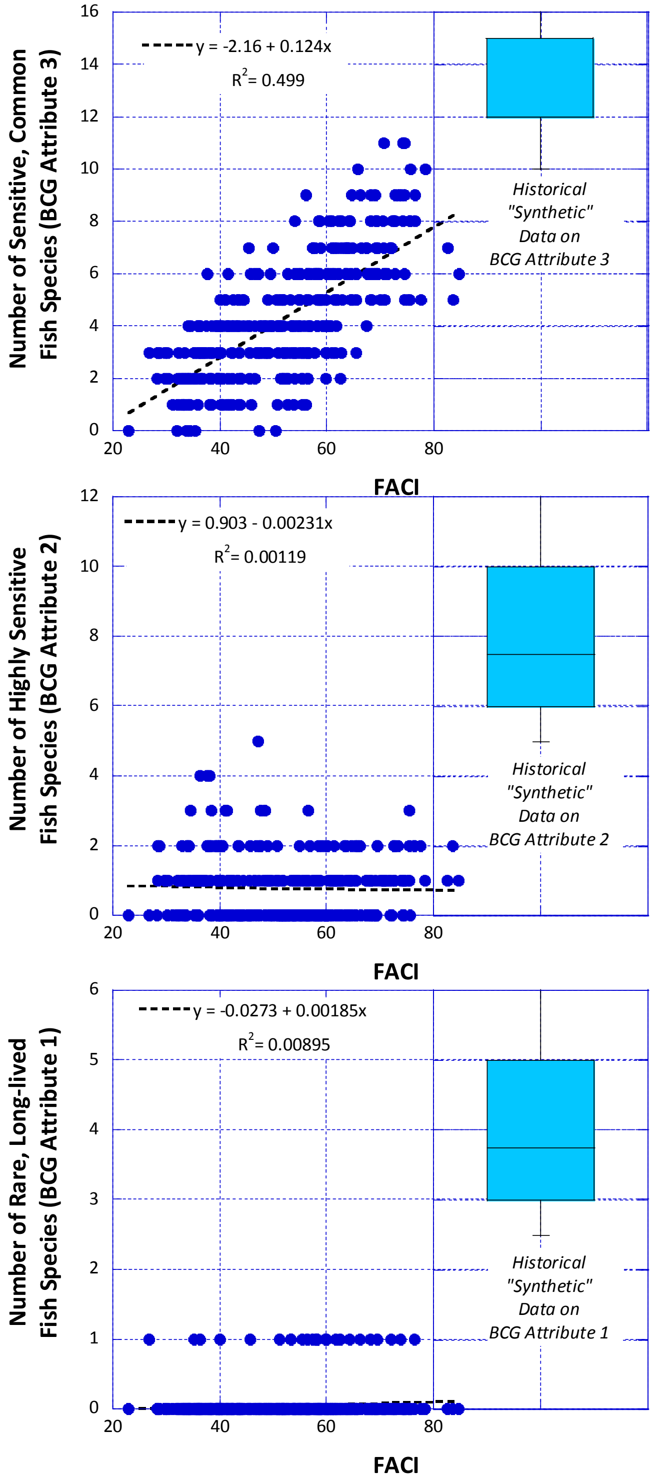


Figure 9. *Scatter plots of the FACI index for existing data vs. BCG attributes 3 (top), 2 (middle) and 1 (bottom) from this data. Historical distribution of synthetic data for these attributes for the UMR is illustrated with a box plot to the right of each box.*

One thing is readily apparent, that all three reaches have about the same levels of historical attributes. The unimpounded or open river is especially enlightening because it is presently the most highly modified of all three reaches examined here and that is especially reflected by a higher proportion of tolerant and exotic individuals (Figure 7). It also raises questions about whether or not to extend the impounded indices and stressor gradients to the open river. Presently, the open river was treated separately from the impounded UMR in the derivation and calibration of the GRE fish index (GRFIn) and the distinct stressor gradient will result in different thresholds. **The BCG analysis suggests that the attribute I-III and attribute VI characteristics of the historical fish assemblage were similar between the impounded and open river, thus raising questions about having two fish indices and two stressor gradients.** The OR GRFIn has eight metrics compared to the impounded GRFIn having 10 metrics presumably due the inherently different character of the OR fish assemblage. While each GRFIn lacks metrics that include attribute I-III species (except indirectly via other metrics), the historical presence of these "higher value" BCG attributes suggests that the contemporary OR GRFIn may be lacking in its "coverage" of these attributes. At a minimum it may well argue for extending the impounded GRFIn to the OR and also for placing value on the FACI which contains some of these connections.

