IEPA ATTACHMENT NO. U

Interpreting Illinois Fish-IBI Scores,

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Illinois Environmental Protection Agency

Bureau of Water

Surface Water Section

Definition of biotic integrity

Biotic integrity is the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region (Frey 1975; Karr and Dudley 1981).

The essence of an IBI score

An IBI score represents how much the biotic integrity (in terms of fish metrics) differs at a site from a benchmark set of biological conditions (in terms of the same fish metrics) that reflect a known level of biotic integrity. For Illinois fish IBIs, we define these benchmark conditions--often called "reference conditions"--as the biological conditions expected in Illinois streams least disturbed by human impacts. Therefore, the degree to which an IBI score deviates from the score that best represents the typical reference conditions reflects the relative amount of human impact (i.e., loss of integrity) additional to that already represented by the reference conditions.

How many different levels of biotic integrity can be distinguished?

An Illinois fish-IBI score can range from 0 to 60 in increments of one unit; however, sixty different levels of biotic integrity cannot be distinguished. Earlier versions of Illinois fish IBIs recognized five distinct integrity classes, each defined by a subrange of the maximum possible range (12 - 60) of IBI scores (Karr et al. 1986; Table 1).

Table 1. Integrity classes, each represented by a subrange of Illinois fish-IBI scores (from Karr et al. 1986).		
IBI Score	Integrity Class	Attributes
58 - 60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age (size) classes; balanced trophic structure
48 - 52	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress
40 - 44	Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, and highly skewed trophic structure; older age classes of top predators may be rare.
28 - 34	Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
12 - 22	Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.

The ability to distinguish among various levels of biotic integrity can be determined objectively by examining the precision of an IBI. For example, for an IBI that has a maximum possible scoring range from 0 to 100 and a precision of 10% (i.e., ± 5 points), one could reasonably expect to be able to distinguish among ten integrity classes. Several studies have shown that the among-year and within-year precision of fish IBIs can range from about 5% to 30% (Steedman 1988; Fore et al. 1994: based on mean of three IBI scores per site; Mebane et al. 2003), with a central tendency of about 10% (Lyons 1992; Hughes et al. 1998) to 15% (Karr et al. 1987; Yoder and Rankin 1995).

We have only preliminarily determined the precision of the new Illinois fish IBIs. Ideally, determining the precision of the Illinois fish IBIs requires repeated sampling (through time and across space) at a set of locations that reflect the entire range of possible IBI scores and stream-sampling situations throughout Illinois. Additionally, to determine how much IBI-score variability is attributable to factors other than human impact, the repeated samples collected per location must occur over a period of time or interval of space in which no meaningful change in the level of human impact has occurred. Variability in IBI scores attributable to among-year variation could be quantified by sampling each site in at least two consecutive years. Variability in IBI scores attributable to within-year variation could be quantified by sampling each site at least twice in the same sampling season, but separated enough in time to limit the effect of the first sampling bout on subsequent ones. Preliminary information from a limited set of repeatedly sampled Illinois stream sites indicates about 17% precision (i.e., $\pm$ 5 points) in the new fish IBIs (Holtrop and Dolan 2003). Based on this preliminary estimate—which is consistent with the results of aforementioned studies—any Illinois IBI-score difference of ten or less should not be interpreted as a meaningful difference in biotic integrity. Consequently, using an Illinois fish IBI, one can expect to be able to distinguish among, at most, six integrity classes. Given that more analysis is needed to examine the variability of Illinois fish IBIs and to test the ability to distinguish consistently among biotic-integrity classes, we conservatively suggest five preliminary integrity classes.

How does one divide the possible range of IBI scores into five integrity classes?

No definitive rules exist for dividing an IBI-score range into subranges that each represents an integrity class. Illinois fish IBIs were originally divided into five uneven classes with scoring gaps between each class (Table 1; Karr et al. 1986); however, Karr et al. (1986) did not provide explicit rationales for establishing these scoring subranges. To define integrity classes, some IBIs simply have been divided into equal subranges. For example, Barbour et al. (1996) divided into fourths the entire possible range of scores for a multimetric macroinvertebrate index developed for Florida streams. The upper fourth of the scoring range was considered "Very Good" integrity, the lower fourth was considered "Very Poor", and the middle was divided into "Good" and "Poor" classes.

More recently, Barbour et al. (1999) recommended, "Because the metrics are normalized to reference conditions and expectations for the stream classes, any decision on subdivision should reflect the distribution of the scores for the reference sites." Several IBI developments are consistent with this recommendation; they define integrity classes--each represented by a corresponding scoring subrange--that are based on particular percentile values of the distribution of IBI scores in a set of reference-condition biological samples. For interpreting a macroinvertebrate IBI in Wyoming streams, Jessup and Stribling (2002) used the 25th percentile of IBI scores of reference samples as the threshold between "Good" and "Fair" integrity classes. The IBI subrange above the 25th-percentile threshold was divided into two equal parts to indicate "Good" and "Very Good" integrity classes. The subrange below the 25th percentile was divided into three equal parts to yield "Fair", "Poor", and "Very Poor" classes. For a fish IBI (Davis and Scott 2000) and a macroinvertebrate IBI (Klemm et al. 2003) in mid-Atlantic highland streams, developers also used the 25th percentile of reference-condition scores as the threshold between "Good" and "Fair" integrity classes. They used the subrange below the 5th

percentile (Davis and Scott 2000) or the 1st percentile (Klemm et al. 2003) of reference-condition scores to define a third integrity class, "Poor". Ohio EPA (1988; Yoder and Rankin 1995) used the 25th percentile of reference-condition scores as the threshold between "Good" and "Fair" integrity classes; scores above the 75th percentile represented an "Exceptional" class.

We use a similar approach for defining biotic-integrity classes based on Illinois fish-IBI scores. We use the approximate 25th and 75th percentile values of IBI scores of least-disturbed samples to guide the delimiting of integrity classes. We divide the range of IBI scores below the 25th percentile (i.e., IBI=45) of least-disturbed samples equally into three integrity classes. The range above the 25th percentile is divided into two integrity classes at another threshold slightly above the 75th percentile value of IBI scores (Figure 1).

