USGS
science for a changing world

Prepared in cooperation with the National Park Service

Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1.0

Open-File Report 2007-1302

U.S. Department of the Interior
U.S. Geological Survey

Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1

By James C. Petersen, B.G. Justus, H.R. Dodd, D.E. Bowles, L.W. Morrison, M.H. Williams, and G.A. Rowell

Prepared in cooperation with the National Park Service

Open-File Report 2007-1302

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS--the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Petersen, J.C., Justus, B.J., Dodd, H.R., Bowles, D.E., Morrison, L.W., Williams, M.H., and Rowell, G.A., 2008, Methods for monitoring fish communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1: U.S. Geological Survey Open-File Report 2007-1302, 94 p.

Contents

Figures

Tables

Conversion Factors, Datums, and Selected Abbreviations

Multiply	By	To obtain
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
cubic meter (m^3)	35.31	cubic foot ($ft^{3)}$)
liter (L)	0.2642	gallon (gal)
meter per second (m/s)	3.281	foot per second (ft/s)
cubic meter per second (m^3/s)	35.31	cubic foot per second ($ft^{3)}$)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F = (1.8 \times °C) + 32$

Horizontal coordinate information is referenced to the North American datum of 1983 (NAD 83).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C).

AGFC	Arkansas Game and Fish Commission
BUFF	Buffalo National River
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
GIS	Geographic information system
GPS	Global Positioning System
GRTS	Generalized Random Tesselation Stratified
HTLN	Heartland Network
I&M	Inventory and Monitoring
IBI	Index of Biotic Integrity
MDC	Missouri Department of Conservation
MORAP	Missouri Resource Assessment Partnership
MWSW	Mean wetted stream width
NAWQA	National Water-Quality Assessment
NPS	National Park Service
NRDT	Natural Resource Database Template
OZAR	Ozark National Scenic Riverways
QA/QC	Quality assurance/quality control
RBP	Rapid bioassessment protocol
SOP	Standard operating procedure
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1.0

By James C. Petersen[1], B.G. Justus[1], H.R. Dodd[2], D.E. Bowles[2], L.W. Morrison[2], M.H. Williams[2], and G.A. Rowell[2]

Abstract

Buffalo National River located in north-central Arkansas, and Ozark National Scenic Riverways, located in southeastern Missouri, are the two largest units of the National Park Service in the Ozark Plateaus physiographic province. The purpose of this report is to provide a protocol that will be used by the National Park Service to sample fish communities and collect related water-quality, habitat, and stream discharge data of Buffalo National River and Ozark National Scenic Riverways to meet inventory and long-term monitoring objectives.

The protocol includes (1) a protocol narrative, (2) several standard operating procedures, and (3) supplemental information helpful for implementation of the protocol. The protocol narrative provides background information about the protocol such as the rationale of why a particular resource or resource issue was selected for monitoring, information concerning the resource or resource issue of interest, a description of how monitoring results will inform management decisions, and a discussion of the linkages between this and other monitoring projects. The standard operating procedures cover preparation, training, reach selection, water-quality sampling, fish community sampling, physical habitat collection, measuring stream discharge, equipment maintenance and storage, data management and analysis, reporting, and protocol revision procedures. Much of the information in the standard operating procedures was gathered from existing protocols of the U.S. Geological Survey National Water Quality Assessment program or other sources. Supplemental information that would be helpful for implementing the protocol is included. This information includes information on fish species known or suspected to occur in the parks, sample sites, sample design, fish species traits, index of biotic integrity metrics, sampling equipment, and field forms.

[1] U.S. Geological Survey.

[2] National Park Service.

Introduction

Buffalo National River (BUFF), in north-central Arkansas, and Ozark National Scenic Riverways (OZAR), in southeastern Missouri, are the two largest units of the National Park Service in the Ozark Plateaus physiographic province (fig. 1). In general the two parks have a similar environmental setting. The rich fish communities are important components of the ecosystems of the two parks. The environmental setting and fish communities of the two parks are described in more detail in the “Protocol Narrative” section of the report.

The purpose of this report is to provide a protocol (hereafter called the Ozark Rivers Fish Community Protocol within this report) that will be used by the National Park Service to sample fish communities and collect related water-quality, habitat, and streamflow data in BUFF and OZAR to meet inventory and long-term monitoring objectives. This report was prepared in cooperation with the Heartland Network (HTLN) Inventory and Monitoring (I&M) Program of the National Park Service. Although the Ozark Rivers Fish Community Protocol was specifically prepared for use at these two parks, the protocol should be helpful for planning of similar sampling at other National Park Service units. In addition to fish sampling methods, the protocol describes pre- and post-sampling activities such as planning, data analysis and reporting, and care of equipment. The protocol includes (1) a protocol narrative, (2) several standard operating procedures (SOPs), and (3) supplemental information helpful for implementation of the protocol.

The protocol narrative provides background information about the protocol such as the rationale of why a particular resource or resource issue was selected for monitoring, information concerning the resource or resource issue of interest, a description of how monitoring results will influence management decisions, and a discussion of the linkages between this and other monitoring projects. The narrative also gives an overview of the various components of the Ozark Rivers Fish Community Protocol, including measurable objectives, sampling design, field methodology, data analysis and reporting,

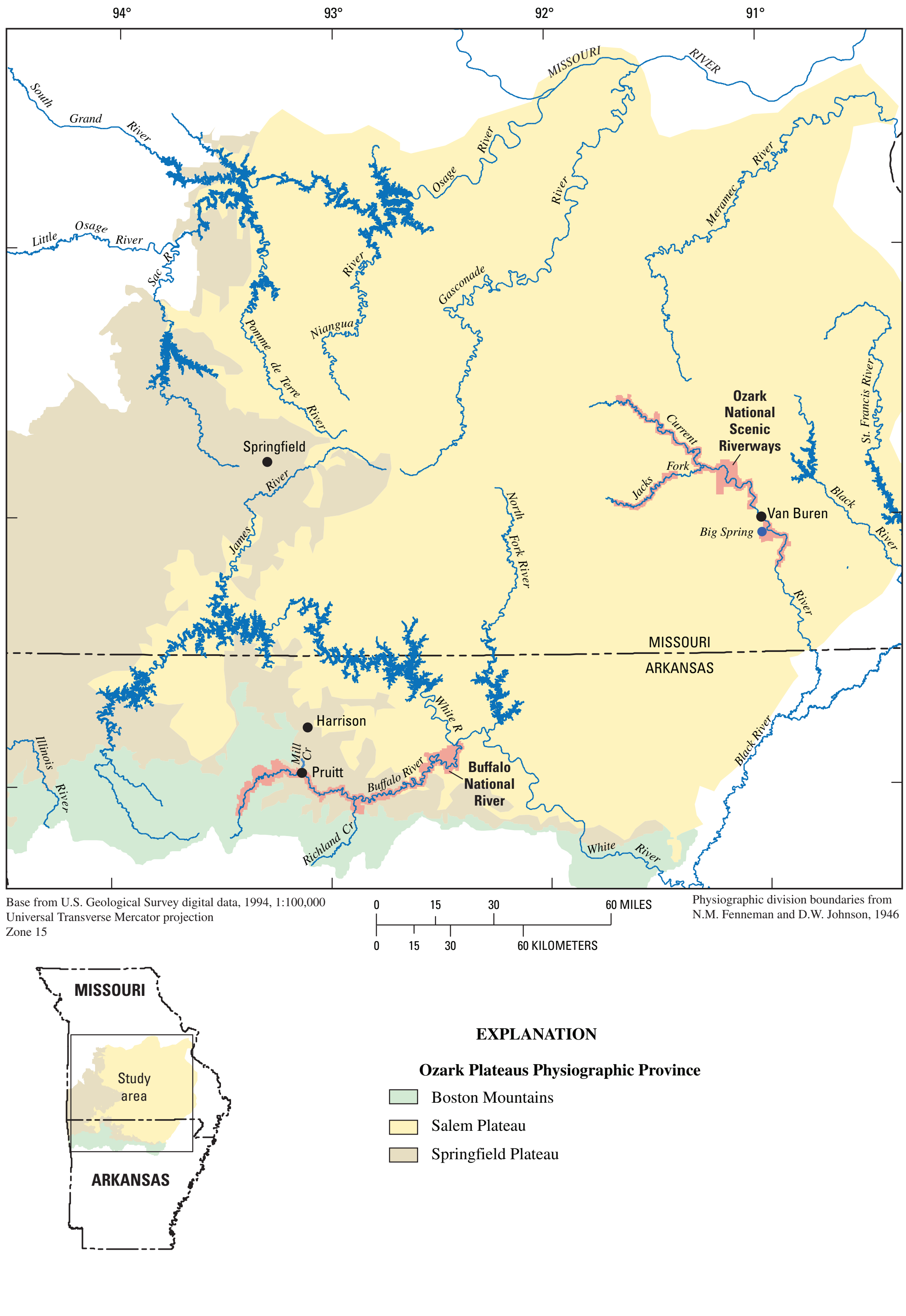


Figure 1. Location of Buffalo National River and Ozark National Scenic Riverways.

personnel requirements, training procedures, and operational requirements. The narrative also summarizes the history of decision-making that accompanied protocol development.

The SOPs cover preparation, training, reach selection, water-quality sampling, fish community sampling, physical habitat collection, measuring stream discharge, equipment maintenance and storage, data management and analysis, reporting, and protocol revision procedures. Much of the information in the SOPs was gathered from existing protocols of the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program or other sources. All of the SOPs are written to provide information that can be used to maximize the accuracy, representativeness, and completeness of the fish community data.

Supplemental information includes information such as species lists, sample site lists, comparison of this protocol to other fish community sampling protocols, species lists, species characteristics lists, index of biotic integrity metric lists, and field forms. The supplemental information is included in separate appendixes at the end of the report.

Protocol Narrative

The protocol narrative provides background information about the protocol. The narrative also gives an overview of the various components of the protocol and summarizes the history of decision making that accompanied protocol development.

Background and Objectives

The extents of BUFF and OZAR are limited to relatively narrow bands along much of the Buffalo River (BUFF) and the Jacks Fork and Current River (OZAR) (fig. 1). Consequently, these streams and the associated natural and historic characteristics are major, unifying features of each park.

In general, the two parks have a similar environmental setting. Water quality is generally very good, typically exhibiting low nutrient concentrations, small amounts of sediment, and low concentrations of trace elements and pesticides (Bell and others, 1997; Davis and Bell, 1998; Petersen and others, 1998; Mott and Luraas, 2004). Both parks are in the Springfield or Salem Plateaus, which are typified by limestone and dolomite geologic formations. Karst features, such as sinkholes, caves, springs, and sections of streams that interact with ground water by gaining or losing streamflow, are common in the Springfield and Salem Plateaus. However, much of the drainage area of the upstream part of the Buffalo River is within the Boston Mountains physiographic area, which is typified by sandstone and shale. While springs are relatively common in the Buffalo River Basin, they are not the primary contributor to its base flow, and some sections of the Buffalo River become dry during the summer because of a lack of substantial spring flows (Moix and Galloway, 2005). In comparison, several large springs at OZAR constitute a large part of the base flow of the Jacks Fork and Current River and water temperatures of the Current River are low enough to support a trout population (Panfil and Jacobson, 2001). Some of the springs that flow into the Jacks Fork and Current River are large with annual mean discharges exceeding 0.3 cubic meter per second (m^3/s) (Vineyard and Feder, 1974). At OZAR, Big Spring has an annual mean discharge of 12.6 m^3/s; the annual mean discharge of the Current River upstream from Big Spring is about 57 m^3/s (Hauck and Nagel, 2004). Because a much smaller portion of the base flow of the Buffalo River comes from springs, water temperatures typically are warmer than in the Jacks Fork and Current River (Panfil and Jacobson, 2001).

The fish communities of the Buffalo, Jacks Fork, and Current Rivers and their tributaries are important components of the river ecosystems of these parks. The Ozark Plateaus is one of the richest areas of the United States for fish species. More than 175 native and introduced species of fish occur in the Ozark Plateaus and adjacent areas (Petersen, 1998). Petersen and Justus (2005) and Petersen (2005) reported 74 species of fish from BUFF, and 112 species of fish have been reported to occur in or near OZAR (National Park Service, 2005) (appendixes 1 and 2). Some of these species are unique to the Ozarks. The Buffalo and Current River Basins are considered “hot spots” for at-risk fish and mussel species (species with a vulnerable or imperiled ranking by The Nature Conservancy and the Natural Heritage Network) because of the presence of 10 or more at risk species (Master and others, 1998). Because some fish species, including several darters, minnows, and madtoms, are considered intolerant of habitat alterations (Robison and Buchanan, 1988; Pflieger, 1997; Dauwalter and others, 2003), fish community characteristics are useful as a monitoring tool to assess changes in water and habitat quality. In addition to their value as environmental indicators, direct economic value also can be associated with several fish species of the two parks because of money spent by anglers fishing for species such as bass, trout, and suckers.

The primary objectives for the monitoring described in this protocol are related to temporal changes in fish communities and relations between the fish communities and environmental factors based on sites that were randomly selected in a spatially balanced design. Information obtained by meeting these objectives can be used by park managers to evaluate the effects of past and future activities and management decisions (either by park managers or others) on fish communities. The specific objectives for fish community monitoring in these two parks are: (1) to determine the status and trends in BUFF and OZAR fish communities by quantifying metrics such as species richness, percent tolerant individuals, percent invertivores, and percent omnivores, and using those metrics to calculate multi-metric indices (Karr, 1981; Hoefs, 1989; Dauwalter and Pert, 2004) for the mainstem and tributaries in each park, and (2) to estimate the spatial and temporal natural variability of fish community metric values and indices among collection sites, and examine correlations between metric values and associated habitat values such as stream size characteristics, habitat availability, riparian characteristics, substrate characteristics, and water quality.

Sampling Design

A long-term monitoring program needs to specify how to efficiently sample numerous environmental factors through space and time. An overall sampling design must contain multiple components including: (1) a spatial design -- how sample sites are located and the area of statistical inference, (2) a revisit design -- how frequently sites are sampled, and (3) a response design -- how and what data are collected. To effectively use limited monitoring resources, information derived from a relatively small number of sample sites needs to infer changes over a much larger area. For the inference to be valid, a probability based sample design within a defined reference frame is required.

Spatial Design

Establishing the Sample Frame

An integrated aquatic monitoring plan for both BUFF and OZAR was developed to include the co-location and co-visitation of multiple vital signs (fish, invertebrates, physical habitat, and water quality) (DeBacker and others, 2005). The framework for this plan was conceived in a workshop of biologists, statisticians, and administrators held in July 2004 (McDonald, 2004). This protocol focuses on one of these vital signs, the fish communities. Specifically, this monitoring is concerned with fish inhabiting the mainstem and tributaries located within National Park Service jurisdictional boundaries at BUFF and OZAR.

The sample unit has been defined to accommodate the field protocols for all vital signs. The common sample unit definition is a ‘stretch’ of contiguous stream defined by minimum and maximum length criteria. The geomorphology of these waterways and the resulting biological processes are scale-dependent. For example, as streams become larger, the distances associated with pool-riffle sequences increase. A key characteristic of this overall design is that all aquatic studies should be capable of producing unbiased estimates that are applicable to the entire stretch. While stretches must be long enough to accommodate unbiased estimates for all studies, they do not have to be the same size. Once defined, sample unit boundaries will remain fixed and will be used by all studies under the unified monitoring design.

Two different categories of stretch size were established. In the tributaries and upper mainstem, stretch lengths are 1 to 2 kilometers (km). In the lower mainstem, stretch lengths are 3 to 5 km. Within categories, stretch length is not fixed, but varies depending upon several factors. Stretches were discontinued at natural features, such as at confluences and spring runs. They were also delimited based on changes in Valley Segment Type (VST) (see geographic information system metadata at: http://science.nature.nps.gov/nrdata/metadata.cfm?ID=41269 for OZAR and http://science.nature.nps.gov/nrdata/metadata.cfm?ID=41268 for BUFF), which is based on gradient, streamflow, temperature, and other factors. Stretches in the tributaries were delimited by the flood-plain boundaries. If initial stretches exceeded the maximum stretch length because of a lack of confluences or change in VST the initial stretch was divided into two or more stretches.

The sample frames (finite lists of sample units, designated as stretches; statistical inferences can only be made to sample units that are part of the frame) for BUFF and OZAR were determined based on similar criteria, with the differences reflecting the important biological variations in the river systems in each park. For both parks, the initial sample frame of stretches was constructed through a cooperative agreement with the Missouri Resource Assessment Partnership (MORAP). To determine the sample frame at OZAR, MORAP used Missouri Aquatic Gap datasets, the same datasets used by the Missouri Department of Natural Resources and Missouri Department of Conservation (MDC). This dataset did not exist for Arkansas; therefore, MORAP developed a comparable stream network for BUFF.

MORAP used data from the 1:100,000 National Hydrography Dataset (NHD) that was developed by the USGS and the U.S. Environmental Protection Agency (USEPA). The coverage included arcs representing the centerlines of wide streams, as well as the segments of single line streams. An Arc/Info macro was run on the arc segments to pull select attributes from various NHD tables and attach them directly to the arc component. These stream segments were classified according to a number of variables including temperature, stream size, streamflow, geology, soil texture, relative gradient, valley wall interaction (a surrogate for potential bluff pool habitat), stream size discrepancy, and channel type (see geographic information system metadata website listed above for more detailed information). The dataset was restricted to stream segments that touched the park jurisdictional boundary or other public lands adjacent to the park. Additionally, tributaries to the mainstem river were cut where they crossed the flood plain of the mainstem river. This allowed these segments to be coded as “flood-plain” segments.

For both BUFF and OZAR, the final sample frame consisted of all stretches of the mainstem and tributaries that met the inclusion criteria described below. Each stretch in both frames has associated with it a large number of characteristics based on the geographic information system (GIS) data, which could be used in analyses as covariates or domains, that is, subpopulations of interest with associated estimates of biological characteristics or metrics.

To establish the final sample frame for each park, the following inclusion criteria and procedures were used :

(1) All stretches that were not entirely or partially within the park boundaries were removed (the MORAP dataset included adjacent public lands).

(2) All secondary channels were removed (secondary channels occur where a waterway splits and flows around an island; secondary channels transport the lesser volume of water).

(3) Stretches were stratified as either mainstems of the Buffalo River, Jacks Fork, or Current River, or tributaries of these streams.

Selecting the Stretches to be Sampled

It was deemed desirable for sample sites to be spatially balanced. Spatial balance is important because: (1) all responses are known to be spatially autocorrelated (units close to one another tend to yield correlated responses), and (2) parkwide inferences are desired. When responses are correlated in space, spatial balance can greatly improve the precision of the resulting estimates. Thus, the Generalized Random Tessellation Stratified (GRTS) method of sample selection (Stevens and Olsen, 1999; Stevens and Olsen, 2004) was employed. The GRTS method generates a random sample that is spatially balanced. It allows multiple studies to maximize overlap of selected streams by utilizing a common sample, and allows units to be added easily after an initial sample has been drawn. Additionally, because GRTS samples are not evenly spaced, it is not possible for sample locations to be in phase with a cyclic response.

Perhaps the most desirable characteristic of GRTS is that for any sample size, any subset of stretches in the ordered GRTS sample constitutes a spatially balanced sample. This characteristic is desirable because it allows multiple studies to maximize overlap and adds stretches in a way that guarantees spatial balance. It also allows each rotating panel (for example, in the case of the tributaries; see below) to represent a spatially balanced sample from the entire park.

The S-Draw program developed by Trent McDonald (available at www.west-inc.com/computer.php) was used to draw the GRTS samples, and mainstem sites were weighted by stretch length. S-Draw allows for several options in drawing the sample. The hierarchical structure was randomized (Stevens and Olsen, 1999). The reverse hierarchical ordering option was employed, which assures that any contiguous set of stretches will be spatially balanced (Stevens and Olsen, 2004). A random number seed generated from the system clock was used (the default option).

All GRTS draws were "oversampled," in that more sites were selected and ordered than would be immediately sampled. This allows for increasing the number of sites in the future, if budget allows, without decreasing the overall degree of spatial balance. This also provides flexibility not to sample certain sites if an issue arises and nonsampling is deemed appropriate. In such a case, one would simply move to the next site in the ordered GRTS lists, thus sacrificing only a small degree of spatial balance.

Total annual sample size is limited primarily by budget and personnel. It was determined that 12 sites could be sampled in each park per year. This takes into account complete processing of all samples, and the number of other protocols that will need to be implemented at these sites. At BUFF (which has many tributaries) each year six mainstem sites will be sampled, and six tributaries will be sampled. At OZAR (which has fewer tributaries, but many springs), nine mainstem sites and three tributaries will be sampled. Sampling of springs at OZAR will be accomplished as part of a separate protocol.

Mainstem

A greater degree of control was desired at OZAR for the mainstem than was possible by selecting all sites from the same pool with GRTS, which has a strong random element. The Jacks Fork, upper Current River, and lower Current River (upstream and downstream, respectively, of the confluence with the Jacks Fork) are very different systems, primarily because of the influence of large springs. A total of 130 stretches comprised the sample frame for these mainstems for the Current River and Jacks Fork. Stretches on the Jacks Fork (number=39) and upper Current (number=53) were approximately 1 to 2 km in length. Stretches in the lower Current River above the town of Van Buren, where a break in the park's boundary occurs, were approximately 1 to 2 km in length, but stretches below Van Buren were roughly 3 to 5 km in length. The river below Van Buren has higher flows, in large part because of the input of Big Spring (annual mean discharge of 12.6 m^3/s). A total of 38 stretches were identified on the lower Current River. Because of a preference to have an equal number of sample sites on each of these three mainstem sections the mainstem of OZAR was divided into three sections (stretches from the Jacks Fork, upper Current River, and lower Current River) before selecting the GRTS sample.

The Buffalo River also was divided into lower and upper sections prior to drawing the GRTS sample. The Buffalo River within the park boundary is 198 km long, and crosses three major physiographic areas: the Boston Mountains, the Springfield Plateau, and the Salem Plateau. There is a losing reach on the Buffalo River (Moix and Galloway, 2005) below the confluence with Richland Creek where, during periods of low flow, much or all of the water runs underground for several kilometers before resurfacing at a spring. Thus, the river was divided into an upper section (number=47 stretches) above the natural break at the losing reach, and a lower section (number=27 stretches) below the spring. This break also approximates a major geologic shift, as the upper section includes the Boston Mountains (characterized by sandstone and shale), and the lower section primarily includes the Springfield and Salem Plateaus (characterized by limestone and dolomite). The losing reach was deleted from the frame. The length of the river for the two sections is similar (89 km for the upper, 109 km for the lower); the lower section contains fewer stretches because the stretches are longer. Stretches above the confluence of Mill Creek near Pruitt were approximately 1 to 2 km in length, whereas stretches below this point were approximately 3 to 5 km in length. Again, this change in stretch length reflects changing river morphology as streamflow increases and the riverbed widens.

Following these criteria, GRTS was used to oversample the number of stretches such that half of the sample frame was ordered for OZAR (64 mainstem stretches) and BUFF (37 mainstem stretches). Only the first nine sites at OZAR and six sites at BUFF in the GRTS selection will be sampled (appendix 3); however, this procedure will allow possible increases in sample size in the future or integration of other studies with a larger sample size and still maintain a spatially balanced parkwide sample.

Tributaries

To establish the tributary sample frame, all flood-plain stretches were removed. This was done because those portions of the tributaries within the flood plain of the mainstem are likely to be more variable because of intermittent backwater inundation. These flood-plain stretches represented a relatively short section of most tributaries in both parks. The resulting sample frame contained a large number of stretches. A number of tributaries, although indicated as perennial on 7.5-minute topographic USGS maps, drain relatively small water basins and, according to park personnel, often have low or no flowing water. Thus, the sample frame was revised to include only tributaries of second order and above. Some of the tributaries had multiple stretches within park boundaries. Because all tributaries could not be sampled, and sampling multiple stretches of the same tributary would yield relatively redundant information, the frame was limited to the most downstream stretch of each tributary. The distance between the most downstream stretch and the confluence with the mainstem may be small enough to allow fish communities of the mainstem to affect fish communities in the downstream stretches of the tributaries (Petersen, 2004), however in many cases the available distance upstream from the mainstem is limited by park boundaries. The downstream tributary stretches are separated from the mainstem by the width of the mainstem flood plain, decreasing the influence of the mainstem on tributary fish communities. Because most of these tributaries were relatively small, it was determined that sampling could be accomplished in substantially less than 1 km, and the minimum acceptable distance for tributary stretches within the park boundary was set at 600 meters (m). Reconnaissance surveys were conducted of selected tributaries that, based on a study of maps and consultation with park staff, may have been too far in the flood plain of the mainstem, or may not have had sufficient flow.

At BUFF, an initial set of 37 tributaries satisfied the above criteria. Reconnaissance resulted in adjustment of the flood-plain criteria for two tributaries and elimination of one tributary because of insufficient flow. Ultimately, a total of 32 tributary stretches satisfied the selection criteria and constituted the sample frame at BUFF. Thirty of these stretches will be sampled on a 5-year rotation (the first 30 as ordered by GRTS; appendix 3). If, during the first 5 years, it is determined that any of these first 30 tributaries have to be deleted from the frame, two alternate tributary stretches can be substituted.

