Metric 6: Percent Abundance of Tolerant Species (All)

General

This metric is a modification of one of Karr's original IBI metrics, the percentage of the fish community comprised by green sunfish (Karr 1981). This metric was designed to detect a decline in stream quality from fair to poor. The green sunfish (Lepomis cyanellus) is a species that is often present in moderate numbers in many Midwest streams and can become a predominant component of the community in areas with degraded habitat and/or water quality. This ability to survive and reproduce in disturbed environments makes this species sensitive to changes in environmental quality in severely impacted areas. Although green sunfish are one of the most widely distributed and numerically abundant fish species found in the Midwest they show a decided preference towards smaller sized and low gradient streams. This limits their utility in assessing impacts in larger streams and rivers. Karr et al. (1986) suggested that other species could be substituted for the green sunfish if they respond in a similar manner, i.e., they increase as a proportion of the community in degraded environments. Several species meeting this criterion were included to give this metric an improved sensitivity for the range of stream and river sizes encountered in Ohio. Since individual species have habitat requirements that are keyed to stream size; composition of the tolerant species metric shifts with drainage area and this metric remains useful among small, medium, and large streams and rivers.

Ohio's tolerant species are listed in Table 4-4 (also see Appendix B, Table B-3). This list was based on a numerical and graphical analysis of Ohio EPA's catch data from 1978 through 1985 (Appendix B) and historical changes in the distribution of fish species throughout Ohio (Trautman 1981). Tolerant species are those that 1) are present at a substantial number of sites with original I_{wb} values <6.0 (i.e. fair and poor sites), 2) show either no decline or a historical increase in abundance or distribution (Trautman 1981), and 3) shift towards community predominance with decreasing water and habitat quality (Table 4-3; also see Appendix B).

Wading and Headwaters

Data for headwaters and wading sites were plotted and scored together for this metric (Figure 4-16). No relationship with drainage area was evident up to 10 sq. mi., but became inverse for sites greater than 10 sq. mi. Scoring criteria are given in Tables 4-5 (wading) and 4-7 (headwaters).

Boat Sites

The expected percentage of tolerant species remains constant with increases in drainage area at boat sites (Figure 4-17). Scoring criteria are given in Table 4-6.

Metric 7. Omnivore Metric (All)

General

The Ohio EPA definition of an omnivorous species follows Karr (1981) and Karr et al. (1986) with two important distinctions added. Specialized filter-feeding species which technically are omnivorous are not included. Specialist filter feeders are represented in Ohio by the paddlefish (Polyodon spathula) and brook lamprey ammocoetes. These species are generally sensitive to environmental degradation. Since the omnivore metric is designed to measure increasing levels of environmental degradation due to a disruption of the food base it is not appropriate to include these sensitive, filter feeding species in this metric. This metric was further restricted to those species that did not show feeding specialization and were reported primarily as omnivores in all studies reviewed. This removes such species as channel catfish (Ictalurus punctatus) which may or may not feed as an ominivore under different environmental conditions. Species considered as omnivores are listed in Appendix B, Table B-3.

Wading and Headwaters Sites

The effect of these restrictions limits the omnivore metric to those species that consistently feed as omnivores. Consequently, overall percentages of omnivores are different from Karr (1981) and Karr et al. (1986). To determine appropriate criteria for 5, 3, and 1 IBI scores the Ohio EPA reference sites data base was examined. Furthermore a relationship with drainage area was found for sites less than 30 sq. mi. (Fig. 4-18). Scoring criteria for the wading and headwaters sites is given in Tables 4-5 and 4-7.

Boat Sites

No relationship with drainage area was found for the proportion of omnivores at boat sites (Fig. 4-19). Scoring criteria are given in Table 4-6.

