

8

FISH PROTOCOLS

Monitoring of the fish assemblage is an integral component of many water quality management programs, and its importance is reflected in the aquatic life use-support designations of many states. Narrative expressions such as “maintaining coldwater fisheries”, “fishable” or “fish propagation” are prevalent in state standards. Assessments of the fish assemblage must measure the overall structure and function of the ichthyofaunal community to adequately evaluate biological integrity and protect surface water resource quality. Fish bioassessment data quality and comparability are assured through the utilization of qualified fisheries professionals and consistent methods.

The Rapid Bioassessment Protocol (RBP) for fish presented in this document, is directly comparable to RBP V in Plafkin et al. (1989). The principal evaluation mechanism utilizes the technical framework of the Index of Biotic Integrity (IBI) — a fish assemblage assessment approach developed by Karr (1981). The IBI incorporates the zoogeographic, ecosystem, community and population aspects of the fish assemblage into a single ecologically-based index. Calculation and interpretation of the IBI involves a sequence of activities including: fish sample collection; data tabulation; and regional modification and calibration of metrics and expectation values. This concept has provided the overall multimetric index framework for rapid bioassessment in this document. A more detailed description of this approach for fish is presented in Karr et al. (1986) and Ohio EPA (1987). Regional modification and applications are described in Leonard and Orth (1986), Moyle et al. (1986), Hughes and Gammon (1987), Wade and Stalcup (1987), Miller et al. (1988), Steedman (1988), Simon (1991), Lyons (1992a), Simon and Lyons (1995), Lyons et al. (1996), and Simon (1999).

The RBP for fish involves careful, standardized field collection, species identification and enumeration, and analyses using aggregated biological attributes or quantification of the numbers (and in some cases biomass, see Section 8.3.3, Metric 13) of key species. The role of experienced fisheries scientists in the adaptation and application of the RBP and the taxonomic identification of fishes cannot be overemphasized. The fish RBP survey yields an objective discrete measure of the condition of the fish assemblage. Although the fish survey can usually be completed in the field by qualified fish biologists, difficult species identifications will require laboratory confirmation. Data provided by the fish RBP can serve to assess use attainment, develop biological criteria, prioritize sites for further evaluation, provide a reproducible impact assessment, and evaluate status and trends of the fish assemblage.

Fish collection procedures must focus on a multihabitat approach — sampling habitats in relative proportion to their local representation (as determined during site reconnaissance). Each sample reach should contain riffle, run and pool habitat, when available. Whenever possible, the reach should be sampled sufficiently upstream of any bridge or road crossing to minimize the hydrological effects on overall habitat quality. Wadeability and accessibility may ultimately govern the exact placement of the sample reach. A habitat assessment is performed and physical/chemical parameters measured concurrently with fish sampling to document and characterize available habitat specifics within the sample reach (see Chapter 5: Habitat Assessment and Physicochemical Characterization).

8.1 FISH COLLECTION PROCEDURES: ELECTROFISHING

All fish sampling gear types are generally considered selective to some degree; however, electrofishing has proven to be the most comprehensive and effective *single* method for collecting stream fishes. Pulsed DC (direct current) electrofishing is the method of choice to obtain a representative sample of the fish assemblage at each sampling station. However, electrofishing in any form has been banned from certain salmonid spawning streams in the northwest. As with any fish sampling method, the proper scientific collection permit(s) must be obtained before commencement of any electrofishing activities. The accurate identification of each fish collected is essential, and species-level identification is required (including hybrids in some cases, see Section 8.3.3, Metric 11). Field identifications are acceptable; however, voucher specimens must be retained for laboratory verification, particularly if there is any doubt about the correct identity of the specimen (see Section 8.2). Because the collection methods used are not consistently effective for young-of-the-year fish and because their inclusion may seasonally skew bioassessment results, fish less than 20 millimeters total length will not be identified or included in standard samples.

ELECTROFISHING CONFIGURATION AND FIELD TEAM ORGANIZATION

All field team members must be trained in electrofishing safety precautions and unit operation procedures identified by the electrofishing unit manufacturer. Each team member must be insulated from the water and the electrodes; therefore, chest waders and rubber gloves are required. Electrode and dip net handles must be constructed of insulating materials (e.g., woods, fiberglass). Electrofishers/electrodes must be equipped with functional safety switches (as installed by virtually all electrofisher manufacturers). Field team members must not reach into the water unless the electrodes have been removed from the water or the electrofisher has been disengaged.

It is recommended that at least 2 fish collection team members be certified in CPR (cardiopulmonary resuscitation). *Many* options exist for electrofisher configuration and field team organization; however, procedures will always involve pulsed DC electrofishing and a minimum 2-person team for sampling streams and wadeable rivers. Examples include:

- Backpack electrofisher with 2 hand-held electrodes mounted on fiberglass poles, one positive (anode) and one negative (cathode). One crew member, identified as the electrofisher unit operator, carries the backpack unit and manipulates both the anode and cathode poles. The anode may be fitted with a net ring (and shallow net) to allow the unit operator to net specimens. The remaining 1 or 2 team members net fish with dip nets and are responsible for specimen transport and care in buckets or livewells.
- Backpack electrofisher with 1 hand-held anode pole and a trailing or floating cathode. The electrofisher unit operator manipulates the anode with one hand, and has a second hand free for use of a dip net. The remaining 1 or 2 team members also aid in the netting of specimens, and in addition are responsible for specimen transport in buckets or livewells.
- Tote barge (pramunit) electrofisher with 2 hand-held anode poles and a trailing/floating cathode (recommended for large streams and wadeable rivers). Two team members are each equipped with an anode pole and a dip net. Each is responsible for electrofishing and the netting of specimens. The remaining team member will follow, pushing or pulling the barge through the sample reach. A livewell is maintained within the barge and/or within the sampling reach but outside the area of electric current.

The safety of all personnel and the quality of the data is assured through the adequate education, training, and experience of all members of the fish collection team. At least 1 biologist with training and experience in electrofishing techniques and fish taxonomy *must* be involved in each sampling event. Laboratory analyses are conducted and/or supervised by a fisheries professional trained in fish taxonomy. Quality assurance and quality control must be a continuous process in fisheries monitoring and assessment, and must include all program aspects (i.e., field sampling, habitat measurement, laboratory processing, and data recording).



