USE OF A PRELIMINARY INDEX OF BIOTIC INTEGRITY IN URBAN STREAMS AROUND ATLANTA, GEORGIA

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Abstract. Data from 44 fish assemblage surveys conducted by the U. S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program at 21 stream sites in the vicinity of Metropolitan Atlanta were analyzed to develop a preliminary Index of Biotic Integrity (IBI) for second- to fourth-order streams of the upper Chattahoochee River basin. Thirteen metrics commonly used in IBIs were evaluated by comparing observed responses in the NAWQA data along a gradient of urbanization to expected responses based on the findings of other IBI studies. The urbanization gradient was determined by Principal Components Analysis (PCA) of water and sediment chemistry data. PCA axis 1 scores, which accounted for 55.3 percent of the variance in the data, were strongly positively correlated with human population density ($r^2 = 0.64, p = 0.003$). Eight metrics were selected for inclusion in the preliminary IBI: percentage of 1) gravel-dwellers, 2) benthic invertivores, 3) generalized feeders, and 4) non-native fishes; 5) number of native sucker and 6) minnow species; 7) native species diversity; and 8) identity of, or the dominant nest-associate cyprinid. A ninth sensitive metric, the percentage of tolerant individuals, was omitted from the IBI because it was autocorrelated with the percentage of non-native fishes.

INTRODUCTION

The Index of Biotic Integrity (IBI) (Karr, 1981) has been suggested as a technique to assess the biological integrity of streams. This tool was originally developed to assess the biological integrity of small streams in the Midwest and has since been modified to assess streams in other regions (Fausch *et al.*, 1984; Karr *et al.*, 1986; Miller *et al.*, 1988; Minns *et al.*, 1994). This method of assessment is performed by sampling assemblages or communities (i.e. fishes or invertebrates) and independently scoring several variables (or metrics) that describe the structure, function, and condition of those assemblages (for example, the percentage of generalized feeders). Scores of the individual metrics are determined by comparison with expectations derived from unimpacted or least-impacted reference conditions. The scores of each metric are then summed to provide a measure of the biological integrity or "health" of a system as compared to reference conditions.

The data described herein were collected as part of the U. S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program. The goal of the NAWQA investigation was to assess biological, chemical, and physical aspects of water quality as a function of land-use practices, which entailed collecting a unique combination of chemical and biological data in watersheds representing a gradient of human influence. In the upper Chattahoochee River basin, the focus of the NAWQA investigation was the influence of urban land use on water quality. Although the data discussed herein were not originally intended for the development of an IBI, by using data from sites that span a spectrum of human impact, chemical and biological patterns can be detected, and from those patterns a preliminary IBI can be created that is applicable to the upper Chattahoochee River basin.

This paper presents a preliminary IBI for use in evaluating stream quality in second- to fourth-order streams draining watersheds in the upper Chattahoochee River basin near Metropolitan Atlanta. Other objectives of this paper are to discuss the limitations of this IBI, and to identify future modifications that might be made pending calibration.

SURVEY METHODS AND SITE DESCRIPTION

Fish assemblages were surveyed using a combination of electrofishing and seining techniques (Meador *et al.,* 1993). Between November 1993 and October 1994, fish assemblages were surveyed one to four times in 21 second- to fourth-order tributaries of the upper Chattahoochee River within the Piedmont of northern Georgia (44 samples total). Most sites were chosen in urban or urbanizing watersheds and were largely influenced by nonpoint-source as opposed to point-source inputs (Table 1). Two watersheds, Snake Creek and Flat Shoals Creek, drain primarily forested watersheds and for the purposes of this study represent least impacted sites in the region.

Water chemistry samples were collected during a two-week period by the NAWQA program in June 1993 at a subset of 11 of the 21 study sites. Each site was sampled once during a two-week period for specific conductance, total nitrogen, and total phosphorus. Concentrations of Co, Cr, Ni, Hg, As, Pb, Cd, Zn, and Ag (all Environmental Protection Agency priority metals) (Callahan *et al.,* 1979) were measured in bed sediments in August and September 1993 and also were included in the analysis (Table 2).

