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MODIFICATION AND ASSESSMENT OF AN INDEX OF BIOTIC INTEGRITY TO QUANTIFY WATER RESOURCE QUALITY IN GREAT RIVERS

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ABSTRACT

A measure of stream quality, the index of biotic integrity (IBI), was adapted to great rivers (>3226 km^2) and calibrated using a variety of spatial scales. Fish fauna was sampled at 60 localities within 15 impoundments of the Ohio River drainage, eastern Ohio, West Virginia and Pennsylvania, with boat electroshocker methods during the summers and autumns of 1990–1993 to provide biological information for the IBI. Significant correlation was not found between ecoregion or differing reservoirs; however, the IBI was sensitive to differences in land use and variable industrial and municipal loadings. Species richness, the percentage large river faunal group, the proportion of round-bodied sucker species, the number of centrarchid species, the number of sensitive taxa and the proportion of simple lithophilous spawning species showed the greatest change between riverine and lacustrine habitats within an impoundment. The percentage large river faunal group metric was not significantly different between riverine, transitional and lacustrine habitats; however, the metric reflected significant differences when evaluated with habitat information. The number of centrarchid species was higher in lacustrine habitats, whereas round-bodied sucker species were highest in transitional habitats. The inherent variation of proportional metrics was significantly reduced with the removal of gizzard shad. This modification of the IBI will enhance assessment sensitivity over the original approach designed for wadable streams and rivers.

KEY WORDS: index of biotic integrity; multimetrics; fish community assessment; water resource evaluation

INTRODUCTION

Great rivers are usually the largest watersheds which drain ultimately to marine environments. Simon and Lyons (1995) define great rivers as hydrological units with watershed areas greater than 3226 km^2 and possess a characteristic 'large river faunal group' (Pflieger, 1971). Based on a study of the White River, Indiana a change in species composition was observed in areas with drainage areas less than 3226 km^2. These smaller drainage areas had communities consisting of species transitional between streams and creeks, but did not possess members of the 'large river faunal group'. Stations with drainage areas greater than 3226 km^2 had fish communities consisting of greater than 25% of the 'large river faunal group' (Simon and Lyons, 1995). Monitoring and assessing the great rivers of North America has been largely ignored because of the perception that the sampling efficiency was compromised and representative sampling could not be conducted (Mills *et al.*, 1966; Fausch *et al.*, 1984). The study of the dynamic and complex nature of great river water resource biological integrity has only been recently recognized (Hughes, 1985; Hughes and Gammon, 1987; Simon and Lyons, 1995) for promoting the stability of warm-water fish communities (Gammon, 1973, 1983; Karr *et al.*, 1986).

Quantification of regional and watershed quality are facilitated by the index of biotic integrity (IBI) (Karr, 1981). The IBI uses attributes of the fish community to evaluate anthropogenic effects within a stream reach. The index was developed for small wadable streams and rivers (Karr, 1981; Karr *et al.*, 1986). Several adap-

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tations to the index were made to measure the integrity of large rivers with drainage areas less than 3226 km^2 (Simon and Lyons, 1995); however, no application to great rivers has been evaluated.

The IBI is composed of subcategories, referred to as 'metrics' by Karr (1981). There are seven types of metrics: species richness and composition; species tolerance; trophic composition; fish abundance; reproductive guild; and fish condition. Cumulatively they provide information about the structure and function of the fish community (Simon and Lyons, 1995).

Each metric is calibrated based on a reference or 'least impacted' stream of similar size in the same region (Hughes *et al.*, 1981). These 'least impacted' areas represent the best attainable conditions possible for a watershed within a region (Hughes and Omernik, 1981; Hughes *et al.*, 1981; Hughes and Larsen, 1988). These best attainable attributes define and comprise the reference condition. Unfortunately, great river paired sites of equal biological quality are lacking, which require that expectations be developed from historical and repeated sampling of the same and random stations. Thus the range of IBI community assemblage attributes for great rivers is commonly limited by the uniqueness of each system simply because they are usually the largest stream order. To evaluate the expectations or IBI criteria for assessment, the range of assemblage attributes was scored based on Ohio River mainstem river kilometres, a direct correlate of drainage area (Hughes and Omernik, 1981). As no single river reach may reflect exceptional scores for all metrics because pristine sites do not exist, it is the cumulative data-set which determines patterns or the 'reference condition'. These applications require modification and calibration with respect to land use, topography, soil type, biome and zoogeography (Fausch *et al.*, 1984; Angermeier and Karr, 1986; Burr and Page, 1986; Leonard and Orth, 1986; Karr *et al.*, 1986; Omernik, 1987; Hughes and Larsen, 1988; Miller *et al.*, 1988).

The purpose of this study is to document useful modifications of the IBI for application to great rivers and to assess the IBI as a multimetric indicator of stream resource quality among great river zone types.

STUDY AREA

The study area chosen includes impoundments of the upper Ohio River drainage directly influenced by urban, industrial and municipal dischargers. Included were 15 impoundments of the upper Ohio River which reflect smaller reservoir subsystems of the Monongahela (two impoundments), Allegheny (one impoundment) and upper Ohio River (12 impoundments). All impoundments are found in the upper 565 river kilometres of the Ohio River and have drainage areas greater than 3226 km^2 (Figure 1). Wallus *et al.* (1990) indicate the Ohio River (river kilometre 0) at the confluence of the Monongahela and Allegheny Rivers has a drainage area of 49 500 km^2. The drainage areas of the Monongahela and Allegheny Rivers are 19 200 and 30 300 km^2, respectively.

The study area dissects a single ecoregion, the Western Allegheny Plateau (Omernik, 1987). Within the study area, differences in bedrock geology, potential natural vegetation and soil type are the most prominent natural differences with other adjacent ecoregions. The physiography of the Ohio River basin has been described in Fowke (1933), Fenneman (1946) and Atwood (1940).