Tote barge (pram unit) Electrofishing



8.1.1 Field Sampling Procedures

1. A representative stream reach (see Alternatives for Stream Reach Designation, next page) is selected and measured such that primary physical habitat characteristics of the stream are included within the reach (e.g., riffle, run and pool habitats, when available). The sample reach should be located away from the influences of major tributaries and

FIELD EQUIPMENT/SUPPLIES NEEDED FOR FISH SAMPLING—ELECTROFISHING

- appropriate scientific collection permit(s)
- backpack or tote barge-mounted electrofisher
- dip nets
- block nets (i.e., seines)
- elbow-length insulated waterproof gloves
- chest waders (equipped with wading cleats, when necessary)
- polarized sunglasses
- buckets/livewells
- jars for voucher/reference specimens
- waterproof jar labels
- 10% buffered formalin (formaldehyde solution)
- measuring board (500 mm minimum, with 1 mm increments)^a
- balance (gram scale)^b
- tape measure (100 m minimum)
- fish Sampling Field Data Sheet^c
- applicable topographic maps
- copies of field protocols
- pencils, clipboard
- first aid kit
- Global Positioning System (GPS) Unit

^a Needed only if program/study requires length frequency information

^b Needed only if total biomass and/or the Index of Well-Being are included in the assessment process (see Section 8.3.3, Metric 13).

^c It is helpful to copy fieldsheets onto water-resistant paper for use in wet weather conditions.

bridge/road crossings (e.g., sufficiently upstream to decrease influences on overall habitat quality). The exact location (i.e., latitude and longitude) of the downstream limit of the reach must be recorded on each field data sheet. (If a Global Positioning System unit is used to provide location information, the accuracy or design confidence of the unit should be noted.) A habitat assessment and physical/chemical characterization of water quality should be performed within the same sampling reach (see Chapter 5: Habitat Assessment and Physicochemical Characterization).

2. Collection via electrofishing begins at a shallow riffle, or other physical barrier at the downstream limit of the sample reach, and terminates at a similar barrier at the upstream end of the reach. In the absence of physical barriers, block nets should be set at the upstream and downstream ends of the reach prior to the initiation of any sampling activities.
3. Fish collection procedures commence at the downstream barrier. A minimum 2-person fisheries crew proceeds to electrofish in an upstream direction using a side-to-side or bank-to-bank sweeping technique to maximize area coverage. All wadeable habitats within the reach are sampled via a single pass, which terminates at the upstream barrier. Fish are held in livewells (or buckets) for subsequent identification and enumeration.
4. Sampling efficiency is dependent, at least in part, on water clarity and the field team's ability to see and net the stunned fish. Therefore, each team member should wear polarized sunglasses, and sampling is conducted only during periods of optimal water clarity and flow.
5. All fish (greater than 20 millimeters total length) collected within the sample reach must be identified to species (or subspecies). Specimens that cannot be identified with certainty in the field are preserved in a 10% formalin solution and stored in labeled jars for subsequent laboratory identification (see Section 8.2). A representative voucher collection must be retained for unidentified specimens, very small specimens, new locality records, and/or a particular region. In addition to the unidentified specimen jar, a voucher collection of a

ALTERNATIVES FOR STREAM REACH DESIGNATION

The collection of a representative sample of the fish assemblage is essential, and the appropriate sampling station length for obtaining that sample is best determined by conducting pilot studies (Lyons 1992b, Simonson et al. 1994, Simonson and Lyons 1995). Alternatives for the designation of stream sampling reaches include:

- **Fixed-distance designation**—A standard length of stream, e.g., a 150-200-meter reach (Ohio EPA 1987), 100-meter reach (Massachusetts DEP 1995) may be used to obtain a representative sample. Conceptually, this approach should provide a mixture of habitats in the reach and provide, at a minimum, duplicate physical and structural elements such as riffle/pool sequences.
- **Proportional-distance designation**— A standard number of stream channel “widths” may be used to measure the stream study reach, e.g., 40 times the stream width is defined by Environmental Monitoring & Assessment Program (EMAP) for sampling (Klemm and Lazorchak 1995). This approach allows variation in the length of the reach based on the size of the stream. Application of the proportional-distance approach in large streams or wadeable rivers may require the establishment of sampling program time and/or distance maxima (e.g., no more than 3 hours of electrofishing or 500-meter reach per sampling site, [Klemm et al. 1993]).

subsample of each species identified in the field should be preserved and labeled for subsequent laboratory verification, if necessary. Obviously, species of special concern (e.g., threatened, endangered) should be noted and released *immediately* on site. Labels should contain (at a minimum) location data (verbal description and coordinates), date, collectors' names, and sample identification code and/or station numbers for the particular sampling site. Young-of-the-year fish less than 20 millimeters (total length) are not identified or included in the sample, and are released on site. Specimens that can be identified in the field are counted, examined for external anomalies (i.e., deformities, eroded fins, lesions, and tumors), and recorded on field data sheets. An example of a "Fish Sampling Field Data Sheet" is provided in Appendix A-4, Form 1. Space is available for optional fish length and weight measurements, should a particular program/study require length frequency or biomass data. However, these data *are not required* for the standard multimetric assessment. Space is allotted on the field data sheets for the *optional* inclusion of measurements (nearest millimeter total length) and weights (nearest gram) for a subsample (to a maximum 25 specimens) of each species. Although fish length and weight measurements are optional, recording a range of lengths for species encountered may be a useful routine measure. Following the data recording phase of the procedure, specimens that have been identified and processed in the field are released on site to minimize mortality.

