

Chapter 7.0 Fish

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This chapter...

- reviews existing methods for large river fish sampling
- recommends a margin-oriented boat electroshocking sampling approach

Fish are:

- important consumers in large river food webs
- established indicators in biological assessment programs
- valuable connections to cultural, recreation, and economic interests

7.1 Introduction

Fish assemblages are commonly used as indicators of ecological condition because they represent an important component of the aquatic community, and are of heightened interest to the public (Hocutt 1981, Barbour et al. 1999, Simon 1999, McCormick and Peck 2000, Lazorchak et al. 2000, USEPA 2002). Many States designate aquatic life use-support narratives based on fish assemblage characteristics. Narrative expressions such as “maintaining coldwater fisheries”, “fishable”, or “fish propagation” are prevalent in State standards. Fish are good indicators of ecological

condition because they are relatively long-lived, mobile, feed at every trophic level (e.g., herbivores, omnivores, and predators), and can be relatively easy to identify to species (Plafkin et al. 1989). There are both advantages (many as described above) and disadvantages to using fish in bioassessment programs that should be considered when developing a large river biological assessment program (Table 7-1).

Fish bioassessments use structural and functional attributes of the ichthyofaunal assemblage to evaluate biological condition. This involves careful sampling using standardized field collection techniques, species identification and enumeration, and analyses using measured biological attributes (e.g., density, biomass, etc.) or metric calculations (e.g., feeding types, pollution tolerance measures, taxonomic affiliations, etc.). Data produced by an appropriate fish sampling protocol can be used 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.

Karr (1981) developed a fish assemblage assessment approach known as the index of biotic integrity (IBI), which is commonly used in biological assessment and monitoring programs. The IBI incorporates the zoogeographic, ecosystem, and population aspects of the fish assemblage into a single, ecologically based index. Calculating and interpreting the IBI for a particular area involves a sequence of activities including: fish collection, data tabulation, regional metric selection, and calibration of metrics to expected values. A detailed description of this assessment approach is presented in Karr et al. (1986). Regional IBI modifications 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), Simon (1999), Lyons et al. (2001) and Emery et al. (2003).

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TABLE 7-1. Advantages and disadvantages to using fish as bioindicators.

ADVANTAGES/DISADVANTAGES
<p>Advantages:</p> <ul style="list-style-type: none">• Fish are good indicators of long-term effects and broad habitat conditions because fish are relatively long-lived (3-10+ years).• Fish can be sampled year round; seasonal changes in distributional patterns must be considered.• Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, detritivores, insectivores, planktivores, and piscivores).• Fish are relatively easy to collect and identify to the species level by trained fishery professionals.• Most specimens can be identified in the field and released unharmed, requiring minimal laboratory follow-up.• Environmental requirements, life histories, and distributions of many fish species are well known.• Contaminants often induce identifiable morphological deformities that can be used as indicators of condition (Sanders et al. 1999, Smith et al. 2002).• Fish have high social and cultural value (e.g., sport, subsistence, and commercial fisheries).• Fish are at the top of the aquatic food web and are consumed by humans, making them important for assessing ecological and human health risk.• Aquatic life uses are typically characterized in terms of fisheries (coldwater, coolwater, warmwater, sport, forage). Monitoring fish provides direct evaluation of "fishability" and "fish propagation".
<p>Disadvantages:</p> <ul style="list-style-type: none">• Because of the seasonal mobility of some species, they may be less indicative of localized disturbances.• The initial cost of sampling gear is often considerable (investment cost of gear is offset by minimal lab cost).• Safety concerns are increased due to use of 500-1000 volts (when using boat electrofishing gear) and the potential hazards associated with night electrofishing (Graham 1986).• May require that agencies collaborate to facilitate sampling (possible advantage).

Many studies have shown strong associations (i.e., correlations) between fish IBI results, physical and chemical habitat condition, and human activities that alter stream and river habitat (e.g., dams, agriculture, urban development, etc.) (Karr et al. 1985, Berkman et al. 1986, Leonard and Orth 1986, Ohio EPA 1987, Steedman 1988, Karr 1991, Yoder and Rankin 1995, Ohio EPA 1999). Most of the studies using fish IBIs have been conducted in wadeable streams systems, and the application of IBIs for large river assessment is relatively limited (Hughes and Gammon 1987, Ohio EPA 1987, Oberdorff and Hughes 1992, Hugueny et al. 1996, Ganasan and Hughes 1998, Simon 1999, Gammon and Simon 2000, Lyons et al. 2001, Araujo et al. 2003, Emery et al. 2003, Mebane et al. 2003, Stoddard et al. 2005).

In this chapter, we provide an overview of several different programs (Table 7-2) that have developed and successfully applied different fish sampling protocols to biological assessments in large rivers, including USEPA/EMAP (McCormick and Hughes 2000, Angradi 2006), USGS/NAWQA (Moulton et al. 2002), and ORSANCO (Emery et al. 2003). Although specific definite protocols of sampling and assessment using fish are not proposed, different approaches and techniques are covered and techniques for documenting method performance are suggested. Whatever methods are selected for your program, they should be thoroughly tested to document the quality of data they can produce. It is up to you, as the data user, to ensure these data will meet project objectives.

TABLE 7-2. A comparison of large river program fish sampling approaches.

Program	Protocol Summary	Citation
<i>Environmental Monitoring and Assessment Program (EMAP-Non-Wadeable)</i>	Focus on all but most rare fish. Data collected on richness, guild structure, abundance, size, and anomalies. Sample reach varies: 40X to 100X wetted width, fish sampled along one bank with 14-16 ft electrofishing boat; 50X wetted width, fish sampled along alternating shores by raft. Identified, counted, total length measured, anomalies recorded, and vouchering if needed.	McCormick and Hughes 2000, Hughes and Herlihy accepted, Lazorchak et al. 2000
<i>Environmental Monitoring and Assessment Program: Great River Ecosystems (EMAP-GRE)</i>	Focus on characterizing all but most rare fish in littoral habitat of great rivers. Data collected on species composition, size, and condition. Sample reach is 500 m long along one bank. Electrofishing zone extends out from shore 30 m or to a depth of 6 m, whichever is closer. Fishing time must be 30 minutes or longer at 3000 watts (adjusted as necessary to reduce injury to fish). Use a 5.5 m welded hull, aluminum electrofishing jon boat with 90 hp engine for travel and 25 hp engine for sampling. Identified, counted, total length measured, weighed, anomalies recorded, and vouchering if needed.	Emery et al. 2006
<i>United States Geological Survey-National Water Quality Assessment (NAWQA)</i>	Focus on sampling a representative portion of the fish assemblage. Reach lengths are 20X wetted width (500 m min to 1000 m max). Electrofishing and seining are used. Make two passes along one bank with electrofishing boat. Three seine collections composited from wadeable shoreline areas after electrofishing. Each electrofishing pass and seine composite samples all processed separately. Identified, counted, total length measured, weighed, anomalies recorded, and vouchering if needed.	Moulton et al. 2002
<i>Ohio River Valley Water Sanitation Commission (ORSANCO)</i>	Focus on condition of fish assemblages along Ohio River. Expected index values developed for different habitats. Sample from July to October along 500 m shoreline zones. Night electrofishing used with a boat unit. Identified, total length measured, weighed, anomalies recorded, and habitats noted.	Emery et al. 2003, and <i>See program highlight box</i>
<i>Large River Bioassessment Protocol (LR-BP)</i>	Focus on developing an unbiased and representative sample of fish assemblage within logistical and budgetary constraints. Uses a 2-3 person crew – one boat operator and 1-2 dippers. Targets main channel border habitats. Basic design sample either 500 m paired bank or 1000 m single bank. Reach length may be increased for study-specific needs. Sites <4m, mean thalweg depth are electrofished at day. Sites >4m are preferably electrofished at night. Identified, counted, total length measured, weighed, anomalies recorded, and vouchering if needed.	Flotemersch and Blocksom 2005

7.2 Methods

Several questions related to program development and method selection should be considered prior to beginning a fish bioassessment program:

- What fish sampling permits are required by the State?
- Which habitats should be sampled?
- What should the reach length be for each site?
- What is the appropriate time of day to sample?
- What method and sampling gear should be used?
- Should multiple samples be collected (for population estimates) or only one sample (for richness, relative abundance, and other metric calculations)?
- Should samples be composited or kept separate?
- What is the most appropriate spatial sample design?
- How will specimens be identified?
- What are the indicators that will be used?

