SECTION 4: BIOLOGICAL DATA EVALUATION: FISH

Fish can be one of the most sensitive indicators of the quality of the aquatic environment (Smith 1971). Historically fish have received less attention than other taxonomic groups in stream surveys despite the fact that they represent upper trophic levels and the literature abounds with data on their environmental requirements and life history (Doudoroff and Warren 1957; Gammon 1976). Doudoroff (1951) emphasized the need for thorough fish population studies in connection with water quality assessments. Excepting instances of gross pollution, only fish themselves can be trusted to reliably indicate environmental conditions generally suitable or unsuitable for their existence (Doudoroff and Warren 1957). In one sense, the populations of fish in a river or stream reflect the overall state of environmental health of the watershed as a whole. This is because fish live in water which has previously fallen on the cities, fields, strip mines, grasslands, and forests of the watershed (Gammon 1976). The following are some of the advantages of using fish as indicators of water quality conditions:

1) fish are integrators of community response to aquatic environmental quality conditions; they are the end product of most aquatic food webs, thus the total biomass of fishes is highly dependent on the gross primary and secondary productivity of lower organism groups;

2) fish constitute a conspicuous part of the aquatic biota and are recognized by the public for their sport, commercial and endangered status, and represent the end product of protection for most water pollution abatement programs (i.e. many water quality criteria are based on laboratory tests using fish);

3) fish reproduce once per year and complete their entire life cycle in the aquatic environment; therefore, the success of each year class is dependent upon the quality of the aquatic environment which they inhabit; this is evident in the general condition of the fish community each summer and fall;

4) fish have a relatively high sensitivity to a variety of substances and physical conditions; and

5) fish are readily identified to species in the field and there is an abundance of information concerning their life history, ecology, environmental requirements and distribution available for many species.

Changes in the relative abundance (numbers and weight), species richness, composition, and other attributes are directly influenced by the presence of water quality disturbances and/or habitat alterations. The principal measures of overall fish community health and well-being used by the Ohio EPA is the Index of Well-Being (I_{wb}) developed by Gammon (1976) and modified by Ohio EPA (Appendix C), and the Index of Biotic Integrity (IBI) developed by Karr

(1981). The I_{wb} is based on structural attributes of the fish community whereas the IBI additionally incorporates functional characteristics. Together both indices provide a rigorous evaluation of overall fish community condition. As stated before these are not diversity indices in the traditional sense. Both indices incorporate a much broader range of attributes of fish communities than merely species richness and the proportional relationship of fish numbers.

The presence of permanent, large populations of different fish species is generally considered to be the result of a combination of many favorable factors (Trautman 1942). Factors which account for variations in the distribution and abundance of fishes in streams and rivers include, but are not limited to, stream size, instream cover, stream morphology, depth, flow, substrate, gradient and water quality. Perturbations to the physical and/or chemical quality of a river or stream usually result in varying degrees of stress to one or more fish species. Fish species that fail to adjust to these stresses will be reduced in numbers or be eliminated via mortality, reduced reproductive success, and/or avoidance. The subsequent absence or reduced numbers of fish results in decreased community diversity and abundance, and is reflected by an association predominated by stress tolerant species. Fish can temporarily inhabit chemically or physically degraded areas (especially if refuge areas are close-by), but these are usually functionally degraded assemblages and predominated by tolerant species. Fish communities need not undergo large declines in species richness, relative numbers, or biomass to become degraded. In fact, some forms of perturbation (e.g. habitat modification, nutrient enrichment) can cause fish numbers and biomass to increase with only slight reductions in species richness. The degradation to the community in these instances is more often reflected by significant changes in trophic composition and predominant feeding guilds. The traditional tools that evaluate only community structure (e.g. diversity, numbers) can underrate these important changes.