METHODS

We conducted electrofishing surveys at 60 locations between July and September 1990 to 1993. Only the mainstem Ohio, Monongahela and Allegheny Rivers were sampled, usually near boat launches, distributed among three zone types: riverine, transitional and lacustrine impoundment sites (Thornton *et al.*, 1990). A two- or three-person crew using a boat-mounted Honda model generator, Smith-Root electroshocker with safety switch foot pedal, 300–500 V pulsed, DC output capable of 8–9 A, sampled all stations. Four bow-mounted anodes were constructed from electrical duct tubing, 1·3 m in length, whereas the cathode was the boat hull or four additional pieces electrical duct tubing of equal length attached to the anterior half of the boat. Each station was electrofished on a single shoreline in a downstream direction for a maximum distance of 1000 m. Gammon (1983) indicated that species richness asymptotes at distances of approximately 500 m on the Wabash River. We recorded the sampling time as the time that the power was applied to the

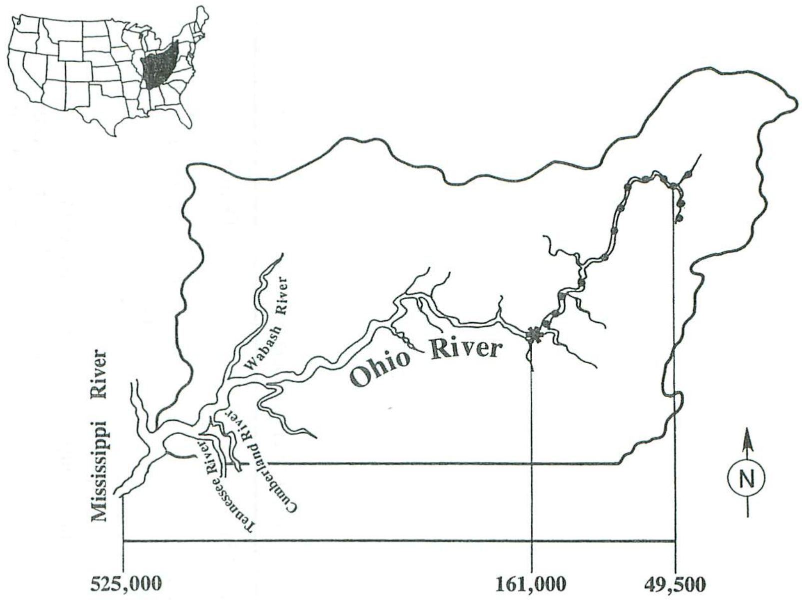

Figure 1. Ohio River mainstem showing the study zone and impoundments containing the sampling sites (denoted by closed circles) between drainage area 49 500 and 161 000 km^2. The intensive survey conducted in the Greenup impoundment is signified by the star and large circle

electrodes and typically averaged 3000 s. The point bars were waded whenever possible. We completed boat sampling in all possible habitats including deep pools, runs and the inside and outside edges of river bends primarily sampling the main channel border and tributary mouths. Riffle habitat is usually lacking in the Ohio River; however, the riverine zone below dams is the most similar to pre-impoundment conditions.

We enumerated all individuals and split fish into game and commercial species and non-game species. We sorted small non-game species into 3 cm size classes and batch-weighed, whereas large game and commercial species are individually measured for total length, weighed and returned alive to the river. We preserved representative voucher specimens and small species (minnows, madtoms, darters) in the field and returned to the laboratory for processing. We identified fish in the laboratory using keys in Gerking (1955), Smith (1973), Trautman (1981) and Wallus *et al.* (1990).

Watershed information, microhabitat and river reach zone (Thornton *et al.*, 1990) were recorded in the field and determined from US Army Corps of Engineers navigation charts. We determined the proportion of the zone with forested riparian zones, channel width and percentage major habitat types qualitatively using procedures from the State of Ohio (Rankin, 1995). We noted great river habitat assessment to reflect the characteristics of the larger watersheds.

Impoundment drainage area characteristics were based on river kilometre as stream order is not considered appropriate for delineating areas of similarity (Omernik and Griffith, 1991). Reference condition expectations are based on river kilometre, and are directly correlated with increasing drainage area. The transition to great river for the Ohio River occurs in the Allegheny and Monongahela rivers. River kilometre acts as a surrogate to identify groups along a spatial drainage network or along 'non-nested' regional drainages for correlation and regression analysis. River kilometres in the Ohio River are opposite to conventional numbering systems with the lowest numbers occurring at the confluence of the Monongahela and Allegheny rivers (denoted river kilometre 0). Negative river kilometres indicate sites in the Monongahela and Allegheny rivers.

Statistical analyses were performed using a three-way mixed model analysis of variance (ANOVA) to determine differences between riverine, transitional and lacustrine zones of individual impoundments

Table I. Comparison of the original index of biotic integrity (Karr, 1981; Karr *et al.*, 1986) for wadable streams and rivers and the modified version for great rivers

Original IBI	Definition	Great river IBI	Definition
Total number of species	Number of fish species excluding hybrids and subspecies	Total number of species	Number of fish species including exotics and excluding hybrids and subspecies
Number of darter species	Number of species of subfamily Etheostomatinae (Percidae). Habitat specialists in small streams and rivers and sensitive species	Percentage large river faunal group	Percentage composition of Pflieger's 'large river faunal group'. These species are great river specialists and decline with loss of associated habitats
Number of sunfish species	Members of family Centrarchidae, exclusive of black basses. Responsive to degraded pool habitat	Number of centrarchid species	Number of members of family Centrarchidae, including black basses. Responsive to pool habitat and structural complexity
Number of sucker species	Members of family Catostomidae, which are long-lived species with sensitivity to habitat and chemical degradation	Percentage round-bodied suckers	Members of genera *Cycleptus*, *Erimyzon*, *Hypentelium*, *Moxostoma* and *Minytrema*. The genera *Catostomus*, *Carpiodes* and *Ictiobus* are excluded as they are habitat generalists and omnivores
Number of intolerant species	Species of many families sensitive to a variety of perturbations. Should be limited to 5–10% of species	Number of sensitive species	Number of species of multiple families that are sensitive to a variety of perturbations. Should be limited to 10% of fauna