At OZAR, an initial set of 34 tributaries satisfied the above criteria. Reconnaissance and consultation with park staff, however, resulted in elimination of 18 tributaries that were determined to have insufficient flow during the time of year selected for sampling (fall). Although many of the tributaries at OZAR do contain some water all year, much of the flow during the summer and fall is underground through the gravel substrate. A total of 16 tributary stretches met the selection criteria at OZAR, and constituted the sample frame. Fifteen of these stretches will be sampled on a 5-year rotation (the first 15 as ordered by GRTS; appendix 3). If, during the first 5 years, it is determined that any tributaries need to be deleted from the frame, an alternate tributary stretch will be substituted.

Establishing Sample Reaches

At each mainstem and tributary stretch, a reach will be established for fish monitoring that satisfies specific requirements necessary to obtain a representative and unbiased sample (see SOP 3 for details on reach selection). The reach length is based on mean wetted stream width (MWSW), allowing inclusion of representative macrohabitats (riffle, run, and pool habitats) located within the stretch; a length of about 20 times the MWSW is used. The downstream end of the reach is located at the head of the second riffle upstream from the lower stretch boundary (fig. 2). Once located, this reach will become a permanent sampling site barring dramatic alterations in channel morphology that would require relocation of the sampling reach.

Temporal Design

At both parks, the revisit design will have an annual revisit panel and a set of rotating panels (table 1, appendix 3). To ensure sufficient representation of monitoring sites on the mainstems, the annual revisit panel will consist of mainstem stretches (n=6 for BUFF, n=9 for OZAR, or 6 and 9 sites sampled each year, respectively). The rotating panels will consist of tributaries (n=6 for BUFF, n=3 for OZAR, or 6 and 3 sites sampled each year, respectively), which will be sampled every 5 years. At BUFF, 30 total tributary stretches will be sampled, while at OZAR (which has fewer tributaries), 15 total tributary stretches will be sampled. Given the limited sample size, this strategy will yield maximum information on trends for the mainstems, and maximum spatial coverage for the tributaries. If the alternative approach was used for the tributaries (maximizing information on trend), we would be able to sample only a small fraction of the total number of tributaries in each park.

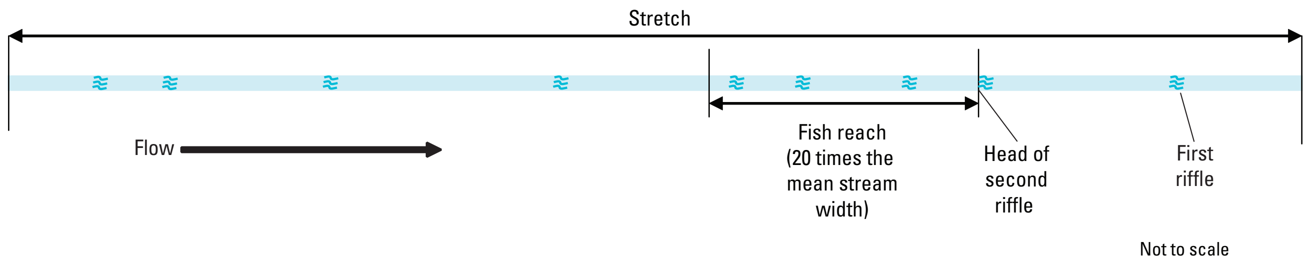


Figure 2. Hypothetical reach location within a stretch.

Table 1. Revisit plans for monitoring studies proposed at Buffalo National River and Ozark National Scenic Riverways.

[An ‘x’ in the year columns indicates all sample units in that panel are to be visited that year]

Study	Revisit notation[1]	Panel number (see appendix 3)	Percent of annual effort	Year 1	2	3	4	5	6	7	8	9	10	11	12
Buffalo National River	[1-0,1-4]	Annual	50	x	x	x	x	x	x	x	x	x	x	x	x
		1	50	x					x					x	
		2			x					x					x
		3				x					x				
		4					x					x			
		5						x					x		
Ozark National Scenic Riverways	[1-0,1-4]	Annual	75	x	x	x	x	x	x	x	x	x	x	x	x
		1	25	x					x					x	
		2			x					x					x
		3				x					x				
		4					x					x			
		5						x					x		

[1] 1-0 indicates an annual panel (1 year of sampling, followed by 0 years of nonsampling). 1-4 indicates a 5-year rotating panel (1 year of sampling, followed by 4 years of nonsampling).

Fish communities at BUFF and OZAR consist of diverse assemblages of species in different developmental stages with various movement patterns or behaviors. Therefore, it is essential that samples are collected within the same timeframe each year to reduce variability in assemblage structure. Mass movement of fish is highest during early spring and late fall/early winter when fish move between overwintering and feeding habitats or make spawning migrations. Because this redistribution of species and large numbers of fish can cause high variability in assemblage composition and structure within a stream, fish monitoring will be conducted once a year during early summer to early fall (May 15 - October 31) when communities are more stable. Sites at BUFF will be sampled in May/June because of the potential drying of the upper mainstem and small tributaries in late summer and fall. At OZAR, sites will be sampled in October when water levels are low to allow for high sampling efficiency. In addition, the number of recreational users (for example, canoers, boaters, and swimmers) is reduced substantially at OZAR in the fall, minimizing disturbance of the sites during sampling. Samples at each park should be collected within a short timeframe (4-5 weeks) to reduce seasonal effects. If this is not possible because of weather conditions, flooding, or other uncontrollable situations, mainstem samples need to be collected within one timeframe and tributaries within another timeframe during the sampling period for each park (summer at BUFF and early fall at OZAR). Following a large, natural disturbance such as a flood, at least 2 weeks should be allowed for stabilization of fish assemblages prior to sampling.

Field Methods and Rationale

Prior to the field season each year, personnel need to review the entire protocol for fish community sampling and begin planning for the field activities. Early review of SOP 1 (preparation) and SOP 2 (training) are particularly important because of potential need to address some matters months before the fieldwork season begins. Fieldwork must be scheduled in advance so that crews can be assigned. Time spent at a sampling site will vary, but 8 or more hours is typical.

Sites generally are sampled in late May through October. Relatively low flows in Ozark streams generally occur in June through October (Adamski and others, 1995) and by July spawning activities will have declined (if not ceased) for most species. Increased leaf fall in late September through October can be of some concern because of reduced visibility caused by the presence of leaves on the surface of some parts of the streams. Sampling location will be determined by random selection of sampling stretches, wetted stream width, and relation of riffle location to downstream end of the sampling stretch (see SOP 3 for details). At each reach, water-quality (SOP 4), fish community (SOP 5), habitat data (SOP 6), and discharge data (SOP 7) will be collected (fig. 3).

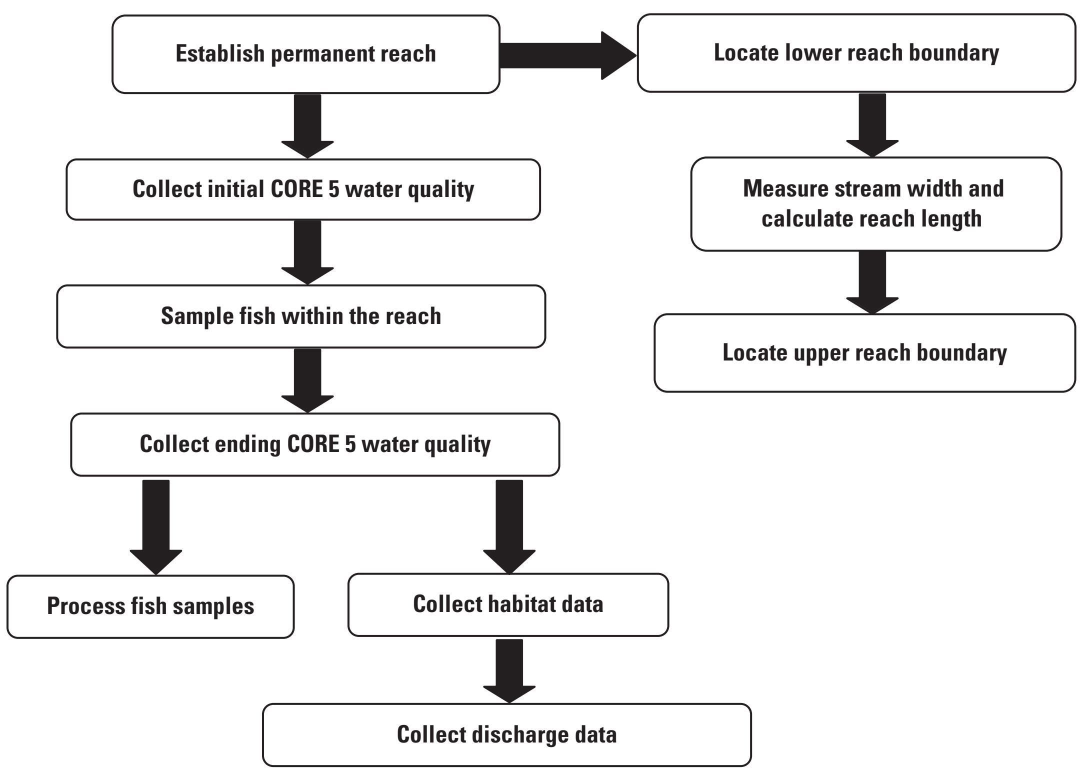


Figure 3. Flow diagram for fish and habitat data collection.

Fish communities will be sampled using electrofishing and seining methods (SOP 5). Depending on stream width and depth, communities will be sampled using backpack, towed barge, or boat electrofishing equipment. At sites where stream depth requires that boat electrofishing be used, towed barge or backpack electrofishing equipment also will be used in shallower areas so that benthic species and other small species can be sampled adequately. Seines can be used in wadeable portions of runs, pools, and backwaters. Riffles will be sampled using backpack or towed barge electrofishing gear in conjunction with kick seines.

When monitoring, it is important to note that gear type and gear efficiency have been shown to affect fish community data. In a study of multiple-year and multiple-reach fish community data from 55 NAWQA sites, Meador and McIntyre (2003) found that among electrofishing methods (backpack, towed barge, and boat), Jaccard (similarity) index and percent similarity index values were significantly greater for backpack electrofishing. Meador and McIntyre (2003) calculated the absolute difference between mean species richness for multiple-reach and for multiple-year samples and found the mean difference for backpack electrofishing, towed barge electrofishing, and boat electrofishing was 0.8 species, 1.7 species, and 4.5 species, respectively. These findings indicated relatively high variability in species richness in samples collected by boat electrofishing among years. In a comparison of the use of backpack electrofishing equipment and a 9.1-m (6-mm mesh) minnow seine in Missouri Ozark streams, Rabeni and others (1997) found that the minnow seine generally was less efficient than the backpack equipment. Efficiencies associated with seining ranged from 0 to approximately 60 percent dependent on the fish species, and efficiencies associated with backpack equipment ranged from approximately 5 to 65 percent. They also found that species richness and Shannon-Weaver diversity values were consistently lower for samples collected with seines than for samples collected with backpack electrofishing equipment. However, when data were corrected for gear efficiency differences, the richness and diversity values were similar. These results (Rabeni and others, 1997; Meador and McIntyre, 2003) suggest that data collected using different gear, or different combinations of multiple types of gear, will be affected by gear type. Therefore, it is imperative that gear type used and sampling effort at a site be consistent across years (see appendix 3). It can be important that multiple gear types be used at a site to obtain a representative sample because of differences in efficiency for collecting certain size fish in specific habitats. For example, large fish in deep pools can be more efficiently collected with boat electrofishing equipment and small benthic species in riffles can be more efficiently collected with backpack equipment. Where appropriate, using multiple types of gear (such as multiple types of electrofishing equipment and seines) can increase the likelihood of collecting all species present within a reach.

When processing samples and recording data, all sample data such as gear used, time spent sampling, electrofishing settings, number of seine hauls, length of stream through which the seine was pulled, and species data collected with the gear type will be recorded separately for each gear and channel type (main channel and backwater/side channel). To the extent practical, individual fish will be identified in the field using appropriate fish identification keys and other information. Specimens that cannot be reliably identified in the field will be preserved for identification in the laboratory (see SOP 5).

There are three alternatives to resolve the problem of analyzing data collected by different gear. First, data can be considered to be affected primarily by the size of the stream when gear type usage is based on the stream size and, therefore, data are treated as being equivalent across all gear types. Second, data can be compared only with other data collected using the same gear types. Third, the raw data can be corrected for differing gear efficiencies before making comparisons across sites associated with different gear types. Analysis for this protocol will use the first approach listed above. Because samples collected with electrofishing gear are based on equivalent effort (time), all electrofishing samples at a reach will be combined for analysis of fish community trends. However, there may be specific monitoring questions where analyzing data by channel type or by electrofishing gear is necessary. Therefore, in the field, data from different channel type and electrofishing gear will be kept separate. Data collected with seines are based on area sampled and will be analyzed separately from electrofishing data.

Habitat data will be collected to establish relations between environmental variables and fish communities and to determine specific factors affecting community composition and structure. A point-transect method will be used to collect data on general channel morphology, fish cover, and bank conditions (see SOP 6). Habitat will be sampled in conjunction with fish sampling and water-quality measurements.

Several different sampling approaches or protocols have been used by State and Federal agencies to quantify status and trends in fish communities. A set of protocols developed by the USEPA--the rapid bioassessment protocols (RBPs) (Barbour and others, 1999)--has been adopted by many State agencies and monitoring groups. These RBPs are designed to give a quick, broad picture of stream quality and fish assemblages throughout a region with minimal field and laboratory efforts. Other monitoring groups also use the EPA Environmental Monitoring and Assessment Program (EMAP) protocols for wadeable (McCormick and Hughes, 1998) and nonwadeable streams (McCormick and Hughes, 2000), and the USGS protocols developed for the NAWQA program (Moulton and others, 2002). These latter two protocols have more rigorous data collection and quantitative methods giving a more complete assessment of fish community composition and structure (for example, collection of fish lengths and weights and more specific designation of reach length). NAWQA protocols or similar methods have been used at several sites at BUFF (Petersen, 1998, 2004) and OZAR (Petersen, 1998).

The Ozark Rivers Fish Community Protocol is based on the NAWQA approach with selected procedures largely following NAWQA protocols. However, some modifications to the NAWQA protocol were necessary to meet specific requirements of this fish monitoring program (appendix 4). These modifications were compiled from EMAP and RBP protocols, other literature related to fish community sampling procedures and considerations, and from a spatial and temporal sampling design for BUFF and OZAR developed during a workshop convened by the NPS in July 2004 at Columbia, Missouri (McDonald, 2004).

The Ozark Rivers Fish Community Protocol shares many similarities with NAWQA, EMAP, and RBP protocols (appendix 4). This protocol is similar to NAWQA protocols in terms of length sampled, electrofishing gear used, and data collection for fish communities. However, two primary differences between this protocol and the NAWQA protocol relate to site selection and electrofishing procedures. In this protocol, the locations of the sampling reaches are randomly selected and spatially balanced rather than using professional judgment or other criteria (see Selecting the Stretches to be Sampled section above). NAWQA sampling sites are selected based on professional judgment and other criteria such as access, presence of streamflow instrumentation, land-use characteristics, and other specific objectives. Objectives of fish community sampling within BUFF and OZAR require that sites be selected randomly. The spatially balanced and random site selection method used in this protocol allows inferences to be made about fish communities in nonsampled areas of the parks.

The second primary difference between this protocol and the NAWQA protocol is the electrofishing effort used. In this protocol, fish communities of wadeable streams are sampled using single pass electrofishing, while NAWQA protocols specify that two passes be used (appendix 4). Single pass electrofishing corresponds with methods described in the RBPs (Barbour and others, 1999) and EMAP protocols (McCormick and Hughes, 1998, 2000). The advantage of single pass electrofishing is that a site can be sampled using fewer manhours at reduced cost; however, this approach has potential limitations. A study by Meador and others (2003) that evaluated 183 NAWQA samples collected at 80 sites using backpack electrofishing equipment found that the number of species collected after two passes was greater than the number of species collected after a single pass in 50.3 percent of the samples. The percentage of the estimated total species richness (based on a two-pass removal model) collected during the first pass averaged 89.9 percent and ranged from 40 to 100 percent. However, Meador and others (2003) did not address the effects of sampling effort, such as seconds of electrofishing time, on the number of species collected and did not specifically address the effects of single-pass or two-pass sampling on relative abundance estimates. Pusey and others (1998) suggested that data from a single pass alone may compromise the ability to relate fish community structure to environmental conditions. However, Simonson and Lyons (1995) found that catch per effort (catch per unit time in one pass) provided the same values for species richness and percent species composition as depletion sampling (three to four passes) and took only one-fourth the time required for depletion sampling. This study reported an average of 10 species collected with three to four passes compared to 9 species with a single pass of a towed electrofishing barge (Simonson and Lyons, 1995); greater differences in the number of species collected might occur in Ozark streams with greater species richness. Meador and others (2003) also concluded that multiple pass electrofishing at a large number of sites across a large geographic area may not be cost effective.

Differences between this protocol and the EMAP and RBP protocols also are associated with sampling effort (appendix 4). For wadeable streams, EMAP sampling efforts can be distributed in a specific manner between transects within the reach, specific time limits (minimum of 45 minutes, maximum of 3 hours) are used, and reach lengths are 40 times the wetted channel width. For RBP, reach length criteria considerations are described, but specific length criteria are not given. In nonwadeable streams, electrofishing in the EMAP protocol is restricted to the area along one bank and use of a boat; while the RBP protocols are not designed for nonwadeable streams. Other differences are that, for the EMAP and RBP protocols, block nets are sometimes used at the ends of the reach and seining is not required. Potential disadvantages associated with these methods include the time and effort required to establish transects, to monitor the distribution of effort (sampling time) between the transects, and to set block nets. Using EMAP protocols, restriction of sampling of nonwadeable streams to boat electrofishing of a single bank may lead to undersampling of species that are less associated with streambanks and more associated with mid-channel pools and runs, and undersampling small benthic species such as darters, madtoms, and sculpins. Repeatable sampling of mid-channel areas in nonwadeable streams can be difficult, however, because of the patchiness of habitats and their associated species.

A number of reach length determination methods have been recommended for monitoring fish communities. The Ozark Rivers Fish Community Protocol follows the NAWQA protocol (Fitzpatrick and others, 1998; Moulton and others, 2002), which specifies reach lengths of approximately 20 MWSW (at low flow) and a reach generally ranges from 150 to 300 m for wadeable streams and from 500 to 1,000 m for nonwadeable streams. The EMAP protocols recommend sampling of 40 times MWSW with a minimum reach length of 150 m. However, Dauwalter and others (2003) developed their Index of Biotic Integrity (IBI) for wadeable Ozark Highlands streams in Arkansas for a reach length of 51 times the MWSW. Applying these two multipliers to nonwadeable sections of the lower Buffalo River would result in reach lengths of approximately 1,200 to 3,000 m, and reach lengths in lower sections of the Current River could exceed 2,000 to 5,000 m. Because sampling a reach length of more than about 2,000 m is logistically and monetarily impractical, and because metrics based on relative abundance data for reaches of 20 MWSWs and 80 MWSWs were not significantly different ($p<0.05$) (Dauwalter and Pert, 2004), sampling a reach length of 20

MWSWs should adequately describe most aspects of the fish communities of sites. Although Dauwalter and Pert (2004) found IBI values calculated from reaches of 20 MWSWs were significantly different from IBI values collected from reaches that were 50 MWSWs, these values were not substantially lower (less than 5 IBI units). An advantage of using similar reach lengths at BUFF and OZAR will be direct comparison of IBI scores.

Data Management

Data management procedures are an important part of any long-term monitoring program in that they provide data consistency, data security, and availability over time. Therefore, care must be taken to ensure that adequate time and personnel are available for accurate data recording, data entry and verification, and analysis. At the core of this data management is the monitoring database organized by primary and ancillary data.

Primary data consist of reach identification and site description, sampling personnel, sampling date, sampling time, equipment description, sampling duration, and fish community data. Examples of ancillary data records include identification of various environmental characteristics.

Data processing typically involves the following steps: data entry, data verification, data validation and backups/storage (see SOP 9 for details on each step). Data entry consists of transferring field data from field sheets into a monitoring database using data-entry forms. Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source, usually paper field records. Validation procedures seek to identify generic errors, such as missing, mismatched, or duplicate records, as well as logical errors specific to particular projects. Spatial validation of location coordinates can be accomplished using GIS. Global Positioning System (GPS) points are validated against DRGs (digital raster graphic files) or DOQQs (digital ortho-quarter quadrangles) for their general location.

Frequent backups are critical for preventing loss of long-term data. Full backup copies of the monitoring project are stored at an off-site location for safe keeping. Additional digital copies are forwarded to the NPS (WASO) NR-GIS Data Store (http://science.nature.nps.gov/nrgis/), NatureBib (http://www.nature.nps.gov/nrbib/), and NPSpecies Database (http://science.nature.nps.gov/im/apps/npspp/index.cfm) Systems.

Analysis and Reporting

Analysis

To provide park staff with information about the natural resources they manage, a long-term monitoring program needs a reliable reporting system. The data analysis process, however, needs to be flexible enough to allow the use of newly developed statistical and analytical techniques and tailoring of analyses for a variety of audiences. In determining the appropriate statistical approaches for this monitoring protocol, it is crucial to consider the primary audience of the various reports that will result. This primary audience will consist of park resource managers, superintendents, and other staff. Park resource managers and staff may not have an indepth background in statistical methods, and park superintendents may have limited time to devote to such reports. Additionally, protocols such as this one may provide much data on many different types of variables. Thus, to the extent possible, it is important that core data analysis and presentation methods are relatively straightforward to interpret, provide a standard format for evaluation of numerous variables, can be quickly updated whenever additional data become available, and work for many different types of indicators, whether univariate or multivariate. Additionally, the type and magnitude of variability or uncertainty associated with the results should be somewhat intuitive, and it may be necessary to indicate a threshold for potential management action.

There are four main statistical approaches that can be employed with data from long-term monitoring projects: (1) testing hypotheses, (2) estimating biological characteristics or metrics, (3) multivariate analyses, and (4) applying Bayesian methods. When analyzing ecological data, statisticians predominantly employ frequentist methods, and thus many resource managers are not familiar with the interpretation of Bayesian approaches. Furthermore, Bayesian methods are not widely used because they are often difficult to apply, and many researchers are not comfortable specifying subjective degrees of belief in their hypotheses (Utts, 1988; Hoenig and Heisey, 2001). Accordingly, the Bayesian approach is not promoted as the main method of data analysis in this protocol.

Most hypothesis testing approaches involve a null hypothesis of no difference or no change. The problem with such approaches is that the hypothesis under test is trivial (Cherry, 1998; Johnson, 1999; Anderson and others, 2000, 2001) because no populations or communities will be exactly the same at different times. Thus, the interest of this monitoring program is not whether fish communities are changing, but rather in the magnitude of the change, and whether it represents something biologically important. Null hypothesis significance testing relies heavily on P-values, and results primarily in yes/no decisions such as rejecting or failing to reject the null hypothesis. P-values are influenced strongly by sample size, and with a large enough sample size, one may obtain a statistically significant result that is not biologically important. Alternatively, with a small sample size, one may determine that a biologically important result is not statistically significant (Yoccoz, 1991). Thus, traditional null hypothesis testing places the emphasis on the size of the P-value, which is dependent on sample size and rejection of the null hypothesis, whereas more concern should be placed on whether the data support meaningful scientific hypotheses that are biologically significant (Kirk, 1996; Hoenig and Heisey, 2001).

Estimation of biological characteristics or metrics (hereafter referred to as "metric estimation") provides more information than hypothesis testing, is more straightforward to interpret, and easier to compute (Steidl and others, 1997; Gerard and others, 1998; Johnson, 1999; Anderson and others, 2000, 2001; Colegrave and Ruxton, 2003; Nakagawa and Foster, 2004). Metric estimation emphasizes the magnitude of effects and the biological significance of the results, rather than making binary decisions (Shaver, 1993; Stoehr, 1999). There is no formal classification of error associated with metric estimation. One of the primary recommendations from a workshop on environmental monitoring organized by the Ecological Society of America was that trend studies should focus on description of trends and their uncertainty, rather than hypothesis testing (Olsen and others, 1997). Thus, most of the data analysis suggested in this protocol will take the form of metric estimation, rather than null hypothesis significance testing.

Several metrics and analysis techniques have been used to detect trends in fish communities and investigate the relations between fish communities and environmental conditions. Two common approaches are calculation of individual metrics and multiple metric biological indexes (Plafkin and others, 1989; Hughes and Oberdorff, 1998; Barbour and others, 1999; Simon, 1999), and multivariate statistics (for examples applying to Ozark fish communities see Petersen, 1998, 2004). Using multiple analytic approaches will provide multiple lines of evidence, increasing the validity and confidence of study conclusions. A detailed summary of calculated metrics and data analysis are given in SOP 10.