Index of Biotic Integrity (IBI)

The Index of Biotic Integrity (IBI) uses an approach similar to that employed in econometric analyses where an array of different metrics are examined. As originally proposed by Karr (1981) and later refined by Fausch et al. (1984) and Karr et al. (1986) the IBI incorporates 12 community metrics. The value of each metric is compared to the value expected at a reference site located in a similar geographic region where human influence has been minimal. Ratings of 5, 3, or 1 are assigned to each metric according to whether its value approximates (5), deviates somewhat from (3), or strongly deviates (1) from the value expected at a reference site. The maximum IBI score possible is 60 and the minimum is 12. Further details about the underlying basis of the IBI and its application are available in Karr et al. (1986).

The individual IBI metrics assess fish community attributes that are presumed to correlate (either positively or negatively) with biotic integrity. Although no one metric alone can indicate this consistently, all of the IBI metrics combined include the redundancy that is needed to accomplish a consistent and sensitive measure of biotic integrity (Angermier and Karr 1986). IBI relies on multi-parameters, a requirement when the system being evaluated is complex (Karr et al. 1986). It incorporates elements of professional judgement, but also provides the basis for quantitative criteria for determing what is exceptional, good, fair, poor, and very poor.

The following describes the metrics of the IBI and how they were derived for headwaters, wading, and boat sites. These analyses and IBI metrics are specifically tailored to Ohio surface waters and Ohio EPA sampling methods.

IBI Metrics

Karr (1981) proposed 12 community metrics within three broad categorical groupings (species richness and composition, trophic composition, and fish abundance and condition) for calculating the IBI. Some of the metrics respond favorably to increasing environmental quality ("positive metrics") whereas others respond favorably to increasing degradation ("negative metrics"). Some respond across the entire range of perturbation whereas others respond strongly to a portion of that range (Table 4-1).

A wide variety of stream and river sizes occur in Ohio. These not only contain differing fish assemblages, but require the use of different sampling methods. Therefore it was necessary to modify the IBI for application to these different stream sizes and make adjustments for different sampling gear. The modifications were made in keeping with the guidance given by Karr et al. (1986). Three basic divisions are made; wading sites, boat sites, and headwaters sites. In Ohio, wading sites have drainage areas that are generally less than 300 square miles (range 21-475 sq. mi.; range of means within the five ecoregions 44-128 sq. mi.), but greater than 20 square miles. Boat sites include streams and rivers that are too deep and large to sample effectively with wading methods. Boat sites generally exceed 100-300 square miles in drainage area (range 117-6479 sq. mi.; range of means for the ecoregions 225-2190 sq. mi.). Headwaters sites are actually sampled with the same gear used at wading sites, but are defined as sampling locations with drainage areas less than 20 square miles (range 1-20 sq. mi.; range of means for the ecoregions 5.5-10.2 sq. mi.). These designations are followed throughout the text. Figure 4-1 provides a flow chart for determining which IBI modification (e.g. wading, headwaters, etc.) should be used to evaluate a particular site.

The IBI metrics used to evaluate wading sites closely approximates those proposed by Karr (1981) and refined by Fausch et al. (1984) and Karr et al. (1986). The minor changes are in conformity with the guidance of Karr et al. (1986). More substantial modifications were necessary for the IBI metrics used for the boat sites and headwaters sites. These changes were made in recognition of the different sampling efficiency and selectivity of the boat methods and the different faunal character of larger streams and rivers. Although headwaters sites are actually sampled with the wading methods (Ohio EPA 1987a) these habitats have a different faunal composition resulting from the strong influence of small channel and substrate size, temporal flow and water availability. It is important that the IBI metrics reflect the character of headwaters fish communities in relation to these critical factors. Each of the original IBI metrics are discussed including any modifications and/or substitutions that were made. A summary of the IBI metrics appears in Table 4-1.

To determine the 5, 3, and 1 values for each IBI metric the reference site data base was first plotted against a log transformation of drainage area for each of the three site designations. All of the reference site data from each ecoregion was combined for each method. Individual metric differences attributable to ecoregional differences are accounted for in the final derivation of the IBI criteria. Each metric was examined to determine if any relationship with drainage area existed. If a positive relationship was found a 95% line was determined and the area beneath trisected following the method used by Fausch et al. (1984). Wading and headwaters sites data were combined for certain common metrics to determine the slope of the 95% line even though scoring for these sites are performed separately. The IBI metric score (i.e. 5, 3, or 1) is then determined by comparing the site drainage area and metric value with the figure constructed from the reference site data base.