6. The data collection phase includes the completion of the top portion of the "Fish Sampling Field Data Sheet" (Appendix A-4, Form 1),

QUALITY CONTROL (QC) IN THE FIELD

1. Quality control must be a continuous process in fish bioassessment and should include all program aspects, from field collection and preservation to habitat assessment, sample processing, and data recording. Field validation should be conducted at selected sites and will involve the collection of a duplicate sample taken from an adjacent reach upstream of the initial sampling site. The adjacent reach should be similar to the initial site with respect to habitat and stressors. Sampling QC data should be evaluated following the first year of sampling in order to determine a level of acceptable variability and the appropriate duplication frequency.
2. Field identifications of fish *must* be conducted by qualified/trained fish taxonomists, familiar with local and regional ichthyofauna. Questionable records are prevented by: (a) requiring the presence of at least one experienced/trained fish taxonomist on every field effort, and (b) preserving selected specimens (e.g., Klemm and Lazorchak 1995 recommend a subsample of a maximum 25 voucher specimens of each species) and those that cannot be readily identified in the field for laboratory verification and/or examination by a second qualified fish taxonomist (see Section 8.2). Specimens must be properly preserved and labeled (refer to Section 8.1.1, number 5). When needed, chain-of-custody forms must be initiated following sample preservation, and must include the same information as the sample container labels.
3. All field equipment must be in good operating condition, and a plan for routine inspection, maintenance, and/or calibration must be developed to ensure consistency and quality of field data. Field data must be complete and legible, and should be entered on standardized field data forms and/or digital recorders. While in the field, the field team should possess sufficient copies of standardized field data forms and chains-of-custody for all anticipated sampling sites, as well as copies of all applicable Standard Operating Procedures (SOPs).

which duplicates selected information from the physical/chemical field sheet. Information regarding the sample collection procedures must also be recorded. This includes method of fish capture, start time, ending time, duration of sampling, maximum and mean stream widths. The percentage of each habitat type in the reach is estimated and documented on the data sheet. Comments should include sampling conditions, e.g., visibility, flow, difficult access to stream, or anything that may prove to be valuable information to consider for future sampling events or by personnel unfamiliar with the site.

8.2 LABORATORY IDENTIFICATION AND VERIFICATION

Fish records of questionable quality are prevented by preserving specimens (that cannot be readily identified in the field) for laboratory examination and/or a voucher collection for laboratory verification. Specimens must be properly preserved (e.g., 10% formalin for tissue fixing and 70% ethanol for long-term storage) and labeled (using museum-grade archival labels/paper, and formalin/alcohol-proof pen or pencil). Labels should contain (at a minimum) site location data (i.e., verbal description and site coordinates), collection date, collector's names, species identification (for fishes identified in the field), species totals, and sample identification code and/or station number. All samples received in the laboratory should be tracked using a sample log-in procedure (Appendix A-4, Form 2). Laboratory fisheries professionals *must* be capable of identifying fish to the lowest possible taxonomic level (i.e., species or subspecies) and should have access to suitable regional taxonomic references (see Section 8.4) to aid in the identification process. Laboratories that do not typically identify fish, or trained fisheries professionals that have difficulty identifying a particular specimen or group of fish, should contact a taxonomic specialist (i.e., a recognized authority for that particular taxonomic group). Taxonomic nomenclature *must* be kept consistent and current. Common and scientific names of fishes from the United States and Canada are listed in Robins et al. (1991).

8.3 DESCRIPTION OF FISH METRICS

QUALITY CONTROL (QC) FOR TAXONOMY

1. A representative voucher collection must be retained for unidentified specimens, small specimens, and new locality records. In addition, a second voucher jar should be retained for a subsample of each species identified in the field (e.g., Klemm and Lazorchak 1995 recommend a subsample of 25 voucher specimens of each species). The vouchers must be properly preserved, labeled, and stored in the laboratory for future reference (see Section 8.2).
2. Voucher collections should be verified by a second qualified fish taxonomist, i.e., a professional other than the taxonomist responsible for the original field identifications. The word "validated" and the name of the taxonomist that validated the identification should be added to each voucher label. Specimens sent from the laboratory to taxonomic specialists should be recorded in a "Taxonomy Validation Notebook" (see Chapter 7), noting the label information and date sent. Upon return of the specimens, the date received and findings should also be recorded in the notebook (and the voucher label), along with the name of the person who performed the validation.
3. Information on samples completed (through the identification/validation process) will be tracked in a "Sample Log" notebook, to track the progress of each sample (Appendix A-4, Form 2). Sample log entries will be updated as each step is completed (e.g., receipt, identification, validation, archive).
4. A library of taxonomic literature is essential for the aid and support of identification/verification activities, and must be maintained (and updated as needed) in the laboratory. A list of selected taxonomic references is provided in Section 8.4.

Through the IBI, Karr et al. (1986) provided a consistent theoretical framework for analyzing fish assemblage data. The IBI is an aggregation of 12 biological metrics that are based on the fish assemblage's taxonomic and trophic composition and the abundance and condition of fish. Such multiple-parameter indices are necessary for making objective evaluations of complex systems. The IBI was designed to evaluate the quality of small Midwestern warmwater streams but has been modified for use in many regions (e.g., eastern and western United States, Canada, France) and in different ecosystems (e.g., rivers, impoundments, lakes, and estuaries).

The metrics attempt to quantify a biologist's best professional judgment (BPJ) of the quality of the fish assemblage. The IBI utilizes professional judgment, but in a prescribed manner, and it includes quantitative standards for discriminating the condition of the fish assemblage (Figure 8-1). BPJ is involved in choosing both the most appropriate population or assemblage element that is representative of each metric and in setting the scoring criteria. This process can be easily and clearly modified, as opposed to judgments that occur after results are calculated. Each metric is scored against criteria based on expectations developed from appropriate regional reference sites. Metric values