Biological metrics are commonly used by scientists to compare the condition of the biological community at multiple sites (Simon, 1999) or across time. A metric is a characteristic of the biota that changes in a predictable way with increased human disturbance (Barbour and others, 1999). Attributes of the fish community such as degree of tolerance to disturbance, habitat and substrate preferences, spawning preferences, and trophic status (appendix 5) are measures frequently reflected in metrics making it possible to determine relations between biological communities and environmental conditions.

An extension of the metric approach is to combine multiple metrics into an IBI. This index is used as an indicator of overall stream quality, enabling investigators to compare conditions at multiple sites (Karr, 1981; Barbour and others, 1999; Simon, 1999) or at a single site across time. Prior to use of fish communities as bioindicators, aquatic invertebrate communities were, and still are, used as indicators of stream quality (Hilsenhoff, 1977). Because of the popularity of fish with the general public and stakeholders, fish communities are the most commonly used bioindicator for investigating ecological relations using the IBI approach (Barbour and others, 1999; Simon, 1999).

One of the first fish IBIs (appendix 6) developed by Karr (1981) has been modified for use in many other regions and countries (Hughes and Oberdorff, 1998; Simon, 1999). IBI's have been created for three ecoregions in Arkansas (Hlass and others, 1998; Dauwalter and others, 2003; Justus, 2003; Dauwalter and Jackson, 2004) and for Ozark Highland streams (Hoefs, 1989; Dauwalter and others, 2003; and Matt Combes, Missouri Department of Conservation, written comm., 2006). Hoefs (1989) modified metrics and scoring criteria from Karr's (1981) original index for use in the Current River Basin (appendix 7) in southeastern Missouri. Hoefs' IBI is specific to the Current River, and has not been submitted for rigorous peer review. The existing IBI used by the MDC contains modified metrics from various IBIs to assess fish communities in the Ozarks (Matt Combes, Missouri Department of Conservation, written comm., 2006) (appendix 8). Again, this Missouri IBI has not been rigorously peer reviewed and may not be applicable to HTLN monitoring data because this IBI is based on methods and equipment used specifically in the MDC stream assessment program. Within the next 5 years, a regionally based IBI for Missouri may be developed through joint efforts of MDC and the University of Missouri (Matt Combes, Missouri Department of Conservation, oral comm., 2006). Once developed and peer reviewed, the new Missouri IBI will be evaluated for use in the Current River watershed. Dauwalter and others (2003) evaluated 38 candidate metrics and selected 7 metrics for an IBI applicable to fish communities in wadeable streams of the Ozark Highlands (appendix 9). Because the IBI by Dauwalter and others (2003) was developed for the Ozark Highland region and has been peer reviewed, this IBI will be used for assessing fish community conditions and stream quality in BUFF and OZAR.

Multivariate analyses are another commonly used statistical method to explain variability in community data and attribute that variability to specific environmental variables or gradients (Gauch, 1982; Jongman and others, 1995; Everitt and Dunn, 2001; Timm, 2002). Multivariate techniques differ from univariate or bivariate analyses in that the former techniques generate a hypothesis from the biological data rather than disproving a null hypothesis, and the effectiveness improves as the number of variables increase (Williams and Gillard, 1971). Two multivariate techniques commonly used to analyze community data include ordination and classification (Gauch, 1982; Jongman and others, 1995; Everitt and Dunn, 2001; Timm, 2002).

Control charts also will be employed in data organization and analysis. Control charts, developed for industrial applications, indicate when a system is going 'out of control,' by plotting through time some measure of a stochastic process with reference to its expected value (Beauregard and others, 1992; Gyrna, 2001; Montgomery, 2001; Morrison, in press). Control charts may be univariate or multivariate, and can represent many different types of variables. Control charts have been applied to ecological data (McBean and Rovers, 1998; Manly, 2001), including fish communities (Pettersson, 1998; Anderson and Thompson, 2004) and natural resources within the NPS's inventory and monitoring program (Atkinson and others, 2003). Control charts contain upper and lower control limits specifying thresholds beyond which variability in the indicator (estimated metric) reveals a biologically important change is occurring, and warns that management may need to act. Control limits can be set to any desired level.

Although the primary approach to organizing and analyzing data will consist of metric estimation combined with the use of control charts, the use of other statistical methods are not ruled out at this time. Because of the nature of this long-term monitoring program, other approaches (some which may not have even been developed yet) may be appropriate at different points in time, depending upon the needs of the resource managers and questions of interest.

A formal power analysis for this protocol was not conducted for three reasons (Morrison, 2007): (1) The primary purpose of conducting a prospective power analysis is to determine whether the proposed sample size is adequate. Because sample size for this monitoring program is determined primarily by budget, an increase in sample size is not possible regardless of the result of any power analysis. Furthermore, in many analyses sample size will equate with number of years; in this case, analyses will simply become more powerful over time. (2) Statistical power is dependent upon the hypothesis under test and the statistical test used. Over the course of this long-term monitoring program, different questions will be of interest, and various hypotheses could be evaluated. Thus, there is no single "power" relevant to the overall protocol. Estimating power at this point in the context of such a long-term, multifaceted monitoring program could be potentially misleading, as the test this power is based upon may rarely (or never) actually be employed. (3) Most data analyses will take the form of metric estimation with control charts, rather than null hypothesis significance testing. When estimating metrics, there is no associated statistical power.

Reporting

To distribute findings about the resource in a timely manner, it is necessary to distribute results, including data analysis, interpretations, and recommendations from fish community monitoring on an annual basis to park managers and State agencies. Annual reports will be submitted to the superintendents and resource management staff of each park and to the HTLN program. The purpose of annual reports is to update general findings and status of the fish community. These reports will not deviate substantially from year to year in terms of structure or analyses used (see SOP 11). Scientific collection permits are required in Arkansas and Missouri and must be renewed annually. As part of the permit process, an annual report of the collection activities must be sent to the Arkansas Game and Fish Commission (AGFC) and the MDC.

More extensive summary reports containing trend analysis and detailed explanations of findings will be completed every 5 years. The purpose of these reports is to describe trends in fish communities and habitat quality, determine relations between environmental conditions and fish assemblages, and interpret relations between observed trends and park management or land-use changes. Summary reports will be sent to park superintendents and resource management staff and to HTLN.

Personnel Requirements and Training

The personnel required to conduct fish community sampling depends on several variables including those related to safety, accessibility, and stream size. Safety and time considerations largely determine how many personnel are necessary for fish sampling, particularly when site access is poor (because poor site access may require a larger crew). Stream size also dictates the number of personnel needed. For example, smaller sites may require only three to four people, while larger sites require a minimum of five to six. Therefore, based on the size range of sites sampled in this program and the potential difficulties in accessing random sites, fish community monitoring will require a minimum crew of five each year. The crew will be made up of the fisheries biologist (project manager), two aquatic ecologists, and two seasonal technicians. The aquatic program leader will also participate in fieldwork as their schedule permits, and occasional assistance from park staff or State agencies may be necessary.

Critical to the success of a monitoring program is a high level of consistency in field collection and data analysis from year to year. To obtain this consistency, it is necessary to have a competently trained staff and, preferably, the same staff every year (SOP 2). For the field crew, the fisheries biologist (project manager) and two aquatic ecologists will remain relatively consistent from year to year. The project manager is responsible for implementing the monitoring protocol, leading fish community surveys, and training all crewmembers. Because the aquatic ecologists on the crew will be fairly consistent from year to year, they will also help the project manager train crewmembers as well as help with fish surveys. Training should be done prior to each field season with each crewmember reviewing the SOPs outlined in this protocol. Training should include discussions with crewmembers on safety protocols for fieldwork (SOP 2), demonstrations on proper use of water-quality meters (SOP 4), GPS units, and electrofishing/seining equipment (SOP 5), and practice of proper sampling techniques and fish identification (SOP 5).

In addition to implementing the monitoring, the project manager, in collaboration with the data manager, is responsible for managing the collected data. The project manager will be responsible for data collection and entry, data verification and validation, and data analysis and reporting. The data manager is responsible for database design and modification, archiving and securing the data, and dissemination of the data. The data manager also is responsible for constructing adequate quality assurance/quality control (QA/QC) procedures and automating report generation based on the project manager's analysis needs.

Operational Requirements

Annual Workload and Field Schedule

Twelve sites will be sampled annually in each park. Sampling will begin in early summer at BUFF and early fall at OZAR. A minimum of 12 to 14 days will be necessary to complete fish monitoring at each park. However, the amount of field-person days will depend primarily on site location, logistics, and weather. Because of crew safety and protection of field equipment, fish monitoring will not be conducted in inclement weather, such as thunderstorms. Thus, specific dates will not be designated for fieldwork, but a month-long period will be scheduled for sampling each park.

Facility and Equipment Needs

Fish community monitoring will require a laboratory to process preserved specimens, in addition to office space and storage needs for equipment. The laboratory, presently stationed at Missouri State University (Springfield, Missouri), must contain a sink; a flame proof, hazardous materials cabinet for storage of preservatives; a work bench; a dissecting microscope for identifying small specimens; and shelves for storing specimens. Electronic equipment that is temperature sensitive, such as data loggers and meters, should be stored in the laboratory or office. Equipment not sensitive to temperature fluctuations, such as generators, boat motors, and nets, should be stored in a small shed. A summary of field equipment is located in appendixes 10-14.

Startup Costs and Budget Considerations

Startup costs and annual budgets are important considerations for any monitoring program. Annual costs (in 2007 dollars) for conducting monitoring are summarized in table 2. Many network staff including the program coordinator, quantitative ecologist, and project leader play a role in this monitoring effort and their contributions are accounted for in the salary line item. Expenses for fieldwork are based on a minimum crew of five people (table 2). Occasional assistance from park staff and State agencies may be necessary to complete fish sampling and will offset salary and travel costs for the monitoring program. Field costs will vary from year to year based on participation of park staff and State agencies, skill level of crew, and size of crew. Startup cost for field equipment includes the purchase of a boat electrofishing unit, two backpack electrofishing units, a towed barge unit, boat motor, and various field equipment (such as waders, nets, and gloves) (appendix 12). A majority of the items included under field equipment are for long-term use and will only need to be purchased during the startup phase of the program (such as boat electrofishing unit, and boat motor). Supplies include: (1) items that need to be replaced or replenished every year, such as jars and preservative for specimens, and waterproof paper for recording data, (2) items used for maintenance of field equipment, such as oil for boat motors, and (3) equipment shared among projects (such as GPS units and cameras).

Table 2. Estimated annual costs for salaries, equipment, supplies, travel, and other expenditures.

Expense categories	Estimated cost (2007)
Salary	$99,553
Field/office equipment	$1,710
Supplies	$1,140
Computer hardware and software	$950
Fieldwork travel	$3,610
Vehicle lease	$2,280
Overhead to Missouri State University	$625
Administrative support to Wilson's Creek National Battlefield	$1,470
Laboratory fees	$2,500
Total	$113,838

Protocol Revision

Revisions to this protocol may be necessary for several reasons, including the development of new statistical approaches or more informative metrics and the improvement of data-collection methodology. Therefore, documentation of protocol revisions is mandatory for maintaining consistency in data collection and analysis between the earlier and the revised version. The purpose for dividing the protocol into the Protocol Narrative and supporting SOPs is to organize the protocol such that minor changes do not require a revision of the entire protocol. The Protocol Narrative is a general overview on the background and justification for the monitoring project and an overview of sampling design and methodology. In contrast, SOPs contain more detailed information on completing tasks required for monitoring. SOPs may need to be revised more frequently than the Protocol Narrative, and changes to SOPs do not require revision of the Protocol Narrative section unless major changes are made. All versions of the Protocol Narrative and SOPs must be archived in a protocol library, and a history log must be filed. Detailed steps on how to change the protocol and document these revisions are located in SOP 12.

Protocol for Monitoring Fish Communities

The protocol for monitoring fish communities of BUFF and OZAR, as part of activities of the NPS HTLN, is provided in the following SOPs. These SOPs provide information on preparation, training, site selection, fish community sampling, equipment maintenance and storage, data management, data analysis, reporting, and protocol revisions.

The Ozark Rivers Fish Community Protocol (Protocol Version 1.0 and version 1.0 of each SOP) has been developed to incorporate sound methods for collecting and analyzing fish community data at BUFF and OZAR. However, revisions may be necessary as new and improved sampling methods or statistical techniques are developed. A Revision History Log is included at the beginning of each SOP; SOP 12 describes protocol revision procedures.

SOP 1: Preparation Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

At least 2 months prior to fish community sampling, a plan needs to be developed that includes details for personnel, equipment, time requirements, and the sample schedule necessary to complete sampling. As an initial step in the planning process, unfamiliar sites need to be visited by the project manager or the aquatic ecologist stationed at the park and equipment needs and accessibility details noted. This process will help determine the time and number of personnel needed for sampling at a site. As a general rule, small stream sites can be sampled within a half day; however, larger and inaccessible sites require 8 hours or more to sample.

Fish community monitoring will be completed at 12 sites during late spring for BUFF (May – June) and during early fall for OZAR (October). Twelve field days should be planned for OZAR. At least fourteen days should be scheduled at BUFF, because access to sample sites in the lower Buffalo River requires a minimum 2 days to complete with overnight camping. Based on the number of sample sites and the potential for inclement weather, a month should be scheduled to complete fish sampling in each park.

Initial selection of the appropriate sampling equipment is necessary before reliable, representative fish community data can be collected. Equipment that is needed for fish sampling and assessment of habitat and water-quality conditions is listed in appendixes 10 through 14. When selecting equipment for sampling, equipment should be matched to stream size for optimal and, perhaps more importantly, consistent sampling efficiency. Boat electrofishing units with large generators may be necessary for thorough sampling of large streams, while backpack electrofishing units or towed electrofishing barges are suitable for sampling small streams. If distance to the stream and bank slope are not excessive (for example, a distance less than 500 m from vehicle access) and enough personnel are available, sampling equipment such as small boats and electrofishing generators can be carried to the stream.

Some State and Federal agencies are permitting authorities for the natural resources that they manage and oversee. To ensure that the equipment planned for sampling meets the requirements of permitting authorities and is best suited for the conditions that will be encountered, the project manager needs to determine if special regulations exist for any water body where sampling is planned. If threatened or endangered species are known or suspected to occur at any sampling site, the U.S. Fish and Wildlife Service (USFWS) must be contacted to determine specific stipulations associated with sampling within the species' respective range, regardless of the specific location of the sampling sites. Once general sampling information is known, the AGFC or the MDC should be contacted (depending on the location of the sampling sites) and the procedures for obtaining collection permits and submitting sample results should be determined. Although all sampling sites will be on NPS property, it may be necessary to cross private property to reach some sites, and permission from landowners needs to be acquired where appropriate.

All equipment should be gathered at least 1 month prior to the field season and checked to ensure that equipment is in working condition and that supplies such as paper for data sheets and preservative for specimens are available. All sampling gear should be inspected, particularly nets that tear frequently and electronic equipment such as backpack shockers, flow meters, and water-quality meters, to ensure there is no damage. A field notebook for the sampling season should be prepared with pages for entry of sampling schedules, crewmember names, sites visited, field hours per day, and any conditions or circumstances that may influence how data are reported. Trip reports, which are linked to the fish community database, are based on information recorded in the field notebook; therefore, it is important that notebooks are clearly organized for ease of data entry.

SOP 2: Training Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

Training requirements generally fall into two categories: sampling and safety. Sampling crews need to be able to work in the field in a manner that will maximize the quality of the information collected and ensure their safety. Prior to field season, the fisheries biologist and aquatic ecologists should review this protocol and operation manuals for water quality (for example, dissolved oxygen meter), habitat (for example, flow meter), and electrofishing equipment (for example, backpack shocking unit). In the field, additional crewmembers will be instructed on procedures and use of equipment by the fisheries biologist or the aquatic ecologists.

Sampling Efficiency and Consistency Considerations

An experienced sampling team will result in optimized efficiency and consistency of the sampling effort. The fisheries biologist (project manager) should have extensive experience in boat operation and electrofishing procedures and have completed the USFWS electrofishing course (Principles and Techniques of Electrofishing); at least one person onsite with an electrofishing crew is required to have completed the course. The aquatic ecologists on the crew also should be familiar with boat and electrofishing gear operation prior to the field season and will be trained on these techniques by the fisheries biologist, if necessary.

One important consideration is that the team conducting the fish sampling and habitat data collection remain intact when possible, or if different teams or team members are utilized, they sufficiently understand the importance of consistent sampling. When team members alternate or change, the fisheries biologist (with assistance from the aquatic ecologists) will explain the importance of consistent sampling, provide an overview of sampling equipment, and demonstrate electrofishing and habitat data collection techniques.

Another consideration specific to fish sampling personnel is that the fisheries biologist have taxonomic expertise and the fisheries biologist and aquatic ecologists be familiar with the local fish fauna. Prior to the field season, the fisheries biologist and aquatic ecologists need to re-familiarize themselves with the fish fauna by examining preserved specimens located in the reference collection (see SOP 5 for collection of reference specimens). The fisheries biologist will train other crewmembers in coarse identification of specimens, separating them into groups such as sunfish, sculpins, minnows, and darters to aid in initial sorting and processing of fish.

One last consideration for consistency in data collection is that at least one person on the crew have competent data recording abilities. If possible two people should have competent abilities, one for fish processing and one for habitat collection. This will ensure that the numerous fish measurements and counts will be recorded accurately and habitat data will be recorded on the correct form for each transect. Prior to recording data, the fisheries biologist or aquatic ecologist will explain and demonstrate to the crewmember how to record data on the field forms.

Safety Considerations

Safety qualifications of the sampling crew are an important consideration prior to conducting field sampling. In particular, some field-sampling activities carry a real potential for personal injury or death. Safety considerations include elements of planning, equipment use and maintenance, and behavior of crewmembers. Before the field season, all crewmembers are required to read the Heartland Network Safety Plan and Procedures (Cribbs, 2006) that describes potential dangers and abatement actions for field and laboratory/office work. This document includes safety on boating/canoeing, fishery/stream surveys, electrofishing, dehydration, camping, office work, general/winter driving, and hazardous materials. Each crewmember must sign and date an annual review form stating that they have read and understand the safety plan.

Two Department of the Interior (DOI) training courses are required for some crewmembers. All DOI employees that operate a motorboat are required to have completed the DOI motorboat operator course. At least one member of an electrofishing crew is required to have completed the USFWS electrofishing course.

Sampling teams must always have at least two crewmembers; no one should sample alone. NPS employees must wear properly fitting U.S. Coast Guard approved personal floatation devices (PFDs) when in canoes or other boats and should wear PFDs when wading in fast current. Each sampling team needs a first aid kit, a cellular or satellite telephone, and an emergency contact list (including medical facilities closest to each sampling site) in the boat or in each field vehicle. Safety requirements stipulate that prior to sampling at least two crew-members must be adequately trained in first aid and cardio-pulmonary resuscitation (CPR) techniques. Prior to sampling with new team members, the electrofishing team coordinators (the fisheries biologist and aquatic ecologists) need to explain basic safety rules and be sure that new personnel understand all safety signals and know the location of all safety switches on the electrofishing equipment.

SOP 3: Reach Selection Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

A detailed description of stretch designation and selection was discussed in the protocol narrative. Briefly, sampling stretches were selected randomly using a method known as Generalized Random Tessellation Stratified (GRTS) sampling (Stevens and Olson, 2004). Within each stretch, a sampling reach will be designated for fish community monitoring.

The reach is the representative portion of the stretch that is sampled. Sampling reaches will be established using a combination of geomorphic characteristics, such as stream width, stream depth (wadeable or nonwadeable), geomorphology (distribution of riffles, runs, and pools), and local habitat disturbance. In accordance with NAWQA protocols (Fitzpatrick and others, 1998), reach lengths should be approximately equal to 20 times the MWSW at low flow with a minimum length of 150 m in small wadeable streams (those less than 1.5 m deep in most of the channel) and a maximum of 1,000 m in large nonwadeable streams.

In general, the downstream boundary of the mainstem and tributary sampling reaches will be placed at the head of the second riffle located upstream from the downstream stretch boundary (fig. 2). This is to ensure that mainstem reaches are not present in the confluence zone of the tributary or spring run that may designate the lower stretch boundary, and to ensure that the tributary reaches are out of the flood-plain area of the mainstem.

The upstream boundary of the reach will be located at a distance approximately 20 MWSWs upstream from the downstream boundary. However, the reach must include portions of all available geomorphic channel units (riffles, runs, pools) typical of the stretch to ensure a representative sample. Thus, reach length (and, therefore, the upper boundary placement) may need to be extended to guarantee all typical channel units are included in the sample. The upstream boundary of the reach also needs to be determined such that the reach avoids features such as bridges, dams, waterfalls, and major tributaries by at least 10 MWSWs. If the upstream boundary falls too close to a feature, then the location of the reach can be moved upstream or downstream to avoid the feature. Preferably, the downstream boundary of the relocated reach should be at the head of a riffle. Also, if the reach is near a bridge, it is preferable to move the reach upstream from the bridge, but be aware that "low-water bridges" can act as low-head dams with differing effects during periods of low and high streamflow.

Upstream and downstream boundaries will be temporarily marked with flagging tape during fish sampling. During initial establishment of the permanent reach, boundaries will be documented using a GPS unit. Proper use of GPS units for collecting location data can be found at the following website: *http://www1.nature.nps.gov/im/units/htln/datamanagement.cfm.*

Reach descriptions, GPS locations, and reach identification code are recorded on the field sheets (appendixes 15 through 20). Each reach has a unique identification code that begins with the first four letters of the river (BUFF = Buffalo, CURR = Current, JACK = Jacks Fork), followed by a letter designating the reach as a mainstem site (M) or tributary (T), and a number designating that particular reach (see appendix 3 for list of reach identification codes). Both mainstem sites and tributaries in the selected sampling frame are numbered consecutively downstream, starting at the upstream-most site or tributary as 01. For example, CURRM01 is the first (or most upstream site) on the mainstem of the Current River and CURRT05 is the fifth tributary that will be sampled on the Current River (that is, four tributaries in the sampling frame are located upstream from this tributary).

SOP 4: Documenting CORE 5 Water-Quality and Weather Conditions Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

This SOP addresses the equipment (see appendixes 10 and 11) and methods required to measure CORE 5 water-quality variables (temperature, dissolved oxygen, specific conductance, pH, and turbidity) and weather conditions in association with fish monitoring in HTLN parks. Detailed guidance for measuring CORE 5 variables, including training, calibration, QA/QC, data archiving, meter specifications, field measurements, and trouble shooting, can be found in the Documenting CORE 5 Water Quality Variables SOP located at: *http://www1.nature.nps.gov/im/units/htln/fish.cfm.* This SOP was prepared using guidance and language from National Park Service/Water Resources Division (2007a) and Wagner and others (2006). The methods described in this SOP are specific to this protocol and do not conform completely to USGS methods for collection of water-quality data.

For each reach, a crewmember will record their initials and the reach identification (ID) code, date, reach location and description, stretch number, general weather conditions, and water-quality variable values on the field form (appendix 15). Water-quality variables and air temperature will be measured at the site prior to and following fish sampling to obtain data on the range of water-quality conditions during sample collection (using discrete sampling – see next section).

Two approaches to recording CORE 5 data will be used in this protocol: (1) Discrete measurements using hand-held instruments, and (2) Unattended measurements using data loggers or sondes.

Discrete CORE 5 Sampling with Hand-Held Meters

Discrete CORE 5 measurements using hand-held meters do not reflect changes in water quality, such as diurnal fluctuations or those associated with a hydrologic event, that are likely to have occurred in the stream. However, these measurements serve two general purposes: (1) they represent the natural condition of the surface water at the time of sampling, although they are not intended to be a precise measure of water-quality condition in the stream, and (2) they serve as a cross-check for CORE 5 measurements using unattended CORE 5 data sondes (see next section).

Unattended CORE 5 Measurements with Data Logging Sondes

CORE 5 water-quality variables measured with small intervals (generally minutes to hours) between repeated measurements are considered continuous because few if any substantial water-quality changes are likely to go unrecorded. When the goal is to characterize events of short duration, but such events are difficult to capture manually using discrete measurements (see above), continuous monitoring is appropriate. Continuous monitoring of CORE 5 variables helps address questions concerning daily or seasonal variability, or short-term changes (such as precipitation related events) that might not be apparent or prevent accurate understanding of long-term data. Continuous monitoring also provides the most comprehensive temporal dataset upon which to evaluate variability through time. Such information is necessary to document correlations, possible cause and effect relations, and differentiate natural variability from anthropogenic-induced change to an aquatic system.

Analysis and Reporting

CORE 5 data will be analyzed using summary statistics (mean, median, range, standard deviation, standard error) for each site and date. This information will be presented in summary and synthesis reports to support fish collection data.