To relate these attributes to the currently used assessment tools we correlated the number of sensitive, common species of BCG attribute 3 to the GRFIn and FACI indices; both indices showed a significant correlation with this indicator (Figure 8 and 9, top). There was, however, was no apparent correlation between BCG attributes 1 and 2 and either the GRFIn or the FACI (Figures 8-9, middle and bottom). The pattern with the CIBI was similar to the FACI and is not shown. The strong correlation with the sensitive common species suggests that this attribute could be useful in understanding the consequences of choosing various statistically derived thresholds. The lack of correlation with attributes 1 and 2 may well be explained to the large difference between historical conditions and existing conditions in the UMR. It also could be that populations of these species in the main channel samples, many of which are off main channel habitat dependent, may be more related to the losses of connectivity with the off main channel habitats than with the conditions in the main channel itself. If this is indeed true then it emphasizes the importance in understanding the connections with historical conditions and building this into the assessment process.

Using the BCG to Underpin Selection of Tiered CWA Goals for the UMR

The practical utility of these analyses to the present task of setting appropriate and attainable thresholds for the suite of UMR biological indices that have been selected for use in completing the first biological assessment of the UMR for CWA purposes would be greatly enhanced if those indices could be linked to the BCG, if even only indirectly. Herein we examine using our BCG to underpin the selection of tiered CWA thresholds derived using multimetric indices such as the GRFIn and FACI in the UMR. BCG levels 1 and 2 essentially reflect natural or near-natural conditions. Levels 3 and 4 represent conditions that reflect biological assemblages that have been subjected to increasing levels of stress, but still retain sufficient biological attributes that are consistent with the interim goal of the CWA (e.g., protection and propagation of fish). Level 5 represents a level of stress that is increasingly inconsistent with this goal and is therefore unacceptable and considered as impaired. This suggests the need for remediation such that the overall biological condition improves the assemblage condition to level 4 at least. If such improvement is precluded by activities that cannot be remediated and which "qualify" under the 40 CFR Part 131 existing use and use attainability analysis provisions, a Use Attainability Analysis must be conducted to demonstrate that the assemblage condition cannot be feasibly restored and to document the factors that are most limiting.

For the current UMR the majority sites fall between BCG levels 3 and 5 with few in levels 1, 2 or 6. Without a site specific identification of BCG level for each site we can examine the number of BCG attribute 3 species (number of sensitive, common fish species) found at each site which was more strongly correlated with the GRFIn and FACI and the scarcer BCG level 1 or 2 species. Based on BCG attribute 3, we can estimate BCG tier cutoffs for the GRFIn, FACI, and CIBI.

Figure 10 reflects plots of the GRFIn, FACI and CIBI vs. the number of BCG attribute 3 species at each UMR site. The "synthetic" data is coded with blue squares to distinguish it from the current sampling data (green circles) and we coded the lower, un-impounded river with solid orange circles. We also added the small group of "synthesized" highly degraded sites as well (red triangles). All three indices reflect a positive relationship with the number of BCG attribute 3 species (Figure 10); the curve is a locally weighted regression that minimizes the effect of outliers. The breaks in these curves illustrate some patterns in these relationships that can be used to support various options for selecting appropriate thresholds. The break in the curves in these relationships with the weighted BCG may be aided by the availability of the synthetic data to "complete" the curves (Figure 10) and may be even more informative if higher aquatic life tiers are considered. The tighter relationship between the FACI and CIBI and BCG attribute 3 species compared to the GRFIn is likely related to the broader use of similar metrics in the these indices and a somewhat broader basis for their construction. The GRFIn was design to maximize the association with a derived Stressor Gradient (Pearson et al. In Press). The CIBI was formulated to better separate high and low performing sites beyond the current range of that index based on currently available data. Data on the UMR is also missing from the time period when point source water quality stressors were most severe (1950s-1980s). The availability of such data, which was modeled as we did the "pristine" historical conditions, may also enhance change point analyses and to calibrate multimetric indices to make them more sensitive to extremes of the disturbance gradient (e.g., CIBI). Although the CIBI was originally calibrated for smaller rivers the application of the method can illuminate change points since the other indices were calibrated to accommodate estimates of historical assemblage condition.

Conclusions

The UMR, like many Midwest rivers has been subjected to a series of perturbations, minimally starting with pre-Columbian activities by humans, but accelerating greatly with European settlement beginning in the 19th century. Some of the historically common UMR species are now rare, but most remain present if even in limited numbers and distribution. We are however, past the "nadir" (i.e. low-point) for large rivers, which was associated with the gross pollution from untreated industrial and human wastewater sources during the 19th and much of the 20th century.

Our initial BCG for the UMR provides a theoretical “endpoint” for consideration of condition thresholds and as such it can form a basis for better informed discussions of attainability. The BCG can be used to provide a narrative backup to the statistical impairment thresholds derived by Miltner et al. (2011). The “distance” between the present environmental conditions and the “natural” environmental conditions that once existed in the UMR leaves much room for restoration, but we need to be aware of where the current UMR fish assemblage “is at” with respect to the currently used indices such as GRFIn and FACI. The fact that many of the historically common fish species are still present indicates that habitats still exist to support at least relict populations of the BCG attribute 1-3 species.