Metric 8. Proportion as Insectivores (All)

This metric is designed to be sensitive over the middle range of biotic integrity. A low abundance of insectivorous species can reflect a degradation to the insect food base of a stream (Karr et al. 1986). As disturbance increases the diversity of benthic insects decreases, production becomes more variable, and the community often becomes predominated by a few taxa (Jones et al. 1981). Thus, specialist feeders such as specialist insectivores will decrease and be replaced by generalist feeders such as omnivores. This represents a modification from Karr et al. (1986) using insectivorous Cyprinids alone.

Wading and Headwaters Sites

We differ from Karr et al. (1986) by excluding two species that are generalized and opportunistic in their feeding habits; creek chub and blacknose dace. Inclusion of these two species as insectivores in a West Virginia study resulted in a negative correlation between insectivores and the IBI (Leonard and Orth 1986), when the relationship should have been positive (Angermier and Karr 1986). Exclusion of these generalist feeders follows the reasoning of Leonard and Orth (1986) who felt that the current definitions of trophic groupings were often arbitrary. The ecological function scored by these metrics was best served by describing species as specialist (e.g. specialized insectivores) or generalist feeders (Appendix B, Table B-3).

Scoring criteria for this metric show a positive relationship with drainage area up to 30 sq. mi. for the headwaters and wading sites (Figs. 4-20). Scoring criteria are listed in Tables 4-5 and 4-7.

Boat Sites

Insectivores show no drainage area effect (Fig. 4-21) and criteria were established using the alternate trisection method.

Metric 9. Top Carnivores (Wading, Boat)
Proportion of Pioneering Species (Headwaters)

General

Karr (1981) developed the top carnivore metric to measure community integrity in the upper functional levels of the fish community. In designating a species as a top carnivore we followed Karr (1981) and Karr et al. (1986). Species which feed primarily on other vertebrates or crayfish are included in this metric (Appendix B, Table B-3). As with the omnivore metric, species which display feeding plasticity are excluded (e.g. channel catfish).

Wading Sites

Karr (1981) indicated that expectations for the proportion of top carnivores should change with drainage area. An examination of the Ohio EPA data base reveals that no relationship exists between the proportion of top carnivores and drainage area at sites greater than 20 sq. mi. An examination of the Ohio data base for wading sites yielded the same criteria as that proposed by Karr et al. (1986; Fig. 4-22; Table 4-5). No trisection method was employed in deriving the scoring criteria.

Boat Sites

No drainage area related trend was observed for boat data which displayed consistent and higher top carnivore proportions for all drainage areas (Fig. 4-23). The criteria listed in Table 4-6 were derived using best professional judgement in examining the reference sites data base. No trisection procedure was used in deriving the scoring criteria.

Headwaters

An examination of the headwaters stream data base revealed that top carnivores are virtually absent or in very low abundance at headwaters sites. A metric is needed for the headwaters sites that reflects the degree to which the community may be temporal thus reflecting the permanence of the headwater stream habitat. Smith (1979) identified certain small stream species in Illinois as "pioneering" species. These are species which are the first to reinvade sections of headwater streams that have been dessicated by prolonged periods of dry weather. These species also predominate in unstable environments that have been affected by temporal desication and/or anthropogenic stresses. Thus a high proportion of pioneering species is an indication of a habitat that is temporally not available, under stress, or both. Scoring criteria for this method are listed in Table 4-7 as determined by trisection (Fig. 4-24).

Metric 10: Number of Individuals in a Sample (All)

General

This metric assesses population abundance as the number of individuals per unit of sampling effort. This metric is most sensitive at the low to middle end of biotic integrity when polluted sites yield fewer individuals (Karr et al. 1986). In such cases the normal trophic relationships are disturbed enough to have severe effects on fish production or directly reduce fish abundance through toxic effects. As integrity increases total abundance increases and becomes more variable (Figure 4-25) with natural factors such as ionic concentration, temperature, and amount of energy reaching the stream surface. However, certain perturbations, such as channelization with canopy removal, can lead to increases in the abundance of fishes, especially tolerant species (e.g. bluntnose minnow). Thus inclusion of these species may obscure negative environmental change. To decrease the variability in scoring of this metric and to avoid rewarding disturbed sites the relative number of individuals excludes species designated as tolerant (Table 4-3).