NPSTORET

Collected water-quality data that has been successfully subjected to QA/QC will be exported to NPSTORET (SOP 9). Only summary data for a site and collection period, in addition to pertinent metadata, will be submitted. Instructions for preparing and exporting water-quality data to this archival facility can be found at the following website: *http://www.nature.nps.gov/water/infoanddata/index.cfm*

SOP 5: Fish Community Sampling Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

This SOP presents methods for collecting representative samples of stream fish communities that closely follow in methodology, wording, and scope the NAWQA protocols described in Moulton and others (2002) and Walsh and Meador (1998). The methods have been modified where appropriate to meet the specific objectives of the NPS to collect representative samples and measure changes in fish communities from streams in BUFF and OZAR. A representative sample contains most, if not all, species in the stream at the time of sampling in numbers proportional to their actual abundance. Each reach contains various instream habitats (riffles, runs, glides, and pools), substrates, and hydrologic conditions. Many fish species are specialized for specific habitat conditions and their occurrence in the stream is determined largely by the relative abundance of aquatic habitats.

Electrofishing Overview

Electrofishing is viewed as the single most effective method for sampling stream fish communities (Bagenal, 1978; Barbour and others, 1999) and involves the use of electricity to capture fish. A high-voltage potential is applied between two or more electrodes that are placed in the water. The voltage potential can be created with either direct current (DC) or alternating current (AC) using a pulsator; however, because of less harm to fish from the use of DC, only DC will be used for this fish monitoring program. DC produces a unidirectional, constant electrical current. Pulsed DC is a modified direct current that utilizes a sequence of cyclic impulses to immobilize fish. The frequency of the pulses produced when using pulsed direct current can be adjusted by the operator and usually ranges from 15 to 120 pulses per second (pps; or Hertz, Hz).

Some fish are more susceptible to electrofishing injury, and injury rate can vary by fish species, environmental conditions, and electrofishing techniques. Salmonids (Dalbey and others, 1996; Kocovsky and others, 1997; Ainslie and others, 1998) and larger fish (McMichael and others, 1998) are more susceptible to injury than other fish. Pulse frequencies greater than 30 pps have proven to be more effective in collecting fish but appear to cause spinal injuries, particularly in trout and salmon species (Coffelt Manufacturing, Incorporated, cited in Meador and others, 1993). Pulse rates of less than 30 pps have caused low incidence of injury, but are generally ineffective in collecting fish. Therefore, a pulse-frequency range from 30 to 60 pps is generally used to optimize collection effectiveness with a minimum potential for damage to fish. However, Dolan and Miranda (2004) suggested that electrofishing with intermediate to high duty cycles (pulse frequency X pulse duration X 100, as percent) could reduce injury and mortality to warmwater fish. These intermediate to high (36 to 100 percent) duty cycles tested by Dolan and Miranda (2004) had pulse frequencies of 60 to 100 pps and pulse durations of 6 milliseconds or were non-pulsed DC. While fishing, the operator should note the behavior of the fish so that adjustments can be made to the output of the electrofishing unit. To minimize mortality rates, Dolan and Miranda (2004) recommended that the power output and electrode system should be managed to induce narcosis (a state of induced immobility with slack muscles) and prevent tetany (immobility with rigid muscles) of large individuals.

Water conductance also affects the response of the fish to the electrical field and is the single most important limiting abiotic factor in electrofishing effectiveness. Low-conductance water is highly resistant to the flow of electrical current and the electrical field is limited to the immediate area of the electrode. High-conductance water produces the opposite effect by concentrating a narrow electrical field between the anode and cathode (Meador and others, 1993). Water in most streams of BUFF and OZAR has moderate values of specific conductance (typically about 150 to 400 microsiemens per centimeter at 25 degrees Celsius, µS/cm) (Hauck and others, 1996; Mott and Luraas, 2004). Water in the upper mainstem and some tributaries of the Buffalo River, however, has lower specific conductance (typically about 50 to 150 µS/cm) than water from other areas of the two parks. In low-conductance water, higher voltage is needed to immobilize fish, while in high-conductance water, lower voltage is needed to achieve the same result and to minimize potential damage to the fish. However, conductance will vary from site to site and from year to year; therefore, some pre-sampling experimentation is necessary.

Water clarity also affects electrofishing success and determines which techniques will be used. In clear streams, fish can see the electrofishing crew or boat. Evasion will be the response to both the electrical field and the presence of the crewmembers. In turbid streams, immobilized fish may be difficult to see resulting in low capture efficiency. At both BUFF and OZAR, water clarity is high and therefore, specific ambush or herding techniques (described within this SOP) will be used to increase capture rate.

Seining Overview

Although electrofishing is the most effective fish sampling method, it is biased toward collection of large-sized fish (Wiley and Tsai, 1983; Dolan and Miranda, 2003), and seining is a common collection method often used to complement electrofishing (Bagenal, 1978; Nielsen and Johnson, 1983). Seining is a highly effective method for sampling small-sized individuals that are less than about 10 cm total length (Bayley and Herendeen, 2000).

Wadeable streams and shallower parts of nonwadeable streams are sampled using a "common sense" seine (about 3 x 1.2 m with a 6.44-mm mesh size) or a bag seine, depending on the size of the stream. Use and effectiveness of a particular seine depend on the channel units (for example, riffles, runs, pools), channel size and features, and instream habitats present in the sampling reach. The presence of submerged objects such as woody snags, large cobble, or boulders in a sampling area makes it difficult to collect representative samples. Therefore, the potential for collecting a representative and repeatable sample should be evaluated before seining an area. Seines are most commonly used in wadeable streams with smaller substrates such as gravel or sand with little or no woody debris. In nonwadeable streams, seines are generally used to collect smaller fish along banks or in shallow backwater areas.

A second method of seining is known as kick seining. This method involves shortening the length of a common sense seine by rolling the seine onto the brails. The seine then is placed within a riffle, and the substrate is kicked to dislodge benthic fish species that then are carried by the current into the seine. This technique also is used in combination with backpack or towed barge equipment, whereby the crewmember holding the anode will shock down into the seine while kicking the substrate. However, using electrofishing equipment with a seine is an electrofishing method and not strictly a seining technique.

Sampling Methods for Wadeable Streams

Electrofishing

Wadeable streams generally are less than 1.5 m deep, but may contain some areas that are substantially deeper. Backpack and towed electrofishing gears are used for sampling fish in wadeable streams. Backpack electrofishing with a single anode is usually most effective in shallow (less than 1 m), narrow (less than 5 m wide) streams. Towed barge electrofishing gear (multiple anodes) is usually more effective in wide (greater than 5 m) wadeable streams with pools deeper than 1 m. Channel width, depth, and access need to be considered before choosing between backpack and towed electrofishing gear. In some situations, it may be desirable to use a combination of backpack and towed electrofishing gear; for example, the backpack might be used in long, shallow riffles (or in conjunction with riffle kicking) and the towed gear in the deeper sections of the stream.

Electrofishing techniques for wadeable streams require an electrofishing crew consisting of three to six individuals. When using backpack electrofishing gear, one crewmember is designated as the operator; with towed gear, three crewmembers are designated as operators (two operate the anodes and one operates the barge and generator). Regardless of the gear used, two crewmembers (or netters) are assigned to collect stunned fish with dip nets and place fish in buckets. One additional crewmember is sometimes needed to assist in netting fish and to transfer netted fish into buckets or into a flow-through holding container (or live cage) if dissolved oxygen concentrations are low and water temperatures are high within the buckets. For safety reasons, all crewmembers must wear non-breathable waders and low-voltage rubber gloves, and they also should wear polarized sunglasses to enhance their ability to see fish that have been immobilized by the electrical field.

Techniques for collecting samples using either backpack or towed electrofishing gear are generally similar in riffle-pool streams. To obtain a representative sample using single-pass electrofishing, thorough sampling along both banks of the stream and in mid-channel areas will be completed at each reach. All types of instream habitat features such as woody snags, undercut banks, macrophyte beds, or large boulders, and geomorphic channel units (riffles, pools, runs) should be sampled. This technique requires electrofishing from one edge of the water to the other in a "zig-zag" pattern, while attempting to sample all types of habitat features and channel units within the reach in proportion to their occurrence (fig. 4). In reaches that have substantial and diverse habitat features along the banks (such as woody snags/tree roots, and boulder fields), it may be necessary for the crew to sample along one bank for a distance and then move back downstream and sample critical habitat along the opposite bank.

The electrofishing crew should begin electrofishing at the downstream boundary of the sampling reach and proceed upstream. Sampling in an upstream direction in wadeable streams is preferred over sampling in a downstream direction for several reasons (Hendricks and others, 1980). Disturbance caused by electrofishing crews walking in the stream increases turbidity, thereby greatly reducing visibility and sampling efficiency. Also, sampling in an upstream direction allows stunned fish to drift downstream, thus facilitating their capture by the netters. Generally, the distance that the net is held downstream from the anode increases with current velocity and turbidity. It is also important to have one netter near the anode to collect fish stunned by the anode and an additional netter downstream

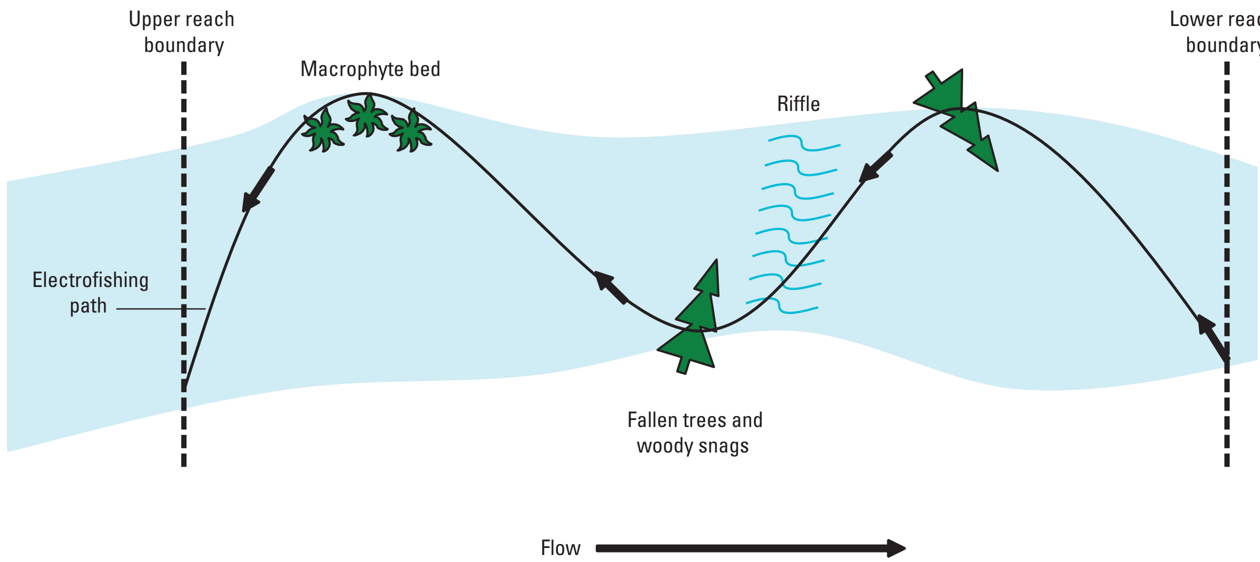


Figure 4. Single pass zig-zag sampling technique used in electrofishing wadeable streams.

from the cathode to collect fish that are stunned near the cathode or that float down from the anode.

Different fish species have different adaptations and several different electrofishing techniques may be necessary for efficient sampling. In some situations, applying a continuous electrical current to the water is effective. In other situations, it is more effective to apply current intermittently. Using a continuous electrical current, schooling species can be "herded" into confined spaces where they are more susceptible to capture. Fish generally respond to continuously applied electrical current by attempting to avoid exposure to the electrical field. Thus, continuous application of electricity can result in fish moving just ahead and away from the operator. The operator needs to be aware of this response and take advantage of natural barriers where fish can be herded (such as banks, bars, or shallow riffles) to facilitate their capture by the netters. Upon reaching a barrier, fish will turn and attempt to evade the approaching electrical current. Therefore, netters should be alert when approaching barriers so that fleeing fish can be captured.

Another technique that can be used for capturing fish species that flee the weak edge of the electrical field is for the crew to herd the fish toward the operator while the electrofishing equipment is turned off and to begin electrofishing once fish have come within the electrical field. This approach works well in runs or long pools where a crewmember (or two) moves upstream from the fish by getting out of the stream and walking up the bank. Once ahead of the fish, the crewmember returns to the stream and creates a disturbance in the water that drives the fish downstream toward the operator. The electricity is turned off as the crewmember herds the fish back downstream. When the fish are visible and close to the anode, the electricity is turned on to stun them. Use of a small seine as an additional barrier improves the efficiency of this technique.

A third technique, referred to as the ambush technique, can be used for capturing fish species such as black bass and other members of the sunfish family that have affinities for cover, including submerged woody debris, boulders, and bedrock ledges. These species can be captured by approaching the cover with the electricity turned off and thrusting the anode into the cover while turning on the electricity.

Shallow riffles, cascades, and torrents often are very swift and require different electrofishing techniques than run and pool areas. A useful technique for sampling shallow riffles is to have the operator stand beside the habitat to be sampled and sweep the anode across the riffle from upstream to downstream. Stunned fish will be carried downstream and into dip nets or a seine. This technique minimizes escape and avoidance of the electrical field by benthic fish species such as darters and sculpins, which commonly inhabit riffles. Sculpins and darters do not have swim bladders and, therefore, do not float when stunned, but rather roll along the bottom with the water current. Because they lack a swim bladder and have cryptic coloration, these species may not be seen until the net is examined. Swift riffles, cascades, and torrents with large cobble or boulder substrate can be sampled with similar techniques. For these habitats the operator works the anode downstream through the swift current between rocks and through small plunge pools while a dip net or seine is maintained on the bottom and about a meter downstream.

While electrofishing riffles, it may also be necessary for the operator to kick the substrate in shallow or slower riffle areas to dislodge benthic species into a seine (Hendricks and others, 1980; Matthews, 1986; Bramblett and Fausch, 1991). Kicking the stream bottom while electrofishing is an effective technique for collecting these species because it involves disturbing the substrate and allowing the water current to carry fish into a common sense seine. Two crewmembers enter the stream below a riffle and hold the seine in a vertical position above the water and perpendicular to the flow at the downstream edge of a riffle. If the riffle is large (wide and long), the crewmembers may enter the riffle at some intermediate point in the riffle and hold the seine somewhere upstream from the downstream edge of the riffle. The crewmembers then thrust the brails and lead line of the seine to the stream bottom. The brails are slightly angled downstream so that the flow forms a slight pocket in the seine. It is important that the lead line be on the stream bottom. It may be necessary to remove some rocks from beneath the lead line so that there are no gaps between the seine and the stream bottom. It may also be necessary for the crewmembers that are holding the seine to reach around the front of the brail with one leg and place a foot on the lead line to keep it in close contact with the stream bottom. Upstream from the seine, one or two crewmembers vigorously disturb (or kick) the substrate and electrofishes by moving the anode back and forth while moving toward the seine. After reaching the seine, crewmembers lift the seine out of the water by grabbing the lead line of the seine. For safety reasons, it is important for crewmembers to coordinate turning off the power to the electrofishing equipment before reaching for the lead line of the seine.

In the field, samples collected with different electrofishing gear and in different channel types (main channel and backwater/side channel) will be processed separately. For each gear used in each channel type at a reach (for example, backpack in main channel, towed barge in main channel, seine in backwater, or backpack in backwater), fish data will be entered on separate field forms and gear type and time sampled will be recorded (appendix 16). Riffle samples that are collected by kicking into a seine while electrofishing are considered to be electrofishing samples and, therefore, can be combined in the field with samples collected in the same channel type using the same gear. For example, if backpack electrofishing was used in run and pool channel units in the main channel of a stream and backpack electrofishing with kicking into a seine was used in the riffles, then samples from all three channel units are considered to be from the same channel type (main channel) and, therefore, combined. However, if a towed barge was used in run and pool channel units and a backpack with kicking into a seine was used in riffles, then samples from the towed barge must be recorded separately from those collected with the backpack. In the field, samples from backwater areas and isolated side pools will always be kept separate even when sampled with the same gear type used on the main channel of the stream. Electrofishing will be the predominate method used in the main channel, while electrofishing and seining will be used in the backwater/side channels. For analysis, all electrofishing data will be combined for the entire reach (main channel and backwater/side channel). However, there may be specific monitoring questions that would require analyzing the data by gear or channel type; therefore, it is important to process the data separately in the field.

Seining

Runs and pools of streams can be sampled using a common sense seine or a bag seine, depending on the size (channel width and depth) of the stream. Generally, a common sense seine would be used in reaches where backpack electrofishing gear was used and a bag seine would be used in reaches where towed barge or boat electrofishing gear was used. Within the reach, specific sites to be seined will most commonly consist of backwaters or side channels with smaller substrates and few instream obstacles (woody debris and boulders, for example) and will be based on professional judgment of the fisheries biologist and aquatic ecologists.

Seining efficiency can be improved by observing several guidelines. First, submerged objects (woody snags, large cobble, and boulders) make seining difficult, and these areas should be avoided when seining. Electrofishing gear should be used to draw fish out from submerged objects. Second, seining should be completed in a downstream direction, which has been demonstrated to be the most effective seining technique (Hendricks and others, 1980); however, seining in a downstream direction may not be effective in swift currents. Third, seining speed should be slightly faster than the stream current; faster seining speeds will push water in front of the seine and force fish away from the seine. Fourth, maintaining contact between the lead line and the bottom of the stream and angling the brails back to keep the net bottom well forward of the float line will minimize the potential for escaping fish. Lastly, when the seine haul is finished, the seine is beached by pivoting the seine and dragging it onto the shore.

Riffle dwelling species (such as darters and sculpins) can be sampled using kick seining *without* the use of electrofishing gear. This technique can be used when electrofishing gear is not available or when it is restricted because of presence of threatened or endangered species. Similar to the technique of electrofishing while kicking into a seine, kick seining requires two crewmembers to stand at the downstream end of the riffle with a common sense seine while one or two crewmembers kick into the net. Dislodged fish are carried by the swift current into the net.

The approximate time (effort), number, and length (meters) of seine hauls should be recorded on the field sheets (appendix 16). During field processing and analysis, fish collected by seining should be kept separate from fish collected using electrofishing methods. For example, if backpack electrofishing and seining are used to sample backwaters within a reach, then these samples must be kept separate because of differences in efficiencies of the gear types. Seining methods will be predominately used in backwaters. However, if seining is used in both main channel and backwaters, all samples collected by this method will be combined for analysis of fish community composition.

Sampling Methods for Nonwadeable Streams

The following sections describe electrofishing and seining methods for sampling nonwadeable streams. Nonwadeable streams generally are greater than 1.5 m deep through most of their areas, although wadeable sections can be somewhat common.

Electrofishing

Nonwadeable streams are sampled using electrofishing boats or using boats in addition to towed barge or backpack electrofishing gear in shallow riffle areas. The basic components of the boat electrofishing unit include a generator, pulsator (control box), cathode (usually the boat), boom (aluminum or polyvinyl chloride tubing used to support electrical cables in front of the boat bow), and anodes (cable droppers attached to the end of the boom in front of the boat bow). The boat should be large enough to hold all the equipment and provide safe and adequate work space for the crew. Generally, flat-bottomed aluminum hull boats are preferred, because metal hulled boats are easy to ground. A boat electrofishing crew should consist of one boat operator and one or two net handlers who collect the fish with long-handled (greater than 3 m) dip nets. Each crewmember will have access to a safety switch which will stop electrical current flow in the event of an emergency. Special training is required to operate this system. The driver should be skilled at maneuvering the boat as effectively as possible to allow crewmembers the best opportunity to capture stunned fish. As with wadeable electrofishing methods, all crewmembers must wear waders and low-voltage rubber gloves and should wear polarized sunglasses.

Sampling with an electrofishing boat begins at the upstream boundary of the sampling reach and proceeds downstream by maneuvering the boat along one shoreline and mid-channel areas in a zig-zag pattern (the opposite shoreline and mid-channel areas will be sampled in a second pass, again proceeding upstream to downstream; fig. 5). Position the boat so the bow is angled downstream and toward the bank. This allows the boat operator to reverse direction (generally upstream and away from the banks) and not pass over stunned fish. The electrofishing boat is operated at a speed equal to or slightly greater than the current velocity. Periodically, the boat should be slowed to less than current speed so that fish drifting with the current may be more easily observed. Sampling is conducted in a downstream direction because fish are usually oriented upstream (into the current) and will either swim into the approaching electrical field or turn to escape downstream.

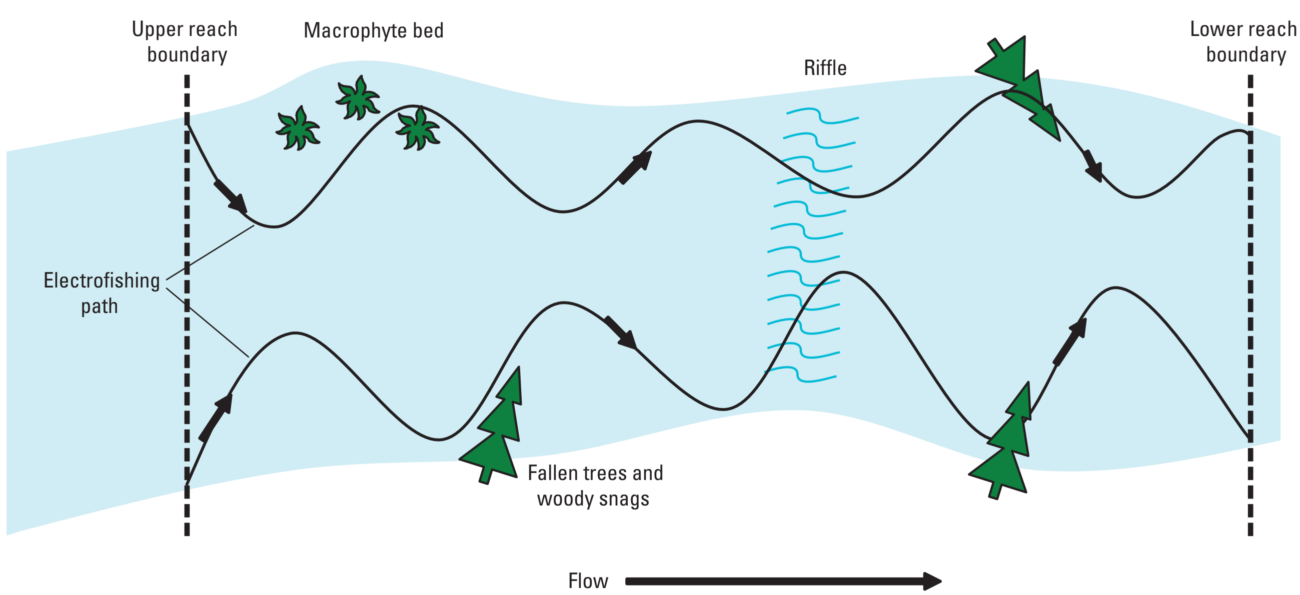


Figure 5. Double pass zig-zag sampling technique used in boat electrofishing for nonwadeable streams.

In turning to escape downstream, fish orient themselves perpendicular to the electrical field, thereby exposing a greater surface area of the fish to the electrical field that renders them more susceptible to capture. Also, when fish are stunned they are carried downstream by the flow, providing greater opportunity for capture.

Intermittent application of electrical current while drifting downstream generally should be used for large, nonwadeable streams. In areas with clear or shallow water and submerged structure, intermittent application of current may be more effective than continuous application. Fish are approached with the current off. When the anodes are in position near the fish, the current is applied. Instream habitat features, such as woody snags and fallen trees, are sampled by maneuvering the boat close to the habitat feature with the electrical current off. As the anode is placed near the habitat feature, the electrical field is generated and the boat is backed away from the habitat feature. This will cause the fish to be pulled away from the habitat feature to facilitate their capture. When boat electrofishing, the duration for applying electrical current should be increased at submerged structures. Fish located in deeper water (2 to 3 m) may require 5 to 10 seconds of current before a response is observed. This duration increases as water temperature decreases. Captured fish are placed into containers on the boat and processed after completion of the first electrofishing pass, if necessary. Fish data collected by boat electrofishing in the main channel will be kept separate on the field forms from data collected in backwater/side channel.

Nonwadeable streams of the Ozark Plateaus often are wadeable in large parts of the sampling reach. For example, a stream may be nonwadeable in some areas because of large, long pools but wadeable in riffles, runs, and along pool margins. In such situations, a towed barge or a backpack electrofisher should be used in the wadeable parts of the stream. In wadeable riffles, electrofishing while kicking into a seine is the most effective technique for collecting benthic riffle species. This technique for nonwadeable streams is similar to that described above for wadeable streams. For nonwadeable streams, electrofishing will be the predominate method used in the main channel. In situations where samples are collected using multiple types of electrofishing gear, samples are processed separately with crewmember initials, electrofishing effort, and fish data (lengths, weights, and counts) recorded on separate field forms (appendix 16). Similar to wadeable streams, samples collected from backwater/side channel habitat are processed separately regardless of gear type used. For analysis, all data collected with electrofishing gear will be combined for the entire reach.