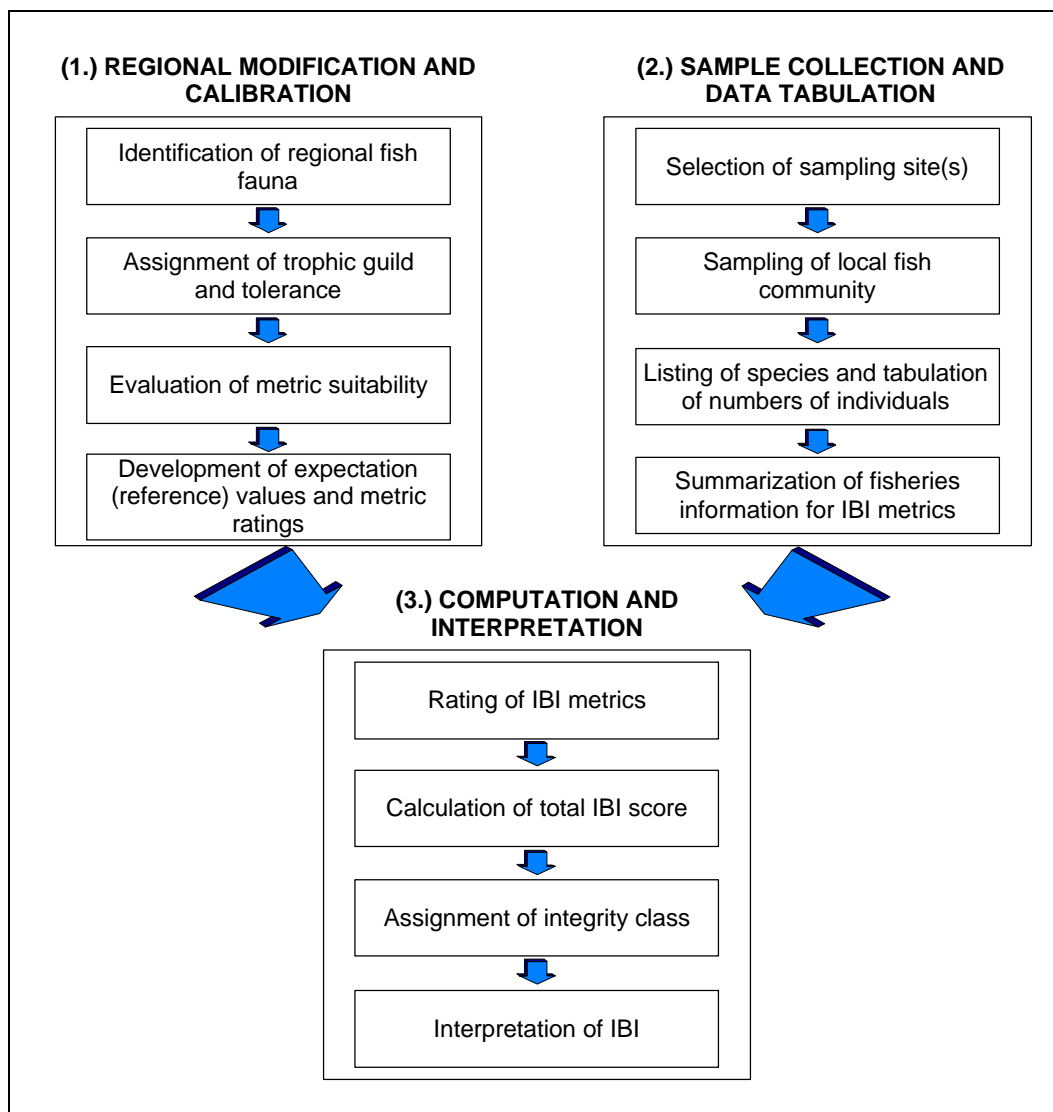


Figure 8-1. Sequence of activities involved in calculating and interpreting the Index of Biotic Integrity (adapted from Karr et al. 1986).

approximating, deviating slightly from, or deviating greatly from values occurring at the reference sites are scored as 5, 3, or 1, respectively. The scores of the 12 metrics are added for each station to give an IBI ranging from a maximum of 60 (excellent) to a minimum of 12 (very poor). Trophic and tolerance classifications of selected fish species are listed in Appendix C. Additional classifications can be derived from information in State and regional fish texts, by objectively assessing a large statewide database, or by contacting authors/originators of regional IBI programs or pilot studies. Use of the IBI by water resource agencies may result in further modifications. Many modifications have occurred (Miller et al. 1988) without changing the IBI's basic theoretical foundations.

The IBI serves as an integrated analysis because individual metrics may differ in their relative sensitivity to various levels of biological condition. A description and brief rationale for each of the 12 IBI metrics is outlined below. The original metrics described by Karr (1981) for Illinois streams are followed by substitutes used in or proposed for different geographic regions and stream sizes. Because of zoogeographic differences, different families or species are evaluated in different regions, with regional substitutes occupying the same general habitat or niche. The source for each substitute is footnoted below. Table 8-1 presents an overview of the IBI metric alternatives and their sources for various areas of the United States and Canada.

EXAMPLES OF SOURCES FOR METRIC ALTERNATIVES

Karr et al. (1986)
Leonard and Orth (1986)
Moyle et al. (1986)
Fausch and Schrader (1987)
Hughes and Gammon (1987)
Ohio EPA (1987)
Miller et al. (1988)
Steedman (1988)
Simon (1991)
Lyons (1992a)
Barbour et al. (1995)
Simon and Lyons (1995)
Hall et al. (1996)
Lyons et al. (1996)
Roth et al. (1997)
Simon (1999)

8.3.1 Species Richness and Composition Metrics

These metrics assess the species richness component of diversity and the health of resident taxonomic groupings and habitat guilds of fishes. Two of the metrics assess assemblage composition in terms of tolerant or intolerant species.

Metric 1. Total number of fish species Substitutes (Table 8-1): Total number of resident native fish species and salmonid age classes.

This number decreases with increased degradation; hybrids and introduced species are not included. In coldwater streams supporting few fish species, the age classes of the species found represent the suitability of the system for spawning and rearing. The number of species is strongly affected by stream size at most small warmwater stream sites, but not at large river sites (Karr et al. 1986, Ohio EPA 1987).

Metric 2. Number and identity of darter species Substitutes (Table 8-1): Number and identity of sculpin species, benthic insectivore species, salmonid juveniles (individuals); number of sculpins (individuals); percent round-bodied suckers, sculpin and darter species.