It is strongly advised that consensus-driven responses to these and similar questions be prepared and signed-off on by key staff who will be involved in the collection, analysis, and use of the resulting data. This should occur prior to the data collection process and will greatly increase the level-of-success achieved by the project.

Most fish collection procedures use a multi-habitat sampling approach, sampling habitats in relative proportion to their local availability as determined during site reconnaissance. Sample reach lengths vary among studies, but generally attempts to encompass most if not all prevailing habitats. The exception is when habitat features are so large that a reach length encompassing all habitats is unrealistic. In such cases, the development of habitat specific criteria should be considered. When placing the reach, it is important that it not be located to purposefully avoid manmade obstacles such as bridges, rip-rap, road crossings, or channelization as the potential influence of these features are relevant to assessing overall river condition (Lazorchak et al. 2000). However, study-specific needs may necessitate that such features be avoided.

When compared to wadeable streams, accessibility issues on rivers are two-sided in that they can be reduced or increased depending on the nature of the site. This may be more true of studies assessing fish assemblages than other assemblages because of the substantially more bulky equipment required. If the site is remote yet the river is navigable, access by boat may be easier than by foot. However, in free-flowing low-gradient systems, navigation along the channel may be impeded by shallows, log jams, or other obstacles. In such cases where a pre-selected reach cannot, in a safe and reasonably efficient manner, be accessed, it should be left out and not forced; if this situation occurs, a replacement reach should be randomly selected from a list of alternate reaches. However, caution should be exercised to not declare sites unsampleable out of convenience. This could bias results by skewing sites sampled towards those that are potentially more impaired because of their accessibility or reason for accessibility (e.g., presence of a boat ramp because the site is impounded).

A habitat assessment is typically performed and physical/chemical parameters are measured concurrently or just prior to fish sampling, to document and characterize available habitat within the sample reach (Chapter 4). It is extremely important for experienced fisheries scientists to be involved in the adaptation and application of field protocols and the taxonomic identification of fishes. Since most protocols specify field identification and release of captured fish, fish bioassessment data quality and comparability are assured through the use of qualified fisheries professionals, consistent methods, and correctly applied quality control activities.

While electrofishing is most commonly used, it is only one of several fish sampling procedures that may be useful as part of a bioassessment program. Fish sampling methods can be broadly categorized as either passive or active. Passive sampling methods include those that use hoop (Figure 7-1), fyke, trap, and gill nets, or hook-based methods such as trotlines (Hubert 1996). Many of these methods have high species selectivity in that they are most effective for specific species, guilds, or size classes of fish and thus may only effectively sample a segment of the assemblage. However, because of their efficiency at collecting the targeted organisms, they are frequently used by resource managers to attain species-specific information. Active sampling methods include electrofishing, seining, and trawling (Hayes et al. 1996). Table 7-3 summarizes some advantages and disadvantages of common non-electrofishing sampling techniques.

While all fish sampling methods are generally considered selective to some degree, electrofishing has proven to be the most comprehensive and effective single method for collecting fishes (Figure 7-2) from streams and rivers (Vincent 1971, Gammon 1973 and 1976, Novotny and Priegel 1974, Ohio EPA 1987, Davis et al. 1996, Barbour et al. 1999, Simon and Sanders 1999). There are situations, however, where approaches other than electrofishing (e.g., seining, trawling) may be preferred or necessary. As an example, electrofishing is limited in some river reaches with endangered fish (Barbour et al. 1999) or mussels. This concern seems warranted since studies have shown that spinal injuries and associated hemorrhages occur in over 50% of fish examined internally subsequent to being electroshocked (Snyder 2003). Another example is when collections are required in river systems that lack the solutes necessary (e.g., conductivity $<10 \mu\text{S}/\text{cm}$) to effectively pass the electrical current through the water due to regional geological characteristics. This is less likely, however, in large rivers that accumulate solutes from diverse landscape types. Excessively high conductivities (e.g., 1,000-3,000 $\mu\text{S}/\text{cm}$; Hill and Willis 1994), such as in brackish waters and at sites where non-natural inputs artificially raise the conductivity, reduce the effectiveness of electrofishing as well (Reynolds 1996).

7.2.1 Electrofishing

Although numerous agencies electrofish, the equipment used, the electrofishing configuration, and the field design applied may vary greatly. Variables that often differ include the sampling design (e.g., habitat sampled), whether the electrofishing is conducted during the day or night (Section 7.2.1.1), the mesh of the dip net, number of netters, the power of the electrofishing unit and generator, and the size of the boat. An assortment of electrofishing equipment may be necessary to cover the range of habitats in large rivers. It is not uncommon for field teams targeting rivers to need equipment that ranges from tote-barges to large electrofishing boats.



FIGURE 7-1. Use of a hoop net as a passive fish sampling method.

TABLE 7-3. Advantages and disadvantages of non-electrofishing sampling approaches including passive (e.g., hoop, fyke, and gill nets, and trotlines) and active (e.g., seines, trawls) sampling gears.

ADVANTAGES/DISADVANTAGES
<p>Advantages:</p> <ul style="list-style-type: none"> • potentially a low cost alternative to electrofishing (design dependent) • no electrical components • require little specialized training • can yield precise data on the components of the fish assemblage the gear targets • effectiveness not impaired by conductivity or turbidity <p>Disadvantages:</p> <ul style="list-style-type: none"> • selectivity of the gear • require multiple trips to a site (although seines only require one trip) • spatial coverage of a site may be limited • ineffective or difficult to deploy in swift water areas (e.g., runs or rapids) • passive methods only sample fish that are moving • potentially high mortality and bycatch (study dependent) • effort required to reduce disease transmission across sites • repair and maintenance of gears • large trawls require large boats



FIGURE 7-2. Net retrieval of fish stunned by boom-shockers, an active method.

The performance of equipment and field personnel can greatly affect the results of an electrofishing effort, potentially leading to bias. The type of boat and electrofishing equipment, equipment settings, electrode arrays, field conditions, and skill of the crew will all influence the catch. Among required skills is that the boat driver be able to navigate the boat in a manner that assures the safety of themselves and the crew while assuring the collection of a high quality sample. The boat operator is also usually required to monitor electrofisher performance to assure uniform application of the electrofishing field across the sampling site.

Once a sample has been collected, accurate fish identifications in the field are essential. This is an important component for quality control of bioassessment programs and requires extensive training and study, knowledge of regional distributions, and proper allowance of time in the field to do a thorough job. Regardless of skill level, some specimens will have to be returned to the laboratory for identification/verification. It is strongly recommended that field crews be adequately trained. Additionally, the crew lead should possess broad electrofishing experience attained under the leadership of a qualified professional.