[[insert Figure 1]]

Interpreting an Illinois fish-IBI score

Simply defining the scoring subrange of each biotic-integrity class does not provide an interpretation of the meaning of each class. Using IBI scores to guide sound resource-management, conservation, and regulatory decisions requires knowledge and understanding of the environmental setting reflected by an IBI score, and ultimately, of the degree to which the reference conditions--on which all IBI scores are based--reflect an absolute level of biotic integrity. Because an Illinois IBI score simply reflects the *relative* amount of deviation from the level of integrity expected in Illinois environmental settings least disturbed by human impact, understanding the meaning of the IBI score that best represents Illinois reference (i.e., least-disturbed) conditions provides the necessary basis for interpreting all other scores.

Based on the infroamtion used in this study, an Illinois fish-IBI score of 50 represents the level of integrity that best reflects least-disturbed conditions in Illinois; 50 is the median score for the set of least-disturbed samples used. However, this score does not represent necessarily an exceptionally high, absolute level of biotic integrity. Rather, it merely represents the level of integrity occuring in the chemical, physical, and biological conditions considered as least-disturbed (by human impacts) during the period in which the fish samples used to develop the IBIs were collected: 1982 through 1998. Because no undisturbed streams existed in Illinois during this period, these biological reference conditions already reflect some human impact to the watersheds, streams, and fish assemblages throughout the state. Consequently, the degree to which an IBI score deviates below 50 reflects the relative amount of human impact *additional to* that already represented by the reference conditions.

Additional to the need for understanding the absolute level of biotic integrity represented by the reference conditions used to develop an IBI, valid interpretation of an IBI score requires an understanding--albeit imperfect--of the range of environmental conditions that the index can possibly reflect.

If an Illinois-IBI score of 50 (i.e., reflecting the typical least-disturbed conditions) does not necessarily reflect an exceptionally high, absolute level of biotic integrity, then where--along the continuum of biotic integrity from 0% to 100%--does an Illinois fish-IBI score of 50 fit? We know of no quantitative, completely objective procedure to answer this question, much like there is no definitive way to show how far a person is from being 100% healthy or to determine the maximum allowable ambient concentration of cadmium that ensures 100% protection of aquatic life. Nonetheless, although we cannot perfectly quantify biotic integrity from 0% to 100%, we can use a quantitative measure of biotic integrity (e.g., an IBI score) to distinguish consistently among various, less-extreme levels of integrity.

We describe each integrity class in terms of the changes (i.e., deviation from the reference conditions) in the fish metrics with increasing human impact (Table 2; Figures 5 and 6). These changes are relative, providing limited information about the absolute level of biotic integrity represented by an IBI score. To aid the interpretation of Illinois fish-IBI scores, we also describe each integrity class in terms of direct measures of human impact, thus helping one understand where a relative measure of biotic integrity (an IBI score) fits along an absolute scale of biotic integrity. The chemical and physical conditions that help describe each integrity class are based on the limited set of watershed and site-specific measures that we used to rate each fish sample for disturbance (Figures 2, 3, and 4). The descriptions in Table 2 do not address all of the possible ways that humans impact the integrity of streams and their watersheds (Karr and Dudley 1981; Karr et al.

1986; Yoder and Rankin 1998), but they do provide information integral to interpreting the meaning of each of the five integrity classes. These disturbance measures serve as explicit surrogates for the degree of naturalness (Angermeier 2000), a property on which the meaning of biotic integrity directly depends (Frey 1975; Karr and Dudley 1981).

Unlike several IBI developments cited in this report, we do not label each integrity class (Figure 1; Table 2) with a term that reflects quality (e.g., Very Good, Good, Poor). By avoiding such value-laden terms, we emphasize that biotic integrity is an inherent, quantifiable property of the environment (Frey 1975; Karr and Dudley 1981; Steedman and Haider 1993; Angermeier and Karr 1994; Karr and Chu 1999; Angermeier 2000; National Research Council 2001). Intrinsically, a measure of biotic integrity reflects very little about how humans value a particular stream resource; determining the biotic integrity of a stream differs distinctly from determining the resource value (to humans) of that stream. However, because humans commonly value higher biotic integrity more than lower integrity—as reflected in the objectives of the Clean Water Act—an IBI provides one of several possible ways to help distinguish a highly valued resource from one of lesser value.

How will Illinois fish-IBI scores be used to assess attainment of Aquatic Life Use?

Since 1986 the Illinois Environmental Protection Agency has been using fish-IBI scores to help assess attainment of Aquatic Life Use in Illinois streams (Illinois EPA 1986; 2002). Most recently, two IBI-score thresholds (based on previous versions of Illinois fish IBIs) have been used to help determine one of three possible attainment outcomes: full support, partial support, or nonsupport (Figure 7). An understanding of the Clean Water Act goals and objectives relevant to aquatic life can guide the selection of IBI-score thresholds for assessing Aquatic Life Use. In this context, "full support" of Aquatic Life Use reasonably could be interpreted as meeting the Clean Water Act's interim aquatic-life goal (PL 92-500: Water Pollution Control Act Amendments of 1972). This interim goal is to achieve water quality that provides, wherever attainable, for the protection and propagation of fish, shellfish, and wildlife (Clean Water Act Section 101(a)(2)). Karr and Dudley (1981) point out some critical distinctions between this interim goal and the Clean Water Act's ultimate objective to restore and maintain the "...chemical, physical, and biological integrity of the Nation's waters..." Implicit in this objective is the maintenance of, at least, a moderate level of biotic integrity and ultimately a restoration to high levels. Consequently, a more-farsighted interpretation of "full support" of Aquatic Life Use could be the level at which (at least) moderate to high biotic integrity exists. However, because the levels of absolute biotic integrity that are actually attainable in Illinois streams remain mostly undcoumented, it seems reasonable for now to define Aquatic Life Use attainment as meeting the interim aquatic-life goal. Specifically, we set the IBI-score threshold that helps define "full support" (of Aquatic Life Use) at a level of absolute biotic integrity that reflects minimal attainment of the interim goal.

Recently, USEPA and natural-resource specialists from various states and tribes have begun to address Aquatic Life Use attainment and attainability by defining various levels of biological condition along a gradient associated with levels of human impact. To date, qualitative descriptions of biological structure and function have been adopted to define various levels of this "biological condition gradient". In turn, these descriptions have been helpful in interpreting attainment thresholds for the interim aquatic-life goal and the "biological integrity" objective of the Clean Water Act (see www.epa.gov/emap/html/pubs/docs/groupdocs/symposia/symp2002/Davies.pdf). We use a similar approach to interpret the levels of absolute biotic integrity represented by each Illinois fish-IBI integrity class (Table 2).