Understanding stressor conditions along a biological gradient from pristine to highly degraded is fundamental to questions related to the feasibility of restoration along such a gradient. The linkages between species abundances and TIVs used to understand the stressor gradient can be strengthened by excluding variables not shown to be important in reaches of the UMR and including more consideration of hydrological indicators, many of which are potentially available through USGS flow statistics, flow models, and the Index on Hydrological Alteration (IHA) flow software. If we use generate synthetic assemblages that likely existed during highly degraded conditions we can also infer the stressor levels at that time using the TIV approach. Nestler et al. (2010) attempted to quantify the issues in performing “environmental benefits analysis” and used IHA indicators to explore variation in fish assemblage similar along the UMR. Such an analysis could be expanded to include the synthetic fish assemblage generated herein along with extrapolated IHA indicators. Finally, the construction of more formal and broad-based BCG could be used to add an explicit biological basis and description to the derivation of CWA goal thresholds.

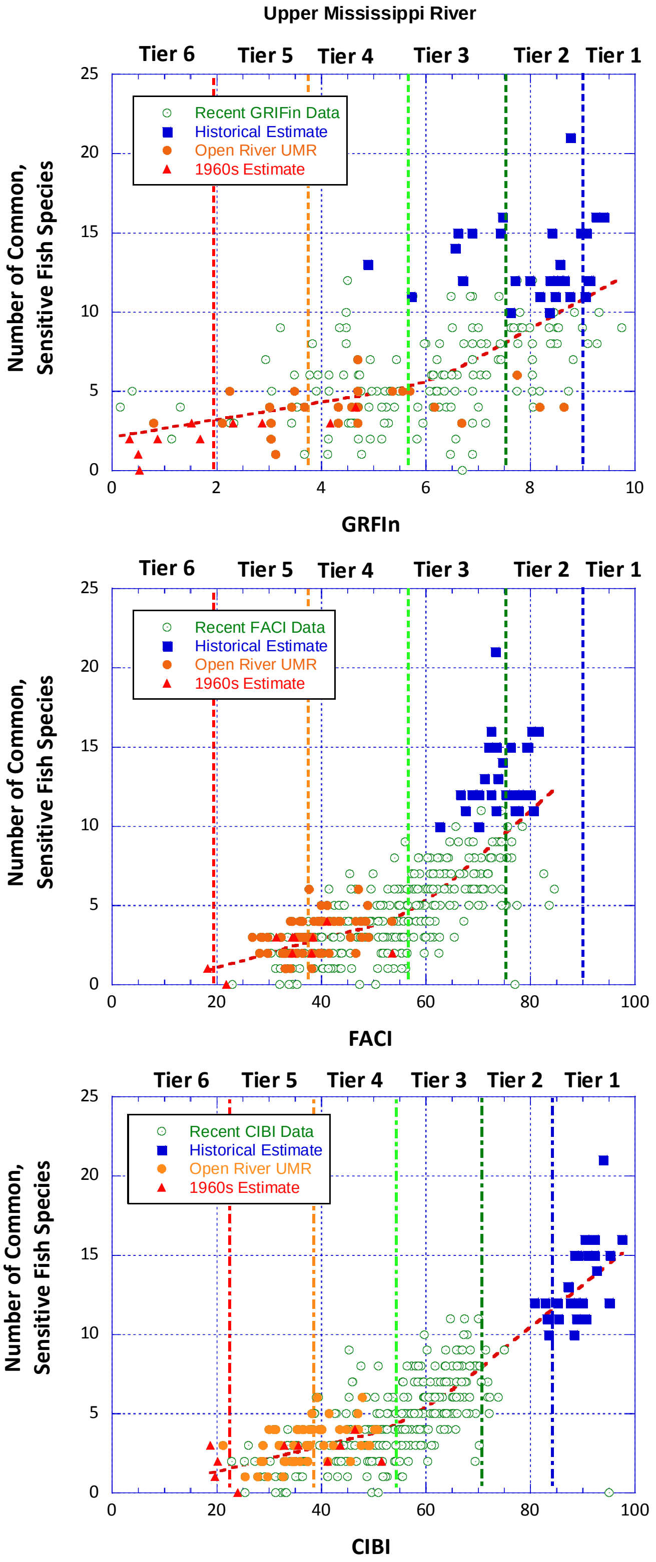


***Figure 10**. Plot of the GRFIn (top), FACI (middle), and CIBI (bottom) vs. the number of BCG attribute species (common, sensitive) for sites in the UMR. Historical calculations were not available for the GRFI, but were extrapolated from correlations with FACI.*

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Appendix Table 1. List of fish species collected or reported from the upper Mississippi river, State endangered, threatened, and special concern status, draft designations for the first six BCG attributes.