Percentage green sunfish	In the midwest, the green sunfish increases in relative abundance in degraded streams. Suggests other species may be just as appropriate, e.g. carp, goldfish, black bullhead	Percentage tolerant species	Percentage of a number of species from multiple families which increase in relative abundance in degraded habitats
Percentage omnivores	Percentage of animals which take a considerable amount of plant (25%) and animal (25%) material	Percentage omnivores	Percentage of animals which take a considerable amount of plant (25%) and animal (25%) material
Percentage insectivorous cyprinids	Percentage relative abundance of cyprinids which eat insects. Decline in relative abundance is correlated with degradation	Percentage insectivores	Cyprinids are not dominant in great rivers, thus this metric reflects all insectivores found in great rivers
Percentage top carnivores	Percentage of individuals in which adults are predominantly piscivores	Percentage carnivores	Percentage of individuals in which the adults are predominantly piscivores
Number of individuals	Expressed as the catch per unit effort	CPUE	Number of individuals collected with a standard effort and protocol
Percentage hybrids	Percentage of hybrids caused by degradation altering reproductive isolation	Percentage simple lithophils	Percentage of individuals which exhibit a simple spawning behaviour
Percentage disease, tumours, fin damage and skeletal anomalies	Percentage of individuals at a site with poor health. This version includes parasite and protozoan infections	Percentage DELT	Percentage of individuals with poor health, excluding parasitism and protozoan infections

(SAS, 1985). The upstream portion of a reservoir that has important unidirectional flow is referred to as the riverine zone. Transitional stations are intermediate between riverine and lacustrine zones. Lacustrine zones are the portion of the reservoir showing obvious impoundment influences from the downstream dam (Leopold *et al.*, 1964; Newbury and Gaboury, 1993). Over 22 metrics were evaluated to determine which compilation of metrics would provide the best representation of the Great River community assemblage.

RESULTS AND DISCUSSION

Modifying the IBI for use in great rivers

The IBI was developed for wadable, warm-water streams and rivers in the mid-western USA (Karr, 1981; Karr *et al.*, 1986). To adapt this index for application to the great river habitat typical of the Ohio River, several modifications were necessary (Table I). Although the composition of the IBI was modified to reflect the attributes of great river habitat, the same general categories (species richness and composition, species tolerance, trophic composition, fish abundance, reproductive guild and fish condition) were retained.

Metrics that were modified are described in the following sections.

Total number of species. Biological integrity based on the number of species declines when a site is stressed or degraded. We have chosen to retain the inclusion of non-native taxa such as *Cyprinus carpio*, *Carassius auratus* and *Cyprinella lutrensis* as these species are well established in the North American fish assemblage and are ubiquitously distributed in the Ohio River. At extremely polluted sites these species are often those which increase in abundance and under extreme duress separate the presence of aquatic life from no fish. Although the number of exotic or introduced species may be indicative of a loss of integrity (Karr *et al.*, 1986), the difference between lower levels of IBI resolution may be due to colonization of habitats by pioneer or tolerant taxa. Other metrics incorporated into the great river IBI subtract points for the presence of exotics, thus we have chosen to retain exotic species. In instances where a site may be dominated by only exotic species more likely than not a site will score poorly regardless of whether exotics are included in the count of the total number of species.

Proportion of round-bodied sucker species. Sensitive round-bodied catostomids typical of mainstem rivers include members of the genera *Moxostoma*, *Hypentelium*, *Cycleptus*, *Erimyzon* and *Minystrema*. These species are sensitive to thermal loadings and reflect habitat changes in run and pool habitat (Gammon, 1983; Karr *et al.*, 1986). Sucker genera considered tolerant are *Carpiodes*, *Catostomus* and *Ictiobus*. These sucker genera are excluded. White sucker are ubiquitous and are often found in degraded habitats, as well as quality habitats. In addition, members of genera *Carpiodes* and *Ictiobus* are omnivorous suckers which can inhabit thermally stressed and degraded habitats. Inclusion of Ictiobinae in the analysis provides no additional information, reducing the sensitivity of the metric. The metric should increase with improvements in water resource integrity.

Proportion of large river faunal group. Pflieger (1971), in studies of Missouri fish, found a characteristic fauna associated with large rivers, which he termed the large river faunal group. This pattern has been documented in Arkansas (Matthews and Robison, 1988), Kentucky (Burr and Warren, 1986), Illinois (Smith *et al.*, 1971) and Indiana (Simon and Lyons, 1995). Species typical of large rivers were identified (Table II; Pflieger,1971; Goldstein *et al.*, 1994) and the proportion of the large river faunal group showed natural breaks between large and great rivers (Simon and Lyons, 1995). The large river faunal group occurs when river sizes have a greater than 3226 km^2 drainage area. All of our sites in the Ohio River had drainage areas greater than 19 150 km^2. Declines in the proportion of this group indicate changes in great river habitat which affect these species—changes including the destruction of bottomland hardwood wetlands, bank erosion, channelization and dredging, which caused the disappearance of important spawning, nursery and feeding habitats for these species. The large river faunal group proportions decline with great river habitat destruction and decreased river sizes when the area drained is less than 3226 km^2.