Based on the Illinois-IBI integrity classes defined and described in this report (Figure 1; Table 2), we suggest IBI= 40 as a threshold to help distinguish "full support" of Aquatic Life Use from lesser levels of attainment. In the context of the Clean Water Act's interim aquatic-life goal, this threshold seems reasonable; an IBI score of 40 represents the 10th percentile of scores of least-disturbed samples. This score also represents a level of biotic integrity well above the 75th percentile of IBI scores at sites representing the most-disturbed conditions evidenced in the dataset used to develop the new fish IBIs. Whereas, these most-disturbed conditions do not necessarily represent the worst possible conditions in Illinois streams, the limited set of disturbance measures do indicate levels of human impact that have been documented to adversely affect aquatic life, thus decreasing biotic integrity.

We think that explicit definition and description of the biological, chemical, and physical conditions expected to occur at various levels of biotic integrity can help clarify, standardize, and improve the reliability of some of the subjectivity necessarily involved with using IBI scores to help assess attainment of Aquatic Life Use. Subjectivity, guided by knowledge and experience, is necessary for interpreting inherently uncertain measures of the biological, chemical, and physical environment—measures on which natural-resource professionals rely to make decisions (Gregory and Keeney 2002). This subjectivity is not exclusive to interpreting and using biological measures such as an IBI score. For example, considerable uncertainty exists in using quantitative physicochemical measures as decision criteria for use attainment, including concentration thresholds used as water-quality standards (Thurston et al. 1979; Clements and Kiffney 1994; Barnett and O'Hagan 1997; Chapman et al. 1998; Hall and Giddings 2000; National Research Council 2001). Although assessments of designated uses, such as Aquatic Life Use, can never be 100% reliable, they are continually improved by collaborative and iterative development of biological indicators in the context of the chemical and physical conditions to which aquatic life responds (National Research Council 2001). Therefore, although direct measures of aquatic life (e.g., an Illinois fish-IBI score) offer a more reliable way to assess attainment of the Clean Water Act's aquatic-life goals and objectives than do traditional physicochemical comparisons, these biological measures provide only limited information if used alone. Successful interpetation and use of biological indicators requires corresponding information on the physical and chemical settings in which aquatic organisms live; in this way, biological measures, such as an Illinois fish-IBI score, complement rather than replace the utility of more-traditional physicochemical measures.

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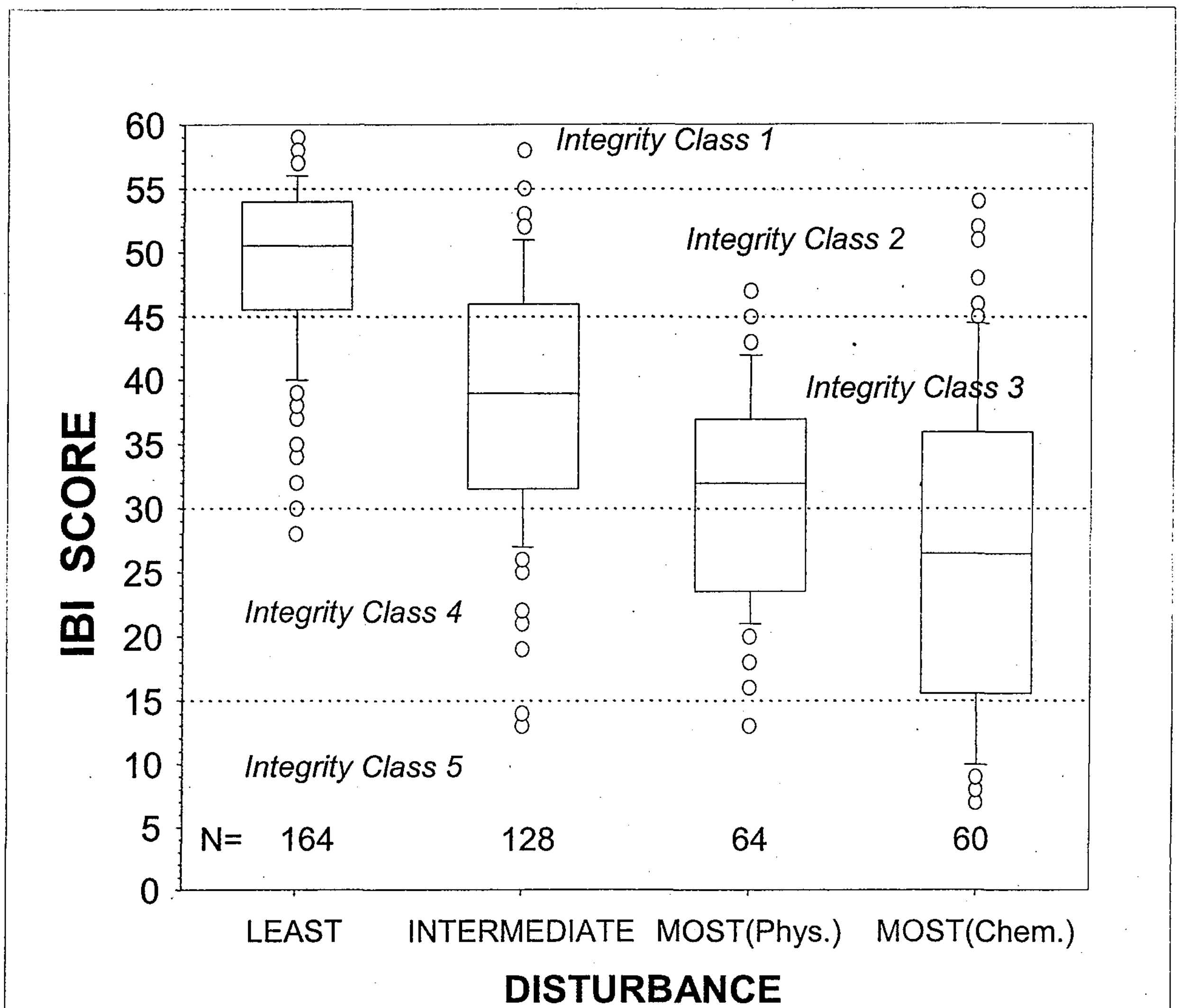

Figure 1. Boxplots of Illinois fish-IBI scores observed in least-, intermediate, or most-disturbed conditions. "MOST(Chem.)" represents samples most "chemically" disturbed, based on site-scale water and sediment physicochemical parameters. "MOST(Phys.)" represents samples most "physically" disturbed, based on various watershed measures and on site-scale measures of in-stream physical habitat. Samples rated most-disturbed for both chemical and physical measures are excluded from these boxplots. Five classes of biotic integrity are indicated by IBI-score subranges. For each boxplot, the rectangle ("box") represents the range of values from the 25th to 75th percentiles; the central half of the observed values occurs in this range. A horizontal line in each "box" indicates the 50th percentile. Vertical lines extending from each box indicate a range from the 10th to 90th percentiles, and points beyond this range represent single observations.