For some of the metrics that showed no positive relationship with drainage area an alternate trisection method was used. A horizontal 5% and 95% line was determined and the area between them trisected. A bisection method was used for the number of individuals metric. For two others (top carnivores, anomalies) the reference site data base was examined and scoring criteria established using best professional judgement. The resultant 5, 3, and 1 values are the same at all drainage areas. A similar method of trisection was used by Hughes and Gammon (1987) for the lower 280 km of the Willamette River, Oregon. A combination of the standard and alternate trisection methods were used for certain metrics, particularly for the wading sites.

Trisection was performed both separately and jointly for wading and headwaters sites, depending on the metric. All boat sites were trisected separately.

Metric 1. Total Number of Indigenous Fish Species (All Methods)

General

This metric is used with all three versions of the IBI (Table 4-1). Exotic species (Appendix B, Table B-3) are not included. This metric is based on the well-documented observation that the number of indigenous fish species in a given size stream or river will decline with increasing environmental disturbance (Karr 1981; Karr et al. 1986). Thus the number of fish species metric is expected to give an indication of environmental quality throughout the range from exceptional to poor. Exotic (i.e. introduced) species present in a system through stocking or inadvertent releases do not provide an accurate assessment of overall integrity and their abundance may even indicate a loss of integrity (Karr et al. 1986).

Wading and Headwaters Sites

The number of species is strongly affected by drainage area at headwaters and wading sites up to 100 sq. mi. (Fig. 4-2). Determining the IBI score for this metric involves comparing the resultant species richness at the drainage area for the site sampled with the resultant expectations for reference sites of the same drainage area (Figure 4-2). Scoring criteria are listed in Tables 4-5 (wading sites) and 4-7 (headwaters sites).

Boat Sites

Unlike headwaters and smaller wading sites there is no direct relationship between increasing drainage area and species richness at boat sites (Fig. 4-3). Scoring is constant at all drainage areas; criteria are listed in Table 4-6.

Metric 2. Number of Darter Species (Wading, Headwaters)
Proportion of Round-bodied Catostomidae (Boat Method)

General

The darter species metric is reflective of good water quality conditions (Karr et al. 1986). None of the species in this group have been found to thrive in degraded stream conditions (Appendix B). Eleven of the twenty-two Ohio species have been found to be highly intolerant of degraded conditions based on the Ohio EPA intolerance criteria (Appendix B, Table B-1). Life history data on this group show darters to be insectivorous, habitat specialists, and sensitive to physical and chemical environmental disturbances (Kuehne and Barbour 1983). These factors make darter species reliable indicators of good water quality and habitat conditions.

Of the 22 darter species recorded in Ohio seven are commonly found and are not restricted to a particular stream size (Trautman 1981). Nine species are confined to Ohio River basin streams; six are strongly associated with medium and/or large rivers. The Iowa and least darters are restricted primarily to the glaciated areas of Ohio, particulary lakes and swamp habitats. Three species are associated with large water conditions (either rivers or Lake Erie) and can be found in both the Ohio and St. Lawrence River basins. The orangethroat darter (Etheostoma spectabile) is associated with western Ohio prairie or low gradient small streams.

Wading Sites

The darter metric as proposed by Karr (1981) is used for wading sites only (Table 4-1). The method for determining the scoring of the darter species metric follow those recommended by Karr (1981) and Karr et al. (1986). Ohio data were used to derive maximum species richness lines and IBI scoring criteria (Fig. 4-4).

Headwaters Sites

For headwaters sites (i.e. less than 20 square miles drainage area) this metric also includes the mottled sculpin (Cottus bairdi). This species is a benthic insectivore and functions much the same as darters. This results in a greater level of sensitivity in streams that naturally have fewer darter species. The headwaters stream data base was used to define the IBI scoring criteria which vary with drainage area (Fig. 4-5).