Number of centrarchid species. The number of sunfish species increases with quality pool habitat. Karr *et al.* (1986) found sunfish to occupy the intermediate to upper ends of sensitivity of the IBI; however, members of the genus *Micropterus* are not included in the analysis (Karr *et al.*, 1986). The black basses are an

Table II. Great river species indicative of the large river faunal group for the Ohio River's Western Allegheny Plateau (Pflieger, 1971; Simon and Lyons, 1995)

Common name	Scientific name
Silver lamprey	*Ichthyomyzon unicuspis*
Chestnut lamprey	*I. castaneus*
Lake sturgeon	*Acipenser fulvescens*
Shovelnose sturgeon	*Scaphryhncus platoryhncus*
Paddlefish	*Polyodon spathula*
Alligator gar	*Atractosteus spatula*
Shortnose gar	*Lepisosteus platostomus*
Skipjack herring	*Alosa chrysochloris*
Threadfin shad	*Dorosoma petenense*
American eel	*Anguilla rostrata*
Mooneye	*Hiodon alosoides*
Goldeye	*Hiodon tergisus*
Silver chub	*Macrhybopsis storeriana*
Gravel chub	*Erimystax x-punctata*
Speckled chub	*Extrarius aestivalis*
Emerald shiner	*Notropis atherinoides*
Silverband shiner	*N. shumardi*
Spottail shiner	*N. hudsonius*
Mimic shiner	*N. volucellus*
Channel shiner	*N. wickliffi*
Mississippi silvery minnow	*Hybognathus nuchalis*
River chub	*Nocomis micropogon*
Bullhead minnow	*Pimephales vigilax*
Blue sucker	*Cycleptus elongatus*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*I. cyprinellus*
Black buffalo	*I. niger*
Channel catfish	*Ictalurus punctatus*
Blue catfish	*I. furcatus*
Flathead catfish	*Pylodictis olivaris*
Burbot	*Lota lota*
White bass	*Morone chrysops*
Yellow bass	*M. mississippiensis*
Sauger	*Stizostedion canadense*
Walleye	*S. vitreum*
Crystal darter	*Crystallaria asprella*
Eastern sand darter	*Ammocrypta pellucida*
Western sand darter	*A. clara*
Channel darter	*Percina copelandi*
River darter	*P. shumardi*
Freshwater drum	*Aplodinotus grunniens*

important predator in Great Rivers and are one of the most highly sought sport fish. We have modified Karr *et al.*'s metric to include the black basses for great rivers, as did Simon and Lyons (1995) for large rivers. Although the black basses are managed by many resource agencies, often this is in smaller interior rivers and streams. The harvest of black basses as a result of angling tournaments or excessive fishing pressure may require further study to determine if 'real' impacts to the fish community occur. Situations in which an unusually high number of black basses are found (presumably because of stocking) at a site may require the biologist to use best professional judgement in scoring this metric. If expected or representative length range differences are not observed, but rather all are small individuals, then scoring modification procedures may be required. However, as this metric is based on only the presence or

Table III. Great river species identified as tolerant to a wide variety of perturbations for the upper Ohio River

Common name	Scientific name
Longnose gar	*Lepisosteus osseus*
Shortnose gar	*L. platostomus*
Gizzard shad	*Dorosoma cepedianum*
Central mudminnow	*Umbra limi*
Carp	*Cyprinus carpio*
Goldfish	*Carassius auratus*
Red shiner	*Cyprinella lutrensis*
Golden shiner	*Notemigonus crysoleucas*
Bluntnose minnow	*Pimephales notatus*
Fathead minnow	*P. promelas*
Blacknose dace	*Rhinichthys atratulus*
Creek chub	*Semotilus atromaculatus*
River carpsucker	*Carpiodes cyprinus*
Quillback	*C. carpio*
Smallmouth buffalo	*Ictiobus bubalus*
Bigmouth buffalo	*I. cyprinellus*
White sucker	*Catostomus commersoni*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Yellow bullhead	*Ameiurus natalis*
Brown bullhead	*A. melas*
Eastern banded killifish	*Fundulus diaphanus diaphanus*
Freshwater drum	*Aplodinotus grunniens*
White bass	*Morone chrysops*
Green sunfish	*Lepomis cyanellus*

absence of black basses and sunfish, this is not considered to be a significant concern. An increase in centrarchid species indicates an increase in biological integrity.

Number of sensitive species. Only species that are highly intolerant to a variety of disturbances are termed sensitive to detect responses to diverse types of perturbations (Karr *et al.*, 1986). Karr *et al.* (1986) suggest that the number of species categorized as sensitive should be less than 10% of the entire fauna. The disappearance of intolerant species is correlated with increased agriculture and urban development. The rich historical record of Ohio River fish enabled the categorization of species into various sensitivity guilds (Pearson and Pearson, 1989). This historical record facilitated the accurate placement of species based on trends in species decline consistent with that of other workers. Sensitive species include common intolerant species, uncommon or geographically restricted species, and rare or possibly extirpated species.

Number of tolerant species. This metric replaces the proportion of green sunfish *Lepomis cyanellus* (Karr, 1981). Green sunfish are numerically dominant in creeks and small rivers, making them poor indicators for great river habitat. Instead, we have evaluated representative species of great river communities to compile a list of species which responded to degradation in a similar manner to green sunfish in streams. We classified tolerant species on the following criteria: their presence at poor or fair sites, historical increase in abundance and increased tolerance to degraded conditions (Table III). Taxa such as gar (*Lepisosteus* and *Atractosteus*), shad (*Dorosoma*), buffalo (*Ictiobus*), carpsuckers (*Carpiodes*), white sucker (*Catostomus commersoni*), flathead (*Pylodictis olivaris*) and channel catfish (*Ictalurus punctatus*) are representative of degraded thermal and physical habitat regimes (Gammon, 1983). We have also kept those species we considered tolerant from stream and wadable rivers as these species act as opportunistic species when a great river site is degraded. Tolerant species from wadable stream and river sites include taxa such as central mudminnow (*Umbra limi*), bluntnose minnow (*Pimephales notatus*), fathead minnow (*P. promelas*), bullheads (*Ameiurus* sp.) and creek chub (*Semotilus atromaculatus*). These species cumulatively accomplish the same purpose as the green sunfish metric intended.