	State Endangered, Threatened, Special Concern Designation					BCG Species Attributes					
						I	II	III	IV	V	VI
Species	MN	WI	IA	IL	MO	Rare, Endemic, Long Lived	Rare, Sensitive	Sensitive Ubiquitous	Intermediate Tolerance	Tolerant	Non-Native
Silver lamprey								X			
American brook lamprey			T				O				
Chestnut lamprey								X			
Paddlefish						X					
Lake sturgeon	SC	SC	E	E	E	X					
Shovelnose sturgeon							X				
Pallid Sturgeon			E	E	E	X					
Alligator gar				X		X					
Shortnose gar									X		
Spotted gar							X				
Longnose gar									X		
Bowfin									X		
Goldeye		E						X			
Mooneye								X			
Skipjack herring	SC	E					X				
Gizzard shad										X	
Threadfin shad								X			
Alabama shad							X				
Central mudminnow									O		
Grass pickerel			T						X		
Northern pike								X			
Muskellunge						X					
Blue sucker	SC	T					X				
Bigmouth buffalo									X		
Black buffalo	SC	T					X				
Smallmouth buffalo									X		
Quillback									X		
River carpsucker									X		
Highfin carpsucker								X			
Silver redhorse									X		
Black redhorse		E	T				X				
Golden redhorse								X			
Shorthead redhorse								X			
Greater redhorse		T		E		X					
River redhorse		T		T			X				
Northern hog sucker								X			

Appendix Table 1. List of fish species collected or reported from the upper Mississippi river, State endangered, threatened, and special concern status, draft designations for the first six BCG attributes.

	State Endangered, Threatened, Special Concern Designation					BCG Species Attributes					
						I	II	III	IV	V	VI
Species	MN	WI	IA	IL	MO	Rare, Endemic, Long Lived	Rare, Sensitive	Sensitive Ubiquitous	Intermediate Tolerance	Tolerant	Non-Native
White sucker										X	
Spotted sucker									X		
Common carp										X	X
Goldfish										X	X
Golden shiner									X		
Hornyhead chub								O			
Silver chub		SC					X				
Gravel chub	SC	E		T				X			
Speckled chub							X				
Creek chub										O	
Suckermouth minnow									X		
Pugnose minnow		SC	SC			X					
Emerald shiner									X		
Redfin Shiner		T						O			
Striped shiner		E						O			
Common shiner								O			
River shiner									X		
Spottail shiner									X		
Blackchin shiner						X					
Bigeye shiner				E			O				
Spotfin shiner									X		
Bigmouth shiner									X		
Sand shiner									O		
Ghost shiner							X				
Blacknose shiner							X				
Mississippi silvery minnow								X			
Bullhead minnow									X		
Fathead minnow										X	
Bluntnose minnow										X	
Central stoneroller									O		
Grass carp										X	X
Red shiner									X		
Channel shiner									X		
Pallid shiner	SC	E		E	X	X					
Silver carp										X	X
Brassy minnow							X				

Appendix Table 1. List of fish species collected or reported from the upper Mississippi river, State endangered, threatened, and special concern status, draft designations for the first six BCG attributes.

	State Endangered, Threatened, Special Concern Designation					BCG Species Attributes					
						I	II	III	IV	V	VI
Species	MN	WI	IA	IL	MO	Rare, Endemic, Long Lived	Rare, Sensitive	Sensitive Ubiquitous	Intermediate Tolerance	Tolerant	Non-Native
Bighead carp										X	X
Weed shiner		SC	E	E			X				
Carmine shiner							0				
Silverband shiner							X				
Sicklefin chub							X				
Western silvery minnow						X?					
Blacktail shiner						X					
Cypress Minnow				E		X					
Flathead Chub					E	X					
Plains minnow						X					
Sturgeon chub				E		X					
Blue catfish							X				
Channel catfish									X		
Yellow bullhead										X	
Brown bullhead									X		
Black bullhead										X	
Flathead catfish								X			
Stonecat							X				
Tadpole madtom								X			
Freckled madtom			E				X				
American eel		SC				X					
Blackstripe topminnow									X		
Blackspotted topminnow							X				
Western mosquitofish									X		
Striped mullet							X				
Burbot			T			X					
Trout perch							X				
Pirate perch	SC	SC	SC			X					
Brook silverside									X		
Inland silverside								X			
White bass									X		
Striped bass							X				
Yellow bass	SC						X				
White crappie									X		
Black crappie									X		
Rock bass								X			

Appendix Table 1. List of fish species collected or reported from the upper Mississippi river, State endangered, threatened, and special concern status, draft designations for the first six BCG attributes.

	State Endangered, Threatened, Special Concern Designation					BCG Species Attributes					
						I	II	III	IV	V	VI
Species	MN	WI	IA	IL	MO	Rare, Endemic, Long Lived	Rare, Sensitive	Sensitive Ubiquitous	Intermediate Tolerance	Tolerant	Non-Native
Smallmouth bass								X			
Spotted bass								X			
Largemouth bass									X		
Warmouth								X			
Green sunfish										X	
Orangespotted sunfish										X	
Longear sunfish		T					X				
Redear sunfish								X			
Pumpkinseed									O		
Bluegill										X	
Flier							X				
Sauger								X			
Walleye								X			
Yellow perch								X			
Dusky darter							X				
Blackside darter							O				
Slenderhead darter							X				
River darter								X			
Logperch								X			
Crystal darter	SC	E		X	E	X					
Johnny darter									O		
Banded darter								O			
Iowa darter				T			O				
Mud darter		SC						X			
Bluntnose darter		E	E			X					
Western sand darter		SC	T	E		X					
Freshwater drum									X		

Appendix Table 2. Mean collection abundance and probability of capture by Ohio IBI range generated from large river data in the Midwest and extrapolated historical abundance and probabilities for historical (natural) periods for three reaches of the upper Mississippi River (upper impounded – UP; lower impounded – LOW; and not impounded – NOT.

Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
01	001	Silver lamprey	1.4	1.5	1.4	1.2	1.1	4.5	4.5	4.5	2.48	3.95	4.15	4.89	4.52	8	8	8
01	007	American brook lamprey	1	1.3	1.5	1.5	1	1	0	0	0.5	0.47	0.37	0.57	1.01	1	0	0
01	008	Chestnut lamprey	1	2.1	2	3.2	3.8	4	4	4	0.25	0.94	0.84	4.4	15.58	10	10	10
04	001	Paddlefish	1	1	1.4	1	1	1	1.5	2	0.25	0.4	0.65	0.5	0.5	10	10	10
08	001	Lake sturgeon	0	0	0	1.3	2	2	2	2	0	0	0	0.21	1.01	5	5	5
08	002	Shovelnose sturgeon	1.4	1.9	2.7	2.6	2.3	3	5	5	4.09	3.28	4.52	3.26	3.02	20	20	20
08	004	Pallid Sturgeon	0	0	0	0	0	0	1	3	0	0	0	0	0	0	2	5
10	001	Alligator gar	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	5
10	002	Shortnose gar	2.1	3.3	4.5	3.8	1.4	3	5	10	18.09	20.62	11.61	5.32	2.51	5	5	10
10	003	Spotted gar	1	1.2	1.6	1.2	1	0	1	2	0.62	0.6	0.98	0.71	0.5	0	4	4
10	004	Longnose gar	1.6	2.3	3.1	2.7	2.8	20	20	10	24.29	28.85	27.6	30.21	21.11	25	25	20
15	001	Bowfin	1.2	1.4	1.7	1.5	1.7	4	4	2	1.61	2.81	2.42	2.06	1.51	5	5	5
18	001	Goldeye	1.6	2.1	2.9	1.6	2.5	5	7	10	6.44	9.91	4.94	2.2	1.01	5	5	5
18	002	Mooneye	1.3	2.3	2.5	2.6	3	15	10	5	5.08	8.7	11.05	15.11	13.57	25	20	20
20	001	Skipjack herring	1.2	1.8	2.9	4.3	6.2	10	10	20	8.18	11.58	11.93	16.67	14.07	25	25	25
20	003	Gizzard shad	6.7	49.2	48.5	26.2	16.9	50	50	50	69.89	83.73	79.81	79.93	65.33	50	50	50
20	004	Threadfin shad	0	3	2.7	2.4	0	0	2	5	0	0.2	0.61	0.5	0	0	5	5
20	008	Alabama shad	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5
34	001	Central mudminnow	1	0	1	1.5	2.8	5	0	0	0.25	0	0.09	0.57	2.01	4	0	0
37	001	Grass pickerel	1.3	1.5	1.4	1.7	1.3	8	1	0	0.5	1.27	1.59	2.62	7.54	9	2	0
37	003	Northern pike	1	1.6	1.6	2.1	3.1	4	1	0	0.12	1.41	1.4	4.26	14.07	20	10	0
37	004	Muskellunge	2	1	1	1.2	1.7	2	0	0	0.25	0.4	0.56	0.92	7.04	10	0	0
40	001	Blue sucker	1.9	1.7	2.5	3.4	7.6	8	10	20	9.67	7.56	10.21	8.65	9.55	20	20	20
40	002	Bigmouth buffalo	1.7	2	2.7	1.7	2.1	3	5	7	5.82	10.6	10.4	8.23	6.53	20	20	20

Appendix Table 2. Mean collection abundance and probability of capture by Ohio IBI range generated from large river data in the Midwest and extrapolated historical abundance and probabilities for historical (natural) periods for three reaches of the upper Mississippi River (upper impounded – UP; lower impounded – LOW; and not impounded – NOT.

Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
												4						
40	003	Black buffalo	1.3	2.3	2.2	2.9	3.6	5	7	7	1.86	6.29	11.89	19.79	19.6	40	40	40
40	004	Smallmouth buffalo	2	2.7	4.3	6.6	6.7	10	10	10	13.75	27.78	41.91	49.15	33.17	60	60	60
40	005	Quillback	2.4	3.7	4.1	3.5	3.9	5	4	2	8.8	22.36	31.98	46.88	49.75	50	50	25
40	006	River carpsucker	3.5	6.8	8.6	8.6	8.3	8	8	12	37.3	47.19	52.12	53.83	39.7	65	65	65
40	007	Highfin carpsucker	1.3	1.7	1.7	2.3	2.9	3	5	0	3.22	7.43	9.65	13.9	14.07	25	25	0
40	008	Silver redhorse	1.4	1.9	2.8	4.5	8.1	10	5	2	13.01	21.62	41.07	60.99	63.82	75	60	20
40	009	Black redhorse	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0	0
40	010	Golden redhorse	2.3	4.1	8.5	17.3	39.9	40	20	10	17.1	38.69	62.05	84.68	92.46	95	50	25
40	011	Shorthead redhorse	1.8	2.9	5.5	14.9	29.7	30	20	10	13.88	25.37	47.04	63.4	72.36	85	85	25
40	012	Greater redhorse	0	0	0	0	0	5	0	0	0	0	0	0	0	10	0	0
40	013	River redhorse	1	1.4	1.7	2.6	5.4	7	0	0	0.5	1.41	8.39	26.6	50.25	50	0	0
40	015	Northern hog sucker	1.7	3	5.2	10.5	22.2	5	1	0	3.84	14.06	29.65	66.6	92.46	10	2	0
40	016	White sucker	3.9	6	4.2	6.2	6.4	6	1	0	8.05	13.32	7.83	10.57	30.15	7	1	0
40	018	Spotted sucker	2.5	2.9	3.6	3.4	3	4	2	0	2.35	8.5	11.89	15.67	27.14	35	25	0
43	001	Common carp	8.8	10.7	9.1	7.7	8.9	0	0	0	74.72	87.88	79.21	80.64	76.88	0	0	0
43	002	Goldfish	26.7	11.6	4.1	2.1	2.3	0	0	0	9.91	12.58	7.18	3.4	4.02	0	0	0
43	003	Golden shiner	2.7	9	7.7	4.9	5.1	5	3	1	4.21	8.7	6.81	6.52	8.54	5	5	1
43	004	Hornyhead chub	0	1.3	2.7	24.3	13.3	1	0	0	0	0.2	0.28	2.48	12.56	1	0	0
43	006	Silver chub	1.7	2.6	5.8	7.9	6.4	7	15	7	0.87	3.95	10.02	9.93	4.52	10	15	10
43	009	Gravel chub	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	25
43	010	Speckled chub	0	3.2	4.8	4.8	8.2	8	12	20	0	0.33	0.47	0.71	2.51	20	20	20

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Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
43	013	Creek chub	2.6	4.5	3.4	2.4	2.9	2	0	0	1.36	3.95	2.8	5.46	10.55	2	0	0
43	015	Suckermouth minnow	1.9	2.2	7.6	16.3	22	2	4	2	1.98	6.76	12.26	29.57	41.21	5	5	5
43	019	Pugnose minnow	0	0	0	0	2	4	1	1	0	0	0	0	0.5	10	2	2
43	020	Emerald shiner	2.6	10.3	40.3	70.1	65.7	70	7	70	14.13	33.47	51.56	58.37	49.25	80	80	80
43	023	Redfin Shiner	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0
43	025	Striped shiner	3.8	5.4	4.5	9.2	15.7	0	0	5	2.73	6.96	6.9	16.88	41.71	0	0	3
43	026	Common shiner	2	1.5	4.9	21.6	47.8	5	0	0	0.12	0.4	0.37	2.91	10.05	1	0	0
43	027	River shiner	1.2	3.1	9.4	23	3.5	5	20	10	0.74	4.22	11.24	8.65	3.02	10	20	10
43	028	Spottail shiner	4.5	5.2	4.5	5.3	3.7	5	5	1	0.25	1.61	2.84	1.84	1.51	10	10	3
43	029	Blackchin shiner	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0	0
43	030	Bigeye shiner	0	1	1	0	0	0	2	1	0	0.07	0.09	0	0	0	2	1
43	032	Spotfin shiner	7.2	18.8	24.9	28.9	36.6	40	20	10	19.95	51	63.17	77.38	89.45	90	80	50
43	033	Bigmouth shiner	0	2	0	0	4	4	10	1	0	0.07	0	0	0.5	2	4	2
43	034	Sand shiner	2.4	4.5	10	18.4	18.6	9	20	15	2.97	11.58	19.53	39.65	59.3	30	50	40
43	036	Ghost shiner	1.2	5.7	9.1	14.6	1	15	15	15	0.62	2.41	1.63	1.28	0.5	5	5	5
43	037	Blacknose shiner	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0	0
43	040	Mississippi silvery minnow	1.6	9.2	33.8	24.8	26.3	20	20	15	0.62	1.81	2.61	2.27	1.51	5	7	20
43	041	Bullhead minnow	1.2	4.4	6.9	9.1	12.2	15	12	5	1.12	12.65	26.01	36.38	38.19	50	50	20
43	042	Fathead minnow	1.8	4.2	1.7	1.5	1	1	3	1	1.12	1.14	0.84	0.78	2.01	2	2	1
43	043	Bluntnose minnow	14	17.5	14.7	11.8	11.1	11	15	11	8.43	31.12	39.16	57.94	70.85	4	8	4
43	044	Central stoneroller	1.8	2.8	6.9	11.5	36.3	5	5	5	1.61	5.35	11.7	31.56	50.25	5	5	5
43	047	Grass carp	1	1.3	1.2	1.7	1	0	0	0	0.5	0.87	1.59	0.99	1.01	0	0	0
43	048	Red shiner	2	9.9	0	0	1	0	5	5	0.12	0.54	0	0	0.5	0	5	5
43	063	Channel shiner	0	4.3	5.8	12.6	16.8	0	20	20	0	0.8	4.34	6.74	5.53	0	15	15
43	076	Pallid shiner	0	0	1.5	2.7	8.6	10	1	0	0	0	0.09	0.21	3.52	5	1	0
43	079	Silver carp	7	3.4	1.9	1.5	0	0	0	0	0.12	2.48	1.54	0.78	0	0	0	0