These species are sensitive to degradation resulting from siltation and benthic oxygen depletion because they feed and reproduce in benthic habitats (Kuehne and Barbour 1983, Ohio EPA 1987). Many smaller species live within the rubble interstices, are weak swimmers, and spend their entire lives in an area of 100-400 m² (Matthews 1986, Hill and Grossman 1987). Darters are appropriate in most

Mississippi Basin streams; sculpins and yearling trout occupy the same niche in western streams. Benthic insectivores and sculpins or darters are used in small Atlantic slope streams that have few sculpins or darters, and round-bodied suckers are suitable in large midwestern rivers.

Metric 3. Number and identity of sunfish species. Substitutes (Table 8-1): Number and identity of cyprinid species, water column species, salmonid species, headwater species, and sunfish and trout species.

Table 8-1. Fish IBI metrics used in various regions of North America.^a

Alternative IBI Metrics	Midwestern United States	Central Appalachians	Sacramento-San Joaquin	Colorado Front Range	Western Oregon Ohio	Ohio Headwater Sites	Northeastern United States	Ontario	Central Corn Belt Plain	Wisconsin-Warmwater	Wisconsin-Coldwater	Maryland Coastal Plain	Maryland Non-Tidal
1. Total Number of Species	X	X	X	X				X	X			X	X
#native fish species					X	X	X		X	X			
# salmonid age classes ^b				X	X								
2. Number of Darter Species	X	X		X		X			X	X			
# sculpin species					X								
# benthic insectivore species								X					
# darter and sculpin species							X						
# darter, sculpin, and madtom species										X			
# salmonid juveniles (individuals) ^b			X		X		X						
% round-bodied suckers						X ^c							
# sculpins (individuals)			X										
# benthic species												X	X
3. Number of Sunfish Species	X			X		X			X	X			
# cyprinid species					X								
# water column species							X						
# sunfish and trout species								X					
# salmonid species			X						X				
# headwater species						X							
% headwater species						X			X				
4. Number of Sucker Species	X				X	X	X		X	X			
# adult trout species ^b			X		X								
# minnow species				X			X		X				
# sucker and catfish species								X					
5. Number of Intolerant Species	X			X	X	X	X			X	X	X	X
# sensitive species							X		X				
# amphibian species			X										
presence of brook trout								X					
% stenothermal cool and cold water species											X		
% of salmonid ind. as brook trout											X		
6. % Green Sunfish	X												
% common carp					X								
% white sucker				X			X						
% tolerant species						X	X		X	X	X	X	X
% creek chub		X											
% dace species								X					
% eastern mudminnow												X	

Table 8-1. Fish IBI metrics used in various regions of North America.^a

Alternative IBI Metrics	Midwestern United States	Central Appalachians	Sacramento-San Joaquin	Colorado Front Range	Western Oregon Ohio	Ohio Headwater Sites	Northeastern United States	Ontario	Central Corn Belt Plain	Wisconsin-Warmwater	Wisconsin-Coldwater	Maryland Coastal Plain	Maryland Non-Tidal
7. % Omnivores	X			X		X	X	X	X	X			
% generalist feeders		X											
% generalists, omnivores, and invertivores													X
8. % Insectivorous Cyprinids	X											X	
% insectivores					X			X		X	X	X	X ^e
% specialized insectivores		X		X									
# juvenile trout			X										
% insectivorous species						X	X						
9. % Top Carnivores	X					X		X	X	X	X	X	
% catchable salmonids					X								
% catchable trout			X										
% pioneering species						X			X			X	
Density catchable wild trout			X										
10. Number of Individuals (or catch per effort)	X	X	X	X	X	X ^d	X ^d		X	X	X ^d	X	
Density of individuals								X					X
% abundance of dominant species												X	X
Biomass (per m ²)													X ^f
11. % Hybrids	X							X					
% introduced species				X	X								
% simple lithophills						X			X	X			X
# simple lithophills species							X						
% native species			X										
% native wild individuals			X										
% silt-intolerant spawners												X	
12. % Diseased Individuals (deformities, eroded fins, lesions, and tumors)	X	X		X	X	X	X	X	X	X		X	X

Note: X = metric used in region. Many of these variations are applicable elsewhere.

a Taken from Karr et al. (1986), Leonard and Orth (1986), Moyle et al. (1986), Fausch and Schrader (1987), Hughes and Gammon (1987), Ohio EPA (1987), Miller et al. (1988), Steedman (1988), Simon (1991), Lyons (1992a), Barbour et al. (1995), Simon and Lyons (1995), Hall et al. (1996), Lyons et al. (1996), Roth et al. (1997).

b Metric suggested by Moyle et al. (1986) or Hughes and Gammon (1987) as a provisional replacement metric in small western salmonid streams.

c Boat sampling methods only (i.e., larger streams/rivers).

d Excluding individuals of tolerant species.

e Non-coastal Plain streams only.

f Coastal Plain streams only.

These pool species decrease with increased degradation of pools and instream cover (Gammon et al. 1981, Angermeier 1987, Platts et al. 1983). Most of these fishes feed on drifting and surface invertebrates and are active swimmers. The sunfishes and salmonids are important sport species. The sunfish metric works for most Mississippi Basin streams, but where sunfish are absent or rare, other

groups are used. Cyprinid species are used in coolwater western streams; water column species occupy the same niche in northeastern streams; salmonids are suitable in coldwater streams; headwater species serve for midwestern headwater streams; and trout and sunfish species are used in southern Ontario streams. Karr et al. (1986) and Ohio EPA (1987) found the number of sunfish species to be dependent on stream size in small streams, but Ohio EPA (1987) found no relationship between stream size and sunfish species in medium to large streams, nor between stream size and headwater species in small streams.

Metric 4. Number and identity of sucker species. Substitutes (Table 8-1): Number of adult trout species, number of minnow species, and number of suckers and catfish.

These species are sensitive to physical and chemical habitat degradation and commonly comprise most of the fish biomass in streams. All but the minnows are longlived species and provide a multiyear integration of physicochemical conditions. Suckers are common in medium and large streams; minnows dominate small streams in the Mississippi Basin; and trout occupy the same niche in coldwater streams. The richness of these species is a function of stream size in small and medium sized streams, but not in large (e.g., non-wadeable) rivers.