Boat Sites

The proportion of "round-bodied" suckers is substituted for the number of darter species metric for the boat sites. This is done because darter species are not sampled consistently or effectively with the boat methods, although they can occur in the catch. Round-bodied suckers include species of the genera Hypentelium (northern hog sucker), Moxostoma (redhorses), Minytrema (spotted sucker), and Erimyzon (chubsuckers). These species are sampled effectively with the boat electrofishing methods and they comprise a sensitive component of larger stream and river fish faunas, much the same as darters do in the wadable streams. The feeding and spawning requirements of both groups are similar as are their sensitivity to environmental perturbations. Round-bodied suckers are intolerant of high turbidity and siltation, marginal and poor chemical water quality, and the elimination of their riffle-run spawning and feeding habitats. Round-bodied suckers are an important component of midwestern streams and rivers and their abundance is a good indication of good to exceptional water and habitat quality. The white sucker (Catostomus commersoni) is not included in this metric since it is a highly tolerant species (Appendix B, Table B-3) and not reflective of the intent of this metric. This metric does not change with drainage area (Fig. 4-6); scoring criteria are listed in Table 4-6.

Metric 3. Number of Sunfish Species (Wading, Boat)
Proportion of Headwaters Species (Headwaters)

General

This metric follows Karr (1981) and Karr et al. (1986) by including the number of sunfish species (Centrachidae) collected at a site, excluding the black basses (Micropterus spp.). The redear sunfish (Lepomis microlophus) is not included because, in Ohio, it is introduced and only locally distributed. The nine species which are included are listed in Appendix B (Table B-3). Hybrid sunfish are also excluded from this metric.

This metric is included as a monitor of ecosystem degradation. Specifically, it is a measure of the degradation of their preferred habitats and food items. Differing from suckers and darters, preferred habitats are generally located in quiet pools where sunfish spend much of their time near some form of instream cover (Pflieger 1975). As such they are sensitive to the degradation of pool habitats. Preferred food items include midwater and surface invertebrates in addition to benthic forms (Pflieger 1975; Becker 1983). Other attributes which make this metric well suited for Ohio streams are: conditions described by early settlers were apparently conducive for sunfish (Trautman 1981), there are a number of species which are widely distributed in all stream and river sizes (Trautman 1981), and they are effectively captured by electrofishing. The primary range of sensitivity for this metric is from the middle to high end of the index (Karr et al. 1986).

Wading and Boat Sites

The number of sunfish species is not affected by increasing drainage area at wading and boat sites (Figures 4-7 and 4-8). Scoring criteria for the wading and boat sites are listed in Tables 4-5 and 4-6.

Headwaters Sites

The number of sunfish species metric is replaced with the number of headwaters species at sites with drainage areas less than 20 square miles. The number of sunfish species in headwater streams tends to be quite low and may be controlled more by pool quality alone than overall stream quality. A group of nine species are classified as headwaters species (see Appendix B, Table B-3). Headwaters species indicate permanent habitat (i.e. water availability) with low environmental stress. They do not show a trend associated with drainage area (Fig. 4-9). The headwaters species criteria are listed in Table 4-7.

Metric 4. Number of Sucker Species (Wading, Boat)
Number of Minnow Species (Headwaters)

General

All species in the family Catostomidae are included in this metric (Appendix B, Table B-3). Suckers represent a major component of the Ohio fish fauna with their total biomass in many samples surpassing that of all other species combined. The general intolerance of most sucker species to habitat and water quality degradation (Karr 1981; Trautman 1981; Becker 1983; Karr et al. 1986) results in a metric with a sensitivity at the high end of environmental quality. In addition the relatively long life spans of many sucker species (10-20 years; Becker 1983) provides a long-term assessment of past and prevailing environmental conditions. Of the 19 species still present in Ohio (one is extinct) seven are widely distributed throughout the state (Table 4-2).

Wading and Boat Sites

There is a definite relationship between the number of sucker species and drainage area at wading sites (Fig. 4-10). Scoring is thus dependent on the drainage area of the site and is accomplished using Fig. 4-10. No relationship between drainage area and the number of sucker species is evident at the boat sites (Fig. 4-11). The compilation of reference site data results in the criteria listed in Table 4-6.