Wading and Headwaters Sites

Drainage area affects the number of individuals at headwaters and wading sites by increasing numbers with drainage area up to just under 8 sq. mi. (Figure 4-26). This relationship became horizontal above 8 sq. mi. Because the relationship between environmental quality and abundance of individuals is not linear a log transformation of the relative number of individuals (excluding tolerant species) was performed. Strong deviations from the expected in a least impacted stream (score of "1") were determined by examining fish numbers in a series of impacted streams and rivers. For both boat and wading sites this break point was 200 individuals (per km and 300 m, respectively). This number approximated the 5% lines in Figures 4-26 and 4-27. Remaining scoring criteria ("5" and "3") were calculated by bisecting the area in between the 5% and 95% lines. This was then used to determine the appropriate IBI metric score for the wading and boat sites (Tables 4-5 and 4-7).

Boat Sites

No relationship with drainage area was found for numbers at boat sites (Fig. 4-27). A bisection between the 5% and 95% lines was used to determine the scoring criteria given in Table 4-6.

Metric 11: Proportion of Individuals as Simple Lithophilic Spawners

This metric was designed as a replacement metric for the proportion of individuals as hybrids. In Ohio streams the hybrid metric was not a consistent indication of water quality or habitat problems per its original intent. Hybrids have been observed to occur in high quality Ohio streams (e.g. minnow hybrids), can arise from sensitive parent species (e.g. longear sunfish), are often times absent from headwaters streams and severely impacted streams, and they can be difficult to identify. Although the frequency of hybridization has often been associated with habitat degradation this did not appear consistently enough in the Ohio EPA data base to distinguish this type of impact.

Spawning guilds have been shown to be affected by habitat quality (Berkman and Rabeni 1987) and have been suggested as an alternative IBI metric (Angermier and Karr 1986). Fish that exhibit simple spawning behavior and require clean gravel and/or cobble for successful reproduction (i.e. "lithophilous") appear to be the most environmentally sensitive of the spawning guilds. These simple lithophilic species broadcast their eggs which then come into contact with the bottom substrate. Eggs then develop in the interstitial spaces between sand, gravel, and cobble sized substrate particles. Berkman and Rabeni (1987) found a significant negative correlation between simple lithophilic spawners and the percentage of silt in riffles. Historically some simple lithophilic spawners have suffered population declines in Ohio, due in part to increased silt loads in streams (Trautman 1981). Some simple spawners do not require clean substrates and often have buoyant, adhesive, or fast developing eggs and photoactic larvae that have minimal contact with the substrate (Balon 1975). These are termed simple miscellaneous spawners. Fish species that exhibit a more complex spawning behavior can minimize the effects of silt and pollution by depositing their eggs away from silt on the undersurfaces of rocks (e.g. fantail darter, bluntnose and fathead minnows) or, by building nests and guarding and caring for the eggs (e.g. most sunfishes). These are termed complex with and without parental care. Designations of Ohio fish species appears in Appendix B, Table B-3.

Because of their unique sensitivity to environmental disturbances, particularly siltation, simple lithophilic species are used.

Wading and Boat Sites

No relationship with drainage area was observed at wading sites (Fig. 4-27). Thus scoring was accomplished using the alternate trisection method. Simple lithophils are a major component of the fish communities in these streams, reflecting the importance of clean gravel and cobble substrates. A partial relationship between the proportion of simple lithophilic species and drainage area was found at the boat sites (Fig. 4-28). This involved a decreasing trend at sites with drainage areas greater than 600 square miles. This is

apparently related to the increased proprtion of groups such as buffaloes, carpsuckers, gars, gizzard shad, which are classified as simple miscellaneous spawners (Balon 1975).