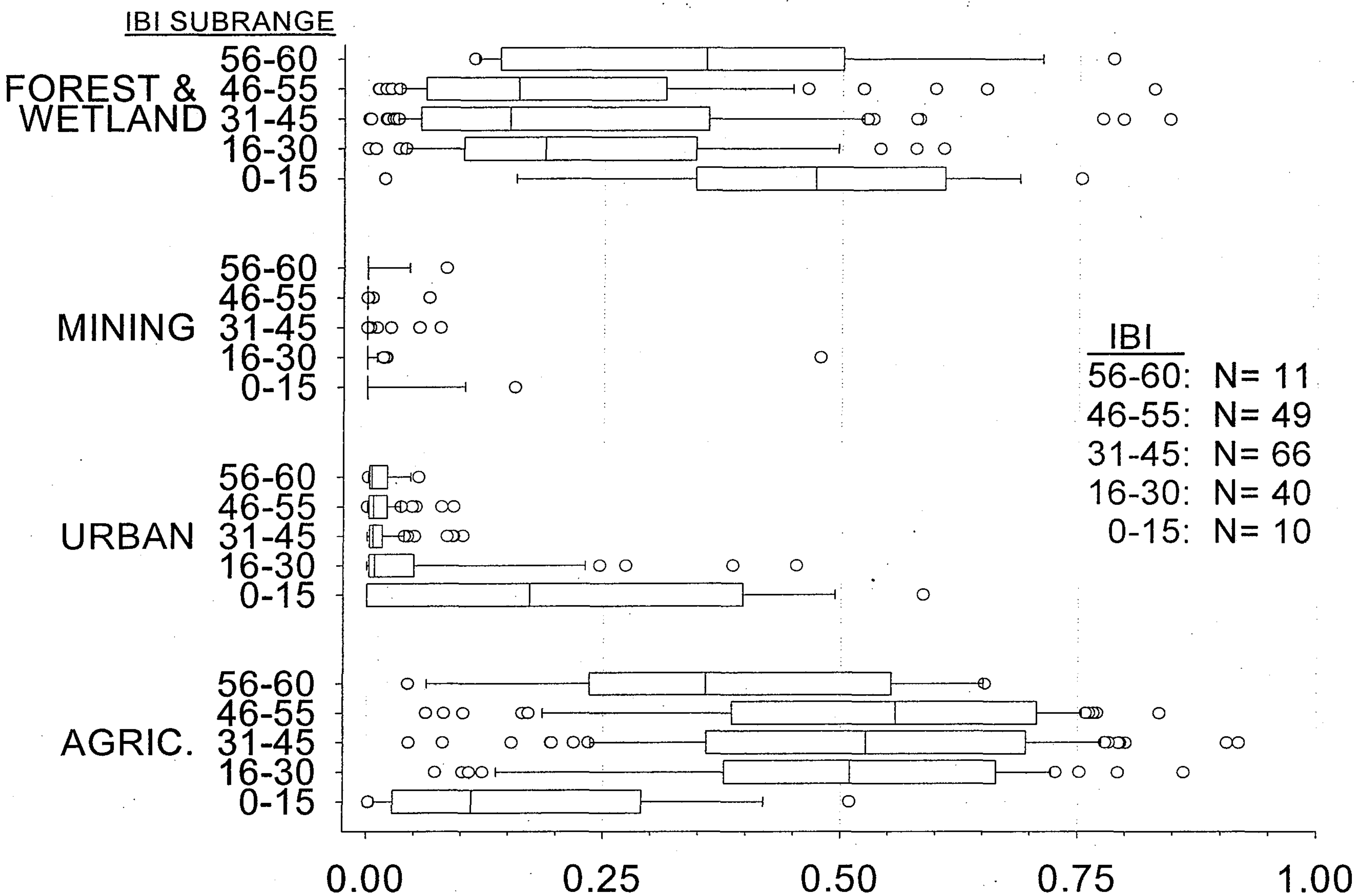

Figure 2. Boxplots of selected watershed land-use/cover measures used to rate fish samples for level of human impact (disturbance). Each boxplot represents the distribution of disturbance-measure values for fish samples (count= N) in which the IBI score is within each of five subranges (i.e., integrity classes; also see Figure 1). The GIS watershed polygons used for analyses were created before this IBI project; we did not create a watershed for each IBI site; therefore, only fish samples at sites located near the most-downstream point of each watershed are considered in these boxplots. Please see Figure 1 for further explanation of the boxplots.