Environmental factors can also influence electrofishing performance. These factors include time of day, wind, excessive amounts of flotsam or macrophytes, bottom substrate, water depth, cover, conductivity, temperature, water clarity, and any additional deviations from normal water conditions (e.g., flow rate, water level, dissolved oxygen, etc.) that might result in the collection of anything other than a representative sample. All of these conditions should be evaluated, recorded, and considered prior to initiating the collection of what should be a representative sample of the fish assemblage. Additionally, recent research that compared electrofishing designs in large rivers of the eastern and central USA (Flotemersch and Blocksom 2005) showed that the degree to which a river has been impounded plays a critical role in electrofishing performance. In short, daytime electrofishing was less productive per unit of effort at sites

where the depth exceeded 4 m, as is frequently the case at impounded sites. Hence, different electrofishing designs (e.g., day vs night; see Section 7.2.1.1) and metrics may be required to adequately describe different types of systems or parts of systems.

7.2.1.1 Day and Night Electrofishing

At riverine locations where the diel movements of fish significantly influence the efficiency of electrofishing efforts, varying the time electrofishing is conducted may aid in most efficiently meeting study objectives. Research comparing the catches between day and night electrofishing sessions has shown that catches can be significantly different (Sanders 1991, Andrus 2000, Dumont and Dennis 1997, Simon and Sanders 1999). For example, Sanders (1991) found that day sampling collected 9 species not collected during night sampling, while night sampling collected 17 unique species and 2 hybrids previously unreported from the study area. Overall, night catches contained significantly more species, higher numbers and weights of fish, and were compositionally more evenly distributed than day catches (Sanders 1991, Simon and Sanders 1999); all qualities advantageous to the bioassessment of a site. Andrus (2000) reported that in alcoves and main channel reaches of the Willamette River, Oregon, night electrofishing yielded more taxa and a greater abundance of fish than daytime electrofishing. Increase in catch was attributed to fish migrating into the alcoves at night and fish being more vulnerable to electrofishing at night because of positioning in the water column. Nonetheless, the data requirements of the study should be consulted prior to deciding whether day or night electrofishing is most appropriate. It would be improper to night electrofish for a study targeting a species almost exclusively collected during the day.

While preferable for some scientific collection purposes, some concerns have been raised about the safety and logistical problems of night electrofishing (e.g., navigation in the dark, fatigue) (Graham 1986). Specific problems that have been cited include difficulty identifying shallow water, unexpectedly entering fast and shallow water, a limited ability to see downstream hazards such as log jams, and difficulty in setting reach lengths with electronic rangefinders (Andrus 2000). To address such problems, Andrus (2000) recommended visiting the site during the day prior to sampling so the crew can become familiar with the site and complete tasks that may be difficult in the dark.

7.2.1.2 Sample Reach

Considerable research has been conducted on the determination of sufficient sample reach lengths for large rivers (e.g., Gammon 1976, Penczak and Mann 1993, Yoder and Smith 1999, Cao et al. 2001, Lyons et al. 2001, Hughes et al. 2002, Maret and Ott 2004, Flotemersch and Blocksom 2005, Hughes and Herlihy, accepted). As seen in Table 7-4, reach lengths found suitable for rivers vary in length and form (i.e., fixed distance vs multiples of the wetted width). Some of these differences can be attributed to the geographic area of the work, system type (e.g., high gradient vs low gradient rivers), and the evaluation parameter(s) used to determine sample sufficiency.

Most electrofishing designs call for shocking a continuous length of shoreline. However, other options exist. For example, Hickman and McDonough (1996) discuss the development and use

of an electrofishing design on Tennessee River valley reservoirs that shocks 15 independent 300-m shoreline zones. Dominant habitat features in each electrofishing run and at each gill-net set are recorded to determine habitat influences on metric results. The electrofishing catch is supplemented with 10 overnight experimental gill net sets. To mitigate the effects of one sample on the next, a 50-m shoreline section between each electrofishing run is not sampled. For additional reading on this design, consult Jennings et al. (1995) and McDonough and Hickman (1999).

TABLE 7-4. A comparison of different reach lengths found suitable for bioassessment of rivers.

	Reach length	Geographic Area	Evaluation Parameter
Fixed Distance			
Gammon 1976	500-2000 m	Wabash River, Indiana	Assemblage parameters
Meador et al. 1993	500-1000 m	United States	Representative sample
Penczak and Mann 1993	500-1000 m	Pilica River, Poland	Species richness
Yoder and Smith 1999	500/1000 m	Ohio large/great rivers	Representative sample
Lyons et al. 2001	1600 m	Wisconsin rivers	Species richness
Flotemersch and Blocksom 2005	500-1000 m (both banks)	Mid-Western rivers	Assemblage parameters
Angradi 2006	500 m	Great Rivers	Representative sample
Emery et al. 2003	500 m	Ohio River	Representative sample
Multiples of the Wetted Width (MWW)			
Hughes et al. 2002	85 MWW	Oregon raftable rivers	Species richness
Maret and Ott 2004	30-40 MWW	Idaho rivers	IBI scores
Hughes and Herlihy, 2006	50 MWW	Oregon raftable rivers	IBI scores

When selecting a reach length, or conducting research for setting reach length, it is important to consider several factors including the question being addressed by the study, the level of resolution (precision and accuracy) required to address the question, and the statistical approach that will be used to analyze any resulting data. Ideally, the sampling effort applied is the minimum required that will allow stated study objectives to be addressed (Angermeier and Smogor 1995, Patton et al. 2000). Just as critical is ensuring that reach length is balanced with available resources, logistical constraints, and safety issues. A detailed discussion covering issues related to setting reach length for bioassessment of riverine biotic assemblages is provided in Chapter 3 of this document.

7.2.1.3 Generalized Electrofishing Protocols

Boat electrofishing techniques are often very similar across protocols (e.g., Ohio EPA 1987, Reynolds 1996, McCormick and Hughes 2000). Yoder and Smith (1999) provide insight into the intricacies involved in the successful navigation of an electrofishing boat within a sample reach. Table 7-5 lists activities that should be performed prior to leaving the launch site.

TABLE 7-5. Preparation activities onshore at launch site.

-
- Check generator oil and fill tank with gas (wipe up any spillage).
 - Attach and inspect anode arrays.
 - Attach the cathode.
 - If the target site is in close proximity to the launching point, the anode booms should be positioned for electrofishing. Otherwise, travel with the booms in their stowed position.
 - Complete all necessary electrical connections between the generator, the variable voltage pulsator box, and the anode booms.
 - Review and confirm that all gear is in the boat.
 - Assure crew members have donned personal floatation devices.
 - If the target reach is in close proximity to the launch site, the crew can prepare for electrofishing activities. Otherwise, assure all gear is properly stowed for travel to the site.
-

Establishing the Reach

Upon arrival at the site, the first task is to delineate the targeted reach to be sampled (see Table 7-4 for common reach length examples).

- Examine the immediate area for influences of major tributaries and bridge/road crossings (i.e., the site should be sufficiently upstream to decrease influences on overall habitat quality). If an influence disruptive to the integrity of the sample exists that would fall within the estimated limits of the sample zone, the decision may be made to slide the reach either up or downstream. If the sample zone is relocated, an effort should be made to retain the original site identifier (i.e., latitude and longitude) in the reach.
- The exact location (i.e., latitude and longitude) of the downstream limit of the designated reach should then be recorded on the appropriate field data sheet(s). If a GPS unit is used to provide location information, the accuracy or design confidence of the unit should be noted.
- Designate (i.e., flag) the downstream extent of the reach on both the left and right banks (or on one particular bank if choosing a single bank sample). Several methods can be used for locating the upstream end of the reach, but the two most common techniques use a laser rangefinder or the “distance traveled” feature of a GPS unit or alternate equipment (e.g., depth finder) with GPS capabilities.

Preparing for Electrofishing of the Reach

With the sample reach established, the crew can prepare for electrofishing.

- Discuss the layout of the reach, any hazards or obstacles observed when the reach was established, and discuss how each will be addressed.
- Prepare the live well by filling it to a suitable level with fresh river water and assure aeration devices are functioning. A large live well (>300 L) should be used to ensure adequate holding capacity for all fish collected in a long reach (e.g., 500 m). A strong and reliable aerator should be used to maintain oxygen levels. If a large number of

fish are captured, it may be necessary to periodically change the water in the live well. Usually this is done after the electrofishing run has been completed, just prior to processing the fish, or continually during processing.