IBI DEVELOPMENT

Thirteen metrics that have been previously included in other IBIs (Fausch *et al.*, 1984; Karr *et al.*, 1986; Miller *et al.*, 1988; Minns *et al.*, 1994) were tested for inclusion in the upper Chattahoochee River basin IBI (Table 3). The metrics were evaluated for applicability following four steps as follows. First, Principal Components Analysis (PCA) was performed on

Table 1. Watershed characteristics and final IBI scores for the 21 sites surveyed by the USGS NAWQA program. Numbers in parentheses indicate range in IBI scores for sites where more than one survey was conducted.

Site Name	USGS station ID	1990 population density (people/km^2)	Watershed type	Drainage area above site (km^2)	Average IBI score (range)
Flat Shoals Creek	02339965	4	forest	113	34.7 (34-36)
Ivy Creek Tributary	02334812	13	urbanizing	5	28
Snake Creek	02337500	29	forest	90	37.0 (36-38)
Sweetwater Creek	02336795	59	urbanizing	108	30
Big Creek at State Route 29	02335580	96	urbanizing	92	26
Ivy Creek	02334814	122	urbanizing	48	26
Suwanee Creek	02334865	151	urbanizing	105	28
Big Creek Near Roswell	02335760	218	urbanizing	263	20
Suwanee Creek at Woodward Mill Road	02334740	254	urbanizing	33	30
Noses Creek	02336968	381	urban	112	24
Kelly Mill Branch	02335535	475	urban	8	24
Willeo Creek	02335790	605	urban	41	25.3 (22-28)
Nancy Creek	02336380	769	urban	87	16
Olley Creek	02336986	777	urban	35	24
Sope Creek	02335870	800	urban	78	28.5 (28-30)
Sewell Mill Creek	02335868	824	urban	28	28.0 (28-28)
Nickajack Creek	02336610	876	urban	53	28.0 (24-32)
Utoy Creek	02336728	914	urban	86	8.7 (8-10)
Rottenwood Creek	02335910	1,050	urban	47	14.0 (12-16)
Peachtree Creek	02336300	1,252	urban	217	13.5 (12-16)
Proctor Creek	02336529	1,585	urban	48	8.7 (8-10)

chemical data collected at 11 of the 21 sites for which data were available (12 variables total, PCA with varimax rotation). The purpose of the PCA was to determine a single variable (the first principal component) that explained the majority of variation in chemistry and contaminants between the eleven sites (Table 2). Habitat data were not included in the analysis because they did not help to distinguish among sites when included in the PCA (DeVivo, 1996).

Second, linear regression analysis was performed between site scores along the first PCA axis and several variables that characterize human watershed use (population density, percent impervious surface, percent forested land use) to determine which single watershed-scale variable best explained the majority of chemical variation between the sites. The variable best correlated with PCA scores was population density (r^2 = 0.64, p = 0.003), and this variable was assumed to represent a gradient of chemical watershed disturbance associated with urban land use across all 21 sites where fishes were surveyed. Although habitat variables were not used in determining that human population density correlated well with watershed disturbance, the metrics tested also respond similarly to habitat degradation and therefore reflect both physical and chemical effects on biological water quality (Karr *et al.,* 1986).

Third, human population density was then used to qualitatively assess which of the 13 metrics were sensitive across the gradient of watershed disturbance. This evaluation was performed by comparing observed responses based on the NAWQA data to expected responses as reported in other IBI studies. In the fourth step, those metrics that were (a) sensitive across the human influence gradient, and (b) not autocorrelated with other metrics, were selected for inclusion in the final IBI and scores were assigned to those metrics.

Metric Selection

Of the thirteen metrics evaluated, nine were sensitive to watershed disturbance (i.e. the observed and expected responses agreed) and four were insensitive (Table 3). Eight metrics were selected for inclusion in the preliminary IBI. Of the eight metrics, four describe assemblage structure, three describe assemblage function, and one describes abundance of non-native fishes. The ninth metric (percentage of tolerant individuals) was

Table 2. Proportion of the variation explained by PCA Axes 1 through 3 and significant factor loadings of variables along those axes.