Metric 5. Number and identity of intolerant species. Substitutes (Table 8-1): Number and identity of sensitive species, amphibian species, and presence of brook trout.

This metric distinguishes high and moderate quality sites using species that are intolerant of various chemical and physical perturbations. Intolerant species are typically the first species to disappear following a disturbance. Species classified as intolerant or sensitive should only represent the 5-10 percent most susceptible species, otherwise this becomes a less discriminating metric. Candidate species are determined by examining regional ichthyological books for species that were once widespread but have become restricted to only the highest quality streams. Ohio EPA (1987) uses number of sensitive species (which includes highly intolerant and moderately intolerant species) for headwater sites because highly intolerant species are generally not expected in such habitats. Moyle (1976) suggested using amphibians in northern California streams because of their sensitivity to silvicultural impacts. This also may be a promising metric in Appalachian streams which may naturally support few fish species. Steedman (1988) found that the presence of brook trout had the greatest correlation with IBI score in Ontario streams. The number of sensitive and intolerant species increases with stream size in small and medium sized streams but is unaffected by size of large (e.g., non-wadeable) rivers.

Metric 6. Proportion of individuals as green sunfish. Substitutes (Table 8-1): Proportion of individuals as common carp, white sucker, tolerant species, creek chub, and dace.

This metric is the reverse of Metric 5. It distinguishes low from moderate quality waters. These species show increased distribution or abundance despite the historical degradation of surface waters, and they shift from incidental to dominant in disturbed sites. Green sunfish are appropriate in small midwestern streams; creek chubs were suggested for central Appalachian streams; common carp were suitable for a coolwater Oregon river; white suckers were selected in the northeast and Colorado where green sunfish are rare to absent; and dace (*Rhinichthys* species) were used in southern Ontario. To avoid weighting the metric on a single species, Karr et al. (1986) and Ohio EPA (1987) suggest using a small number of highly tolerant species (e.g., alternative Metric 6— percent abundance of tolerant species).

8.3.2 Trophic Composition Metrics

These three metrics assess the quality of the energy base and trophic dynamics of the fish assemblage. Traditional process studies, such as community production and respiration, are time consuming to conduct and the results are equivocal; distinctly different situations can yield similar results. The trophic composition metrics offer a means to evaluate the shift toward more generalized foraging that typically occurs with increased degradation of the physicochemical habitat.

Metric 7. Proportion of individuals as omnivores. Substitutes (Table 8-1): Proportion of individuals as generalist feeders.

The percent of omnivores in the community increases as the physical and chemical habitat deteriorates. Omnivores are defined as species that consistently feed on substantial proportions of plant and animal material. Ohio EPA (1987) excludes sensitive filter feeding species such as paddlefish and lamprey ammocoetes and opportunistic feeders like channel catfish. In areas where few species fit the true definition of omnivore, the proportion of generalized feeders may be substituted (Leonard and Orth 1986).

Metric 8. Proportion of individuals as insectivorous cyprinids. Substitutes (Table 8-1): Proportion of individuals as insectivores, specialized insectivores, insectivorous species, and number of juvenile trout.

Insectivores, primarily insectivores, are the dominant trophic guild of most North American surface waters. As the invertebrate food source decreases in abundance and diversity due to habitat degradation (e.g., anthropogenic stressors), there is a shift from insectivorous to omnivorous fish species. Generalized insectivores and opportunistic species, such as blacknose dace and creek chub were excluded from this metric by Ohio EPA (1987). This metric evaluates the midrange of biological condition, i.e., low to moderate condition.

Metric 9. Proportion of individuals as top carnivores. Substitutes (Table 8-1): Proportion of individuals as catchable salmonids, catchable wild trout, and pioneering species.

The top carnivore metric discriminates between systems with high and moderate integrity. Top carnivores are species that feed, as adults, predominantly on fish, other vertebrates, or crayfish. Occasional piscivores, such as creek chub and channel catfish, are not included. In trout streams, where true piscivores are uncommon, the percent of large salmonids is substituted for percent piscivores. These species often represent popular sport fish such as bass, pike, walleye, and trout. Pioneering species are used by Ohio EPA (1987) in headwater streams typically lacking piscivores. Pioneering species predominate in unstable environments that have been affected by temporal desiccation or anthropogenic stressors, and are the first to reinvade sections of headwater streams following periods of desiccation.

8.3.3 Fish Abundance and Condition Metrics

The last 3 metrics indirectly evaluate population recruitment, mortality, condition, and abundance. Typically, these parameters vary continuously and are time consuming to estimate accurately. Instead of such detailed population attributes or estimates, general population parameters are evaluated. Indirect estimation is less variable and much more rapidly determined.

Metric 10. Number of individuals in sample. Substitutes (Table 8-1): Density of individuals.

This metric evaluates population abundance and varies with region and stream size for small streams. It is expressed as catch per unit effort, either by area, distance, or time sampled. Generally sites with lower integrity support fewer individuals, but in some nutrient poor regions, enrichment increases the number of individuals. Steedman (1988) addressed this situation by scoring catch per minute of sampling greater than 25 as a 3, and less than 4 as a 1. Unusually low numbers generally indicate toxicity, making this metric most useful at the low end of the biological integrity scale. Hughes and Gammon (1987) suggest that in larger streams, where sizes of fish may vary in orders of magnitude, total fish biomass may be an appropriate substitute or additional metric.

Metric 11. Proportion of individuals as hybrids. Substitutes (Table 8-1): Proportion of individuals as introduced species, simple lithophils, and number of simple lithophilic species.

This metric is an estimate of reproductive isolation or the suitability of the habitat for reproduction. Generally as environmental degradation increases the percent of hybrids and introduced species also increases, but the proportion of simple lithophils decreases. However, minnow hybrids are found in some high quality streams, hybrids are often absent from highly impacted sites, and hybridization is rare and difficult to detect. Thus, Ohio EPA (1987) substitutes simple lithophils for hybrids. Simple lithophils spawn where their eggs can develop in the interstices of sand, gravel, and cobble substrates without parental care. Hughes and Gammon (1987) and Miller et al. (1988) propose using percent introduced individuals. This metric is a direct measure of the loss of species segregation between midwestern and western fishes that existed before the introduction of midwestern species to western rivers.