Seining

Nonwadeable streams of the Ozark Plateaus often have wadeable riffles, runs, margins of pools, and backwaters that can be sampled using a bag seine (or, less frequently, a common sense seine). Seining techniques for run and pool habitats are the same as those described in the section of this SOP describing wadeable streams. However, with nonwadeable streams, excessive water depth and flow can be additional factors (in addition to substrate) that adversely affect the use of the seine. In some reaches, it may be that only electrofishing techniques can be used effectively in main channel areas because of swift current in run and riffle habitats and depths in pools. Therefore, seining methods will be used primarily in backwater areas. Location of seining sites will be based on: (1) the fisheries biologist's judgment on effectiveness of this gear type to collect a representative sample, and (2) safety to the crewmembers. Fish from seine hauls should be processed and analyzed separately from those collected with electrofishing gear. If seines are used in the main channel, fish collected in backwaters/side channels will be processed separately in the field. However, for analysis, data collected using seining methods (regardless of channel type) will be combined to examine trends in fish communities at each reach.

Sample Processing Procedures

The goal of processing fish samples in the field is to collect information on taxonomic identification, abundance, and size structure with minimal harm to specimens that will be released alive back into the stream. All captured fish are placed in a live cage, aerated buckets, a boat live well, or other suitable containers for subsequent processing and an effort is made to minimize stress or death to specimens. It may be beneficial to use multiple, portable aerated containers for holding and separating each species. Regardless of the effort made to minimize handling and stress to fish, some mortality will occur. However, minimizing mortality involves recognizing which species are sensitive to handling and prolonged confinement and processing them first. Any fish that are released before the reach is completely sampled should be released downstream from the sampling area to minimize the potential for resampling and sample bias.

Crewmembers should be thoroughly familiar with the fish species in their study area. Identifications are made by a crewmember (fisheries biologist) that is familiar with the fish species commonly found in the study area. The primary references used for identification will be *Fishes of Arkansas* (Robison and Buchanan, 1988) and *Fishes of Missouri* (Pflieger, 1997). Taxonomic nomenclature and common names follow that established by the American Fisheries Society's Committee on Names of Fishes (Nelson and others, 2004). An attempt is made in the field to identify all fish to the species level. Walsh and Meador (1998) can be consulted for additional guidance regarding taxonomic identification.

Some species of fish (such as minnow genera *Notropis* and *Cyprinella*, and stonerollers *Campostoma anomalum, C. oligolepis*) are similar and confirmatory characteristics are either internal (such as pharyngeal teeth) or require exact counts of meristic characteristics (such as the number of lateral line scales or anal fin rays). These species cannot be accurately identified in the field. Accordingly, specimens that cannot be positively identified in the field are preserved, labeled, and identified in the laboratory, and a specimen of each species deposited in a reference collection. Because of the potentially large number of problematic *Campostoma* individuals occurring at some sites, these two species will only be identified to the genus level.

Some identifiable specimens also will be preserved and deposited in a reference collection to aid in instructing crew-members in fish identification prior to the field season and to provide some future assurances about field identifications. In general, some individuals of all non-game species should be preserved, at the discretion of the fisheries biologist. Federally listed threatened and endangered species should not be preserved; other species of concern may be protected by State guidelines or regulations. Walsh and Meador (1998) provide guidance and criteria for the selection of specimens for a reference collection. All preserved specimens will be added to the data sheets once identified.

When processing fish specimens whether in the field or laboratory, a group of 30 individuals of each species will be measured (total length) and weighed. Individuals will be selected using a "blind grab" technique. This technique uses a dip net to make a pass through the entire bucket or holding tank to ensure that fish of various sizes are captured with each "grab." Some species have a large size range with different sizes being collect by specific gears (for example, large sunfish collected with boat and small sunfish collected with backpack). For these species, a blind grab will be taken from samples collected by each gear type and a representative subsample will be measured, keeping data from the gear types separate. For smaller species (those typically smaller than 100 mm; minnows, darters, sculpins, and madtoms, for example), lengths of individuals will be measured and a batch weight will be measured. For species that obtain large sizes (for example, bass, sunfish, catfish, and suckers), each specimen will be measured and weighed individually.

The major steps in processing collections of fish from electrofishing and seining include the following:

1. Sort fish into identifiable and unidentifiable groups, keeping fish collected from different gear types (boat, backpack, barge, seine) and channel types (main channel or backwater/side channel) separate. Process species of concern (for example, sensitive species or rare species) and game species before other identifiable species.

2. Hold fish in a manner consistent with minimizing stress or death. Do not keep fish out of the water longer than necessary to process them.

3. Identify all species (those that can be identified in the field) and measure total length and weight of 30 individuals for each species. Once 30 fish from a species has been measured, the remaining specimens are counted.

4. Record data on the fish field data sheet (appendix 16).
   a. Record the Reach ID (see appendix 3 for list of reaches).
   b. Record the date, gear type used, habitat sampled (main channel, backwater/side channel, or other), sampling effort (time), number of seine hauls and total length of stream seined.
   c. Record the initials of all crewmembers. Record the person identifying/measuring fish, the person recording the data, and those who operated the electrofishing equipment/seine and netted fish.
   d. For each individual of a species, record the total length (TL), weight (WT), and any anomalies (AL) (deformities, eroded fins, lesions, tumors, and black spot) (Smith and others, 2002). For larger fish, record individual weights. For smaller fish, batch weigh 30 specimens. Record the additional number of fish collected for each species under "Species Count." For example, if 46 white suckers were collected at a reach, 30 fish would be measured and weighed and the remaining 16 would be counted (Species Count = 16).

5. Preserve selected specimens (those too small or difficult to identify in the field) for identification in the laboratory or for a reference collection. Specimens will be preserved in 10 percent buffered formalin. For specimens larger than 100 mm, a small incision along the side of the body should be made to allow the formalin to penetrate the body cavity. For each reach, all unidentified specimens collected from the same gear type and channel type (main channel or backwater/side channel) can be preserved in a single jar with a label that contains the reach sampled, date, gear type, habitat type, and sampling effort. All preserved specimens will be identified and kept at the HTLN Aquatic Program Laboratory at Missouri State University in Springfield, Missouri. Specimens preserved for laboratory identification (or for a reference collection) should be noted on the fish community field form (appendix 16) by putting a check mark in the "vouchered column" (Vchrd). Any comments should be noted in the "comments column" (Cmts).

Quality Assurance/Quality Control Procedures

A number of procedures can be implemented to ensure the representativeness and accuracy of data used to describe fish communities of BUFF and OZAR. These procedures must be considered in relation to the objectives of the sampling. They include procedures related to collection of fish specimens and accurate taxonomic identification.

Fish samples should be collected as consistently as possible from year to year. To the extent possible, consistency can be maximized by using the same crew from year to year and at all sites sampled within a single field season. The use of inexperienced crewmembers will decrease the efficiency and consistency of the sampling effort (Hardin and Connor, 1992). Ideally, all sites will be sampled during similar biologic and hydrologic conditions (during base-flow conditions) because doing so will reduce variability associated with fish movements (for example, those related to spawning) and lowered sampling efficiency (because of higher stages, higher velocities, and higher turbidity). To the extent possible, sample gear used and sampling effort (generally, sampling time) should remain consistent at each site from year to year (appendix 3). However, site specific conditions and safety considerations dictate sampling period and equipment used; therefore, implementation of all desired practices may not always be feasible at a reach.

Because it is not desirable to remove all fish specimens from the field to the laboratory for identification, it is important that the person (fisheries biologist) selected for this task have adequate experience in taxonomic identification and be familiar with fish species expected to be collected at BUFF and OZAR. A list of species known or expected to occur within BUFF (appendix 1) and OZAR (appendix 2), or expected to occur in the area, should be consulted prior to sampling. Unidentified specimens, representative individuals of taxa that are not positively identified, and other specimens of special taxonomic value should be preserved in buffered 10 percent formalin and labeled appropriately. Problematic specimens should be verified by an independent taxonomist.

SOP 6: Physical Habitat Collection Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

Habitat composition within a stream is an important component in shaping fish communities. The type and abundance of specific habitats (for example, riffles, woody debris, and pools) will influence species presence and relative abundance, as well as size structure of the populations. Because of its importance to fish, physical habitat data will be collected as part of the fish community monitoring to examine relations between environmental conditions and fish communities. The methods described in this SOP have been modified from NAWQA protocols (Fitzpatrick and others, 1998) to meet the objective of the NPS.

Habitat Collection

Once fish sampling is completed, a crew of two to three persons will collect physical habitat data within that same reach. Equipment necessary to complete habitat sampling is found in appendix 13. Eleven equally spaced transects will be placed perpendicular to flow to collect instream habitat, fish cover, bank stability, and bank vegetation data (fig. 6). For example, a reach of 1,000 m length would have 11 transects placed at 100 m intervals. Crewmembers can either establish all 11 transects prior to data collection by temporarily flagging them, or transects can be located as the crew moves upstream during data collection.

For very wide or deep reaches, it may be necessary to take measurements from a boat or canoe. In this situation, a rope or tagline may be used to stretch across the channel allowing crewmembers to stay on the transect while taking measurements. In some channels with deep and fast flow, it may be difficult or impossible to get a measurement along the transect because of safety considerations. Some reaches may

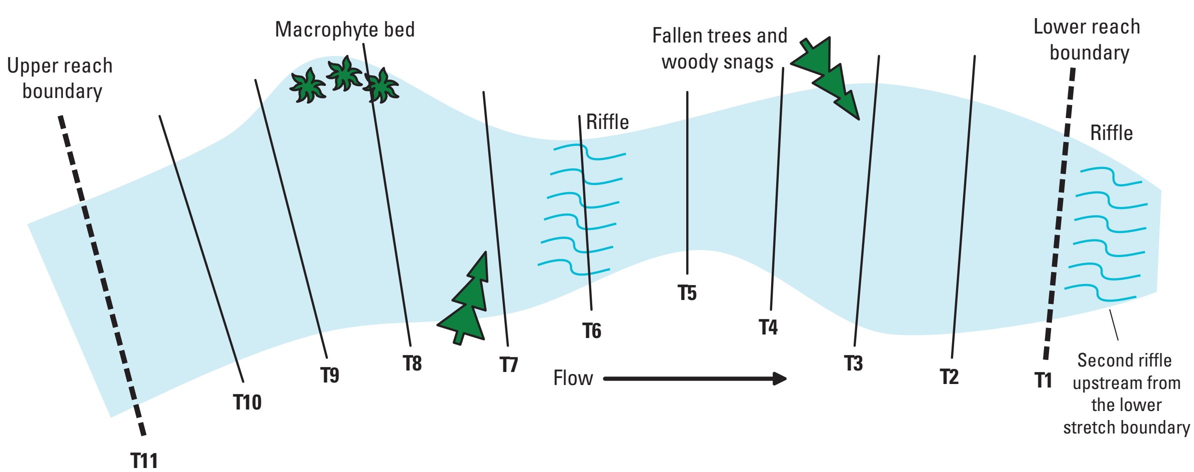


Figure 6. Transect placement for habitat data collection.

also have backwater areas that will need to be recorded separately from the main channel. In backwaters, habitat data are collected at three relatively equally spaced transects and length of the backwater is recorded. When collecting data (in both main channel and backwaters), streambanks are referred to in a downstream perspective. Therefore, if the crew is collecting data in an upstream direction, river right is on the workers' left, and river left is on the right.

Instream Habitat Assessment

At each transect channel morphometry, velocity, substrate, and canopy cover are described. At each transect, wetted width, channel unit type, and pool form (if applicable) are recorded. Definitions of channel unit types can be found in appendix 17. Along the transect, instream habitat is collected at three points (center channel and half the distance between center and the left and right banks, fig. 7). At each point, depth and velocity are measured. A single current velocity reading (see SOP 7) will be measured at 60 percent of the depth from the surface of the water. Dominant substrate size and substrate embeddedness are visually observed within a 10-cm diameter circle around each point (fig. 7). Dominate substrate size is defined as the average substrate size within the circle using the Wentworth scale (fig. 8). For substrate codes 1-3, there are no boxes shown in figure 8 by which to estimate their respective sizes because these substrates are so small. However, the general rule is that code 1 (silt or clay) feels slick between thumb and finger with no evidence of grit. Code 2 (very fine sand) has a barely perceptible gritty feel, and code 3 (fine sand) has a distinct gritty texture. For these three substrate codes, it is necessary to grab a sample from the 10 cm circle for assessment of dominate substrate. Canopy cover also is visually observed by looking directly overhead at each point and categorizing the percentage cover within 1 m upstream and downstream from the transect. If a bridge or other man-made structure is producing the canopy, this should be clearly indicated in the comments section.

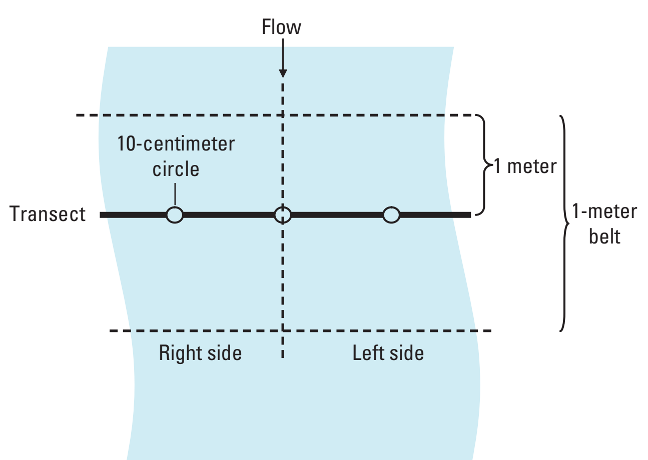


Figure 7. Location of instream habitat and fish cover collection at a transect.

Fish Cover

It is important to document the presence of fish cover in a stream because different species have affinities for various cover types. For example, sunfish species typically inhabit woody structure or boulder fields along the banks and in pools. Therefore, a reach with several snags or large boulders will likely have a large number of sunfish.

To assess fish cover within a reach, all cover types present will be documented along each transect (appendix 18). Filamentous algae, hydrophytes, boulders (size 21 to 23 on the Wentworth substrate sheet, see fig. 8), and any artificial cover are assessed within a 10-cm diameter circle around each point. If artificial cover (cinder blocks and car tires, for example) is present, the type of cover should be noted in the comments section. Small and large woody debris are assessed in a 1-m belt along the transect, dividing the belt into left and right side of center (fig. 7). Small woody debris is defined as being less than or equal to 10 cm in diameter at its largest end, and large woody debris is greater than 10 cm in diameter at its largest end. Fish cover along the banks is assessed within 1 m upstream and downstream from the transect. Cover along the banks include trees, roots, overhanging vegetation, undercut banks, and bluffs within 5 m of wetted edge.

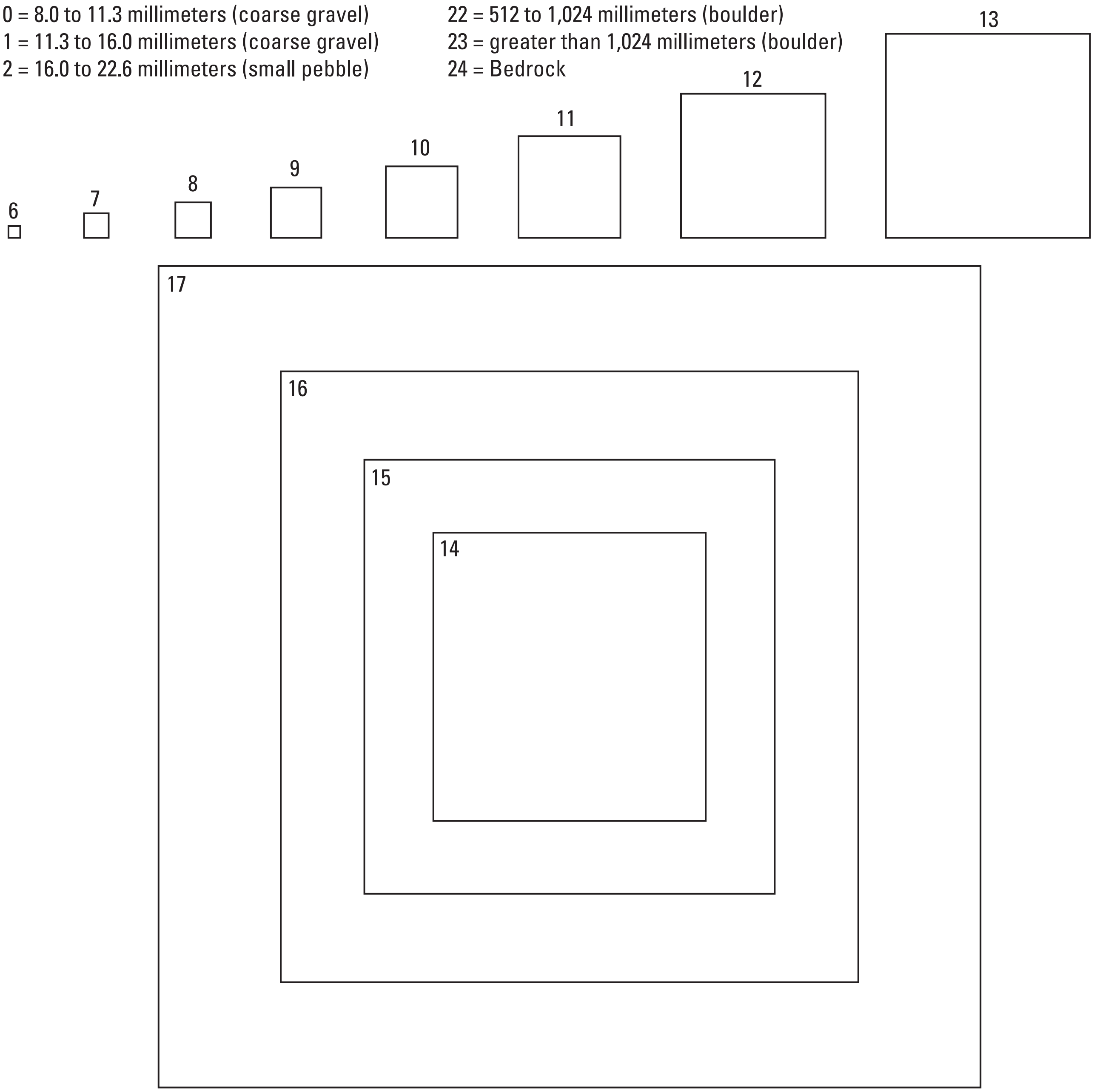
Bank Measurements

Characteristics of the bank and riparian areas can affect instream processes and fish habitat. For example, banks that are mostly bare with steep angles are likely to erode during high flow events, increasing the amount of fine sediment entering the stream. This, in turn, degrades habitat for benthic species (both fish and invertebrates) by burying large gravel/cobble substrates. Therefore, collection of bank stability and vegetation data may help explain fish community composition and abundance.

Before discussing data collection for bank/riparian areas, it is necessary to describe what is meant by the term "bank" (fig. 9). The bank is defined as the area of steep sloping ground bordering the stream that confines the water within the channel at normal water levels and is located between the channel and the flood plain (Fitzpatrick and others, 1998). The flood plain is defined as a flat or gently sloping depositional area adjacent to the stream. At low flows, it may be difficult to determine the location of the bank because of the presence of bars. Bars are defined as areas usually devoid of woody vegetation, such as small trees and shrubs, and contain coarse materials such as sand, gravel, or cobble. These areas

Wentworth Substrate Codes

1 = less than 0.062 millimeter (silt/clay)
2 = 0.062 to 0.125 millimeter (very fine sand)
3 = 0.125 to 0.250 millimeter (fine sand)
4 = 0.25 to 0.50 millimeter (medium sand)
5 = 0.5 to 1.0 millimeter (coarse sand)
6 = 1.0 to 2.0 millimeters (coarse sand)
7 = 2.0 to 4.0 millimeters (fine gravel)
8 = 4.0 to 5.7 millimeters (medium gravel)
9 = 5.7 to 8.0 millimeters (medium gravel)
10 = 8.0 to 11.3 millimeters (coarse gravel)
11 = 11.3 to 16.0 millimeters (coarse gravel)
12 = 16.0 to 22.6 millimeters (small pebble)
13 = 22.6 to 32.0 millimeters (small pebble)
14 = 32.0 to 45.0 millimeters (large pebble)
15 = 45.0 to 64.0 millimeters (large pebble)
16 = 64.0 to 90.0 millimeters (small cobble)
17 = 90 to 128 millimeters (small cobble)
18 = 128 to 180 millimeters (large cobble)
19 = 180 to 256 millimeters (large cobble)
20 = 256 to 362 millimeters (boulder)
21 = 362 to 512 millimeters (boulder)
22 = 512 to 1,024 millimeters (boulder)
23 = greater than 1,024 millimeters (boulder)
24 = Bedrock



Note: Box sizes are approximate and may be affected by printer settings.

Figure 8. Wentworth substrate codes used for instream habitat assessment.

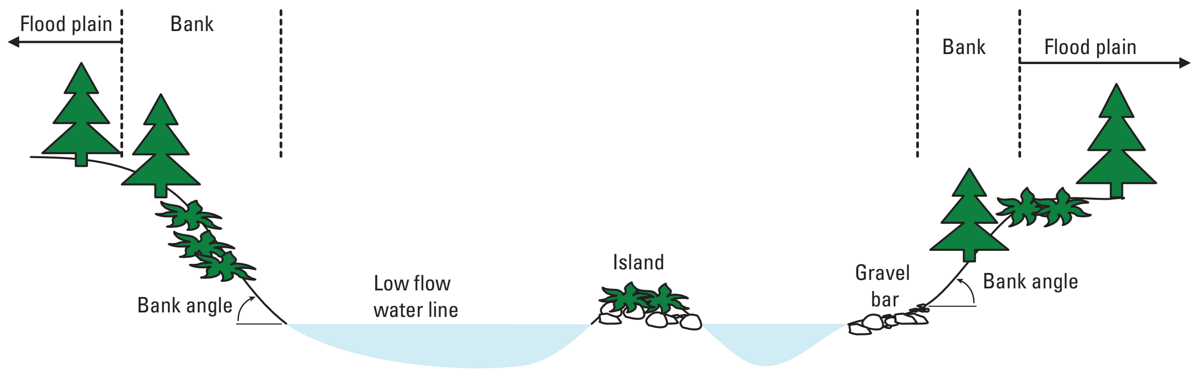


Figure 9. Location of banks and flood plain.

will be covered by water during normal flow (that is, at flows slightly higher than low flow) and therefore, are not considered part of the bank. Each bank measurement begins at the "true" bank (that is, the area of steep slope). In some instances, the bank will begin at the wetted edge. However, if gravel or sand bars are present at a transect, these will not be included in the bank assessment, but will be noted in the comments section by recording the width of the bar from water's edge to the bank.

Islands (stable areas with woody vegetation and mature trees that split or divide the channel) are treated as banks. For reaches with islands, width of the island will be measured at each transect as well as the length of the island that is located within the reach (recorded in the comments section). At transect locations where the channel is split, data will be collected at three points on either side of the island, and the island will be considered the "bank" for measuring bank stability/vegetation because of its stability and role in structuring the channel (fig. 10). This will require recording data on two copies of each data sheet (appendixes 17-19)

Bank characteristics are observed at each transect. Bank stability is visually observed at the transect, and each bank characteristic is categorized (appendix 19). Bank angle and substrate are observed from the bottom of the bank (at wetted edge or at the top base of the bar, if one is present), and the category code is recorded. To assess the bank substrate, the Wentworth scale is used to define the substrate type (silt = code 1, sand = codes 2 – 6, gravel = codes 7 – 16, cobble = codes 17 – 20, boulder = codes 21 – 23; fig. 8), but the category code on the data sheet (and not the Wentworth code is recorded. Percent vegetative cover, bank height, and bank cover are assessed from the bank bottom to 10 m into thebank. For bank cover, more than one cover type may be recorded if two cover types are relatively equal in abundance. Bank cover categories include large trees, small trees/shrubs, grass/forbs, bare rock/sediment, and artificial cover. If artificial cover is present on the bank (for example, rip-rap or concrete structures), the type of cover should be noted in the comments section.

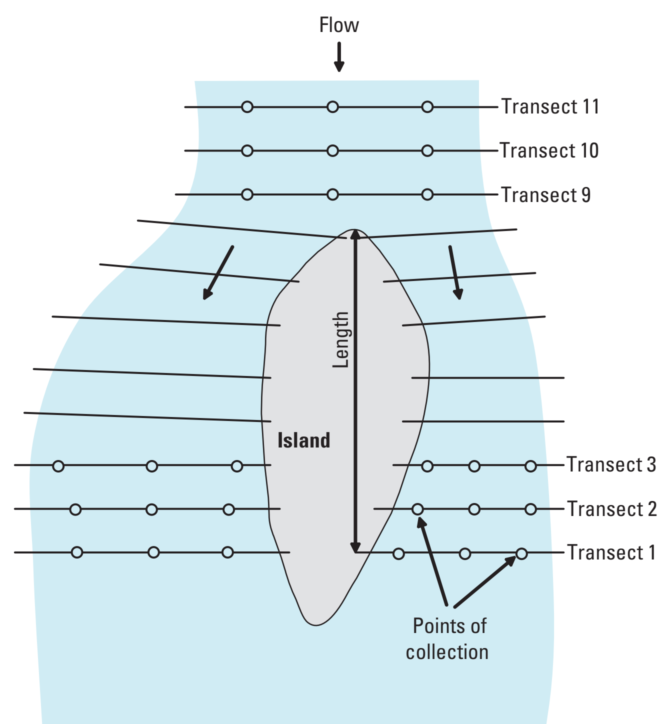


Figure 10. Habitat collection points in a reach with a split channel.