Headwaters Sites

The number of simple lithophilic species is used instead of the proportion of individuals for headwaters. Because headwaters are more likely to be predominated by a few species, some of which may be simple lithophils, the number of simple lithophilic species is a more consistent environmental indicator. This metric is strongly related to drainage area at headwaters sites (Fig. 4-29).

Metric 12: Proportion of Individuals With Deformities, Eroded Fins, Lesions, and Tumors - DELT (All).

General

This metric keys in on the health of individual fish within a community using the percent occurrence of external anomalies and corresponds to the percentage of diseased fish in Karr's (1981) original IBI. Studies of wild fish populations have revealed that these and other anomalies are either absent or occur at very low rates at reference sites, but reach higher percentages at impacted sites (Mills et al. 1966; Berra and Au 1981; Baumann et al. 1987). Common causes of DELT (deformities, eroded fins, lesions, and tumors) anomalies are described in Allison et al. (1977), Post (1983) and Ohio EPA 1987a and include the effects of bacterial, viral, fungal, and parasitic infections, neoplastic diseases, and chemicals. An increase in the frequency of occurrence of these anomalies is generally an indication of stress and environmental degradation which may be caused by chemical pollutants, overcrowding, improper diet, excessive siltation, and other disturbances. Blackspot is not included because the presence and varying degrees of infestion may be natural and not related to environmental degradation (Allison et al. 1977; Berra and Au 1981). Also, analysis of Ohio data has shown no clear relationship between black spot and stream degradation (Whittier et al. 1987). Other parasites are also excluded due to the lack of a consistent relationship with environmental degradation although their effects can resemble and lead to tumors, deformities, and lesions. Prior to using this metric, Ohio EPA (1987a) should be referred to for consistent data recording procedures and as a reference for specific anomalies included in each category.

In Ohio, the highest incidence of DELT anomalies occurs in fish communities downstream from discharges of industrial and municipal wastewater, and areas subjected to the intermittent stresses from combined sewers and urban runoff. Leonard and Orth (1986) found that this metric showed consistent and marked responses between increasing incidence of anomalies and increasing stream degradation. Karr et al. (1986) report that the primary range of sensitivity for this metric is the low end of the IBI. We have also observed this metric to function well in situations where structural measures (i.e. species richness, numbers, biomass) indicate improving conditions. For example, modified Iwb scores indicative of near complete recovery in the Scioto River downstream from Columbus were accompanied by DELT values greater than 3%. This observation shows that subacute stresses are present and that recovery is not as complete as the structural measures alone indicate. Thus this metric can also represent the intermediate to high range of fish community sensitivity to environmental stress.

Wading and Boat Sites

Both the scoring method and criteria for this metric differs from Karr et al. (1986) and was developed by analyzing wading and boat method data from

reference sites sampled in Ohio between 1983 and 1986. For wading sites, the median DELT anomalies was rounded to 0.1% for the highest expected score (between 5 and 3) and the 90th percentile value (1.3%) was used for determining the criteria between 3 and 1. For boat sites, the median DELT anomalies was 1.06% and the 90th percentile was 4.6%. A criteria of 0.5% was chosen for distinguishing between 5 and 3 and the 75th percentile (3.0%) was used for the criterion strongly deviating from the expected (between 3 and 1). We found that one fish would exceed the 0.5% criteria when the sample size contains less than 200 fish. One fish with a DELT anomaly would be accepted at a "5" site and two fish at a "3" site, so these criteria are used when a relative abundance of less than 200 fish is recorded.

Headwaters Sites

The same criteria used for the wading sites are also used for headwaters sites (Table 4-7).