- Check all electrical connections (including on/off switches) and assure anodes (electrofishing booms) and cathode array (if equipped) are in position and secure.
- Crosscheck with crew that all safety gear (e.g., personal floatation devices, watertight rubber linesman's gloves, rubber footwear, hearing protection, and communication gear) is functional.
- Verify that all electrical switches are off, that all non-target organisms (e.g., cattle, waterfowl, and humans) are clear of the water, and that boat surfaces are dry.
- Test and record the conductivity of the water in the area of the sample reach. This information is needed to determine if the conductivity is within the performance specifications of the equipment, to determine preliminary settings for the variable voltage pulsator box, and to track changes at the site through time.
- In an area outside the target reach, start the generator and test for the proper functioning of all equipment (particularly on/off switches). Adjust the variable voltage pulsator box setting for effective electrofishing. Settings for electrofishing will vary greatly across sites. No single setting will work in all places, but a standardized approach for arriving at a setting can be achieved. If no one on the crew has experience in the area being sampled, it is advisable to find a local professional with experience and consult with them prior to heading for the field.
- Experienced or properly trained crew members will be able to determine the effectiveness of pulsator box settings and verify that fish within the electrofisher's field are rolled and relaxed but not rigid. Record pulsator box settings on the field sheets, reset shock-time timer to record total seconds the pulsator is engaged and fishing (often referred to as button time), and record start time.

Electrofishing the Designated Reach

- Collection via electrofishing can begin on either bank at the upstream end of the sample reach. The boat is piloted to proceed in a downstream direction along the main-channel shoreline habitat of each bank at a speed near or slightly exceeding the river velocity (Ohio EPA 1987, Reynolds 1996, Yoder and Smith 1999, McCormick and Hughes 2000). Proceeding at this speed serves two purposes. First, stunned fish will be moving at or near the speed of the boat and the netter(s) is (are) provided the best opportunity to collect stunned fish in front of and on the sides of the boat. Second, keeping the boat in motion serves to help standardize the effort among crews and across sites.
- The effective shoreline electrofishing area will vary within and among sites, but generally follows the shoreline in waters from 0.25 m to 3 m deep.
- As electrofishing proceeds through the reach, minor fluctuations in the observed amperage may be observed. If the amperage deviates significantly, the electrofishing settings (usually percentage applied) should be adjusted to maintain consistent, effective, and humane electrofishing. Significant adjustments to the settings should also be noted on field forms.

- Stunned and collected fish should be placed directly in the livewell as soon as possible. Fish should not be held in the net in the electrical field as this will increase the likelihood of mortality among stunned fish. Netters should collect all stunned fish and avoid being size selective (e.g., netting only large specimens). Try to net all fish seen, but in productive systems this may not be possible. If benthic fish are being missed, an option may be to pivot the boat occasionally or hold the net behind the anode and along the bottom so more are collected. Care should be taken to thoroughly maneuver the electrofisher around objects such as snags, downed trees, piers, boulders, and other potential fish cover until each object yields no more fish.
- During the electrofishing run, rare, sensitive, or excessively large fish may be encountered. If these fish appear overly stressed (as indicated by loss of righting response), the decision may be made to pause the electrofishing effort, process the fish, and release them behind the boat to ensure that they are not recaptured. If this occurs, be sure to pause the clock recording total time electrofished and restart it when fishing is resumed. Button time will not be affected.
- In shallow reaches of some rivers, there may be sections that are non-navigable. In such areas, a small boat (12-14') with a crew of 2 may be used. With this configuration, using oars or push-poles, electrofishing can continue in depths as shallow as 12 cm. In areas where the water depth is shallower, a method used by the Ohio EPA is to have one or more crew members exit the boat and position it at the top of the reach, while the netter takes position downstream. When the okay is given, the operator engages the electrofisher as the netter proceeds upstream netting fish. When the netter reaches the boat, the crew (as a team) repositions the boat further downstream and repeats the activity. When the full extent of the non-navigable section of river has been electrofished, the full crew re-boards the boat, electrofishes the downstream extent of the riffle, and then proceeds downstream as described above.
- Upon arriving at the downstream extent of the reach, the variable voltage pulsator and the generator should be turned off and both the button time and total time should be recorded. Shocking a 500-m reach on one bank generally should take between 20-30 minutes (depending upon flow and fish abundance). All fish should be field processed immediately. Fish that appear overly stressed, or are known to become stressed with increased holding times, should be processed first. If additional passes are part of the study plan, it may be advisable to retain fish in holding nets to eliminate the possibility of repeat capture during additional passes or on the opposite bank. If fish are returned directly to the river, they should be released in an area that ensures that they are not recaptured.
- If multiple passes or both banks are sampled, fish from the first bank (or pass) should be processed before proceeding with subsequent effort. After electrofishing and processing has been completed, fish can be released with the exception of voucher specimens that need to be identified in the laboratory or those retained for other purposes (e.g., fish tissue sampling, histopathological analysis).

Ancillary Data Collected to Characterize the Electrofishing Event

A number of variables are commonly recorded to characterize prevailing conditions while electrofishing, some of which have already been mentioned (e.g., button time, total time, conductivity). Beyond their utility for data analysis, many are highly useful to crews revisiting the site. Many of these variables should be considered as critical data elements to be included in any electrofishing activity. These items include, but are not limited to:

- Location of target site (e.g., latitude and longitude, position of sampling reach to latitude and longitude, and landmarks),
- Time of day electrofishing occurred,
- Habitat variables that may already be part of a larger habitat assessment (e.g., maximum and mean widths, dominant habitats, secchi depth, depth characterization),
- Factors that affect sampling efficiency (e.g., field team's ability to see and net stunned fish, whether polarized sunglasses were worn, prevailing flow conditions, river stage, water clarity, and water color), and
- Items useful to crews conducting future sampling events (e.g., directions, access points, difficulty of access, land owner contact information, potential safety concerns).

7.2.1.4 Electrofisher Configuration and Design (Electrode Arrays)

The size, surface areas, and shape of the electrodes are the most important element of an electrofishing system (Novotny 1990). In combination with the water conductivity, the array configurations determine the system's electrical resistance and the distribution of field intensity that determines the unconfined size and shape of the effective field for a specified voltage output (Snyder 2003). For reasons of sampling efficiency and reduced injury to both fish and incidentally shocked humans and other animals, direct current (dc) is most frequently used to power contemporary electrofishing boats (Reynolds 1996, Snyder 2003).

A contemporary dc powered electrofishing configuration consists of anode and cathode arrays. The anode array usually extends in front of the boat suspended from booms. Anode designs vary greatly among electroshocking boats. Common designs include use of aircraft cable or flexible conduit suspended between two booms, suspension of one or two metal spheres in the water (i.e., Coffelt Sphere), and suspension of a cluster (i.e., umbrella) of cable droppers from one or two booms.

Regarding the cathode side of the circuit, in its simplest form, the boat hull is used as the cathode although this is generally advised against (Reynolds 1996). A commonly employed alternative is using a cathode array attached to the front, side, or on both the front and side of the boat. In most cases, the array is constructed of metal cable suspended into the water from the boat hull. Use of a cathode array (rather than using the boat hull as the cathode) can effectively increase the efficiency of the electrofishing unit by concentrating the effective electroshocking field to the viewable area of the netters. The smaller electrical field requires less power to produce and is generally more stable and uniform (design dependent). Combined, these factors can extend

equipment life reducing the load on the electrical equipment, reduce the injury rate to fish, and reduce the risk presented to incidentally shocked humans and other animals.