Percentage simple lithophilous spawning fish. The original IBI included a metric which documented the proportion of hybrids at a site. Hybrids were thought to increase at degraded sites because behavioural and ecological mechanisms of species segregation were disrupted. However, this metric has been the most difficult to implement as accurate identification of various combinations of certain species, i.e. minnows, sunfish and darters, are compromised. Instead, as a replacement we chose a reproductive guild metric to replace the percentage hybrid metric. The percentage of simple lithophilous spawning fish responds to habitat alterations from siltation and substrate modification. The percentage simple lithophilous spawning fish are reduced with decreases in interstitial pore space (Berkman and Rabeni, 1987).

Percentage insectivores. Community assessment requires the determination of trophic dynamics between all species. Leonard and Orth (1986) indicated that species such as *Semotilus atromaculatus* and blacknose dace *Rhinichthys atratulus* are environmentally plastic and should not be considered insectivores, as diet breadth shifts occur under stressful conditions. The metric should reflect increases in the proportion of insectivores with increases in biological integrity.

The remaining metrics were unchanged and follow Karr *et al.* (1986) (Table I).

Percentage carnivores. Karr (1981) developed the carnivore metric to measure community integrity in the upper trophic levels of the fish community. Opportunistic species, such as channel catfish and creek chubs, were not included in the original IBI nor in this version's metric. Carnivores rely exclusively on fish or a combination of other animals (e.g. crayfish and frogs) in their diet. The presence of top level carnivores indicates a balanced and stable community.

Percentage omnivores. Omnivores are defined as individuals which eat significant amounts of plant and animal material and have the ability, usually indicated by the presence of a long, coiled gut and dark peritoneum, to utilize both (Karr *et al.*, 1986; Goldstein *et al.*, 1994). Species such as central mudminnow, bluntnose and fathead minnows, white sucker, carpsucker and buffalo (see under scoring modifications) represent this trophic state. An increase in the percentage omnivores is caused by decreases in biological integrity.

Catch per unit effort. Catch per unit of effort (CPUE, number of fish per 1000 m) was used as an index of fish relative abundance. A high CPUE is associated with warm, nutrient-enriched agricultural streams (Steedman, 1988); a low CPUE is associated with toxic influences and degraded urban streams. To determine if nutrient or toxic stressors are influencing the calibration of the catch per unit of effort metric, other metrics (e.g. the total number of species, percentage omnivores, number of sensitive species) can be simultaneously evaluated to observe whether these metrics are increasing or declining. This metric showed a large amount of variation as a result of point and non-point source influences on the Ohio River (Figures 2 and 3). Special scoring procedures were utilized (e.g. assign a score of '1') when less than 100 individual fish were collected, as proportional metrics are particularly affected by disruptions in the expected catch.

Percentage of individuals with disease, eroded fins, lesions and tumours (DELT). Only external, easily observable conditions of individual fish are noted for this metric. DELT anomalies include deformities, pus-producing lesions, tumours and eroded fins. We did not include parasitic diseases, such as black spot, or protozoan infections in this version of the great river IBI. Based on information presented by Steedman (1991), the parasitic black spot is only reflective of snail presence. Whittier *et al.* (1987) found no correlation between Ohio stream quality and black spot. Additional parasitic diseases have not been linked with degraded environmental quality. Anomalies are either absent or occur at very low rates naturally, but reach higher percentages at impacted sites (Mills *et al.*, 1966; Berra and Au, 1981). To evaluate the incidence of DELT in great rivers we have chosen to only evaluate fish greater than 200 mm total length (TL). Thus the percentages may reflect much higher proportions of DELT than originally demonstrated in small streams and rivers. Species smaller than 200 mm TL are typically short-lived and

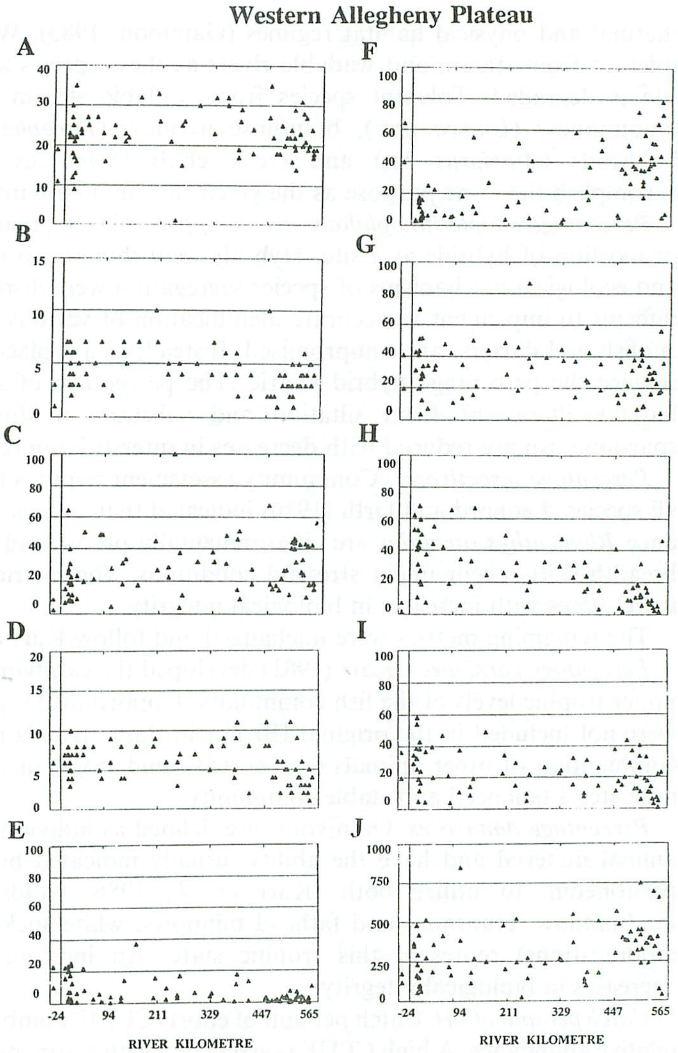

Figure 2. Attributes of the Western Allegheny Plateau ecoregion of the upper Ohio River fish fauna based on night electrofishing from 1990 to 1993. (A) Number of species; (B) number of centrarchid species; (C) percentage large river faunal group; (D) number of sensitive species; (E) percentage round-bodied suckers; (F) percentage omnivores; (G) percentage insectivores; (H) percentage carnivores; (I) percentage simple lithophils; and (J) catch per unit of effort

do not have adequate time to exhibit deleterious disease affects. Increased DELT has been correlated with the lowest levels of biological integrity.