Variable	PCA Axis 1	PCA Axis 2	PCA Axis 3
Specific conductance	0.95180		
Total phosphorus	0.84950		
Total nitrogen	0.72160		
Lead	0.96137		
Silver	0.93735		
Cadmium	0.82526		
Mercury	0.81073		
Arsenic	0.80171		
Chromium		0.90328	
Nickel		0.72516	
Zinc			0.83997
Cobalt			0.75956
Percentage of variation explained by axis	**55.3**	**17.8**	**10.1**

omitted because it was autocorrelated with the percentage of non-native individuals, and the environmental parameter to which fishes were described as tolerant was inconsistent among taxa.

Three cyprinids—bandfin shiners (*Luxilus zonistius*), yellowfin shiners (*Notropis lutipinnis*), and red shiners (*Cyprinella lutrensis*)—of the upper Chattahoochee River basin follow a specialized reproductive behavior: nest association. These fishes hide their eggs in gravel nests built by stonerollers, chubs, sunfishes, and the largemouth bass (for a review, see DeVivo, 1996). The assemblage function metric pertaining to the most abundant native nest associate fish species was not specifically correlated with population density, rather the dominant species within this group changed with increasing population density.

Metric Scoring

With the exception of the "nest associate cyprinid" metric, scoring for each metric (5, 3, or 1) was determined by trisecting the entire range of data (Table 4) (Karr, 1996). The data were trisected without compensating for differences in stream order (e.g. Miller *et al.,* 1988) because fish communities were similar across all the streams evaluated. Karr's (1996) alternate method of metric scoring was chosen because no true reference streams were surveyed in this study. Although two sites in primarily forested (least impacted) watersheds were surveyed by the NAWQA program, the absence of certain cyprinid and sucker species suggests that these sites are not appropriate as reference systems. True reference streams may no longer exist in the Piedmont physiographic province of the upper Chattahoochee River basin.

Although the number of native nest-associate cyprinids decreased with increased watershed development, scores for this metric are determined by the most abundant nest-associate taxon (Table 4). The bandfin shiner is endemic to the system and was the most abundant of these fishes in the least-developed watersheds. Yellowfin shiners are common throughout the upper Chattahoochee River basin and were most abundant in watersheds of intermediate development. Sites with the highest human population often were dominated by the introduced red shiner or were lacking nest-associate fishes altogether.

Table 3. Expected and observed responses of metrics across a gradient of human population density. Metrics denoted with (**) were judged to be sensitive.

Metric	Expected response to disturbance	Observed response
Assemblage Structure		
Number of native taxa	decrease	no trend
Number of individuals	decrease	no trend
**Brillouin diversity index score for native species	decrease	decreased
**Number of native catostomid species	decrease	decreased
**Number of native cyprinid species	decrease	decreased
Number of native *Lepomis* species	decrease	no trend
**Proportion of non-native individuals	increase	increased
**Proportion of gravel-dwelling fishes	decrease	decreased
Assemblage Function		
**Proportion of generalized feeders	increase	increased
**Proportion of benthic invertivores	decrease	decreased
**Dominant native nest associate fishes	decrease	faunal shift
Fish Abundance and Condition		
Proportion of fishes with lesions or parasites	increase	no trend
**Proportion of tolerant individuals	increase	increased

Table 4. Scoring criteria for metrics included in the IBI. Individual metric scores (5, 3, or 1) are determined based on the sampled fauna within each of the structural or functional groups.

Metric	Score criteria		
	5	3	1
Most abundant nest associate cyprinid	*L. zonistius*	*N. lutipinnis*	*C. lutrensis* or none
Gravel-dwellers	>56%	28-56%	<28%
Benthic invertivores	>28%	14-28%	<14%
Generalized feeders	<42%	42-69%	>69%
Brillouin diversity index score for native species	>1.8	1.8-1.2	<1.2
Non-native fishes	<20%	20-40%	>40%
Number of native sucker species	3 or more	1-2	0
Number of native minnow species	7 or more	3-6	1-2

Final IBI Scores

Final IBI scores ranged from 8 to 38 out of a total possible 40 (Figure 1), and were inversely related to human population density. A large degree of temporal variation can be seen around this trend as within-site scores varied by as much as eight points among samples (Table 1). Urban sites had the highest among-sample variance; forested sites only varied by as much as two points (Table 1; Figure 1).