Electrode arrays tend to be easily serviced due to their location and can be reconfigured if necessary to meet site conditions. In general, longer arrays are preferred in deeper waters and shorter arrays may be preferred in habitats where longer arrays may become snagged. To assure efficiency, it is recommended that the surface area of the cathode array be a minimum of twice that of the anode array with some recommending a surface area 10 to 20 times that of the anode array (Bob Hughes, Oregon State University, personal communications). Keeping the surface of the arrays clean and free from build-up is vital to maintaining the performance of the configuration.

For a comprehensive discussion on the basic principles of electrofishing, refer to Reynolds et al. 1996, and the support section available online at www.Smith-Root.com and the list of additional reference and training materials included therein. For additional information on implications of electrode configuration, refer to Beaumont et al. 2006. For a summary of how anode and cathode configuration can influence the extent of the harmful effects of electroshocking on fish, refer to Snyder (2003).

7.2.1.5 Electrofishing Field Team Safety and Organization

Adequate education, training, and experience of all members of the fish collection team are critical for assuring the safety of all personnel and the quality of the data (Barbour et al. 1999). At least one biologist with training and experience in electrofishing techniques and fish taxonomy must be involved in each sampling event. All field team members must be trained in boating safety and electrofishing safety precautions and unit operation procedures identified by the electrofishing unit manufacturer. Any crew member that will be driving the field vehicle, with or without a boat in tow, should attend a safe driving course. It is also recommended that at least 2 fish collection team members are certified in CPR (cardiopulmonary resuscitation). If electrofishing will take place in white water rivers, white water safety courses such as those developed by Rescue 3 International (www.rescue3.com) are also highly recommended.

Proper maintenance of all equipment is an important component of safety in the field. For a boat-based electrofishing crew, this includes maintenance and repair of the boat, motor, and trailer, plus regular inspection of all components of the electrofishing configuration. It is also recommended that the electrofishing boat be annually inspected by a professional electrician for shorts, voltage differences, and general wear of electrical components.

When electrofishing, each team member must be insulated from the water and the electrodes even when in a boat and not wading in the river; therefore, insulative footwear (e.g., knee boots, chest waders) and rubber gloves (linesman's gloves) are required. Likewise, dip net handles must be constructed of insulating materials (e.g., wood, fiberglass). The electrofishing boat should be equipped with functional safety switches (usually standard equipment from electrofisher manufacturers) so that each member of the crew has the ability to interrupt the flow of electricity when needed. Field team members must not reach into the water unless the electrodes have been removed from the water or the electrofisher has been disengaged.

Furthermore, every effort should be made to keep the electrofishing gloves dry. If they become excessively wet, electrofishing should stop and the gloves should be dried. Additionally, efforts should be made to minimize water on the boat deck(s).

The priority of the boat operator is overseeing the safe operation of the boat and general safety of the crew. The netters are likewise charged with assuring safety of the crew. Key responsibilities include providing the operator with information about obstacles in the water while the boat is in motion, and assuring conditions in the holding tank are suitable for specimen survival. Two-person crews are generally used at shallow sites where smaller, lighter electrofishing boats are needed to successfully navigate the river. At sites where the depth of the river permits the use of a larger electrofishing boat, an optional second netter is often added to the crew. Note that the addition of a second netter will increase capture efficiency and potentially influence the collection. Thus, crew configuration should be documented on field sheets and should be part of the permanent record for the resulting data. Table 7-6 provides a checklist of items and gear needed for boat electrofishing. For additional reading on the safety and logistics of ecological sampling on large rivers, see Flotemersch et al. (2001).

7.2.2 Seining

Seining in streams and rivers is generally conducted with a beach seine consisting of uniform mesh, two wings, and a bunt section that holds the catch (Hayes et al. 1996). Scientists with the US Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi regularly use beach seines to evaluate changes in species composition in response to riverine habitat changes (J. Killgore, US Army Corps of Engineers, personal communications). Their research shows that seining often collects equivalent numbers of species as electrofishing, if not more, and provides data that meets their specific study objectives. However, species collected are usually limited to small bodied species. Consequently, the approach may not be appropriate for study objectives that require adequate sampling of large fish that comprise an important component of the fish assemblage in rivers. Their research also shows that effectiveness of seine hauls declines with increasing river size. Seining is also hindered at river locations where physical habitat is complex (e.g., boulders, large amounts of woody debris) or miry (i.e., soft and watery) substrates hinder foot travel.

7.2.3 Trawling

Trawling in inland rivers has recently received increased interest. Trawls are funnel-shaped nets that are towed along the bottom (bottom trawls) or in the water column (midwater trawls). As the net is towed through the water, fish enter the net, become exhausted, and drift to the cod end (rear) of the net until retrieved (Hayes et al. 1996). Variations in net configuration determine what is retained and survivorship (Herzog et al. 2005). Trawling is a commonly used method for sampling oceanic and estuarine habitats (Hayes et al. 1996) and reservoirs (Matsushita and Shida 2001), but has only been used to a limited extent in rivers (Pitlo 1992, Gutreuter et al. 1995, Dettmers et al. 2001, Wildhaber et al. 2003, Stewart and Barko 2005). Herzog et al. (2005) describes the successful application of the Missouri trawl for sampling benthic species in moderate to large size rivers. Stewart and Barko (2005) discuss the use of the same trawl configuration for collecting darter species undersampled by seining. Given these results, it

seems likely that use of trawling will increase in studies targeting benthic species that may be undersampled by other methods (e.g., inventory, monitoring of threatened and endangered species). Similarly, the method's selectivity for benthic species limits its use as a stand-alone method for bioassessment purposes.

TABLE 7-6. Field equipment supply checklist for fish sampling via electrofishing.

<ul style="list-style-type: none"> • scientific collection permit(s) • boat, motor, and trailer • boat electrofisher and associated equipment (generator, variable voltage pulsator, anode poles, cathode, gasoline) • dip nets • insulated waterproof gloves (linesman gloves) • insulated footwear • polarized sunglasses (day-time electrofishing only) • lights/flashlights (for night sampling) • livewells with functioning aerators and water circulation • jars for voucher/reference specimens • waterproof jar labels • 10% buffered formalin (formaldehyde solution) • measuring board^a • balance (gram scale)^b • fish sampling field data sheet • taxonomic references (fish keys) • laser range finder • topographic maps • copies of field protocols • pencils, clipboard • first aid kit • US Coast Guard required safety equipment (personal floatation devices, fire extinguisher, etc.) • cell phone • global positioning system (GPS) unit • tool box

^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

7.3 The Large River Bioassessment Protocol (LR-BP) for Fish

The fish LR-BP is based on results of a study conducted on several Mid-Western rivers using an electrofishing design that permitted examination of the effects of designs and distances on fish assemblage metrics (Flotemersch and Blocksom 2005). While the results of the study likely apply to many rivers outside the study area, consultation of other more regionally specific literature is advised (Table 7-4).

The study concluded that depth plays a critical role in the response of fish assemblages to electrofishing and the resulting metric values. For example, at sites with a mean thalweg depth < 4 m, a daytime main-channel border design that includes electrofishing 1000 m along a single bank or 500 m on paired banks was sufficient to characterize sites for bioassessment purposes. At sites with a mean thalweg depth > 4 m, results were more variable. Therefore, at such sites,

the LR-BP protocol suggests that a switch from daytime to nighttime electrofishing be considered. If night electrofishing is not feasible, the LR-BP suggests increasing the electrofishing distance at these sites to a 1000-m paired-banks design or a 2000-m single-bank design. In addition, metrics based on fish species prone to diel movements should be interpreted with caution.