Metric 12. Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

This metric depicts the health and condition of individual fish. These conditions occur infrequently or are absent from minimally impacted reference sites but occur frequently below point sources and in

THE INDEX OF WELL-BEING (IWB)

The Iwb (Gammon 1976, 1980, Hughes and Gammon 1987) incorporates two abundance and two diversity measures in an approximately equal fashion, thereby representing fish assemblage quality more realistically than a single diversity or abundance measure. The Iwb is calculated using the formula:

$$Iwb = 0.51nN + 0.5 \ln B + \bar{H}_N + \bar{H}_B$$

where

N = number of individuals caught per unit distance sampled

B = biomass of individuals caught per unit distance

\bar{H} = Shannon diversity index, calculated as:

$$\bar{H} = -\sum \frac{n_i}{N} \ln \left(\frac{n_i}{N} \right)$$

where

n_i = relative number or weight of the i th species

N = total number or weight of the sample

THE MODIFIED INDEX OF WELL-BEING (MIWB)

The MIwb (Ohio EPA 1987) retains the same formula as the Iwb; however, highly tolerant species, hybrids, and exotic species are eliminated from the abundance (i.e., number and biomass) components of the formula. This modification increases the sensitivity of the index to a wider array of environmental disturbances.

areas where toxic chemicals are concentrated. They are excellent measures of the subacute effects of chemical pollution and the aesthetic value of game and nongame fish.

Metric 13. Total fish biomass (optional).

Hughes and Gammon (1987) suggest that in larger (e.g., non-wadeable) rivers where sizes of fish may vary in orders of magnitude this additional metric may be appropriate. Gammon (1976, 1980) and Ohio EPA (1987) developed an Index of Well-Being (Iwb) and Modified Index of Well-Being (MIwb), respectively, based upon both fish abundance and biomass measures. The combination of diversity and biomass measures is a useful tool for assessing fish assemblages in larger rivers (Yoder and Rankin 1995b). Ohio EPA (1987) found that the additional collection of biomass data (i.e., in addition to abundance information needed for the IBI) required to calculate the MIwb does not represent a significant expenditure of time, providing that subsampling techniques are applied (see Field Sampling Procedures 8.1.1).

Because the IBI is an adaptable index, the choice of metrics and scoring criteria is best developed on a regional basis through use of available publications (Karr et al. 1986, Ohio EPA 1987, Miller et al. 1988, Steedman 1988; Simon 1991, Lyons 1992a, Simon and Lyons 1995, Hall et al. 1996, Lyons et al. 1996, Roth et al. 1997, Simon 1999). Several steps are common to all regions. The fish species must be listed and assigned to trophic and tolerance guilds. Scoring criteria are developed through use of high quality historical data and data from minimally-impaired regional reference sites. This has been done for much of the country, but continued refinements are expected as more ecological data become available for the fish community.

8.4 TAXONOMIC REFERENCES FOR FISH

The following references are provided as a list of taxonomic references currently being used around the United States for identification of fish. Any of these references cited in the text of this document will also be found in Chapter 11 (Literature Cited).

Anderson, W.D. 1964. Fishes of some South Carolina coastal plain streams. *Quarterly Journal of the Florida Academy of Science* 27:31-54.

Bailey, R.M. 1956. *A revised list of the fishes of Iowa with keys for identification*. Iowa State Conservation Commission, Des Moines, Iowa.

Bailey, R.M. and M.O. Allum. 1962. *Fishes of South Dakota*. Miscellaneous Publications of the Museum of Zoology, University of Michigan, No. 119, 131pp.

Baxter, G.T. and J.R. Simon. 1970. *Wyoming fishes*. Wyoming Game and Fish Department. Bulletin No. 4, Cheyenne, Wyoming.

Baxter, G.T. and M.D. Stone. 1995. *Fishes of Wyoming*. Wyoming Game and Fish Department. Cheyenne, Wyoming.

Becker, G.C. 1983. *Fishes of Wisconsin*. University of Wisconsin Press, Madison, Wisconsin.

Behnke, R.J. 1992. *Native trout of western North America*. American Fisheries Society Monograph 6. American Fisheries Society. Bethesda, Maryland.

- Bond, C.E. 1973. *Keys to Oregon freshwater fishes*. Technical Bulletin 58:1-42. Oregon State University Agricultural Experimental Station, Corvallis, Oregon.
- Bond, C.E. 1994. *Keys to Oregon freshwater fishes*. Oregon State University. Corvallis, Oregon.
- Brown, C.J.D. 1971. *Fishes of Montana*. Montana State University, Bozeman, Montana.
- Clay, W.M. 1975. *The fishes of Kentucky*. Kentucky Department of Fish and Wildlife Resources, Frankford, Kentucky.
- Cook, F.A. 1959. *Freshwater fishes of Mississippi*. Mississippi Game and Fish Commission, Jackson, Mississippi.
- Cooper, E.L. 1983. *Fishes of Pennsylvania and the northeastern United States*. Pennsylvania State Press, University Park, Pennsylvania.
- Cross, F.B. and J.T. Collins. 1995. *Fishes of Kansas*. University of Kansas Press. Lawrence, Kansas.
- Dahlberg, M.D. and D.C. Scott. 1971. The freshwater fishes of Georgia. *Bulletin of the Georgia Academy of Science* 19:1-64.
- Douglas, N.H. 1974. *Freshwater fishes of Louisiana*. Claitors Publishing Division, Baton Rouge, Louisiana.
- Eddy, S. and J.C. Underhill. 1974. *Northern fishes, with special reference to the Upper Mississippi Valley*. University of Minnesota Press, Minneapolis, Minnesota.
- Etnier, D.A. and W.C. Starnes. 1993. *The fishes of Tennessee*. University of Tennessee Press, Knoxville, Tennessee.
- Everhart, W.H. 1966. *Fishes of Maine*. Third edition. Maine Department of Inland Fisheries and Game, Augusta, Maine.
- Everhart, W.H. and W.R. Seaman. 1971. *Fishes of Colorado*. Colorado Game, Fish, and Parks Division, Denver, Colorado.
- Hankinson, T.L. 1929. Fishes of North Dakota. *Papers of the Michigan Academy of Science, Arts, and Letters* 10:439-460.
- Hubbs, C. 1972. A checklist of Texas freshwater fishes. *Texas Parks and Wildlife Department Technical Service* 11:1-11.
- Hubbs, C.L. and K.F. Lagler. 1964. *Fishes of the Great Lakes region*. University of Michigan Press, Ann Arbor, Michigan.
- Jenkins, R.E. and N.M. Burkhead. 1994. *The freshwater fishes of Virginia*. American Fisheries Society. Bethesda, Maryland.