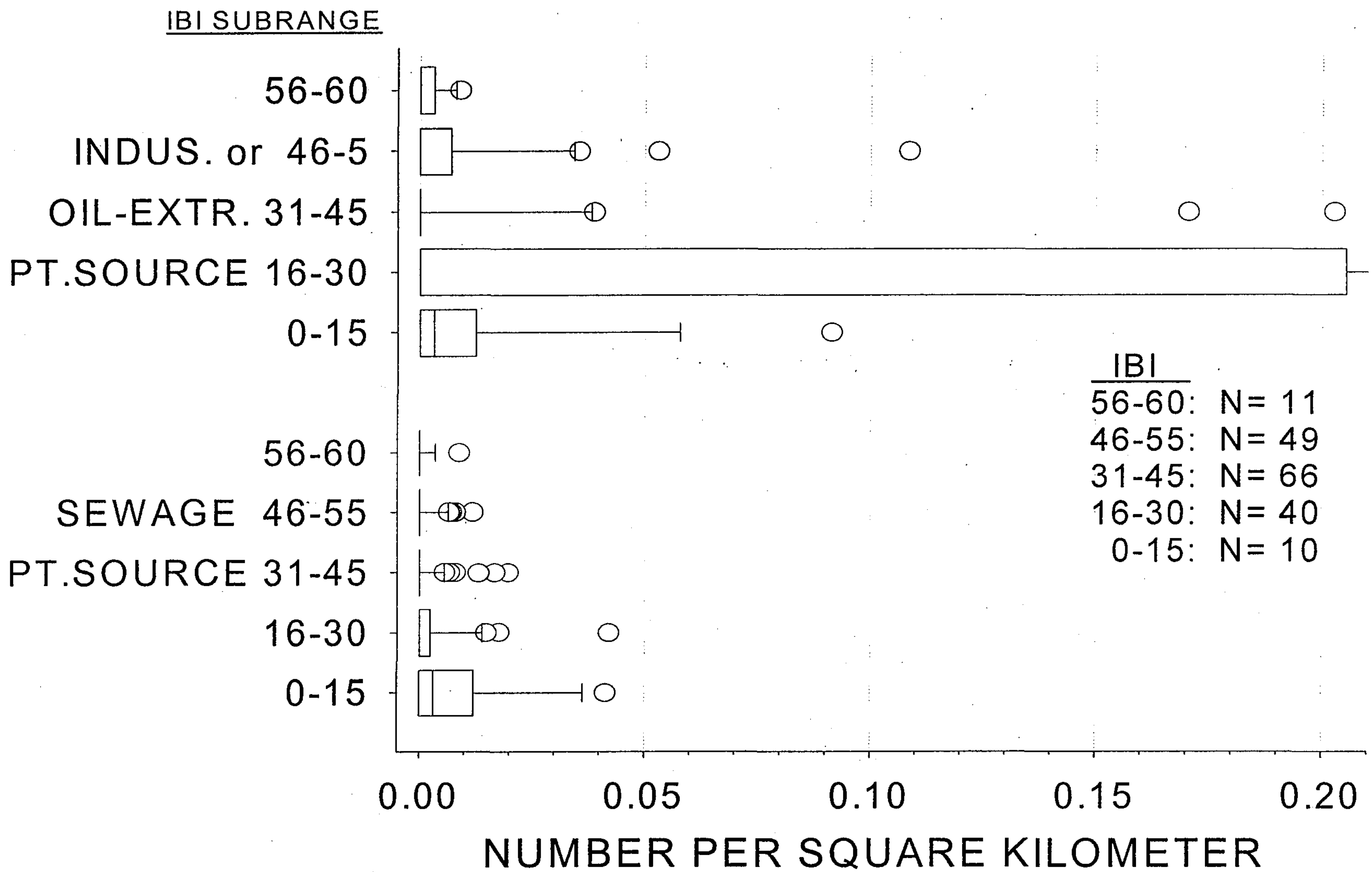

Figure 3. Boxplots of densities of selected point-source measures used to rate fish samples for level of human impact (disturbance) at the watershed scale. Each boxplot represents the distribution of disturbance-measure values for fish samples (count= N) in which the IBI score is within each of five subranges (i.e., integrity classes; also see Figure 1). Only fish samples at sites located near the most-downstream point of each watershed are considered in these boxplots. "INDUS. or OIL EXTR..." are major industrial discharges, industrial landfills, oil wells, or salt wells. "SEWAGE..." are major sewage discharges or sewage-waste landfills. To improve visual resolution at lower values, the x-axis is truncated at a density near 0.20. Please see Figure 1 for further explanation of the boxplots.