The fish LR-BP is quantitative and designed to support bioassessment and monitoring activities of states, regions, tribes and other agencies. It is designed to collect samples that are as unbiased and representative as possible within the logistical realities of fieldwork and constraints of time and budget, and are indicative of the ecological condition of a site when compared to sites of known condition. This sampling approach is not appropriate for qualitative studies that strive to maximize the number of species as a measure of local (alpha) diversity, although data collected using the fish LR-BP could be used to supplement qualitative investigations.

7.4 Sample Processing in the Field

The accurate identification of each fish collected is essential, and species-level identification is required (including hybrids in some cases). Field identifications are acceptable; however, voucher specimens may be retained for laboratory verification, particularly if there is any doubt about the correct identity of the specimen. 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 mm total length are not identified or included in standard samples. During the identification process, be as precise as the data quality objectives require. Common variables that are recorded during the identification process include total count, length, weight, and the presence of external anomalies. Measurement of length may take the form of an actual measurement or placing specimens in size classes.

While processing fish, an assessment of the condition of the fish is often conducted. A widely used and reliable approach for documenting external anomalies as indicators of fish assemblage condition is to record DELT anomalies (deformities, erosions, lesions, and tumors) (Sanders et al. 1999). This is especially true for sites degraded by multiple and cumulative stressors. Documentation of such anomalies is an effective way to communicate information about degraded water quality to resource managers, the regulatory community, and to the general public. Guidelines for more extensive assessment of external and internal anomalies can be found in Goede and Barton 1990, Adams and Ryon 1994, Adams et al. 1993, 1996, Schmitt et al. 1999, and Smith et al. 2002.

7.5 Quality Control in the Field

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 involves 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. To mitigate the effects of intersegmental fish movement, a section of shoreline (e.g., 50m) between successive electrofishing reaches is not sampled. Sampling QC should be performed

on a routine basis to document sampling error (field sampling precision) associated with a dataset and program; as a rule-of-thumb this can result from sampling adjacent reaches from a randomly selected subset of reaches..

Field identifications should be conducted by qualified, trained fish taxonomists who are familiar with local and regional ichthyofauna. Questionable records are prevented by: 1) requiring the presence of at least one experienced/trained fish taxonomist on every field effort, and 2) preserving selected specimens and those that cannot be readily identified in the field for laboratory verification or examination by a second qualified fish taxonomist. An approach for documenting taxonomic precision is suggested in Section 7.7.3. If being retained, specimens must be properly preserved and labeled. When required, chain-of-custody forms must be initiated following sample preservation, and must include the same information as the sample container labels.

All field equipment must be in good operating condition, and a plan for routine inspection, maintenance, and 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) (see also Chapter 2).

7.6 Fish-based Index of Biotic Integrity

Approximately 22 different fish-based indices of biotic integrity have been developed for the assessment of streams and rivers in various regions and of differing types (Simon and Lyons 1995). Among these indices (which vary in terms of the number and complement of metrics), Table 7-7 summarizes seven examples that focus on the assessment of large rivers of the USA. Additional examples from outside the USA include Oberdorff and Hughes (1992), Hugueny et al. (1996), Ganasan and Hughes (1998), and Araujo et al. (2003). For a review on the use of environmental guilds for assessment of the ecological condition of rivers, consult Welcomme et al. (2006). This paper includes a list of ecological guilds, their typical behavior, reaction to changes in hydrograph, and typical species and can be used as a guide for the development of guild classification at the level of individual basins.

In reviewing the table, it is important to keep in mind that rivers vary in physical nature, as do the fauna and flora they support. Consequently, the metrics necessary to assess river condition, as well as metric response, may vary. For example, low levels of stressors (e.g., nutrients and thermal loading) may initially increase metric scores, and lower them at higher stressor levels. This is often observed in cold oligotrophic rivers, but not in warm water rivers. Also in such rivers, we see increases in centrarchids, catostomids, and cyprinids, simply because they are better adapted to such conditions than salmonids, cottids, and petromyzontids. Likewise, biomass increases with nutrient and thermal enrichment of cold oligotrophic systems.

TABLE 7-7. Fish metrics selected for inclusion in biological indexes developed for large rivers.

Metric	Response to General Stressors*	OH EPA Iwb ¹	OH EPA ² FIBI	ORSANCO ORF (In) ³	WI FIBI ⁴	Wabash River IBI ⁶	PN-IBI ⁵	OR ⁷
Species richness and composition								
# native spp.	decrease		X	X	X	X		X
# sunfish spp.	decrease		X	X		X		
# sucker spp.	decrease							X
# sucker spp.(round-bodied)	decrease		X	X	X	X		
% round bodied suckers	decrease		X		X			
% intolerant individuals	decrease						X	
# intolerant spp.	decrease		X	X	X	X		X
% tolerant individuals	increase		X	X		X	X	
# of great river spp.	decrease			X				
% great river individuals	decrease					X		
% simple lithophils	decrease		X	X	X	X		
% non-native individuals	increase			X				X
# non-native spp.	increase						X	
% riverine spp.	decrease				X			
# minnow spp.	decrease							X
# riverine spp.	decrease				X			
% common carp	increase						X	X
% coldwater individuals	decrease						X	
# native coldwater spp.	decrease						X	
# salmonid age-classes (whitefish omitted)	decrease						X	
% catchable salmonids	decrease							X
# sculpin age-classes	decrease						X	
% sculpin individuals	decrease						X	
# sculpin spp.	decrease							X
shannon h (numbers)	decrease	X						
shannon h (biomass)	decrease	X						
Trophic composition								
% omnivores	increase		X			X		X
% invertivores	decrease		X	X	X			
% top-piscivores	decrease		X	X				
% detritivores	increase			X				
% insectivorous	decrease					X		X
% macrovorous	decrease					X		
Fish abundance and condition								
# DELT anomalies	increase		X	X	X			
% DELT anomalies	increase					X	X	X
total biomass of catch	decrease	X			X			X
catch per unit effort (no./distance)	decrease					X		X
catch per unit effort (no/time)	decrease	X	X	X			X	

1 Ohio EPA 1987b: Ohio EPA's Index of Well Being (Iwb)

2 Ohio EPA 1987b: Ohio EPA's Fish Index of Biological Integrity (FIBI) for boatable rivers

3 Emery et al. 2003: ORSANCO's Ohio River Fish Index [ORF(In)]

4 Lyons et al. 2001: Wisconsin's Fish Index of Biological Integrity (WI FIBI) for large warm-water rivers

5 Mebane et al. 2003: Pacific Northwest Rivers Index of Biotic Integrity (PN-IBI)

6 Gammon and Simon 2000: Wabash River Index of Biotic Integrity (PN-IBI)

7 Hughes and Gammon 1987: Wilamette River IBI, Oregon (OR)

* Low levels of stressors (e.g., nutrients, thermal loadings) may initially increase metric scores, and lower them at higher stressor levels.

**Ohio River Valley Water Sanitation Commission (ORSANCO)
Fish Population Monitoring
Protocols for Non-wadeable Rivers**

The Ohio River Valley Water Sanitation Commission (ORSANCO; the Commission) is an interstate agency charged with abating existing pollution in the Ohio River basin and preventing future degradation of its waters. ORSANCO conducts water quality monitoring and assessments on behalf of the Ohio River mainstem states (Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia). The Bimonthly Manual Sampling Program entails the collection of water column grab samples for water quality analysis. Fish assemblages are assessed using ORSANCOS's Ohio River fish index (ORFIn) for evaluating fish assemblage data.