Based on total IBI scores, streams are categorized as either very poor, poor, fair, good, or excellent (Figure 1). Karr (1991) described streams with excellent biotic integrity as those "comparable to the best situations without human disturbance [that include] all regionally expected species for the habitat and stream size, including the most intolerant forms." The two forested sites were the least impacted sites surveyed and were considered reference sites, but neither of these sites received an "excellent" rating. Scores at these sites were either "good" or intermediate between good and excellent ("good to excellent"); all other sites received lesser ratings. Should true reference sites be located, recalibration of the scoring categories will be necessary to fit those sites into the "excellent" category.

DISCUSSION

The utility of the IBI lies in (a) its flexibility because it can be modified to better reflect regional faunas, and (b) its incorporation of multiple metrics reflecting assemblage structure and function, abundance and condition. The preliminary IBI suggested for second- to fourth- order tributaries of the Chattahoochee River around Metropolitan Atlanta has two qualities that make it extremely valuable for immediate use.

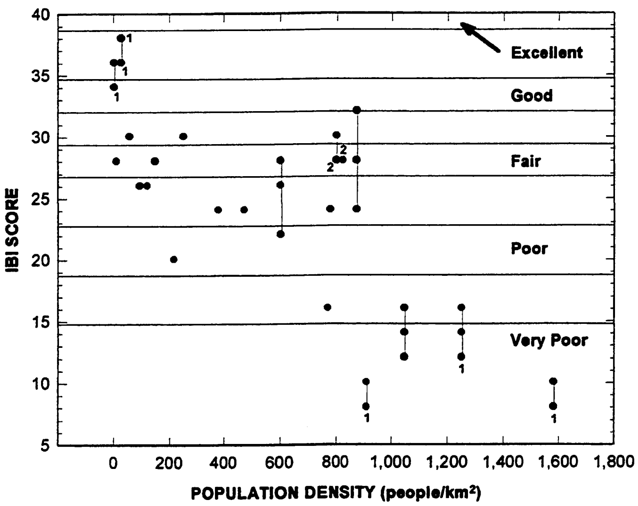

Figure 1. Final IBI scores for streams surveyed by the USGS NAWQA program. Points connected by vertical lines represent multiple surveys from the same location. Numbers indicate quantity of hidden data points.

First, it should be sensitive to multiple types of environmental degradation because it is balanced between four metrics describing assemblage structure, three describing function, and one describing abundance. Second, it is easily applicable to other streams within the upper Chattahoochee River basin whose major influences are not urban-related (such as streams draining watersheds with high poultry-agriculture production), because (a) the fauna is similar, and (b) although the disturbance is different, the selected metrics have been shown to be sensitive across gradients of both physical and chemical degradation (Fausch *et al.,* 1984; Karr *et al.,* 1986; Miller *et al.,* 1988; Minns *et al.*, 1994).

A large degree of variation in IBI scores is seen both within and among sites, particularly in the more urbanized watersheds. This however, is not inconsistent with Fausch *et al.*'s (1990) prediction that environmental degradation increases temporal variation in fish assemblage composition. IBI scores at these sites might therefore be reflecting assemblage instability as a result of watershed development. Replicated surveys should be conducted in less-developed, urbanizing watersheds to verify that temporal variation is in fact a result of environmental quality and not an artifact of sampling error or the IBI itself. With the exception of Nickajack Creek, biotic integrity classification was relatively consistent among samples (Table 1).

Because this IBI is designed based on a relatively small number of sampling locations, it needs to be verified (and possibly modified) as more data become available. The large within-site variation is a potential weakness of this IBI, however the variation likely is a function of environmental quality, as larger temporal variation would be expected in disturbed sites (Fausch *et al.,* 1990). Rescoring of current metrics and the inclusion of metrics that currently seem insensitive pending these additional samples should lower within-site variation in overall IBI scores. At present, the proposed IBI is an exploratory tool that can be immediately implemented to assess the relative biotic integrity of second- to fourth-order tributaries of the Chattahoochee River around Metropolitan Atlanta and to identify those sites with the greatest need for rehabilitation.

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