Scoring the IBI metrics: scoring modifications

We calibrated the great river IBI using monitoring data from sites with drainage areas greater than 19 150 km^2 from the upper Ohio River in the Western Allegheny Plateau (Table IV). However, we recognized that samples with low catch can cause scoring problems in some of the proportional metrics unless adjustments are made to reduce selective biasing of degraded sites (Yoder and Rankin, 1995). Anthropomorphic change can cause a disruption in the food base and result in the capture of few individuals. At such low population levels the normal structure of the community is unpredictable and may cause overrating of the index score (Yoder and Rankin, 1995).

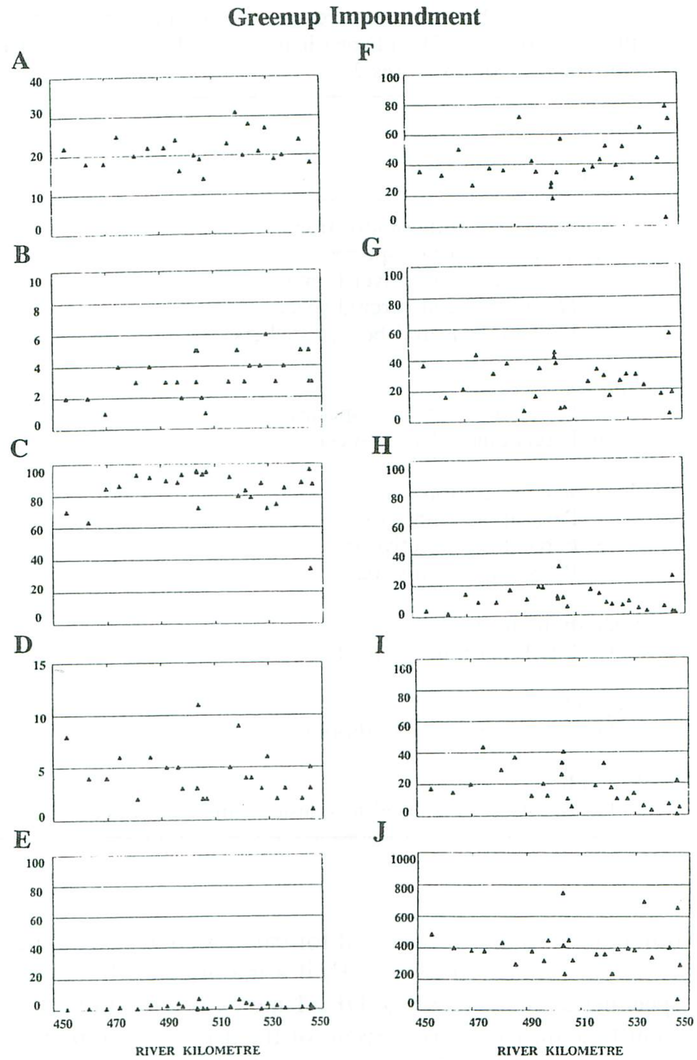

Figure 3. Attributes of the Greenup impoundment fish fauna based on night electrofishing from 1990 to 1993. (A) Number of species; (B) number of centrarchid species; (C) percentage large river faunal group; (D) number of sensitive species; (E) percentage round-bodied suckers; (F) percentage omnivores; (G) percentage insectivores; (H) percentage carnivores; (I) percentage simple lithophils; and (J) catch per unit of effort

The proportional metrics including omnivores, insectivores, carnivores, simple lithophils, DELT and large river faunal group are all systematically scored a '1' when less than 100 individuals are collected at a single great river site. We analysed the proportional metrics including and excluding gizzard shad. Gizzard shad are a schooling species, thus when encountered they are distributed in clumps and in large numbers in the environment. The exclusion of gizzard shad is necessary at all times to reduce inherent variation in the proportion metrics caused by the swamping effect of young of the year clupeids (Figures 4 and 5). By excluding gizzard shad from the analysis more subtle differences from the remainder of the community become more apparent. Professional judgement can be used in giving a site a score of '1' for the omnivore metric if the sample is dominated (>50%) by young of the year generalist feeders. If adult striped shiner, common shiner or spotfin shiner dominate, species which can sometimes act as omnivores, then the insectivore metric can be reduced (scored a '1'). The proportion of simple lithophils rarely deviates from predicted expectations, even without modifying the score; however, a site should routinely receive a score of '1'. Typically, ontogenetic niche shift

Table IV. Calibrated great river index of biotic integrity for the Ohio River drainage of the Western Allegheny Plateau ecoregion. Data beneath associated IBI scores (1–5) are based on a trisection of the information graphically presented in Figures 2–5

Metric	IBI Score		
Metric	1	2	3
Species richness and composition			
1. Total number of species	⩽10	11–20	⩾21
2. Percentage large river faunal group	<26	26·1–53·3	>53·4
3. Number of centrarchid species	⩽2	3–5	⩾6
4. Percentage round-bodied suckers	<13·3	13·3–26·6	>26·7
Species tolerance			
5. Number of sensitive species	⩽3	4–7	>7
6. Percentage tolerant species	>33·3	16·7–33·3	>16·7
Trophic composition			
7. Percentage omnivores	>13·3	6·7–13·3	<6·7
8. Percentage insectivores	<20	20–40	>40
9. Percentage carnivores	<20	20–40	>40
Fish abundance			
10. Catch per unit of effort	<250	251–500	>500
Reproductive guild			
11. Percentage simple lithophils	<20	20–40	>40
Individual condition			
12. Deformities, eroded fins, lesions and tumours (DELT)	<3	1–3	>1

differences are not recognized for categorizing the trophic position of carnivores. The proportion of carnivores can be scored lower ('1') if a majority of the carnivores collected from a site are young of the year specimens. The percentage DELT metric is scored lower ('1') for samples dominated by young fish as sufficient time may not have arisen for the fish to develop anomalies. We have suggested that specimens greater than 200 mm TL are the only individuals that should be assessed for the DELT metric. After sampling at over 5000 stream sites in Indiana, few encounters of minnows, darters and other short-lived species have shown significant effects from DELT anomalies (T. Simon, pers. obs.).