ORSANCO Fish Assemblage Monitoring

ORSANCO developed an index to assess the condition of fish assemblages along 1,580 km of the Ohio River. Representative fish samples were collected from over 700 reaches, including 318 "least-impacted" sites, via standardized nighttime boat-electrofishing. A total of 55 candidate metrics were evaluated (based on attributes of fish assemblage structure and function) to derive a multimetric index of river health for the Ohio River. Metric evaluations considered the variability of these metrics spatially (by river kilometer) and temporally, and their responsiveness to human disturbances (e.g., effluents, turbidity, and embedded substrates). The resulting Ohio River fish index (ORFIn) comprises 13 metrics (Table 7-6) selected because they responded predictably to measures of human disturbance or reflected desirable features of the Ohio River. Two metrics were retained (the number of intolerant species and the number of sucker species [family Catostomidae]) from Karr's original index of biotic integrity. Six metrics were modified from indices developed for the upper Ohio River (the number of native species; number of great-river species; number of centrarchid species; the number of DELT abnormalities; percent individuals that are simple lithophils; and percent individuals that are tolerant species). They included three trophic metrics (the percent of individuals that are detritivores, invertivores, or piscivores), one metric of catch per unit effort, and one metric based on the percent of individuals as nonindigenous fish species. The ORFIn was responsive (i.e., significant negative correlations) to anthropogenic disturbances on substrate and water quality and was significantly lower in the first 500 m below point source discharges than at least-impacted sites nearby. Incorporation of the ORFIn into Ohio River assessments represents an improvement over other physicochemical protocols.

ORSANCO typically conducts fish assemblage studies every year from July through October. Fish samples are taken via electrofishing boat along 500-m shoreline zones at randomly selected sites. Each 500-m zone is marked with fluorescent orange paint or a surveyor's flag. Dissolved oxygen, conductivity, temperature, pH, secchi depth, river stage, and general weather are recorded before sampling begins. Each sample reach is electrofished by boat at night. The fish are netted, weighed, measured, species recorded, any unusual abnormalities are noted, habitats within the zone are recorded, and GPS coordinates are taken at the upstream, midpoint, and downstream section of the zone. These data are then used to calculate the ORFIn score for each site. Each site is classified into one of these habitat classes based on substrata composition. The ORFIn score is then compared with a habitat specific biocriteria value and the proportion of sites falling below the threshold is estimated as the proportion of the pool that is impaired.

7.7 Performance Characteristics for Biological Assessments Using Fish

7.7.1 Field Sampling

Quantitative (QN) performance characteristics for field sampling are *precision* and *completeness* (Table 7-8). Repeat samples for purposes of calculating precision of field sampling are obtained by sampling two adjacent reaches (i.e., adjacent 1000-m single-bank reaches or adjacent 500-m paired-bank reaches [Figure 7-3] or other (see Section 3.1.1). Fish samples from the adjacent reaches (also called quality control [QC] or duplicate samples) must be processed prior to data being available for precision calculations. These precision values are statements of the consistency with which the sampling protocols:

- characterized the biology of the river and
- were applied by the field team,

and thus, reflect a combination of natural variability and systematic error (see Chapter 3).

TABLE 7-8. Error partitioning framework for biological assessments and biological assessment protocols for fish. There may be additional activities and performance characteristics, and they may be quantitative (QN), qualitative (QL), or not applicable (na).

Component Method or Activity	Performance Characteristics				
	Precision	Accuracy	Bias	Representativeness	Completeness
1. Field sampling	QN	na	QL	QL	QN
2. Laboratory sorting/subsampling	na	na	na	na	na
3. Taxonomy	QN	QL	QL	na	QN
4. Data entry	na	QN	na	na	QN
5. Data reduction (e.g., metric calculation)	Na	QN	na	na	na
6. Site assessment and interpretation	QN	QN	QL	QL	QN

The number of reaches for which repeat samples are taken varies, but a rule-of-thumb is a randomly selected 10% of the total number of sampling reaches constituting a sampling effort (whether a yearly, programmatic routine, or an individual project). Metric and index values are used to calculate relative percent difference (RPD), root-mean square error (RMSE), and coefficient of variability (CV) (Table 3-2). Acceptance criteria for each of these would be established based on programmatic capabilities demonstrated via pilot studies, or through analysis of existing datasets produced using the same protocols. These criteria are not data quality thresholds beyond which data points should be considered for discarding. Rather, they are flags for potential problems (errors) in sample collection or processing, are used to help

determine the source(s) of the problems, and can be used to help develop recommendations for corrective actions.

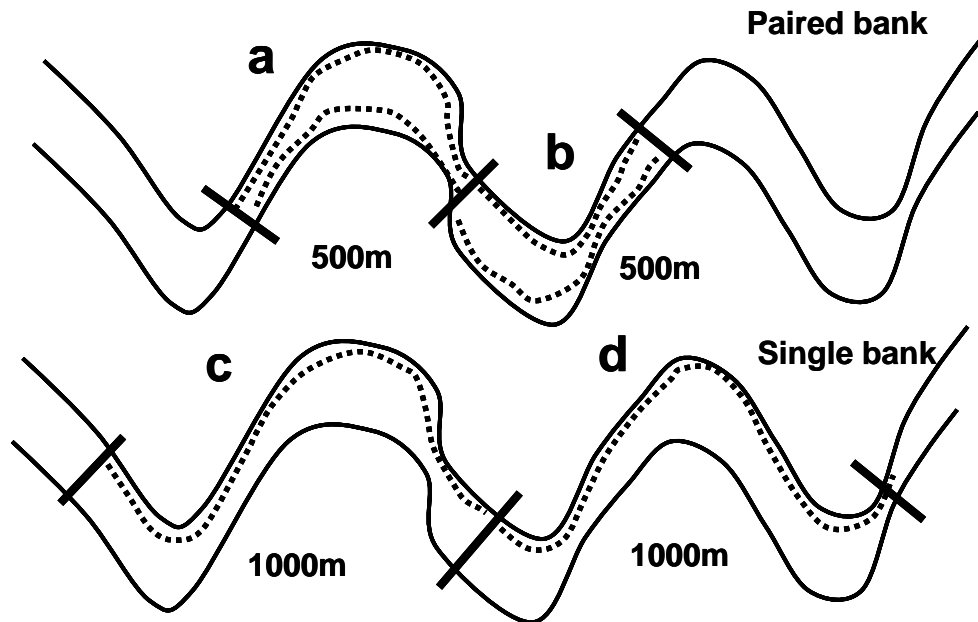


FIGURE 7-3. Two different scenarios for obtaining repeat reaches for large river fish bioassessments. Paired 500-m banks shown by a + b, and 1000-m single-bank approach by c + d (dotted line is where sampling is performed).

Percent completeness (Table 3-2) is calculated to allow communication of the number of valid samples (however validity is judged) that were collected as a proportion of those that were originally planned. This value serves as one summary of overall data quality for a sampling effort and it demonstrates confidence in the final results.

Qualitative (QL) performance characteristics for field sampling are *bias* and *representativeness* (Table 7-8). Attempts to minimize the bias associated with the LR-BP for fish for example, include two components of the field method. First, it is not limited to one or a few habitat types, (it is multihabitat and samples all shore-zone habitats within the reach. Second, allocation of the sampling effort is distributed throughout the entire sampling reach by use of a continuous electrofishing pass, preventing the entire sample from being taken in a shortened portion of the reach. The LR-BP field sampling method is intended to depict the fish assemblage that the physical habitat in the large river shore-zone has the capacity to support.

Accuracy is considered “not applicable” to field sampling (Table 7-8) because efforts to define analytical truth would necessitate a sampling effort excessive beyond any practicality. That is, the analytical truth would be all fish that exist in the river (shorezone electrofishing reach); there is no sampling approach capable of capturing every fish.

7.7.2 Laboratory Sorting/Subsampling

All laboratory-oriented performance characteristics are considered “not applicable” since most fish bioassessment methods assume field processing or sorting of fishes.