Calculation and Interpretation of IBI Scores

Karr et al. (1986) describes eight steps for the logical sequence of IBI calculation (Table 4-8). Step 1, developing expectation criteria for each metric, has been completed using reference site data from across Ohio. Step 3, assigning species to trophic guilds, and Step 4, identification of intolerant species, is also complete (see Appendix B, Table B-3). The following description of Step 2 and Steps 5-8 cover hand calculation of IBI scores. Computer generation of IBI scores, with appropriate cautions, is discussed later.

Step 2 consists of tabulating a list of species (in taxonomic order) captured in a survey and tallying in columns the relative number of each species at each site. Trophic guilds and intolerance status for Ohio fish species are listed in Appendix B, Table B-3.

In Step 5, the biological information needed for each metric is summarized in a worksheet similar that in Table 4-9 compiled for the Hocking River. Actual values (e.g., number of darter species) should be placed in the parentheses. It works best to use separate sheets for each different sampling method application (i.e. wading sites vs. headwaters sites, boat sites vs. wading sites, etc.) because each have different scoring criteria. The drainage area of each site should also be listed (see Appendix E).

Step 6 involves rating each metric for each site sampled. Criteria are found in Tables 4-5, 4-6, and 4-7 and in the individual figures for the five metrics that vary with drainage area. The scoring is arranged so that a "5" approximates what is expected at a reference site, a "3" deviates somewhat from, and a "1" strongly deviates from that expected at an applicable reference site. Care should be taken so that wading sites, boat sites, and headwaters sites samples are scored separately. In severely impacted streams with less than 200 individuals per 0.3 km (wading sites, headwaters sites) or per 1.0 km (boat sites), some of the conventions for scoring the proportional metrics (except for percent tolerant species) are altered following the guidance in Appendix B.

Step 7 is simply the summing of the twelve metric scores for each site. The maximum score possible is 60 (no perturbation); the minimum score, where all metrics deviate strongly from that expected at an applicable reference site, is 12 (extremely degraded).

Step 8 consists of assigning integrity classes to the scores that reflect a general qualitative summary of the community that non-professionals can understand and that are used to determine whether a stream is meeting its assigned use designation. This is discussed in Section 6, "Derivation of Biological Criteria". The procedure used to assign these categories in Ohio streams, which differs somewhat from the classes suggested by Karr et al. (1986), is discussed in this section.

Extremely Few Numbers ("Low-end Scoring")

Samples with extremely low numbers in the catch can present a scoring problem in some of the proportional metrics unless certain adjustments are made. Aquatic habitats that are severely impacted by strong perturbations (e.g. toxic substances, acid mine drainage) usually have a severe disruption of the food base and very low numbers of individuals. At such low population sizes the normal structure of the community is unpredictably altered. The proportion of omnivores, insectivorous fishes, and percent affected by anomalies do not always match expected trends in such situations. Although these metrics would be expected to deviate strongly from the expected in such areas (i.e. score a 1) this is not always the case. In fact the absence or low proportion of these metrics results in metric scores that reflect the opposite of the overall situation.

Scoring very degraded sites without modifying scoring criteria for the proportional metrics can overrate the total IBI score for these sites. To remedy this situation we examined data from known impacted sites to determine a relative numbers criterion below which an alternative scoring mechanism (i.e. "low end scoring") is used for the proportional metrics. These problems are encountered when relative numbers are fewer than 200 individuals per 0.3 km (wading) or 1.0 km (boat). When 200 and fewer individuals are recorded the guidance in Table 4-10 is used making IBI scoring modifications. This was developed by examining the reaction of the IBI metrics for moderately and severely impacted sites (Appendix A).

During the process of tallying catch results, summarizing biological information for each metric, and scoring each metric, the biologist should be assessing the community and examining whether the scoring approximates the conceptual model of an applicable reference site or whether the site they are examining is anomalous for one reason or another. The inherent redundancy of the IBI should greatly reduce the possibility of such anomalies. The possibility does exist, however remote, for the IBI to "incorrectly" characterize a site; thus the biologist should have a thorough knowledge of the local fauna and the data. This is one reason why the Ohio EPA relies on multiple measures (IBI and Iwb) and multiple organism groups (fish and invertebrates) to make decisions on complex water quality issues. Guidelines for the use of the IBI as a water quality criterion is discussed further in Section 7, "Biological Criteria for Ohio Surface Waters".