Headwaters Sites

The number of minnow species is substituted for the number of sucker species at headwaters sites because of the inherently low number of sucker species in small streams. The number of sucker species decreases rapidly with declining drainage area at sites with less than 20 square miles (Fig. 4-10). Examination of the headwaters sites data base revealed that the number of minnow species would serve as a suitable substitute for this metric. As many as 10 different minnow species have been observed at sites as small as 5 square miles. The number of minnow species also is positively correlated with environmental quality. Species such as the redside dace (Clinostomus elongatus), bigeye chub (Hybopsis amblops), and bigeye shiner (Notropis boops) are examples of the sensitive minnow species that should occur in high quality headwaters streams. Other species such as creek chub (Semotilus atromaculatus), bluntnose minnow (Pimephales promelas), and fathead minnow (P. promelas) are tolerant of both chemical degradation and stream dessication. Thus both ends of the environmental tolerance spectrum are covered by this metric. There is a definite relationship between the number of minnow species and drainage area at the headwaters sites (Fig. 4-12). Scoring is thus dependent on the drainage area of the site and is accomplished using Fig. 4-12.

Metric 5: Number of Intolerant Species (Wading, Boat)
Number of Sensitive Species (Headwaters)

General

The number of intolerant species metric is designed to distinguish streams of the highest quality. As a result, the sensitivity of this metric is at the highest end of biotic integrity. Designation of too many species as intolerant will prevent this metric from discriminating among the highest quality streams. Only species that are highly intolerant to a variety of disturbances were included in this metric so that it will respond to diverse types of perturbations; species intolerant to one type of disturbance, but not another were not included (Appendix B).

The criteria used for determining intolerance (Table 4-2) are based on numerical and graphical analysis of Ohio EPA's statewide data base from 1979 through 1985 (Appendix B), Trautman's (1981) documentation of historical changes in the distribution of species within Ohio, and supplemental information from regional ichthyological texts (e.g. Plieger 1975; Becker 1983). Intolerant species are those that decline with decreasing environmental quality and disappear, as viable populations, when the aquatic environment is degraded to the "fair" category (Karr et al. 1986). The intolerant species list was divided into three categories all of which are included in scoring this metric as follows:

1) common intolerant species (designated I in the TOL column of Appendix B, Table B-3) - species that are intolerant, but are still widely distributed in the best streams in Ohio;

2) uncommon or geographically restricted species (designated R) - species that are infrequently captured or that have restricted ranges; and,

3) species that are rare or possibly extirpated (designated S) - intolerant species that are rarely captured or for which we have little recent data.

The list of commonly occurring intolerant species (i.e. those designated I) is within the 5-10% guideline of Karr (1981) and Karr et al (1986). Although the addition of species designated R and S collectively inflates the number of intolerant species above the 10% guideline, no where in the state do these species all occur together at the same time. In the vast majority of cases only one or two usually occur in the same collection.

Wading and Boat Sites

The expected number of intolerant species increases with drainage area among the wading sites (Figure 4-13); however, such a direct positive trend is not evident in the boat sites data (Figure 4-14). In fact intolerants seem to level off and decrease at the larger boat reference sites. Intolerant species in large rivers have likely been reduced (see Appendix B, Table B-3, TOL categories R and S); nevertheless, a score of "5" for this metric has been observed at the best large river reference sites. Large river intolerant species still exist in areas of high integrity in large rivers and are catchable with the boat electrofishing methods. Therefore, scoring criteria remain constant with increasing drainage area for the boat sites (Fig. 4-14 and Table 4-6).

Headwaters

The number of intolerant species metric is modified to include moderately intolerant species for application at headwaters sites. This combination is termed sensitive species (Appendix B, Table B-3). This is done because few or no intolerant species are expected in these streams (Fig. 4-13). The moderately intolerant species meet most of the criteria in Table 4-3. Sensitive species also require permanent pools thus this metric will also aid in distinguishing permanent streams from those with ephemeral characteristics. An absence of these species would indicate a severe stress caused by man-induced perturbation or loss of habitat due to a lack of water. This metric varies with drainage area and scoring is accomplished using Fig. 4-15.