Watershed characteristics

We evaluated the appropriate spatial scales for assessing great river water resource patterns using our Great River IBI for individual impoundments and ecoregion scales (Figures 2–5). The Western Allegheny Plateau ecoregion contains 15 impoundments, which were sampled and evaluated for variance in specific reference condition patterns for each impoundment. The effect of drainage area (all sites were greater than 3226 km^2) was not statistically significant (mixed model ANOVA, $p<0{\cdot}05$) among the 15 impoundments of the upper Ohio River. The position of sites within the Western Allegheny Plateau did not correlate with differences in IBI potential as Osborne *et al.* (1992) found for headwater streams in Illinois, i.e. further downstream sites did not score higher in IBI assessments. Rather, cyclical IBI patterns were sometimes observed based on position within the three impoundment zones. The highest biological integrity was usually associated with the riverine zone and was usually lowest in the artificial lacustrine zone. Typically in streams, metrics often change with increasing drainage area; however, we did not see any correlation between increasing drainage area and metric characteristics. River kilometres in themselves do not reflect anthropomorphic influence, i.e. downstream movement does not always produce a reduction in biological

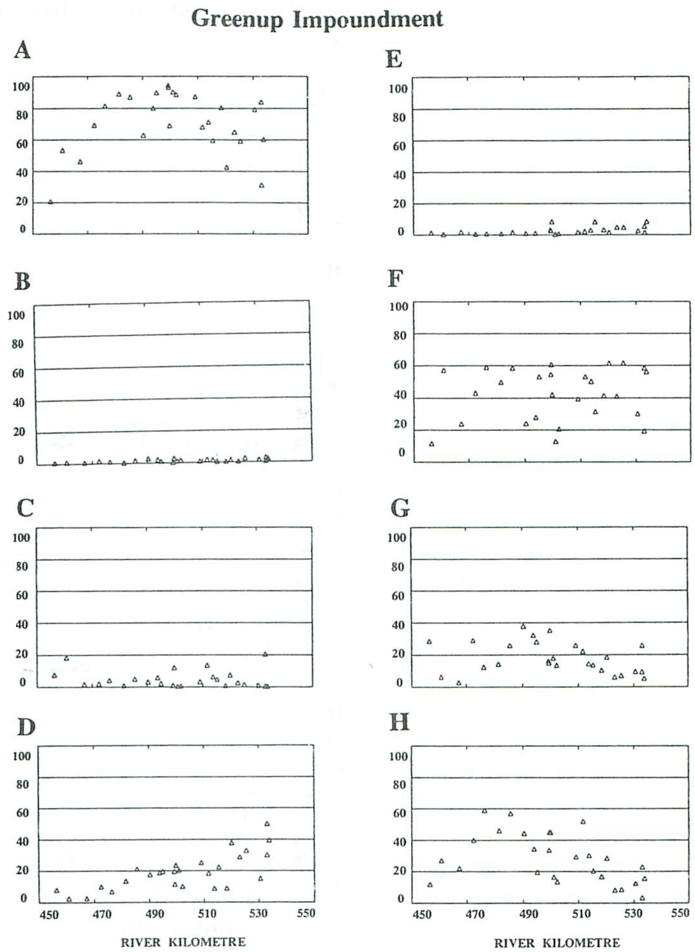

Figure 4. Proportional metrics adjusted to reflect deletion of gizzard shad for the Greenup impoundment of the upper Ohio River based on the same information contained in Figure 3. (A) Percentage large river faunal group; (B) percentage round-bodied suckers; (C) percentage sensitive species; (D) percentage tolerant species; (E) percentage omnivores; (F) percentage insectivores; (G) percentage carnivores; and (H) percentage simple lithophilous spawning fish

integrity. However, the modifications of the Ohio River from a natural flowing system to a series of impoundments are seen in the reduction of the IBI scores.

The relative contribution of proportional metrics excluding gizzard shad significantly reduced the variance of the individual metrics (Figure 4). The metrics which significantly improved included percentage omnivores, percentage large river faunal group and percentage carnivores. Metrics relatively unchanged by the exclusion of gizzard shad included percentage insectivores, percentage simple lithophils and percentage tolerant species. The percentage tolerant species and insectivores both exhibited a wide variance either with or without gizzard shad. This is caused by environmental changes as a result of either enrichment or toxic contributions disrupting the balance of the community. The percentage simple lithophils has been significantly affected in the entire Ohio River. This breeding guild has been reduced in abundance by the construction of the navigation dams on the river, prohibiting migration of many species and increasing silt catchment in the impoundments.