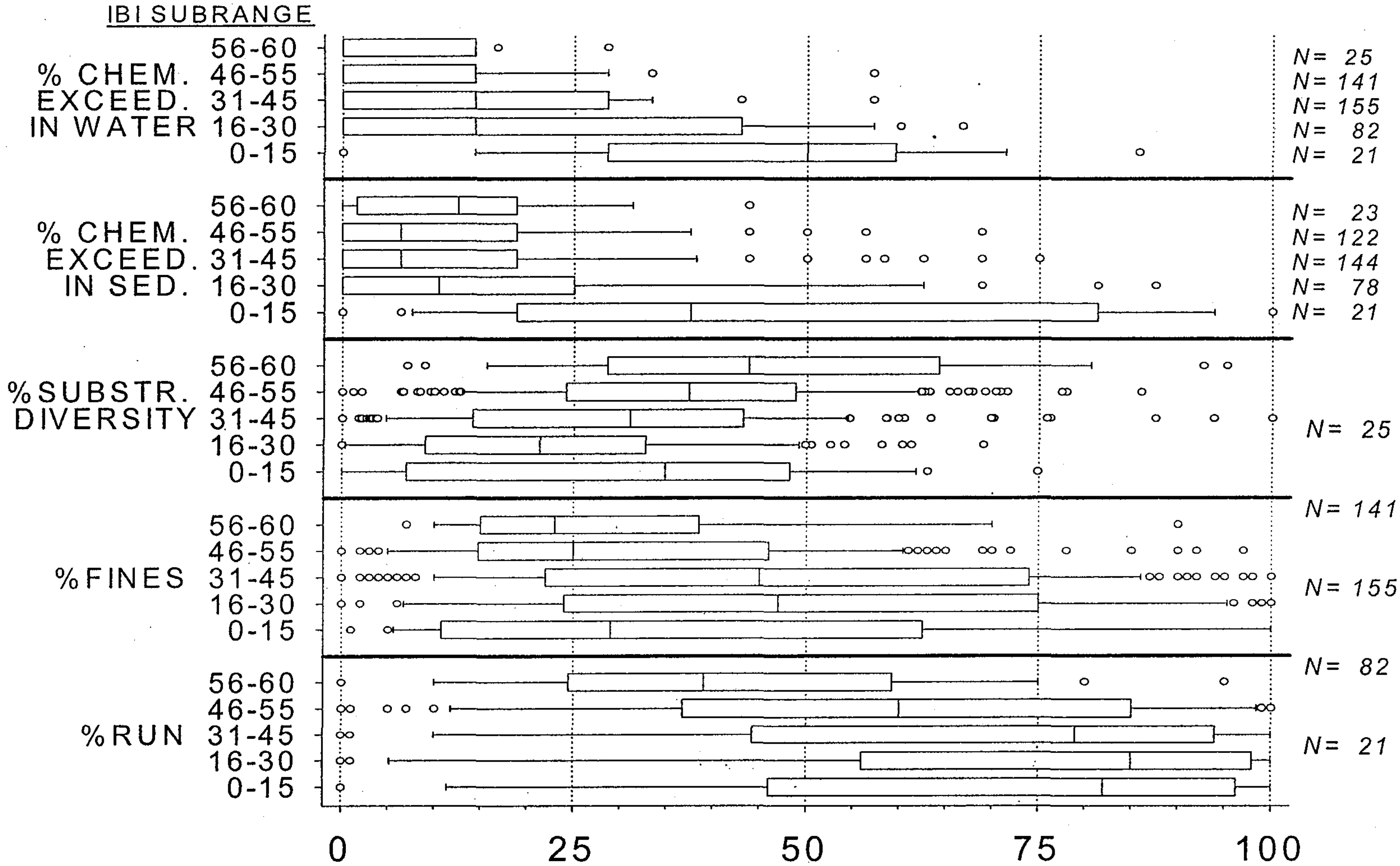

Figure 4. Boxplots of selected measures used to rate each fish sample for level of human impact (disturbance) at the site, at the time of the fish sample. Each boxplot represents the distribution of disturbance-measure values for fish samples (count= *N*) in which the IBI score is within each of five subranges (i.e., integrity classes; also see Figure 1). "%CHEM. EXCEED. IN WATER" and "%CHEM. EXCEED. IN SED." are the percent of a selected set of water or sediment parameters, respectively, at extreme levels (please see footnote in Table 2 for further explanation). Number of fish samples in each integrity class is identical for "%SUBSTR. DIVERSITY", "%FINES", and "%RUN", which are in-stream measures reflecting the composition of the stream bottom and the channel morphology. Please see Figure 1 for further explanation of the boxplots.

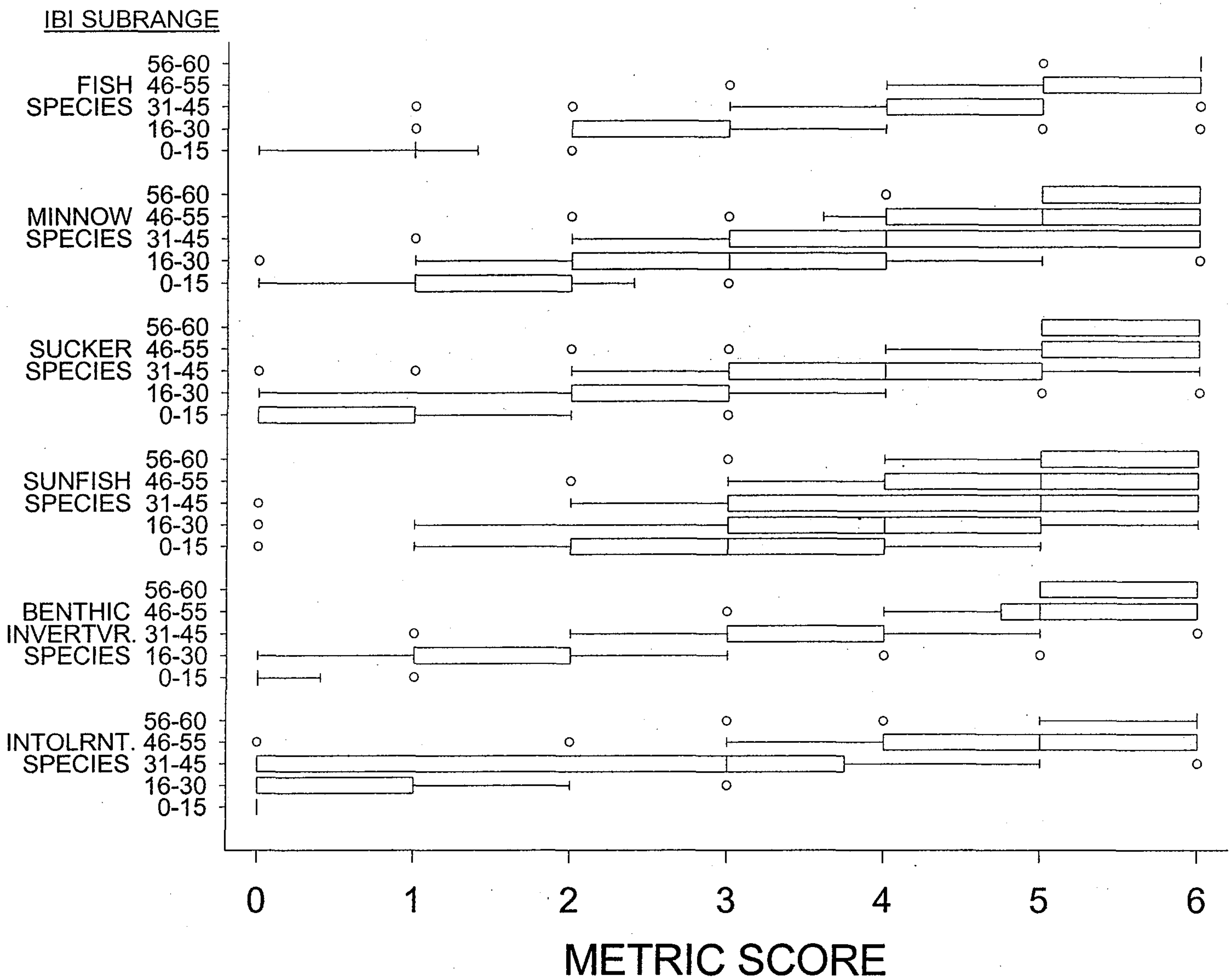

Figure 5. Boxplots of scores of taxa-richness IBI metrics. Each boxplot represents the distribution of metric-score values of fish samples in which the IBI score is within each of five subranges (i.e., integrity classes; also see Figure 1). Twenty-five (N=25) fish samples scored in the highest-integrity class (IBI=56-60). For IBI=46-55, N= 141; for IBI=31-45, N=155; for IBI=16-30, N=82; and for IBI=0-15, N=21.