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Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
43	084	Brassy minnow	0	1	2	1	1	2	0	0	0	0.07	0.05	0.07	0.5	2	0	0
43	113	Bighead carp	1.2	1.5	2.3	1.2	0	0	0	0	0.74	0.4	1.07	0.43	0	0	0	0
43	114	Weed shiner	0	1.3	2	27	0	10	0	0	0	0.27	0.23	0.21	0	5	0	0
43	117	Carmine shiner	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0
43	118	Silverband shiner	0	0	0	0	0	0	2	5	0	0	0	0	0	0	5	5
43	119	Sicklefin chub	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	2
43	120	Western silvery minnow	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	2
43	122	Blacktail shiner	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	2
43	123	Cypress Minnow	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0
43	124	Flathead Chub	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	3
43	125	Plains minnow	0	0	0	0	0	5	5	5	0	0	0	0	0	2	10	5
43	130	Sturgeon chub	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5
47	001	Blue catfish	1.1	1.9	1.5	1	0	0	3	5	0.87	0.67	0.79	0.28	0	0	5	5
47	002	Channel catfish	2.6	5.8	6.8	8.4	7.8	10	15	10	30.73	58.3	67.83	76.1	70.85	80	90	80
47	004	Yellow bullhead	1.8	2.3	1.8	1.7	1.2	3	2	1	2.35	7.36	5.64	7.94	12.56	5	2	1
47	005	Brown bullhead	2	2.6	1.7	1.5	1.3	2	1	1	0.74	2.41	1.49	0.78	1.51	3	1	1
47	006	Black bullhead	2.8	4	1.6	1.5	1	1	2	1	1.24	1.47	0.37	0.43	1.01	1	5	1
47	007	Flathead catfish	3.5	5.3	3.3	2.6	3.1	5	5	5	42.26	42.5	42.05	44.54	35.68	60	60	60
47	008	Stonecat	0	1.1	1.7	1.9	4.4	4	5	5	0	0.54	2.42	11.77	28.64	25	35	35
47	013	Tadpole madtom	0	1.3	1.5	0	3.8	4	2	2	0	0.4	0.09	0	3.02	7	5	5
47	016	Freckled madtom	1	0	1	1	1	0	1	3	0.12	0	0.05	0.14	0.5	0	1	2
50	001	American eel	1	1.3	1.3	1.3	1	5	7	15	0.37	1.27	0.84	0.43	1.51	50	50	50
54	002	Blackstripe topminnow	0	1.7	1.2	1.3	1	1	2	1	0	1	0.84	1.84	3.02	5	5	3
54	005	Blackspotted topminnow	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
57	001	Western mosquitofish	0	4.5	5.1	4.2	2	0	3	0	0	0.87	0.7	1.35	1.01	0	5	0
58	001	Striped mullet	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
60	001	Burbot	0	1	1	2.7	1.9	5	3	1	0	0.07	0.19	1.35	6.53	10	2	1
63	001	Trout perch	0	4.8	2.6	3.8	2.2	5	1	1	0	0.8	0.84	1.13	2.51	5	1	1
68	001	Pirate perch	0	0	2.3	4.8	1	5	3	1	0	0	0.14	0.28	0.5	10	2	1
70	001	Brook silverside	1	4.7	4.8	5.1	5.5	8	5	3	0.62	1.34	6.99	14.8	20.1	20	10	2

Appendix Table 2. Mean collection abundance and probability of capture by Ohio IBI range generated from large river data in the Midwest and extrapolated historical abundance and probabilities for historical (natural) periods for three reaches of the upper Mississippi River (upper impounded – UP; lower impounded – LOW; and not impounded – NOT.

Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
														2				
70	003	Inland silverside	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	10
74	001	White bass	1.4	2.7	3.8	6.1	6.6	10	6	6	11.28	29.99	34.59	38.79	27.64	50	25	25
74	002	Striped bass	1	2.6	2.1	4.6	1	0	0	3	0.5	0.33	1.4	1.99	0.5	0	0	2
74	006	Yellow bass	1	1.4	3.8	2	4	4	4	4	0.25	1.41	0.93	0.85	0.5	2	10	10
77	001	White crappie	1.5	2.5	2.6	1.9	2.4	3	4	3	8.3	19.34	18.04	18.01	13.07	5	15	5
77	002	Black crappie	1.6	2.1	3.5	2.8	3.9	4	8	2	6.82	10.84	17.2	24.54	37.19	20	40	10
77	003	Rock bass	1.6	3.3	4.6	9.6	12.2	15	5	0	2.97	12.25	24.99	44.61	74.37	65	25	0
77	004	Smallmouth bass	1.8	3.6	6.3	12.4	28.8	30	10	3	11.03	34.2	57.72	78.23	95.48	90	20	2
77	005	Spotted bass	1.8	4	6.8	9	17.9	0	0	10	9.05	25.1	42.19	57.3	43.22	0	0	80
77	006	Largemouth bass	2.4	3.9	6	5.6	3.9	4	4	2	9.42	29.05	30.58	41.77	49.25	40	40	5
77	007	Warmouth	2.1	2	2.1	1.4	1.2	2	2	1	0.87	1.67	1.86	3.97	3.02	6	3	1
77	008	Green sunfish	12	17.8	14.2	7.4	7.1	5	5	5	14.87	31.73	35.71	47.94	54.27	10	10	10
77	010	Orangespotted sunfish	3.2	7.6	8	7.1	5.9	5	5	5	3.84	15.33	15.66	18.72	15.58	5	10	5
77	011	Longear sunfish	6.1	8.3	12.8	17.4	24.9	0	1	5	10.9	30.59	47.13	60.35	69.35	0	2	10
77	012	Redear sunfish	2	1.1	1.7	1.3	1.5	0	2	2	0.37	1.41	1.26	2.13	3.02	0	5	5
77	013	Pumpkinseed	3.8	4.8	5.4	5.9	2.2	3	3	0	3.22	9.57	9.04	9.65	13.07	5	5	0
77	028	Bluegill	1	4.3	32.5	19.6	7	0	0	0	0.12	1.94	1.45	1.13	2.01	0	0	0
77	031	Flier	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5
80	001	Sauger	1.2	1.9	3.6	6.1	4.6	5	5	3	7.68	18.47	34.17	44.82	35.68	65	65	40
80	002	Walleye	1.4	2.7	4.1	3.9	5.2	5	5	3	2.48	5.35	7.97	12.55	26.13	30	30	15
80	003	Yellow perch	1.4	3.5	9.5	6	6.4	6	3	0	1.24	2.01	1.86	3.4	13.57	10	3	0
80	004	Dusky darter	1	1.2	1.8	2	3.1	0	0	1	0.37	0.6	2.1	5.04	13.07	0	0	1

Appendix Table 2. Mean collection abundance and probability of capture by Ohio IBI range generated from large river data in the Midwest and extrapolated historical abundance and probabilities for historical (natural) periods for three reaches of the upper Mississippi River (upper impounded – UP; lower impounded – LOW; and not impounded – NOT.

Family & Species Codes		Common Species Name	Mean Abundance per Sample								Mean Probability of Collection							
			IBI Narrative Range					Impounded			IBI Narrative Range					Impounded		
			Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not	Very Poor	Poor	Fair	Good	Exc.	Up.	Low.	Not
80	005	Blackside darter	1	1.3	2.2	5.1	7.1	7	2	0	0.25	1.81	2.7	7.59	25.63	15	3	0
80	007	Slenderhead darter	1.3	1.6	2.1	3	3.9	5	2	2	0.5	0.94	4.71	13.97	27.14	40	20	15
80	008	River darter	0	1	3.8	5.3	5.2	5	5	5	0	0.07	0.75	2.13	3.02	20	40	40
80	011	Logperch	2.5	3.2	3.6	6.2	10.4	10	5	3	1.36	6.96	18.55	45.6	69.85	25	15	5
80	012	Crystal darter	0	0	0	1	9.2	10	5	5	0	0	0	0.14	4.52	10	10	10
80	014	Johnny darter	1.6	1.7	2.6	2.2	2.6	3	2	1	0.99	1.87	3.12	9.93	15.08	3	2	1
80	016	Banded darter	1	1.5	4.6	5.5	10.7	10	5	0	0.12	1.34	4.71	20.92	47.24	25	10	0
80	021	Iowa darter	0	0	5.7	1	4	4	0	0	0	0	0.14	0.07	1.51	4	0	0
80	028	Mud darter	0	1	1	1.4	1	2	1	1	0	0.07	0.09	0.5	0.5	5	5	2
80	032	Bluntnose darter	0	0	1	0	5	5	2	2	0	0	0.05	0	0.5	5	2	2
80	033	Western sand darter	0	0	1	1.4	3.4	4	4	2	0	0	0.09	0.71	3.52	5	5	2
85	001	Freshwater drum	2.9	9.9	12.3	12.3	14.4	15	15	15	36.93	53.68	63.36	67.66	55.78	85	85	85