SOP 7: Measuring Stream Discharge Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

This SOP is guidance for measuring discharge in rivers and streams, specifically at BUFF and OZAR. The methods described in this SOP are specific to this protocol and do not conform to USGS methods for measurement and computation of streamflow. This guidance is applicable to any meter commonly used to measure current velocity, such as Marsh-McBirney, Price AA, and Price pygmy meters. This SOP, however, gives specific guidance for using the FLO-MATE 2000 (Marsh-McBirney) meter because that is the meter currently (2007) used within the HTLN by several parks. The SOP briefly describes conceptual information about how current meters work and describes sampling procedures, calibration processes, general maintenance procedures, and equipment needed for these procedures. Also, guidance will be provided for use of the FLO-MATE meter in the field. If other meters are used, field personnel should review the instruction manual for instrument specific guidance on how to calibrate and operate those particular meters.

Background Information

Stream discharge (Q) is the volume of water passing a cross-section per unit of time and is generally expressed in cubic feet per second (ft^3/s) or cubic meters per second (m^3/s). Discharge is the velocity multiplied by the cross-sectional area. Cross-sectional area is determined by first measuring the width of the stream channel. The cross section is then divided into smaller increments (usually 15 to 20 intervals) and depth and velocity are measured at each increment. The depth and width of the interval are multiplied to get an area for each interval and then each interval area and velocity are multiplied to produce a discharge for each interval. These discharges are summed to produce a total discharge for that cross section of the stream.

Velocity and depth are measured concurrently at each interval using a current meter attached to a wading rod. The rod allows for quick and easy measurements of depth with incremental markings and an adjustable arm that places the current meter at the proper depth for measuring velocity (60 percent of the depth from the surface of the water). Some current meters have rotating cups (AA and pygmy models) while others have a pair of electronic contacts on a small head (FLO-MATE 2000) to measure velocity. The sensor in the FLO-MATE 2000 is equipped with an electromagnetic coil that produces a magnetic field. A pair of carbon electrodes measure the voltage produced by the velocity of the conductor, which in this case is the flowing water. Internal electronics process the measured voltages and output them as linear measurements of velocity. Velocity is displayed as either feet per second or meters per second.

Preparation and Meter Calibration

Prior to using the current meter, inspect the meter, cable, probe, and standard wading rod for obvious defects or damage. If the meter has been stored for more than a couple of weeks the batteries should have been removed, and they should be re-installed according to the battery compartment's instructions. Batteries should be tested by turning the unit on and checking for the low battery display.

The FLO-MATE 2000 should be zero-adjusted before measurements are taken. One calibration per day is needed if the meter is not turned off for a period of several hours. Turning the meter off for short periods of time will not affect the meter's zero calibration as this is stored internally by the meter. For other meters, instruction manuals should be referenced for calibration or zero adjustment procedures. To ensure there is no film on the sensor, clean the sensor before calibration (SOP 8). For zero-adjustment, the meter is turned on and the sensor is attached to the wading rod and placed in a 20-L bucket of water. A zero reading is taken after 10 to 15 minutes to ensure the water is not moving, and the filter value is set at 5 seconds (table 3). To zero the instrument, the STO and RCL keys should be pressed at the same time and the value displayed ("3") should be decremented to zero using the DOWN ARROW key. The number 32 will be displayed and will decrement itself to zero and turn off, showing that the meter is calibrated. Prior to fieldwork, it may be necessary to change default functions, such as measurement units (table 3).

Table 3. Key function summary for the Marsh-McBirney FLO-MATE 2000 velocity meter.

One-key functions
ON/C—Turns unit on. Clears the display and restarts the meter.
OFF—Turns unit off.
UP ARROW—Decrements **FPA**, **rC** and memory location.
DOWN ARROW—Decrements **FPA**, **rC** and memory location.
RCL—Alternates between recall and real-time operating modes.
STO—Stores values in memory.
Two-key functions
ON/C—OFF—Alternates between units of measurement. Also turns beeper on and off.
UP ARROW—DOWN ARROW—Alternates between **FPA** and **rC** filtering
ON/C—STO—Clears memory
RCL—STO—Initiates zero adjust sequence.

Field Measurements

Discharge measurements should be made after other measurements such as temperature, dissolved oxygen, pH, and specific conductance are complete. Discharge measurements require wading across the stream and may cause sediments to stir up, disrupting accurate measurement of other water-quality characteristics. Prior to taking any measurements, the location where discharge will be measured must be determined. An ideal cross section will have the following qualities: (1) the stream channel directly above and below the cross section are straight, (2) there is measurable streamflow, with a stream depth preferably greater than 0.15 m and velocities generally greater than 0.15 m/s, (3) the streambed is a uniform "U" shape, free of large boulders, woody debris, and dense aquatic vegetation, and (4) the streamflow is laminar and relatively uniform with no eddies, backwaters, or excessive turbulence. The cross section will not likely meet all these qualifications but the best location should be selected based on these standards. Any discrepancies with the cross section should be recorded or sketched on the data sheet (appendix 20). Once the cross section is established, the width of the stream is measured with a tape measure to the nearest 0.1 m and the tape is secured across the stream for the duration of the discharge measurement. The cross section is divided into equal intervals, usually 15 to 20 with a minimum of 10 intervals recommended. The number of intervals will be based on stream width; larger reaches will have more intervals. A velocity and depth measurement is recorded for each interval across the stream at the center of each interval (see appendix 20). For example, if the stream is 10 m wide, 20 velocity and depth measurements will be made at 0.5-m intervals and the first measurement will be made at 0.25 m from the water's edge, as shown in figure 11.

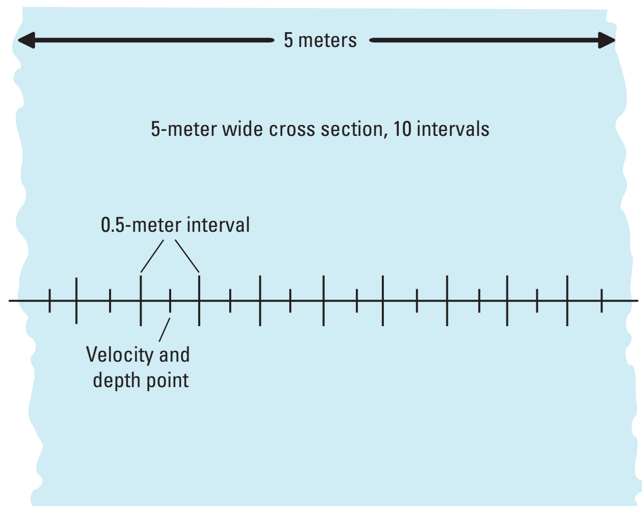


Figure 11. Points for measuring discharge at a hypothetical cross section.

To take a velocity reading, the current meter must be turned on and the sensor securely attached to the wading rod, facing upright. For FLO-MATE 2000, the meter should be set to FPA with 20-second intervals for data collection. During measurement, one person should be measuring discharge and one person should remain on the bank recording data. Measurements start near the water's edge and move to the center of the first interval. With the wading rod as level as possible and perpendicular to the water level, depth is read from the wading rod to the nearest tenth of a centimeter. Once depth has been read, the arm of the rod with the attached sensor should be adjusted to the water depth which will place the sensor at 60 percent of the depth from the surface of the water, a standard depth for measuring velocity in streams. During velocity measurement, the person taking the reading should stand behind the sensor and make sure there is no disturbance (including the sensor cord) around the sensor that interferes with the measurement. It may be necessary for the meter to be adjusted slightly upstream or downstream to avoid boulders or other interferences. Precautions also should be taken to face the sensor directly into the flow of the water, which may not always be directly parallel with the water's edge. In this instance, the rod and sensor may need to be turned slightly with each measurement. If something happens during the measurement, such as movement of the wading rod, the meter can be cleared and the reading started again. Once the time bar completes two cycles, the crewmember calls out the distance from the water's edge, the depth, and then the velocity to the person recording data (appendix 20). The crewmember will continue moving across the stream until measurements have been made at all intervals. When finished, the sensor should be detached from the wading rod and placed back in the mesh side pocket for transportation. If the meter will not be used for several days, the meter should be turned off and the sensor cleaned and stored properly.

SOP 8: Equipment Maintenance and Storage Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

Some equipment maintenance will be necessary to maximize the life of water-quality and fish sampling equipment. Poorly maintained equipment will adversely affect equipment performance, which will decrease accuracy of water-quality readings and sampling efficiency of fish sampling equipment. This will introduce variability into the dataset. After all fieldwork for a field season is completed, some effort to store sampling equipment properly will result in fewer equipment problems at the beginning of the next field season. This SOP describes general maintenance of water-quality and electrofishing equipment.

Water-Quality and Current Meters

Many maintenance and storage functions for water-quality and current meters are instrument specific so it is important to consult the manual (see appendixes 10 and 11 for location of manuals). Cleaning and occasional replacement of membranes (for the dissolved-oxygen meter), sensors, and electrodes is required after extended use or whenever deposits or contaminants appear on the probe. Changing the membrane also includes changing electrolyte fluid within the probe. Generally a clean, lint-free cloth and distilled water can be used to clean deposits from the membrane or sensor. If rinsing the probe in deionized water does not get a sensor clean, soaking the probe in water and dishwashing liquid can be used to remove dirt or debris from the probe. For the current meter, 600 grit sandpaper also can be used to remove debris from the sensor.

Generally, for long-term storage, meters should be protected from dust and excessive heat or cold, and the cable and probe should be stored dry and free of dirt, with the probe in the calibration chamber. For the pH probe, storage requires a moist storage area with proper storage solution. It is never recommended to store probes in deionized or distilled water. For long-term storage, all batteries should be removed from the meters and charged. Meters will be stored in the Aquatic Program Laboratory located on the Missouri State University campus in Springfield, Missouri.

Fish Sampling Equipment

Equipment for fish sampling generally can be classified into one of three categories: mechanical equipment, electronic equipment, and manual equipment. Each category involves varying degrees of maintenance.

Mechanical equipment (generators, outboard motors) should be maintained according to manufacturer's instructions and stored in a shed at Wilson's Creek National Battlefield near Springfield, Missouri. Maintenance of the generator motor is similar to the maintenance required by other small gasoline engines. Fuel, oil, spark plugs, and air filters need to be changed on a routine basis. Carburetion problems (gumming or poor ignition) can be avoided by using gasoline meeting minimum octane requirements and that has been stored for short periods (2 or 3 months maximum). For long-term storage, gasoline stabilizer should be used in generators to prevent condensation and water contamination over the winter. Outboard motors are commercially available as two-stroke and four-stroke designs. The manufacturer's operational manuals for the specific motor type should be consulted to determine appropriate maintenance procedures and service schedules. Gasoline should be drained from boat motors if they will not be used for more than a few months. All manuals should be kept in the Aquatic Program Laboratory so that all personnel responsible for operation can access maintenance information.

Electronic equipment and associated batteries will be stored in a secure, dry location at the Aquatic Program Laboratory at Missouri State University in Springfield, Missouri. Electrofishing pulsators are very durable and require very little maintenance; however, some pulsators may have fuses or circuit breakers for surge protection. Reviewing the operating manual and having replacement fuses or circuit breakers on hand will reduce downtime in the field. Corrosion or tarnishing of electrodes can reduce electrical conductance from the electrofishing boat, barge, or backpack to the water. Electrodes should be inspected prior to each sampling event. Stainless-steel electrodes (anodes and cathodes) can be reconditioned using emery cloth, steel wool, or fine-grained sandpaper. Aluminum anodes on some backpack electrofishing units are better cleaned with sandpaper or a small file.

Over extended time (several years), electrical connections at junction boxes and other connections will sometimes begin to corrode. This corrosion results in a poor connection and can result in a reduction of electrofishing power. Connections should be inspected before each electrofishing season and serviced when necessary.

Electrofishing batteries for backpack units should be charged as soon as possible after sampling is completed. Electrofishing battery chargers capable of a trickle charge, having an automatic shutoff (once the battery is charged), and a voltage tester are preferred and can be purchased from manufacturers of electrofishing gear. Battery voltage should be tested before each sampling effort to be certain that the battery is capable of carrying a full charge. If a battery is not capable of carrying a full charge, time spent electrofishing will be decreased and the battery may need to be replaced.

Manual equipment (nets, gloves, waders, buckets, and safety equipment, for example) should be stored in the Aquatic Program Laboratory or in a storage shed at Wilson's Creek National Battlefield. Nets, seines, waders, and personal floatation devices also require maintenance. Nets and seines should be cleaned with water and allowed to dry before extended storage to prevent moisture damage. Nets and seines should be inspected regularly for tears in the mesh and replaced or repaired. The life of waders and personal floatation devices also will be prolonged if stored in a cool, dark, dry area. Waders stored for an extended period are susceptible to dry rot. Rubber conditioners can be applied to boots to prevent deterioration. Personal floatation devices used for fish sampling should be inspected for rotting or torn sections. Inflatable preservers that use carbon dioxide cartridges for inflation must have the carbon dioxide cartridges replaced periodically and according to manufacturers instructions.

For electrofishing boats that use the boat hull as the cathode and are painted, electrical currents are concentrated in areas where the aluminum is exposed (the paint has been accidentally scratched, for example). In this situation, boat hulls are susceptible to electrolysis, which can result in aluminum pitting and, eventually, leaking. Electrolysis can be controlled by using a boat with the bottom of the hull unpainted, attaching a zinc plate to the hull, or by using cathode droppers independent of the hull. If leaks do occur, welding compounds can be used to patch the boat hull.

SOP 9: Data Management Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

This SOP explains procedures for data management of BUFF and OZAR river fish sampling data. It includes a general description of the data model, and procedures for data recording, data entry, data verification and validation, and data integrity for the primary fish sampling data.

Data management can be divided into (1) the initial design phase that involves defining the data model, its entities and their relations and (2) the procedures necessary to implement the database. Microsoft (MS) Access 2003 is the primary software used for maintaining fish data. Water-quality data will be stored in the National Park Service's NPSTORET database. Environmental Systems Research Institute (ESRI) ArcInfo 9.x is used for managing spatial data associated with field sampling locations. Data products derived from this project will be available at the NPS I&M Data Store and EPA STORET National Data Warehouse. QA/QC guidelines in this document are based on recommendations of Rowell and others (2005) and citations therein.

Data Model

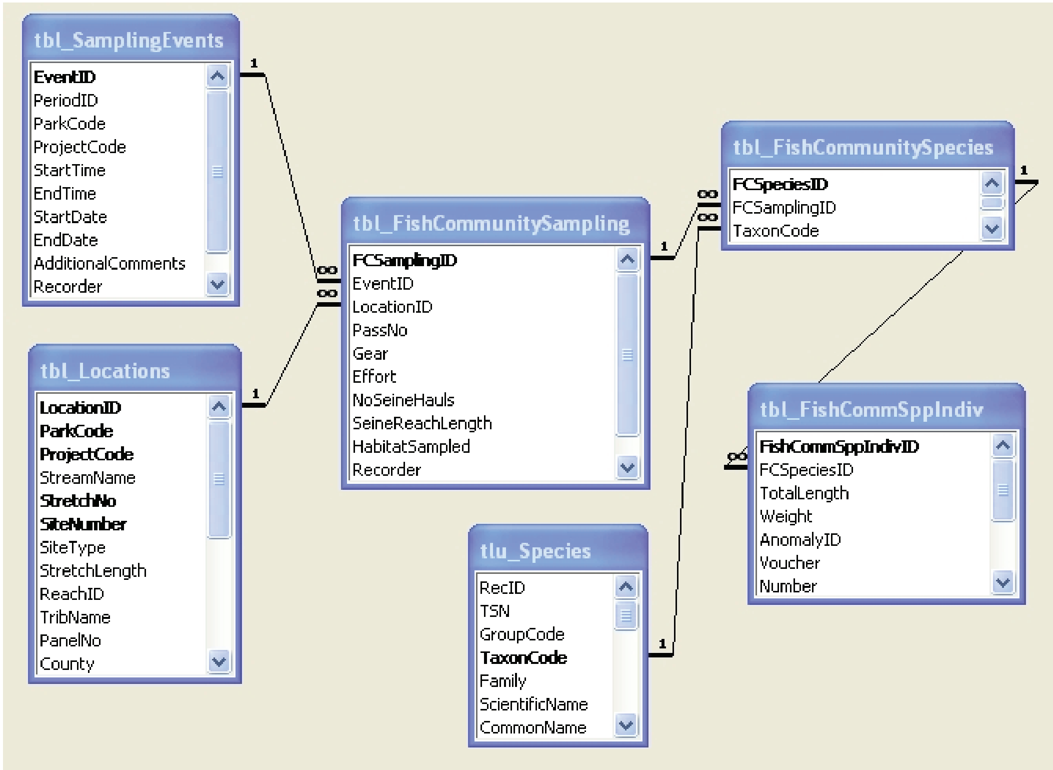
The NPS I&M program has designed the Natural Resource Database Template (NRDT) to be used as a database model for storing vital signs monitoring data in MS Access (National Park Service, 2006). The template has a core database structure that standardizes location and observation data to facilitate the integration of datasets. Developed in MS Access, the database allows users to enter, edit, display, summarize, and generate reports as well as integrate with other NPS Natural Resource data systems such as NPSTORET. Distributed databases, or replicas, allow data entry or modifications from remote locations (such as at BUFF or OZAR offices) and subsequent synchronization with a master database archived on the HTLN server at Missouri State University in Springfield, Missouri. NPS Water Resources Division (WRD) also has designed the NPSTORET database to facilitate archiving NPS data in the EPA STORET database (National Park Service/Water Resources Division, 2007b). NPSTORET is a series of Microsoft Access-based templates patterned after the NRDT and includes data entry templates and an import module. It supports the core data management objectives of data entry and data verification/validation in a referentially constrained environment (related locations, events, and primary data elements).

A generalized NRDT entity relation diagram of the fish community database is given in figure 12. The tables called sampling events (tbl_SamplingEvents) and locations (tbl_Locations) are the two core tables of the database and contain general information pertaining to the field sampling occasion (the when and where of the sample). This includes information such as date and time, river stretch ID and UTM coordinates, and park/project codes. The fish community sampling table (tbl_FishCommunitySampling) serves as the organizing hub for fish data. Other tables include site conditions (tbl_SiteConditions, not shown), habitat data (tbl_BankMeasurmentInfo and tbl_Discharge, not shown), and associated lookup tables (tlu_FishAnomalies, not shown; and tlu_Species).

Generally, the database model is developed from the appropriate tables based on river fish sampling protocols. Prior to table development, the data manager coordinates with project staff to determine data types (byte, text, numeric, for example), precision, and range of values. Acquiring field data forms assists with developing data logic (that is, how data components relate) and identifying indexes and primary keys. The NRDT data dictionary follows standards identified in the NRDT phase 2 and is modified where required. Naming standards follow NPS I&M recommended procedures.

Data Recording

QA/QC procedures related to data recording are important components of any project. Sampling data, including sample methods, effort, weather, water-quality conditions, species abundance data, and habitat data are recorded on the field form (appendixes 15-20) and checked for completeness before leaving a site or within 24 hours of data recording. This will aid in verification and validation of the data after entry into the database. To prevent the complete loss of field form data because of unforeseen circumstances (for example, fire or



Note: tbl_SamplingEvents and tbl_Locations track stream-reach data while tbl_FishCommunitySampling serves as the organizing hub for fish data.

Figure 12. Data model for fish communities monitoring.

flood in the workplace), all field sheets are photocopied and a hard copy located in a separate location from the original. Field sheets are scanned into a computer and electronic copies of the data sheets stored on the HTLN server located at Missouri State University, Springfield, Missouri. This will ensure that at least one copy of the field sheets is available for data entry and verification.

Data Entry

Data entry is accomplished in replica databases using a tiered set of forms. Upon opening the replica, the user is presented with a switchboard (fig. 13) that can be used to access these forms (fig. 14). A preliminary set of forms define the sampling occasion and requires the input of location, period, and event IDs prior to entry of additional data. The other forms address the details of fish occurrence, habitat, and observers, for example, and includes data entry instructions. Once all fields for the preliminary set of forms have been completed, data can be entered for the remaining forms. Additional forms document sampling personnel for each occasion and their specific hours related to the project (such as sampling hours and travel hours). The replicas then are synchronized with the master database and any subsequent data entry in a new replica.

Several features are “built-in” to form properties that enable the user to maximize data entry efforts while minimizing error. These include data input masks for ease of viewing multi-part data (such as park/project codes and date in PeriodID, LocationID, or EventID), “fill-in-as-you-type” to automatically complete a field, default values to autopopulate common values, limiting input values to known ranges (or restricting null values) or providing “drop-down boxes”, and tab indexes to control the order of data entry. Forms also contain fields that require data input or are constrained to properties and integrity of related tables. The “Prevent Deletes” option is enforced in replica databases to ensure data are not inadvertently deleted.

Entering Sampling Occasion Data

The sampling occasion location (“site”, see SOP 3 and appendix 3) is entered by clicking the “Open Locations Form” button on the main switchboard (fig. 13). The user then selects the appropriate Park Code, Site Type, and Sub Type and enters the Site Number and Stretch Number to develop a LocationID (fig. 15). The Stretch Number refers to the MORAP classified stream identifier and is transcribed from the appropriate MORAP StretchID table (see appendix 3 for Stretch ID). Clicking the “Generate LocationID” button passes the user data to a secondary form where additional location data are entered. Note the user data on the first form are at the top of the secondary form and a LocationID has been generated with an input mask to separate Park Code, Project, and LocationID. To exit the location form (as well as all other forms) the user clicks the “Close Form” button.

Note: The three primary data entry buttons at the top (locations, periods, and events).

Figure 13. River fish database switchboard.

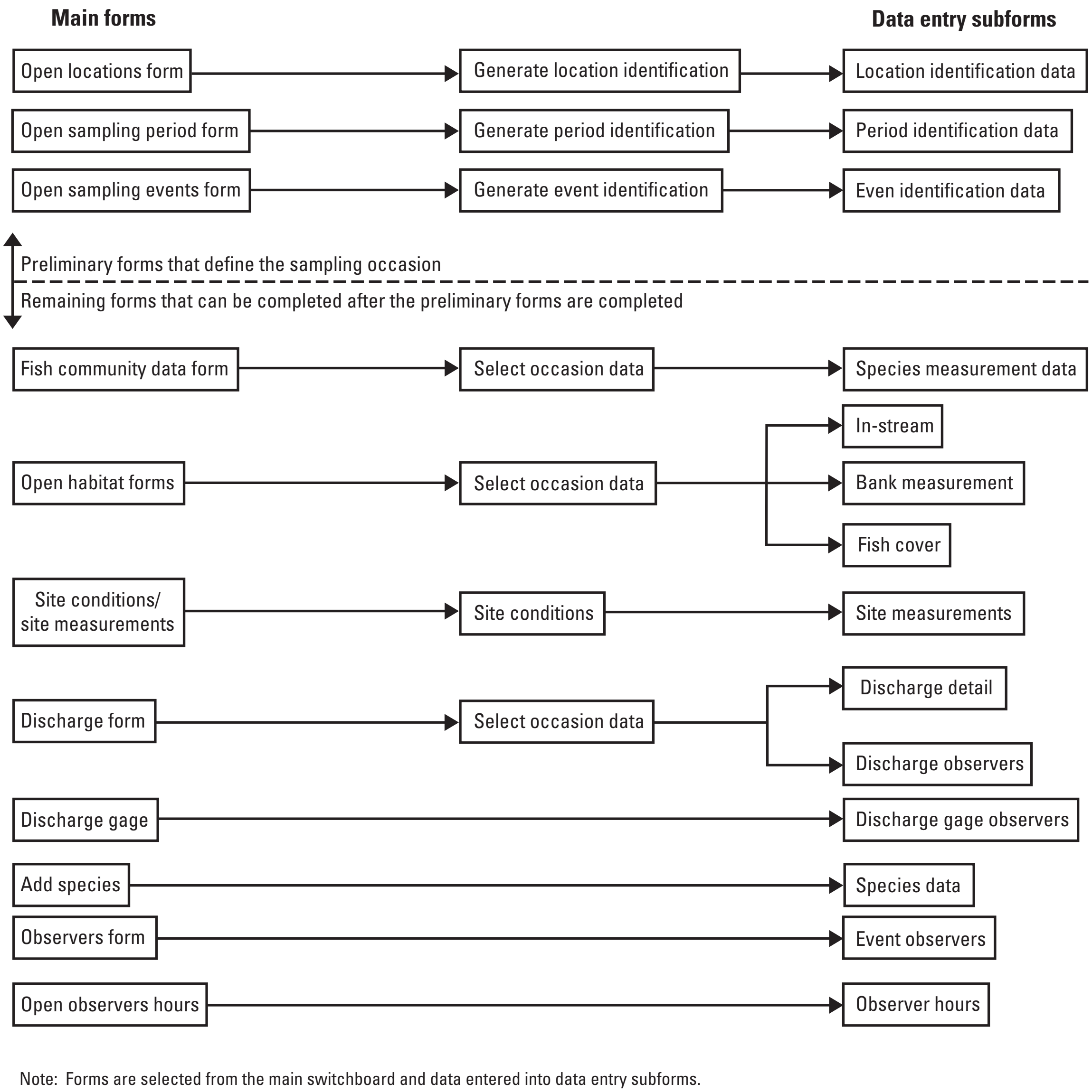


Figure 14. Outline of fish community data forms.