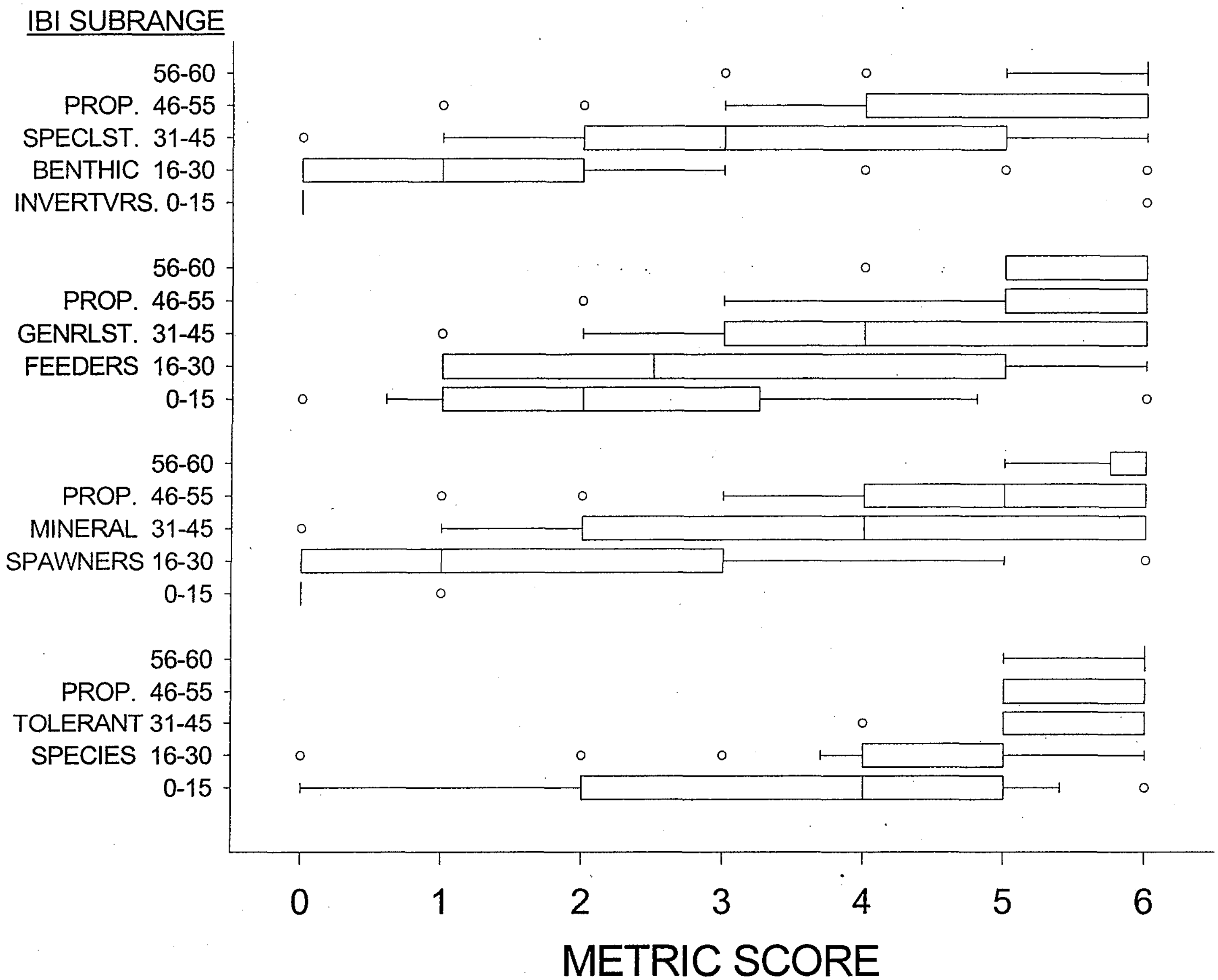

Figure 6. Boxplots of scores of proportional IBI metrics. Each boxplot represents the distribution of metric-score values of fish samples in which the IBI score is within each of five subranges (i.e., integrity classes; also see Figure 1). Twenty-five (N=25) fish samples scored in the highest-integrity class: IBI=56-60. For IBI=46-55, N= 141; for IBI=31-45, N=155; for IBI=16-30, N=82; and for IBI=0-15, N=21.

Table 2. Classes of biotic integrity for Illinois fish IBIs. Descriptions are based on conditions depicted in Figures 2 – 6; numbers of samples are provided in those figures. "Typical" conditions are defined by the interquartile range (i.e., from the 25th to 75th percentile values) of disturbance-measure values observed nearest in time, as possible, to the collection of the fish sample. Selected additional description addresses less-"typical" observations.

IBI-Score Subrange	Biotic-Integrity Class	Description of Typical Biological, Physical[1], and Chemical[2] Conditions
56 – 60	1	Biotic integrity is higher than that expected in Illinois streams that reflect the typical reference (i.e., least-disturbed) conditions. as currently defined. The number of native fish species is greater than that in streams reflecting the current, typical reference conditions primarily due to presence of intolerant species. Reproductive and trophic functional structure appear balanced. The typical physical and chemical conditions have been evidenced as follows. Watershed conditions include absence of major sewage point sources and sewage-waste landfills. Industrial point sources, oil-extraction point sources, or industrial landfills occur at 0--0.001 per square kilometer. Strip mining (post 1949) is absent (but 2 of 11 sites had 1.8% and 3.8%). Other watershed-scale impacts include 22--42% agricultural and 0.3--0.7% urban land use, in the stream corridor (240 meters centered on stream channel). From 13 to 49% forest or wetland are present in the stream corridor. At the site scale, 0--14% of physicochemical parameters in water and 0--19% of physicochemical parameters in sediment are at extremes. Channel morphology consists of 41--74% riffle or pool channel units, and 16--38% of the stream bottom consists of particles smaller than fine gravel, except for streams with naturally higher amounts of sand or clay [[provide regional exceptions here?]]. Diversity of substrate particle-size classes is 2.18—3.62 (29—64% of maximum observed; reciprocal of Simpson's D diversity index).