- Kuehne, R.A. and R.W. Barbour. 1983. *The American darters*. University of Kentucky Press, Lexington, Kentucky.
- La Rivers, I. 1994. *Fishes and fisheries of Nevada*. University of Nevada Press. Reno, Nevada.
- Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. *Atlas of North American freshwater fishes*. North Carolina Museum of Natural History, Raleigh, North Carolina.
- Lee, D.S., S.P. Platania, C.R. Gilbert, R. Franz, and A. Norden. 1981. A revised list of the freshwater fishes of Maryland and Delaware. *Proceedings of the Southeastern Fishes Council* 3:1-10.
- Loyacano, H.A. 1975. *A list of freshwater fishes of South Carolina*. Bulletin No. 580. South Carolina Agricultural Experiment Station.
- Markle, D.F., D.L. Hill, and C.E. Bond. 1996. *Sculpin identification workshop and working guide to freshwater sculpins of Oregon and adjacent areas*. Oregon State University. Corvallis, Oregon.
- McPhail, J.D. and C.C. Lindsey. 1970. *Freshwater fishes of northeastern Canada and Alaska*. Bulletin No. 173. Fisheries Research Board of Canada.
- Menhinick, E.F. 1991. *The freshwater fishes of North Carolina*. University of North Carolina, Charlotte, North Carolina.
- Miller, R.J. and H.W. Robinson. 1973. *The fishes of Oklahoma*. Oklahoma State University Press, Stillwater, Oklahoma.
- Minckley, W.L. 1973. *Fishes of Arizona*. Arizona Game and Fish Department, Phoenix, Arizona.
- Morris, J.L. and L. Witt. 1972. *The fishes of Nebraska*. Nebraska Game and Parks Commission, Lincoln, Nebraska.
- Morrow, J.E. 1980. *The freshwater fishes of Alaska*. Alaska Northwest Publishing Company, Anchorage, Alaska.
- Moyle, P.B. 1976. *Inland fishes of California*. University of California Press, Berkeley, California.
- Mugford, P.S. 1969. *Illustrated manual of Massachusetts freshwater fish*. Massachusetts Division of Fish and Game, Boston, Massachusetts.
- Page, L.M. 1983. *Handbook of darters*. TFH Publishing, Neptune, New Jersey.
- Page, L.M. and B.M. Burr. 1991. *A field guide to freshwater fishes*. Houghton Mifflin Company, Boston, Massachusetts.
- Pflieger, W.L. 1975. *The fishes of Missouri*. Missouri Department of Conservation, Columbia, Missouri.

- Robison, H.W. and T.M. Buchanan. 1988. *The fishes of Arkansas*. University of Arkansas Press, Fayetteville, Arkansas.
- Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell. 1994. *Freshwater fishes of the Carolinas, Virginia, Maryland, and Delaware*. University of North Carolina Press. Chapel Hill, North Carolina.
- Scarola, J.F. 1973. *Freshwater fishes of New Hampshire*. New Hampshire Fish and Game Department, Concord, New Hampshire.
- Scott, W.B. and E.J. Crossman. 1973. *Freshwater fishes of Canada*. Bulletin No. 1984. Fisheries Research Board of Canada.
- Sigler, W.F. and R.R. Miller. 1963. *Fishes of Utah*. Utah Game and Fish Department. Salt Lake City, Utah.
- Sigler, W.F., and J.W. Sigler. 1996. *Fishes of Utah: A natural history*. University of Utah Press, Ogden, Utah.
- Simon, T.P., J.O. Whitaker, J. Castrale, and S.A. Minton. 1992. Checklist of the vertebrates of Indiana. *Proceedings of the Indiana Academy of Science*.
- Simpson, J.C. and R.L. Wallace. 1982. *Fishes of Idaho*. The University of Idaho Press, Moscow, Idaho.
- Smith, C.L. 1985. *Inland fishes of New York*. New York State Department of Environmental Conservation, Albany, New York.
- Smith, P.W. 1979. *The fishes of Illinois*. Illinois State Natural History Survey. University of Illinois Press, Urbana, Illinois.
- Smith-Vaniz, W.F. 1987. *Freshwater fishes of Alabama*. Auburn University Agricultural Experiment Station, Auburn, Alabama.
- Stauffer, J.R., J.M. Boltz, and L.R. White. 1995. *The fishes of West Virginia*. Academy of Natural Sciences of Philadelphia.
- Stiles, E.W. 1978. *Vertebrates of New Jersey*. Edmund W. Stiles Publishers, Somerset, New Jersey.
- Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. *The fishes of New Mexico*. University of New Mexico Press, Albuquerque, New Mexico.
- Tomelleri, J.R. and M.E. Eberle. 1990. *Fishes of the central United States*. University Press of Kansas, Lawrence, Kansas.
- Trautman, M.B. 1981. *The fishes of Ohio*. Ohio State University Press, Columbus, Ohio.
- Whitworth, W.R., P.L. Berrien, and W.T. Keller. 1968. *Freshwater fishes of Connecticut*. Bulletin No. 101. State Geological and Natural History Survey of Connecticut.

Wydoski, R.S. and R.R. Whitney. 1979. *Inland fishes of Washington*. University of Washington Press.