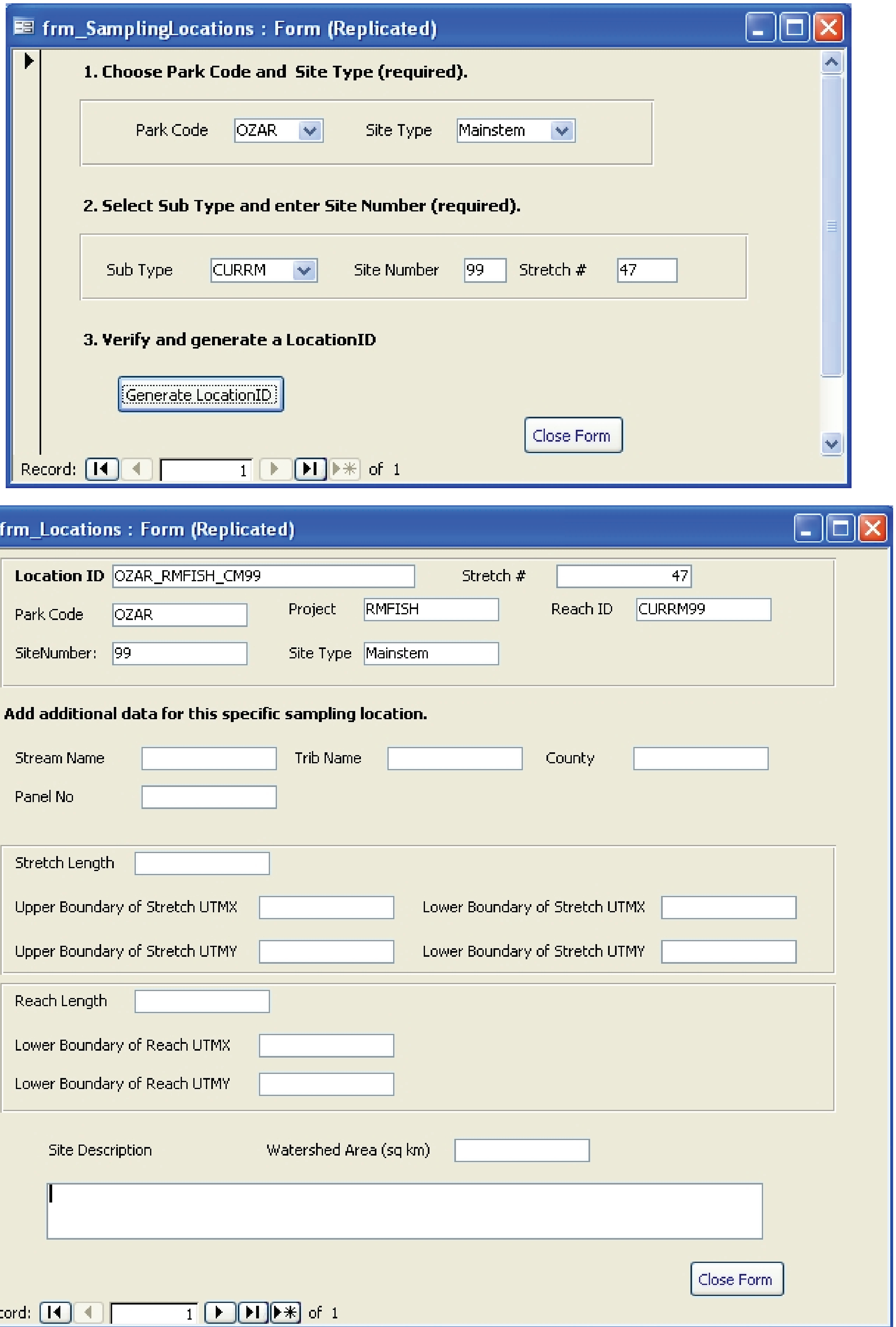


Figure 15. Detailed location forms for fish data.

The sampling occasion period (the entire sampling timeframe for each park; for example, 01-Oct-2007 to 16-Nov-2007 for OZAR) is entered on the sampling period form (fig. 16) by clicking the “Open Sampling Period Form” button (fig. 13). The user then selects the appropriate Park Code and Project and uses the calendars to select the start and end dates of the sampling period timeframe to develop a PeriodID (fig. 16). Clicking the “Generate Sampling PeriodID” button passes the user data to a secondary form where the user reviews then accepts the PeriodID and protocol version by clicking the “Verify” button. Note the user data on the first form are at the top of the secondary form and a PeriodID has been generated with an input mask to separate Park Code, Project Code, and beginning date of the sampling period.

The sampling occasion event (the specific date of the sample within the sample timeframe; for example, 17-Oct-2007 for a sample location at OZAR) is entered on the sampling event form (fig. 17) by clicking the “Open Sampling Events Form” button (fig. 13). The user then selects the Park Code, Project Code, and PeriodID and uses the calendars to select the start and end dates of the sampling event to develop an EventID (fig. 17). Clicking the “Generate Sampling EventID” button passes the user data to a secondary form where the user enters additional event data. Note the user data on the first form are at the top of the secondary form and an EventID has been generated with an input mask to separate Park Code, Project Code, and the date of the event.

Entering Fish Data

After inputting sampling occasion data (locations, period, and events), the user can begin to enter additional fish data (such as individual fish data and corresponding water-quality and habitat data for the sampling location and event). The following paragraphs describe data entry for the additional data and can be used in any order.

Fish community data are entered (fig. 18) by clicking the “Fish Community Data Form” button (fig. 13). Park Code, LocationID, EventID, Gear, and Habitat Sampled are selected and Pass Number, Effort, Seine Reach Length and Number of Seine Hauls are entered specifically for that sampling occasion. Clicking the “Fish ID Crew” button opens a form used to document who identified and recorded the fish data and clicking the “Fish Shocking Crew” button opens a form used to document specific crewmembers and their field task (for example, the person electrofished, seined, or both). Clicking the “Continue” button in either form will allow the addition of multiple entries and clicking the “Return” button will allow the user to exit the form. The user then selects species information by selecting the scientific name (fig. 18) and entering additional data specific to the one species. Species data comprise three types: individual fish, batch weighed fish, and extra fish. Individual fish data consist of a subsample of 30 individuals of each species that were measured (total length), weighed, and any anomalies noted (Anomaly Description is set to default to N, no anomaly). After selecting a scientific name, the user enters total length and weight and selects Anomaly Description (if required). If the individual was retained and preserved the Voucher box is checked. Number refers to the number of individuals and defaults to one. The additional batch fields are ignored and any comments to that individual fish are noted. The user is then returned to the Total Length field and continues entering data for that species. Batch weighed fish consist of those smaller species that were individually measured (total length), but weighed in groups. Similar to individual fish data, the user selects a scientific name and enters the total length. Weight is left blank and any anomaly for that specific individual is documented by selecting the Anomaly Description and, if retained, the Voucher box checked. As in the individual fish, Number defaults to one. The Batch Weight box is checked, a BatchID is entered (for example, entering 1, 2, or 3, depending on if it’s the 1st, 2nd, or 3rd batch of fish being weighed) and the weight of those batch weighed fish is entered in Batch Weight. For subsequent entry of batch weighed fish the Batch Weight box is left unchecked, BatchID is set to that batch number, and Batch Weight defaults to zero. Any comments to that individual fish are noted and the user is returned to the Total Length field to continue entering data for that species. Extra fish are those collected and merely counted. The user selects a common name and enters the number collected in the Number field and any comments for those extra fish (other fields are ignored). When all fish species data are entered for that fish community the user clicks the “Close Form” button to close the form.

Entering Habitat and Discharge Data

Habitat data are entered by clicking the “Open Habitat Forms” button on the main switchboard (fig. 13) and selecting the appropriate Park Code, LocationID, EventID, and Habitat Type from the drop down boxes. The user then chooses the appropriate Transect Number from the Instream Habitat Assessment, Fish Cover, or Bank Measurements data entry section of the form. For the Instream Habitat Assessment form, the user enters additional fields such as Channel Unit, Pool Form, and Width. Clicking on a habitat form passes the selected user data to secondary habitat forms. The user then enters channel morphology data (depth, velocity, or substrate), selects the appropriate fish cover data for presence/absence (for example, hydrophytes, small woody debris, and undercut bank), and enters bank stability measurements (bank angle, percent vegetation cover) and bank cover types (trees, shrubs, grass). Each habitat subform is provided with a “Continue” button that allows the user to advance to the next observation and the “Return” button to exit the form. When finished entering habitat data the user will be returned to the initial habitat form and exits the form by clicking the “Close Form” button.

Discharge data are entered by clicking the “Discharge Form” button on the main switchboard (fig. 13) and selecting the appropriate Park, LocationID, EventID, and Habitat Type from the drop down boxes. The user then enters discharge measurement units (for distance, depth, velocity) in either

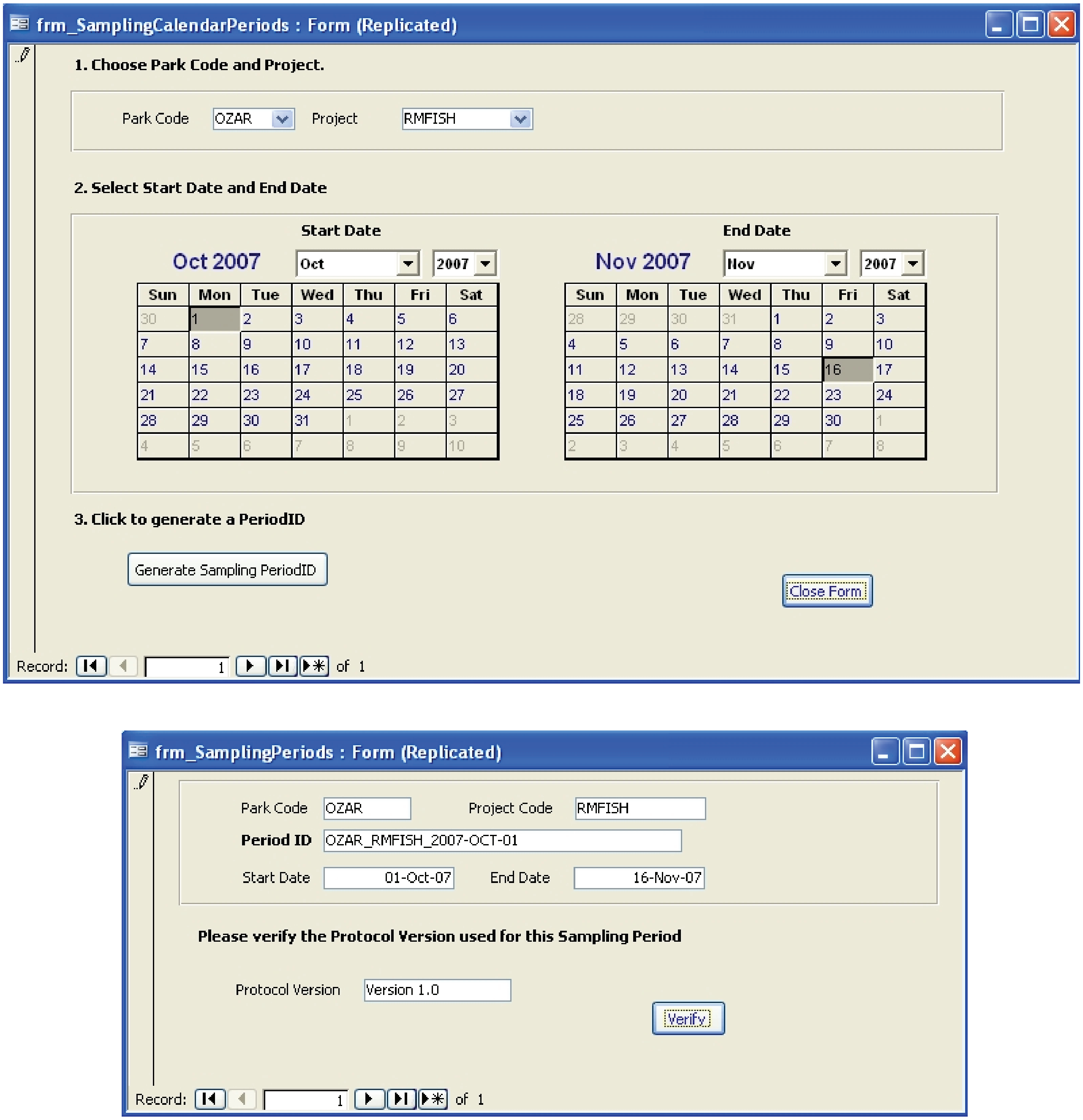
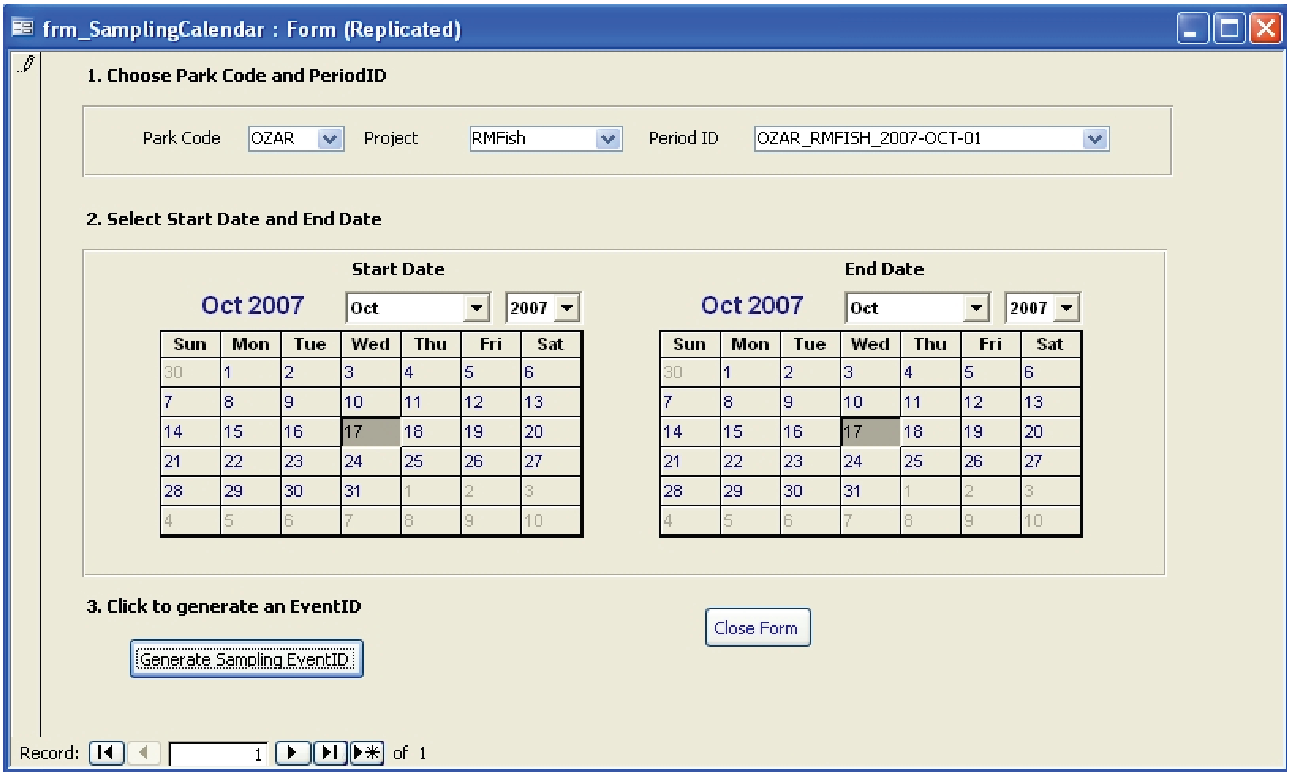


Figure 16. Sampling period forms for fish data.



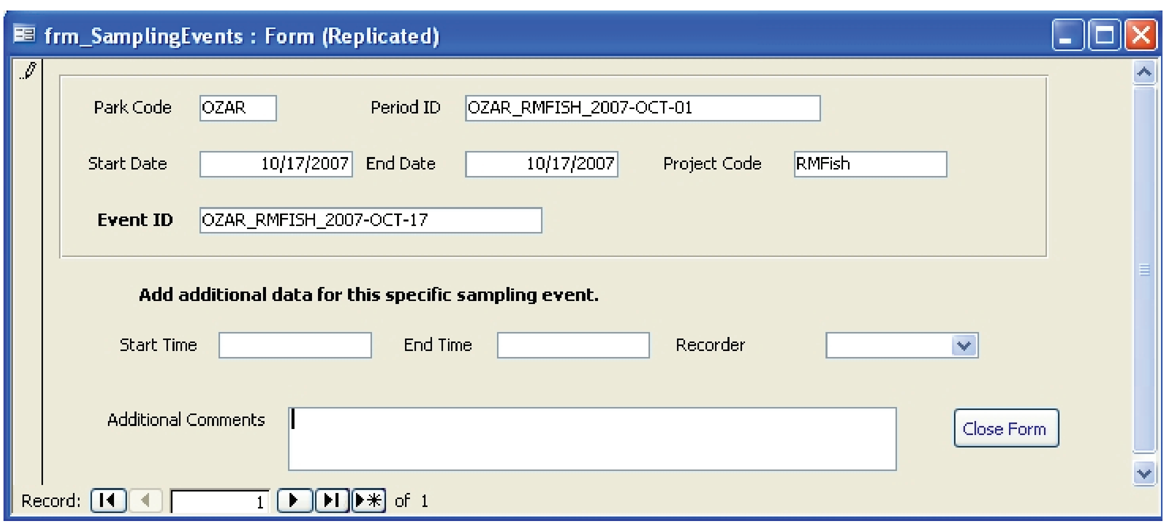


Figure 17. Sampling event forms for fish data.

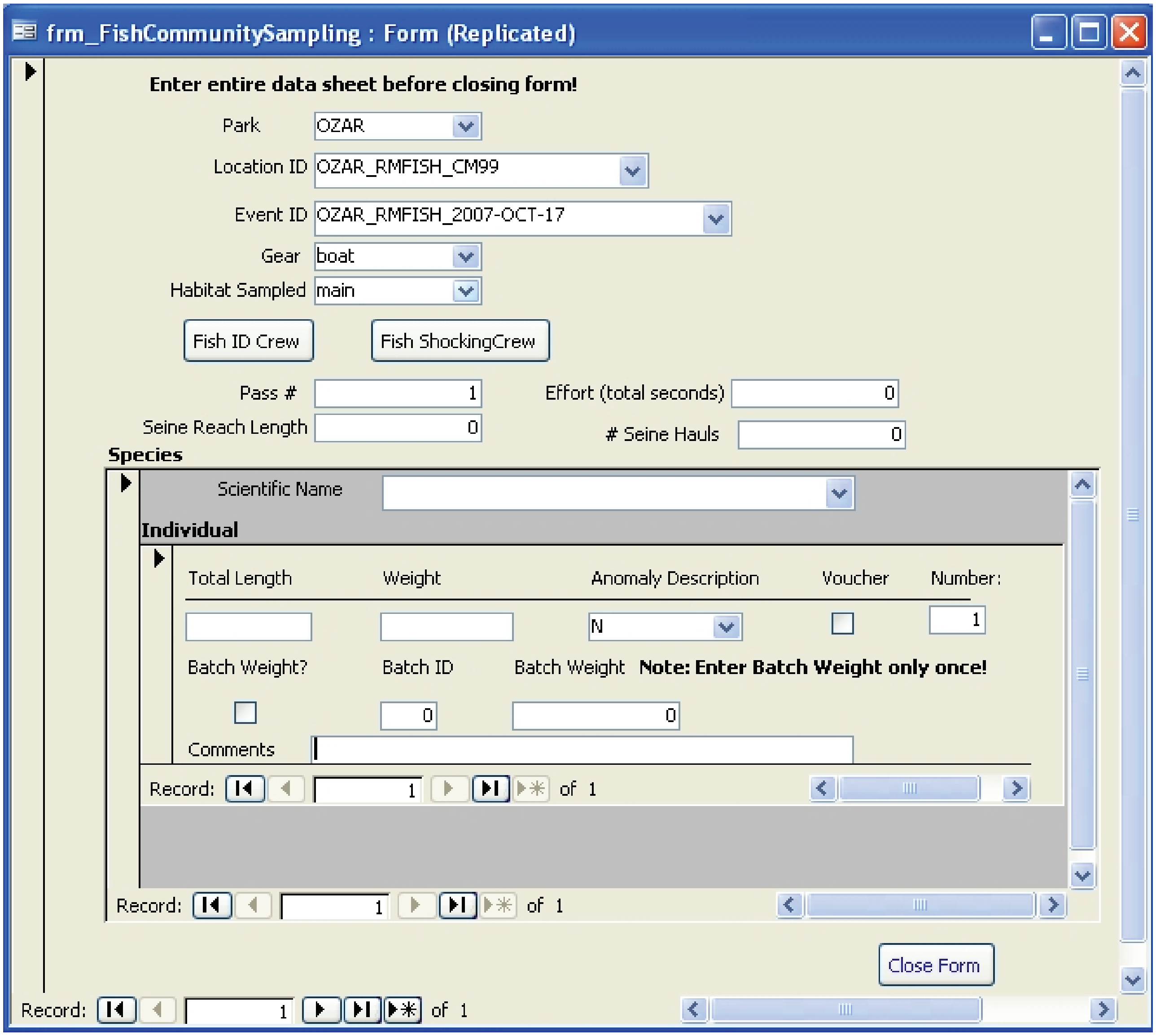


Figure 18. Fish community data form.

English or metric units. Individual depth and velocity readings are then entered in the discharge detail form. The user clicks the “Continue” button to enter the next replicate data and the “Return” button to exit the form. Summary data collected from established gaging stations are entered by clicking the “Discharge Gage” button on the main switchboard and selecting the appropriate Park, LocationID, EventID and entering the summary Discharge data value.

Entering Water-Quality Data

Water-quality data (CORE 5) collected by hand-held meters are entered by clicking the “Site Conditions/Measurements Form” button on the main switchboard (fig. 13) and selecting the appropriate LocationID and EventID. Additional weather condition data (such as percent cloud cover, precipitation, and wind intensity) and beginning/ending measurements for temperature, dissolved oxygen, pH, specific conductance, and turbidity are entered. Water-quality data collected by unattended CORE 5 data loggers (sondes) are uploaded from the logger using the manufacturer’s accompanying software program and saved in MS Excel. Data then are edited to correct any missing data because of logger maintenance (downtime) and validated to determine if the data meet the expected range requirements or critical limits.

CORE 5 water-quality summary data then are entered into NPSTORET by using the direct data entry templates or the import module. Coordinate data for logger locations are collected in accordance with the current HTLN spatial data collection techniques and entered into NPSTORET. Metadata are then entered for each characteristic/parameter. An NPSTORET database then is sent to the NPS WRD staff on an annual basis for initial QA/QC and subsequent upload into the WRD master copy of the EPA STORET.

Data Verification

Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source, usually paper field records. Data tables are queried to produce specific sets of data (for example, fish community data and bank measurement data) and exported to Excel worksheets (by using the QAQC Data button, fig. 13). These worksheets then can be compared to the original field data sheets to identify missing, mismatched, or redundant records. A design master then is used to correct or delete errors through data edit forms. As data are edited, built-in table triggers store the original record in a backup audit table and can be recovered where necessary (audit tables mirror the data table).

Data Validation

Although data may be correctly transcribed from the original field forms, they may not be accurate or logical. For example, field crews collect data per occasion (location and event) and the resident data should reflect this. At any given occasion, fish sampling is conducted in each reach during the sampling event and can be validated by querying the ID number for these values. A query of these data should reflect these conditions and confirm the coincident (relational) nature of the database.

As annual data are amassed in the database, validation is conducted by query and comparison among years to identify gross differences. For example, species A may be recorded at a location in a specific year, but not in previous years, thus representing a possible new locality. The design master then is used to correct or delete errors through data edit forms.

Once verification and validation are complete, the dataset is turned over to the HTLN Data Manager for archiving and storage. These data then can be used for all subsequent data activities.