The above caveats are purposely mentioned prior to the description of computer generated IBI scores. Karr et al. (1986) give strong cautions about the possible misuses of the IBI including computer generated score calculations. Total IBI scores themselves, calculated without an in-depth analysis of the fish communities, can be an inappropriate measure of environmental quality. However, when the components of the IBI and the fish community are examined by a trained biologist, computer generation of IBI scores can serve to enhance the overall evaluation by reducing time spent on calculations and increasing the time available for IBI score interpretation.

Index of Well-Being

The results of river studies in which the Index of Well-Being (Iwb) was used have shown a positive relationship between this index and the quality of the water and habitat. This approach relies on the assertion that least impacted stream segments support a larger variety and abundance of fish than stressed segments in the same system. This hypothesis has been tested and verified in several different situations (Gammon 1976; WAPORA 1978; Gammon et al. 1981; Yoder et al. 1981; Ohio EPA 1982) and confirms the value that this method has for monitoring environmental quality, measuring the effectiveness of water pollution control programs, and determining attainment of Clean Water Act goals (i.e. fishable waters, biological integrity). The Ohio EPA has used a set of guidelines employing ranges of the Iwb and narrative descriptions of community structure and function to assist in establishing attainable use criteria and to determine attainment of Clean Water Act goals since 1980 (see Section 8).

The Iwb incorporates four measures of fish communities that have traditionally been used separately; numbers of individuals, biomass, and the Shannon diversity index (H) based on numbers and weight (two separate calculations). The computational formulas for the Iwb and Shannon index are given in Table 4-11. Relative abundance (numbers and weight) data are derived from pulsed D.C. electrofishing catches where sampling effort is based on distance rather than time (Gammon 1976). Ohio EPA bases relative abundance on a per kilometer basis for boat methods and on a 0.3 kilometer basis for wading methods (Ohio EPA 1987a).

The Iwb presents some advantages over the IBI particularly in the calculation of site scores. Unlike the IBI the Iwb is the result of a mathematical calculation based on the results of standardized sampling. While this may appear to be an undesirable attribute based on the cautions given by Karr et al. (1986), we view this as an advantage in having a result that is comparable from site to site, as long as field sampling is performed according to specifications (Ohio EPA 1987a). In addition we have found that the additional collection of biomass data (required to calculate the Iwb) is not a significant expenditure of time as long as subsampling techniques are used (Appendix C).

A modification of the original Iwb was recently developed (Appendix C) which makes the index more sensitive to a wider array of environmental disturbances, particularly those that result in shifts in community composition without large reductions in species richness, numbers, and/or biomass. The modified Iwb retains the same computational formula as the conventional Iwb developed by Gammon (1976). The difference is that any of 13 highly tolerant species, hybrids, or exotic species are eliminated from the numbers and biomass components of the Iwb. However, they are included in the two Shannon index calculations. This modification eliminates the "undesired" effect caused by a high abundance of tolerant species, but retains their

"desired" influence on the Shannon indices. We have also found that examining the difference between the original Iwb and modified Iwb can be of value. An increasing difference between the modified and original Iwb is a direct indication of the influence of tolerant species which in turn is correlated with a loss of integrity in the fish community.

Calculation of modified Iwb scores for electrofishing samples is best performed with the aid of a computer. The data requirements are somewhat more rigorous than the IBI since standardized relative numbers and biomass data is required and the Shannon index and Iwb calculations themselves involve log functions. Other requirements include sampling effort based on distance following the procedures outlined in Ohio EPA (1987a). Data collected in any different manner will simply not be comparable to the Ohio EPA reference site data base.