46 – 55	2	Biotic integrity is similar to that expected in Illinois streams that reflect the typical reference conditions, as currently defined. Relative to condtions in Integrity Class 1, the number of native fish species is reduced primarily due to loss of some intolerant species. Reduced abundances of mineral-substrate spawners indicate slight imbalance in reproductive functional structure. Trophic fiunctional structure appears balanced. The typical physical and chemical conditions have been evidenced as follows. Watershed conditions include absence of major sewage point sources and sewage-waste landfills. Industrial point sources, oil-extraction point sources, or industrial landfills occur at 0--0.007 per square kilometer. Strip mining (post 1949) is absent (but 5 of 49 sites had 0.04--6.5%) Other watershed-scale impacts include 39--71% agricultural and 0.2—2.1% urban land use, in the stream corridor (240 meters centered on stream channel). From 6 to 31% forest or wetland are present in the stream corridor. At the site scale, 0--14% of physicochemical parameters in water and 0--19% of physicochemical parameters in sediment are at extremes. Channel morphology consists of 15--63% riffle or pool channel units, and 15--46% of the stream bottom consists of particles smaller than fine gravel, except for streams with naturally higher amounts of sand or clay. Diversity of substrate particle-size classes is 2.00--3.00 (24--49% of maximum observed; reciprocal of Simpson's D diversity index).
31 - 45	3	Biotic integrity is lower than that expected in Illinois streams that reflect the typical reference conditions, as currently defined. Number of native fish species is reduced from reference conditions primarily due to further loss of intolerant species, but also due to loss of sucker species and benthic-invertivore species. Reduced abundances of specialist benthic invertivores and increased abundances of generalist feeders indicate slight to moderate imbalance in trophic functional structure. Further reduction in abundances of mineral-substrate spawners indicates moderate imbalance in reproductive functional structure. The typical physical and chemical conditions have been evidenced as follows. Watershed conditions include absence of major sewage point sources, sewage–waste landfills, industrial point sources, oil-extraction point sources, and industrial landfills. Strip mining (post 1949) is absent (but 6 of 66 sites had 0.01--7.7%). Other watershed-scale impacts include 36--70% agricultural and 0.2--1.5% urban land use, in the stream corridor (240 meters centered on stream channel). From 5 to 34% forest or wetland are present in the stream corridor. At the site scale, 0--29% of physicochemical parameters in water and 0--19% of physicochemical parameters in sediment are at extremes. Channel morphology consists of 6--56% riffle or pool channel units, and 22--74% of the stream bottom consists of particles smaller than fine gravel, except for streams with naturally higher amounts of sand or clay. Diversity of substrate particle-size classes is 1.57--2.77 (14--43% of maximum observed; reciprocal of Simpson's D diversity index).

16 - 30	4	Biotic integrity is much lower than that expected in Illinois streams that reflect the typical reference conditions, as currently defined. Number of native species is reduced further from reference condtions due to near-complete loss of intolerant species and further pronounced loss of sucker species and benthic-invertivore species. Imbalance of fish-community structure is evidenced as indiscriminate loss of species across major families (minnows, suckers, sunfish). Further reductions in abundances of specialist benthic invertivores and mineral-substrate spawners indicate moderate to extreme imbalance in trophic and reproductive functional structure. The typical physical and chemical conditions have been evidenced as follows. Watershed conditions include 0--0.002 major sewage point sources or sewage-waste landfills and 0--0.20 industrial point sources, oil-extraction point sources, or industrial landfills per square kilometer. Strip mining (post 1949) is absent (but 5 of 40 sites had 0.4--47%). Other watershed-scale impacts include 37--66% agricultural and 0.2--3.6% urban land use, in the stream corridor (240 meters centered on stream channel). From 10 to 34% forest or wetland are present in the stream corridor. At the site scale, 0--25% of physicochemical parameters in water and 0--43% of physicochemical parameters in sediment are at extremes. Channel morphology consists of 2--44% riffle or pool channel units, and 24--73% of the stream bottom consists of particles smaller than fine gravel, except for streams with naturally higher amounts of sand or clay. Diversity of substrate particle-size classes is 1.37--2.34 (9--33% of maximum observed; reciprocal of Simpson's D diversity index).
0 - 15	5	Biotic integrity is much lower than that expected in Illinois streams that reflect the typical reference conditions, as currently defined. Number of native species is reduced further due to pronounced, indiscriminate loss of species across major families (minnows, suckers, sunfish) with a concurrent increase in the proportion of tolerant species. Intolerant species are absent; benthic-invertivore species are nearly absent. Pronounced reductions in abundances of specialist benthic invertivores and mineral-substrate spawners indicate extreme imbalance in trophic and reproductive functional structure. The typical physical and chemical conditions have been evidenced as follows. Watershed conditions include 0--0.012 major sewage point sources or sewage-waste landfills and 0--0.010 industrial point sources, oil-extraction point sources, or industrial landfills per square kilometer. Strip mining (post 1949) is absent (but 2 of 10 sites had 5% and 15%). Other watershed-scale impacts include 1--25% agricultural and 0--40% urban land use, in the stream corridor (240 meters centered on stream channel). From 35 to 52% forest or wetland are present in the stream corridor. At the site scale, 29--57% of physicochemical parameters in water and 19--81% of physicochemical parameters in sediment are at extremes. Channel morphology consists of 5--52% riffle or pool channel units, and 11--62% of the stream bottom consists of particles smaller than fine gravel, except for streams with naturally higher amounts of sand or clay. Diversity of substrate particle-size classes is 1.30--2.95 (7--48% of maximum observed; reciprocal of Simpson's D diversity index).

[1] The watershed conditions of each fish sample (collected during 1982-1998) are represented by measures of land use/cover based on satellite imagery of conditions in 1991-1995, supplemented by existing statewide spatial databases (Illinois Department of Natural Resources 1996). The GIS watershed polygons used for analyses were created before this IBI project; we did not delineate a watershed for each IBI site. Thus, only fish samples at sites located near the most-downstream point of each watershed were considered in the statistical summaries of watershed-scale measures. Few samples were available to depict watershed conditions for the highest (N=11) and lowest (N=10) integrity classes; therefore, for these classes, the "typical" conditions described are merely best approximations.
"Physical" conditions at the site scale are represented by a single sample of in-stream physical habitat that was collected nearest in time as possible to each fish sample. All selected physical-habitat samples were collected during the "summer", base-flow period (approximately June through mid-October)

[2] Physicochemical conditions at sites are represented by the percent of parameters for which concentrations were extreme. For most parameters, extreme concentrations were those higher than the 85th percentile value in samples co-collected nearest in time as possible with fish, throughout the state during 1982 - 1998. For percent dissolved-oxygen saturation and pH, values outside the 15th-85th percentile range were considered "extreme". The single water and single sediment sample collected nearest in time as possible to the fish sample were selected to represent the physicochemical conditions at the site at that time. All selected physicochemical samples were collected during the "summer" , base-flow period (approximately June through mid-October). Water parameters were: total ammonia, nitrate/nitrite, total phosphorus, boron, percent dissolved-oxygen saturation, pH, conductivity, and total suspended solids. Sediment parameters were: total phosphorus, Kjeldahl nitrogen, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, zinc, percent volatile solids, total polychlorinated biphenyls, total DDT, dieldrin, and total chlordane.