7.7.3 Taxonomy

Precision and *completeness* are QN performance characteristics that are used for taxonomy (Table 7-8). Precision of taxonomic identifications is calculated using percent taxonomic disagreement (PTD) and percent difference in enumeration (PDE) (Table 3-2), both of which rely on the raw data (list of taxa and number of individuals) from whole-sample re-identifications. The primary taxonomy is completed by the project taxonomist (T1); the re-identifications are performed by a secondary, or QC, taxonomist (T2) as blind samples. Since large river fish samples are typically processed in the field, this re-identification process would need to be conducted in the field. The “secondary” taxonomist could be a member of the electrofishing crew, or a second taxonomist could be brought on site on occasion, solely for the purpose of these performance checks. The number of identifications in agreement between the two sets of results, as an inverse proportion of the total number of individuals in the sample ($(1 - [\text{number of agreements}]) / N$), is precision of the taxonomic identifications. For example, the percent difference in sample counts by each of the taxonomists is “percent difference in enumeration (PDE)”. PTD and PDE are evaluated individually, and can be used to indicate the overall quality of the taxonomic data, and if there is a problem, to help identify what is causing the problem. The number of samples for which this analysis is performed will vary, but 10% of the total sample lot (project, program, year, or other) is an acceptable rule-of-thumb. Exceptions are that large programs (>~500 samples) may not need to do >50 samples; small programs (<~30 samples) will likely still need to do at least 3 samples. In actuality, it will be program-specific and the number of samples re-identified will be influenced by multiple factors, such as how many taxonomists are doing the primary identification (there may be an interest in having 10% of the samples from each taxonomist re-identified) and how confident the ultimate data user is with the results. Mean PTD and PDE across all re-identified samples is an estimate of taxonomic precision (consistency) for a dataset or a program. Percent taxonomic completeness (PTC; [Table 3-2]) quantifies the proportion of individuals in a sample that are identified to the specified target taxonomic level (lowest practical taxonomic level, species, genus, family, or other, including mixed levels). Results can be interpreted in a number of ways: the individuals in a sample are damaged juvenile, or hybrid (increasing the difficulty of identification), many are damaged with diagnostic characters missing (such as coloration, fins, etc.), or the taxonomist is inexperienced or unfamiliar with the particular taxon.

Accuracy and *bias* are QL performance characteristics for taxonomy (Table 7-8). Accuracy requires specification of an analytical truth. For taxonomy, the analytical truth includes: 1) the museum-based type specimen (holotype, or other form of type specimen), 2) specimen(s) verified by a recognized expert in that particular taxon, or 3) unique morphological characteristics specified in dichotomous identification keys. Determination of accuracy is considered “not applicable” for this kind of taxonomy (most often used in routine monitoring programs) because it is focused on characterizing the sample; taxonomic accuracy, by definition, would be focused on individual specimens. Bias in taxonomy results from use of obsolete

nomenclature and keys, imperfect understanding of morphological characteristics, inadequate optical equipment, and poor training. Neither of these performance characteristics is considered necessary for field fish taxonomy in that they are largely covered by the estimates of precision and completeness. For example, although it is possible that two taxonomists would put an incorrect name on an organism, it is considered a low probability that they would put the same incorrect name on that organism.

7.7.4 Data Entry

Efforts to understand the quality of data entry activity may seem trivial. However, the impact of errors can be substantial, and, if undiscovered and uncorrected, can become amplified through the assessment process. This performance characteristic quantifies the number of correctly-entered data values as a proportion of the total number of data values entered. The process involves having a QC person, distinct from the staff doing the primary data entry, check all data values (100%) against the original handwritten datasheets. With the datasheets as the analytical truth, the rate of errors is the *accuracy* of the data entry (Table 7-8). As errors are found, they are corrected electronically. For their Wadeable Streams program, Mississippi DEQ found that the two data types with the highest error rates were the datasheet header information (e.g., stream name, latitude/longitude, date of site visit, names of field staff) and streambed particle size data (Mississippi DEQ 2003). This allowed corrective actions to be focused where needed. All other performance characteristics are considered not applicable.

7.7.5 Data Reduction (e.g., Metric Calculation)

For most biological assessment programs, raw data are the list of taxa found at a site (in a sample) and the number of individuals recorded for each taxon. Preparation of those data for analysis requires conversion to metrics (Table 7-7) or other terms; metric calculation is a form of data reduction. When electronic spreadsheets or other data manipulation techniques are used, queries are often built to perform both complex and simple calculations. If queries are not performing as intended, or links to the raw data are incorrect, errors in metric values can occur. *Accuracy* of data reduction is a QN performance characteristic (Table 7-8) that helps ensure database/ computer calculation routines are performing as intended. A subset of metric values is hand-calculated using only the taxonomic and enumeration data, which are then compared to those that result from the computer queries. A recommended approach involves calculating one metric for multiple samples (e.g., systematic, every third sample), as well as all metrics for at least one sample. If differences are found, each value should be checked for errors in the calculation process (hand calculator vs computer algorithm), and corrections made.

7.7.6 Site Assessment and Interpretation

QN performance characteristics for site assessment and interpretation are *precision*, *accuracy*, and *completeness* (Table 7-8). Site assessment precision is based on the narrative assessments from the associated index scores (e.g., good-fair-poor) of the reach duplicates. It quantifies the percentage of duplicate samples that receive the same narrative assessments. These comparisons are done for a randomly-selected 10% of the total sample lot. Table 7-9 shows that, for this example dataset, 79% of the replicates returned assessments of the same category (23 out of 29);

17% were 1 category different (5 of 29); and 3% were 2 categories different (1 of 29). Accuracy is the proportion of samples for which the biological index correctly identifies sites as impaired; the calculation is discrimination efficiency (DE) (Table 3-2). DE is a value that is developed during the index development and calibration process. Percent completeness (%C) is the proportion of sites (of the total planned) for which valid final assessments were obtained.

QL performance characteristics for site assessment and interpretation are *bias* and *representativeness* (Table 7-8). The final assessment of a site can be biased if a small number of reference or stressor sites are used during the calibration process. Low numbers of stressor sites can potentially result in high discrimination efficiencies that are spurious. If interpretation of assessment results fails to consider abnormal or extreme hydrologic or climatic events, or other non-natural catastrophic and localized events, results could be considered non-representative of ambient conditions.

TABLE 7-9. Assessment results shown for sample pairs taken from 29 sites, each pair representing two adjacent reaches (back to back). Assessment categories are 1-good, 2-fair, 3-poor, and 4-very poor.

Site	Replicate 1		Replicate 2		Categorical Difference
	Narrative	Assessment Category	Narrative	Assessment Category	
A	Poor	3	Poor	3	0
B	Poor	3	Poor	3	0
C	Good	1	Good	1	0
D	Poor	3	Very Poor	4	1
E	Fair	2	Fair	2	0
F	Poor	3	Fair	2	1
G	Poor	3	Poor	3	0
H	Very Poor	4	Very Poor	4	0
I	Very Poor	4	Very Poor	4	0
J	Poor	3	Poor	3	0
K	Poor	3	Poor	3	0
L	Very Poor	4	Very Poor	4	0
M	Very Poor	4	Very Poor	4	0
N	Poor	3	Fair	2	1
O	Poor	3	Poor	3	0
P	Poor	3	Poor	3	0
Q	Poor	3	Very Poor	4	1
R	Poor	3	Poor	3	0
S	Fair	2	Very Poor	4	2
T	Fair	2	Fair	2	0
U	Good	1	Good	1	0
V	Poor	3	Fair	2	1
W	Fair	2	Fair	2	0

TABLE 7-9. Continued.

Site	Replicate 1		Replicate 2		Categorical Difference
	Narrative	Assessment Category	Narrative	Assessment Category	
X	Poor	3	Poor	3	0
Y	Poor	3	Poor	3	0
Z	Very Poor	4	Very Poor	4	0
AA	Poor	3	Poor	3	0
BB	Fair	2	Fair	2	0
CC	Poor	1	Poor	1	0