We completed an intensive survey of the Greenup impoundment (river kilometres 450–547), which provided an unique opportunity to study more detailed changes in metric response with anthropomorphic change. Biological integrity was the highest in the riverine zone below the upstream Gallipolis dam (river

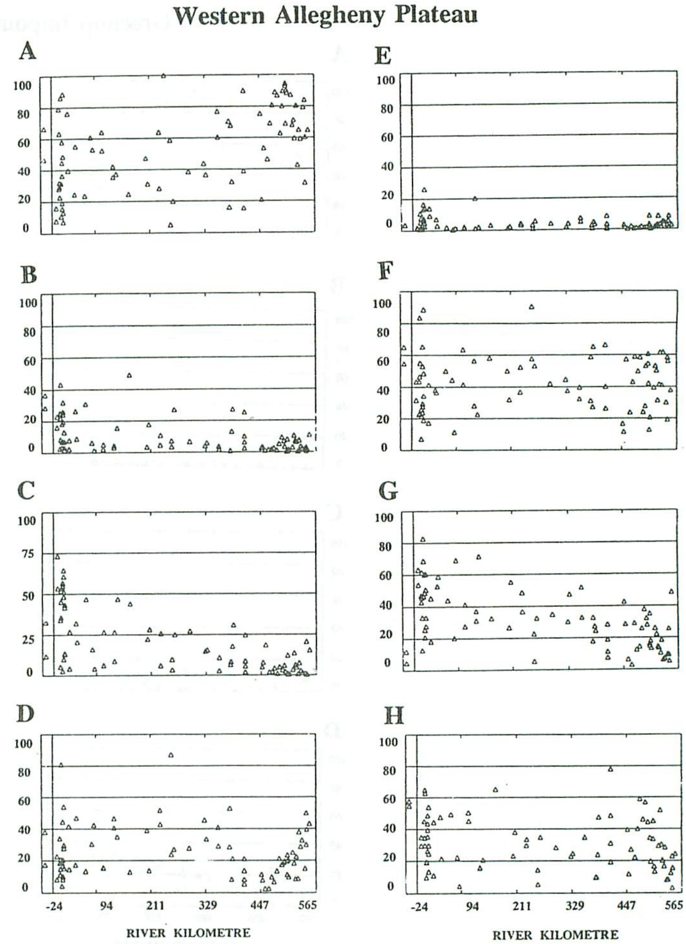

Figure 5. Proportional metrics adjusted to reflect deletion of gizzard shad for the Western Allegheny Plateau ecoregion of the upper Ohio River based on the same information contained in Figure 2. (A) Percentage large river faunal group; (B) percentage round-bodied suckers; (C) percentage sensitive species; (D) percentage tolerant species; (E) percentage omnivores; (F) percentage insectivores; (G) percentage carnivores; and (H) percentage simple lithophilous spawning fish

kilometre 450) and reflected the various impacts associated within the impoundment (Figure 6). Nutrient inputs, toxicity related to effluent discharges and habitat destruction from channel maintenance, construction activities and dredging greatly affect the potential 'reference condition' developed for the individual impoundment. The intensive sampling design showed that biological integrity declined near the lacustrine zone upstream of the Greenup dam (river kilometre 547). Although we suggest that it is critical to evaluate potential metric criteria performance on an impoundment specific basis, we do not recommend the development of reference conditions from individual small watershed areas. As metrics did not differ with increasing drainage area within the Western Allegheny Plateau ecoregion, we suggest that the assimilation of upstream drainage area and affects are interpreted in the great river IBI. The potential anthropogenic effects caused within a particular impoundment will reduce the comparability of impoundments if reference conditions are developed separately, regardless of habitat quality or associated impacts.

We evaluated patterns in metric performance using the Greenup impoundment data set and tested for significance (mixed model ANOVA, $p < 0{\cdot}05$) for the remaining 15 impoundments. Species richness and composition and reproductive guild metrics showed statistically significant results between riverine and lacustrine zones. Stanford *et al.* (1988) indicated that hydrological equilibrium is attained below dams as energy is balanced along the river continuum. Riverine zone sites possessed the highest number of sensitive

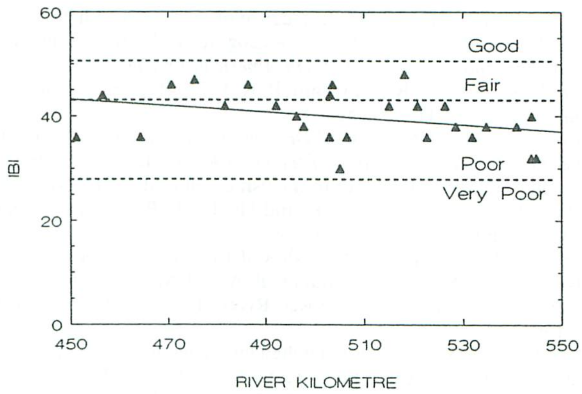

Figure 6. Longitudinal trends in the Greenup impoundment depicting associated IBI values from the upstream riverine zone (river kilometre 450) to positions downstream in the lacustrine zone at Greenup dam (river kilometre 550). The declining trend is shown by the oblique line

species and higher proportions of simple lithophils compared with the reservoir portion of the same impoundment. Likewise, lacustrine zone habitat was significantly different from riverine zones possessing higher species richness, highest number of centrarchid species, higher proportions of tolerant species and higher proportions of omnivores. Transitional zone sites differed significantly only in the single metric, proportion of round-bodied suckers. The proportion of large river faunal group, catch per unit effort, proportion of insectivores and percentage carnivores did not differ significantly within the three impoundment zones.

The current study demonstrates that the original IBI metrics developed for wadable creeks and small rivers (Karr, 1981; Karr *et al.*, 1986) need modification for the assessment of great rivers. The revised metrics used to construct the great river IBI are sensitive to anthropogenic changes associated with impoundment, channelization, dredging, siltation and industrial and municipal dischargers. Some scoring modification and treatment of data are necessary to reveal subtle differences, which may be masked by the presence of large numbers of clustered young of the year. A few of the modifications include: (1) exclusion of gizzard shad from data analysis to prevent data bias; (2) proportional metrics need to be systematically scored '1' (lowest individual metric score) if less than 100 individual fish are collected; and (3) DELT anomalies should only be analysed for specimens greater than 200 mm TL to avoid biasing data for those species either not long-lived or not exposed for sufficient duration to develop deformities, eroded fins, lesions or tumours. Biological reference condition expectations need to be developed within a regional framework and metric performance tested on an individual impoundment basis.

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