Spatial validation of sample coordinates can be accomplished using the ArcMap component of ArcGIS (ESRI, 2007). Coordinate data are maintained in the Access database and can be added to an ArcMap project and compared with existing features (park boundaries, USGS Digital Ortho Quarter Quadrangles, National Hydrography Dataset hydrography) to confirm that coordinate data are valid.

File Organization

The various databases, reports, and GIS coverages used and generated by HTLN create a large number of files and folders to manage. Poor file organization can lead to confusion and data corruption. As a standard data-management technique, files pertaining to the project are managed in their own folder: Analysis (for data analysis), Data (for copies of archived data as well as data sheets), Documents (for supporting materials related to the project), and Spatial info (for various spatial data and GIS coverages). The database is managed in a Databases folder and contains prior versions and backups in subfolders.

Version Control

Prior to any major changes of a dataset, a copy is stored with the appropriate dataset version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived datasets is handled by adding a floating-point number to the file name, with the first version being numbered 1.00. Each major version is assigned a sequentially higher whole number. Each minor version is assigned a sequentially higher number incremented by 0.1. Major version changes include migrations across Access versions and complete rebuilds of front-ends and analysis tools. Minor version changes include bug fixes in front-end and analysis tools. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

Replication

The Aquatics Program relies on distributed databases to allow remote users to enter/revise data and is accomplished through database replication consisting of a design master and replicas. The design master is stored on the server at Missouri State University in Springfield, Missouri and can be directly accessed for local data entry/revisions or design changes. A replica is created for users without access to the server and is distributed for data-entry activities. When a user has finished data activities with the replica, it is returned and synchronized with the design master.

Backups

Secure data archiving is essential for protecting data files from corruption. Once a dataset has passed the QA/QC procedures specified in the protocol, a new metadata record is created using the NPS Metadata Tools (stand alone or within ArcCatalog) or Dataset Catalog. Backup copies of the data are maintained at an onsite location in the Aquatic Program Laboratory at Missouri State University in Springfield, Missouri and at an offsite location at Wilson's Creek National Battlefield. An additional digital copy is forwarded to the NPS I&M Data Store. Tape backups of all data are made at regular intervals and will be made minimally, once per week, with semi-annual tapes permanently archived.

Data Availability

Currently (2007), data are available for research and management applications for those database versions where all QA/QC has been completed and the data have been archived. Data can be transferred using ftp or by e-mail (where files are smaller than a few megabytes). Monitoring data generally will become available for download directly from the NPS I&M Data Store. Metadata for the fish community database are developed using ESRI ArcCatalog 9.x and the NPS Metadata Tools and Editor extension and will be available at the NPS I&M GIS server (http://science.nature.nps.gov/nrdata/). Water-quality data will be stored at the EPA STORET National Data Warehouse and be publicly accessible via the internet. Additionally, data requests can be directed to:

Heartland I&M Network
Attn. Database Manager
Wilson's Creek National Battlefield
6424 W. Farm Road 182
Republic, MO 65738-9514

SOP 10: Data Analysis Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

Conclusions of ecological studies based on fish and other biological, chemical, and physical data are used by resource managers to better comprehend underlying system processes and develop environmental and management policies that best serve the resource. This, in turn, could have substantial ecological and economical repercussions and should be an important consideration for investigators responsible for data interpretation. Therefore, every effort should be made to collect reliable data and use statistical analyses that are straightforward and will result in confident interpretations.

Primary approaches to analyzing fish data are metric estimation with use of control charts and multivariate statistics. Biological metrics are commonly used by investigators at all levels (private, State, tribal, and Federal, for example) to compare the condition of the biological community at multiple sites (Simon, 1999) or examine trends over time. Barbour and others (1999) define a metric as a characteristic of the biota that changes in an expected direction with increased anthropogenic disturbance. Using these characteristics (appendix 5) allows investigators to determine the importance of environmental conditions, clarify which habitat factors play a large role in shaping fish communities, and identify specific sources of impairment (Karr, 1981).

By combining multiple metrics and results for those metrics into a single index of biotic integrity (IBI), investigators can determine the overall quality of the fish community. An IBI also can be used to compare overall ecological conditions over time and between sites, providing that the selected metrics have a relation to variables responsible for impairment (Karr, 1981; Barbour and others, 1999; Simon, 1999). To assess fish community conditions at BUFF and OZAR, the IBI developed for Ozark Highland streams by Dauwalter and others (2003) will be used (appendix 9).

Metrics and estimated variables for analysis of river fish communities include:

1. Species richness (number of species) for the entire sample reach.

2. Simpson's Diversity Index (D) for entire sample reach. Simpson's Diversity Index is preferable to the Shannon diversity index and will be used for data analysis because this index is independent of sample size. Simpson's Diversity Index is calculated with the following formula:

$$D = \sum_{i=1}^{s} \left(\left(n^2 - n \right) / \left(N^2 - N \right) \right)$$

where S = number of species,
n = number of individuals of ith species, and
N = sum of n.

3. Catch per unit effort. For electrofishing, catch per minute for the entire reach (combining gear types) will be calculated for all species combined. For seine data, catch per area will be calculated.

4. Average length and weight for each species in the reach (combining gear types).

5. Percent composition by biomass for each species in the reach (combining gear types). To calculate this, average weight of a species will be multiplied by number caught to obtain individual species biomass. Individual biomass is divided by area of the sample reach to get biomass/area for each species. To obtain percent composition, biomass/area for each species is divided by total biomass/area.

6. Index of biotic integrity (Dauwalter and others, 2003) for the entire sample reach. This IBI consists of seven metrics that are calculated and scored. Individual metric scores are totaled for an IBI score at that sample reach. The metrics are: (1) number of darter, sculpin, and madtom species; (2) percent of individuals as green sunfish, bluegill, yellow bullhead, and channel catfish; (3) percent of individuals as algivorous/herbivorous, invertivorous, and piscivorous; (4) percent of individuals as invertivores; (5) percent of individuals as top carnivores; (6) number of lithophilic spawning species; and (7) percent of individuals with black spot or an anomaly. Specifics on calculation of and scoring of metrics can be found in Dauwalter and others (2003).

Using several of these estimated variables listed above, control charts can be employed to determine trends and changes in fish communities (Morrison, in press). The construction and interpretation of control charts is covered in many texts focusing on quality control in industry (Beauregard and others, 1992; Gyrna, 2001; Montgomery, 2001). The application of control charts for ecological purposes, however, is relatively straightforward. The use of control charts in environmental monitoring is discussed in the texts by McBean and Rovers (1998) and Manly (2001), although not as detailed as the texts referenced above focusing on industrial applications. Many different types of control charts could be constructed, depending upon the type of information desired. For example, control charts can be used to evaluate variables or attributes (for example, count data, richness, or number of intolerant taxa), to focus on measures of central tendency or dispersion, and in univariate or multivariate analyses.

Although some of the above-mentioned texts discuss the use of multivariate control charts (using the Hotelling T2 statistic), this approach is only practical for a small number of variables, and assumes a multivariate normal distribution. In general, species abundances are not distributed as multivariate normal (Taylor, 1961), and traditional multivariate procedures are frequently not robust to violations of this assumption (Mardia, 1971; Olson, 1974). A new type of multivariate control chart recently has been described for use with complex ecological communities (Anderson and Thompson, 2004). A software application entitled ControlChart.exe is available for constructing these types of multivariate control charts (see Anderson and Thompson, 2004). Multivariate temporal autocorrelation will violate the assumption of stochasticity upon which this method is based, however, and it is important to test for temporal autocorrelation using Mantel correlograms prior to using this method.

Multivariate analysis is another frequently used analysis technique and involves methods used to explain variability in community data and to identify the environmental variables that best explain, and have an assumed responsibility for, the variability measured (Gauch, 1982; Jongman and others, 1995; Everitt and Dunn, 2001; Timm, 2002). Multivariate techniques elicit a hypothesis from the biological data rather than disproving a null hypothesis. Two commonly used multivariate techniques include: ordination (such as principal components analysis, canonical correspondence analysis, and detrended correspondence analysis) and classification (such as two-way indicator species analysis). Detailed discussion of these methods can be found in several texts (Gauch, 1982; Jongman and others, 1995; Everitt and Dunn, 2001; Timm, 2002).

Rather than requiring a list of specific data analyses, the data analysis process should be flexible enough to allow the use of newly developed statistical and analytical techniques and tailoring of analyses for a variety of audiences with a variety of questions about the aquatic resources at the parks. This primary audience will consist of park resource managers, superintendents, and other staff who may not have an indepth background in statistical methods or may have limited time for evaluation of these analyses. Thus, to the extent possible, it is important that core data analysis and presentation methods are relatively straightforward to interpret, provide a standard format for evaluation of numerous variables, can be quickly updated whenever additional data become available, and work for many different types of indicators, whether univariate or multivariate. Additionally, the type and magnitude of variability or uncertainty associated with the results should be somewhat intuitive, and it may be necessary to indicate a threshold for potential management action. More detailed analysis of the data generally will benefit from the use of multiple data-analysis methods.

SOP 11: Reporting Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

Results from the fish monitoring program will be reported by the NPS annually to park managers and superintendents of each park (table 4) prior to the start of monitoring the following year (BUFF in May and OZAR in October). A copy of annual reports also will be kept on file with the HTLN office of the National Park Service, Republic, Mo. The content of annual reports will include location of sites, methodology used, and data analysis such as number of species caught, diversity, relative abundance, and IBI (see SOP 10 for detailed list of variables). Before distribution to park staff, annual reports will be internally reviewed by at least two HTLN staff to evaluate grammatical soundness and metric calculations.

Scientific collection permits for Arkansas and Missouri are required for collection of fish data. Renewal of the permit requires a report be submitted to the AGFC and the MDC describing the results of collection activities. This report typically includes a description of sampling locations, sampling gear, number and taxa of collected specimens, and specimen disposition. Requirements occasionally change, and permit requirements need to be consulted each year. Reports for permit renewal are less detailed than annual reports submitted to park staff and HTLN.

More comprehensive summary reports containing results from multivariate statistics, control chart analysis, and detailed explanations and interpretations of findings will be completed every 5 years with summary reports replacing annual reports in those years (table 4). These reports will be sent to park superintendents and resource management staff and will be on file at the HTLN office. Comprehensive reports will be sent to State agency personnel who have participated in data collection or have expressed interest in the summary data. Prior to dispersal of a summary report, an internal review by HTLN staff will be completed by the HTLN Quantitative Ecologist and a staff member knowledgeable of the monitoring program. This internal review provides not only review of the technical writing, but also evaluation of statistical methods and interpretations of the results.

For both annual and comprehensive reports, the template for regional natural resource technical reports will be followed (http://www.nature.nps.gov/publications/NRPM/index.cfm). Natural resource reports are the designated medium for disseminating high priority, current natural resource management information with managerial application. The natural resource technical report series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the NPS's mission. Standards for scientific writing as recommended in the CBE Style Manual (Council of Biological Editors Style Manual Committee, 1994) should be used, and reports should be direct and concise. Refer to the CBE Style Manual (Council of Biological Editors Style Manual Committee, 1994), Writing with Precision, Clarity and Economy (Mack 1986), Strunk and White (2000), Day and Gastel (2006), and Goldwasser (1999) for writing guidelines. All reports will be dispersed through the HTLN website: http://www1.nature.nps.gov/im/units/htln/reports.cfm.

Table 4. Summary of report types released by National Park Service and review procedures.

[HTLN is Heartland Network Inventory and Monitoring Program]

Type of report	Purpose of report	Primary audience	Review procedure	Frequency
Annual status reports for specific protocols	Summarize monitoring data collected during the year and provide an update on the status of selected natural resources. Document related data-management activities and data summaries.	Park resource managers and external scientists	Internal peer review by HTLN staff	Annual
Executive summary of annual reports for specific protocols	Same as annual status reports but summarized to highlight key points for non-technical audiences.	Superintendents, interpreters, and the general public	Internal peer review by HTLN staff	Simultaneous with annual reports
Comprehensive trends, analysis, and synthesis reports	Describe and interpret trends in individual vital signs. Describe and interpret relations among observed trends nd factors such as park management, known stressors, and climate. Highlight resources of concern that may require management action.	Park resource managers and external scientists	Internal peer review by HTLN staff	Every 5 to 7 years

SOP 12: Protocol Revision Version 1.0

Revision History Log:

Previous version number	Revision date	Author	Changes made	Reason for change	New version number

The Ozark Rivers Fish Community Protocol (Protocol Version 1.0 and version 1.0 of each SOP) has been developed to incorporate sound methods for collecting and analyzing fish community data at BUFF and OZAR. However, revisions may be necessary as new and improved sampling methods or statistical techniques are developed. Protocol and SOP versions later than version 1.0 are considered separate documents that (although based on Protocol Version 1.0 and version 1.0 of each SOP) may be authored by a different group of individuals, reviewed by different individuals or entities, and may not be USGS publications. All revisions to this protocol should be made in a timely manner to allow for review of the new version of the protocol. Minor changes to sampling techniques, such as adding additional seine hauls, will require revision of relevant SOPs, while major changes to the study design or underlying sampling methodology will require revision of the Protocol Narrative. Minor changes to the protocol will require internal review by HTLN staff. However, major revisions to the protocol (for example, changes in study design) will require an outside review by regional NPS staff and experts from other agencies familiar with fish community monitoring.

Documenting revisions to this protocol is mandatory for maintaining consistency in data collection and analysis between versions. All versions of the Protocol Narrative and SOPs must be archived in a protocol library. Documentation of changes to the protocol will be filed in the Revision History Log located within each SOP. Items recorded in the log include: previous version number, revision date, person (author) revising the protocol, specific changes made, reason for changes, and the new version number. Once changes have been made, the version number of the protocol will increase by 0.1 (starting with the original protocol at version 1.0). Revisions to the protocol also will be recorded in the fish community database under a field identifying the protocol version in use at time of data collection. This will ensure that staff managing the data and running analyses are aware of revisions in collection techniques that may require changes in database design or analytical procedures. Once revisions are complete, the new version will be posted on the HTLN website: http://www1.nature.nps.gov/im/units/htln/fish.htm

Summary

Buffalo National River (BUFF), in north-central Arkansas, and Ozark National Scenic Riverways (OZAR), in southeastern Missouri, are the two largest units of the National Park Service in the Ozark Plateaus physiographic province (fig. 1). The purpose of this report is to provide a protocol that will be used by the National Park Service to sample fish communities- and collect related water-quality, habitat, and stream discharge data of BUFF and OZAR to meet inventory and long-term monitoring objectives.

The protocol includes (1) a protocol narrative, (2) several standard operating procedures and (3) supplemental information helpful for implementation of the protocol. The protocol narrative provides background information about the protocol such as the rationale of why a particular resource or resource issue was selected for monitoring, information concerning the resource or resource issue of interest, a description of how monitoring results will inform management decisions, and a discussion of the linkages between this and other monitoring projects. The SOPs cover preparation, training, reach selection, water-quality sampling, fish community sampling, physical habitat collection, measuring stream discharge, equipment maintenance and storage, data management and analysis, reporting, and protocol revision procedures. Much of the information in the SOPs was gathered from existing protocols of the USGS NAWQA program or other sources.

All of the SOPs are written to provide information that can be used to maximize the accuracy, representativeness, and completeness of the fish community data. SOP 1 describes preparations that should be completed prior to fish community sampling. SOP 2 describes training requirements related to sampling and safety. SOP 3 describes sampling reach designation. SOP 4 addresses the equipment and methods required to measure water-quality variables (temperature, dissolved oxygen, specific conductance, pH, and turbidity). The fish community sampling SOP (SOP 5) includes methods for sampling fish communities and for processing samples. Methods are described for using backpack, towed barge, and boat electrofishing equipment and seines in wadeable and nonwadeable streams. Wadeable streams will be sampled using a single-pass method and nonwadeable streams will be sampled using a two-pass method. SOP 6 describes methods for collecting physical habitat data that will be collected as part of the fish community monitoring to examine relations between environmental conditions and fish communities. SOP 7 provides guidance for measuring discharge in streams associated with the fish community sampling. SOP 8 describes equipment maintenance necessary to maximize the life of water-quality and fish sampling equipment. SOP 9 explains procedures for data management of BUFF and OZAR river fish sampling data. SOP 10 describes methods that can be used to analyze the fish community, water-quality, and physical habitat data. SOP 11 describes the reporting requirements associated with the annual monitoring. SOP 12 describes methods for making revisions that may be necessary as new and improved sampling methods or statistical techniques are developed.

Supplemental information that would be helpful for implementing the protocol is included. This information includes information on fish species known or suspected to occur at the parks, sample sites, sample design, fish species characteristics, index of biotic integrity metrics, sampling equipment, and field forms.

References Cited

Adamski, J.C., Petersen, J.C., Freiwald, D.A., and Davis, J.V., 1995, Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma: U. S. Geological Survey Water-Resources Investigations Report 94-4022, 69 p.

Ainslie, B.J., Post, J.R., and Paul, A.J., 1998, Effects of pulsed and continuous DC electrofishing on juvenile rainbow trout: North American Journal of Fisheries Management v. 18, p. 905-918.

Anderson, D. R., Burnham, K. P., and Thompson, W.L., 2000, Null hypothesis testing: Problems, prevalence, and an alternative: Journal of Wildlife Management, v. 64, p. 912-923.

Anderson, D. R., Link, W.A., Johnson, D.H., and Burnham, K.P., 2001, Suggestions for presenting the results of data analyses: Journal of Wildlife Management v. 65, p. 373-378.

Anderson, M. J. and Thompson, A.A., 2004, Multivariate control charts for ecological and environmental monitoring: Ecological Applications, v. 14, p. 1921-1935.

Atkinson, A. J., Fisher, R.N., Rochester, C.J., and Brown, C.W., 2003, Sampling design optimization and establishment of baselines for herpetofauna arrays at the Point Loma Ecological Reserve: U.S. Geological Survey, 39 p.

Bagenal, Timothy, 1978, Methods for assessment of fish production in fresh waters: Oxford, Blackwell Scientific Publications, 365 p.

Barbour, M.T., Gerritsen, J., Snyder, B.D. and Stribling, J.B., 1999, Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002. Office of Water. U.S. Environmental Protection Agency, Washington, D.C. [variously paginated].

Bayley, P.B. and Herendeen, R.A., 2000, The efficiency of a seine net: Transactions of the American Fisheries Society, v. 129, p. 901-923.

Beauregard, M. R., Mikulak, R.J., and Olson, B.A., 1992, A practical guide to statistical quality improvement: Opening up the statistical toolbox: New York, Van Nostrand Reinhold, 469 p.

Becker, G.C., 1983, Fishes of Wisconsin: Madison, Wisconsin, University of Wisconsin Press, 1,052 p.

Bell, R.W., Davis, J.V., Femmer, S.F., and Joseph, R.L., 1997, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—organic compounds in surface water, bed sediment, and biological tissue, 1992-95: U.S. Geological Survey Water-Resources Investigations Report 97-4031, 30 p.

Bramblett, R.G., and Fausch, K.D., 1991, Fishes, macroinvertebrates, and aquatic habitats of the Purgatoire River in Pinon Canyon, Colorado: Southwestern Naturalist, v. 36, p. 281–294.

Council of Biological Editors Style Manual Committee, 1994, Scientific style and format: The CBE manual for authors, editors, and publishers. 6th edition.: New York, Cambridge University Press, 825 p.

Cherry, S., 1998, Statistical tests in publications of The Wildlife Society: Wildlife Society Bulletin, v. 26, p. 947-953.

Colegrave, N. and Ruxton, G.D., 2003, Confidence intervals are a more useful complement to nonsignificant tests than are power calculations: Behavioral Ecology, v.14, p. 446-450.

Cribbs, J. T., 2006, Heartland Network Safety Plan and Procedures: U.S. National Park Service, Heartland I&M Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Mo., 66 p.

Dalbey, S.R., McMahon, T.E., and Fredenberg, W., 1996, Effect of electrofishing pulse shape and electrofishing-induced spinal injury to long-term growth and survival of wild rainbow trout: North American Journal of Fisheries Management, v. 16, p. 560-569

Dauwalter, D.C. and Jackson, J.R., 2004, A provisional fish index of biotic integrity for assessing Ouachita Mountain Streams in Arkansas, U.S.A.: Environmental Monitoring and Assessment, v. 91, p. 27-57.

Dauwalter, D.C., Pert, E.J., and Keith, W.E., 2003, An index of biotic integrity for fish assemblages in Ozark Highland Streams of Arkansas, Southeastern Naturalist, v. 2, p. 447-468.

Dauwalter, D.C., and Pert, E.J., 2004, Management briefs--effect of electrofishing effort on an index of biotic integrity: North American Journal of Fisheries Management, v. 23, p. 1247-1252.

Davis, J.V, and Bell, R.W., 1998, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—nutrients, bacteria, organic carbon, and suspended sediment in surface water, 1993-95, 56 p.

Day, R.A. and Gastel, B., 2006, How to write and publish a scientific paper, 6th edition: Westport, Conn., Greenwood Press, 320 p.

DeBacker, M.D., Young, C.C. (editor), Adams P., Morrison L., Peitz D., Rowell G.A., Williams M., Bowles D, 2005, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype monitoring program vital signs monitoring plan: U.S. National Park Service, Heartland I&M Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Mo., 104 p.

Dolan, C.R., and Miranda, L.E., 2003, Immobilization thresholds of electrofishing relative to fish size: Transactions of the American Fisheries Society, v. 132, p. 969-976.

Dolan, C.R., and Miranda, L.E., 2004, Injury and mortality of warmwater fishes immobilized by electrofishing: North American Journal of Fisheries Management, v. 24, no. 1, p. 118-127.

ESRI, 2007, GIS and mapping software: accessed October 17, 2007 at URL http://www.esri.com/software/arcgis/index.html

Etnier, D. A. and Starnes, W.C., 1993, The fishes of Tennessee: Knoxville, Tennessee, The University of Tennessee Press, 681 p.

Everitt, B.S., and Dunn, G., 2001, Applied Multivariate Data Analysis, 2nd edition, 342 p.

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States (Map): Washington, D.C., U.S. Geological Survey.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and Gurtz, M.E., 1998, Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 98-4052, 67 p.

Gauch, H.G., Jr., 1982, Multivariate analysis in community ecology. Cambridge, U.K., Cambridge University Press, 298 p.

Gerard, P. D., Smith, D.R., and Weerakkody, G., 1998, Limits of retrospective power analysis: Journal of Wildlife Management, v. 62, p. 801-807.

Goldstein R.M., and Meador M.R., 2004, Comparisons of fish species traits from small streams to large rivers: Transactions of the American Fisheries Society v. 133, p. 971-983.

Goldwasser, L, 1999, A collection of grammatical points: Bulletin of Ecological Society of America, v. 79, p. 148-150.

Gyrna, F. M., 2001, Quality planning and analysis: From product development through use: New York, McGraw-Hill Irwin, 752 p.

Hardin, S. and Connor, L.L., 1992, Variability of electrofishing crew efficiency, and sampling requirements for estimating reliable catch rates: North American Journal of Fisheries Management, v. 12, p. 612–617

Hauck, H.S., Huber, L.G., and Nagel, C.D., 1996, Water resources data—Missouri, water year 1995: U.S. Geological Survey Water Data Report MO-95-1, 320 p.

Hauck, H.S., and Nagel, C.D., 2004, Water resources data—Missouri, water year 2003: U.S. Geological Survey Water Data Report MO-03-1, 776 p.

Hendricks, M.L., Hocutt, C.H., and Stauffer, J.R., Jr., 1980, Monitoring of fish in lotic habitats, in Hocutt, C.H., and Stauffer, J.R., Jr., eds., Biological monitoring of fish: Lexington, Mass., Lexington Books, p. 205–231.

Hilsenhoff, W.L., 1977, Use of arthropods to evaluate water quality of streams: Wisconsin Department of Natural Resources Technical Bulletin No. 100, p. 1-15.

Hlass L. J., Fisher, W.L., and Turton, D.J., 1998, Use of the index of biotic integrity to assess water quality in forested streams of the Ouachita Mountains Ecoregion, Arkansas: Journal of Freshwater Biology, v. 13, no. 2, p. 181-192.

Hoefs, N.J., 1989, Applying the index of biotic integrity to resource inventory in the Current River Basin, Missouri: unpublished Masters thesis, Colorado State University, Fort Collins, Colo., 111 p.

Hoenig, J. M. and Heisey, D.M., 2001, The abuse of power: The pervasive fallacy of power calculations for data analysis: The American Statistician, v. 55, p. 19-24.

Hughes, R.M., and Oberdorff, T. 1998. Applications of IBI concepts and metrics to waters outside the United States and Canada, in Simon, T.P., ed., Assessment and approaches for estimating biological integrity using fish assemblages: Boca Raton, Florida, Lewis Press, p. 79-93.

Jenkins, R. E. and Burkhead, N.M., 1994, Freshwater fishes of Virginia: Bethesda, Maryland, American Fisheries Society, 1,080 p.

Johnson, D. H., 1999, The insignificance of statistical significance testing: Journal of Wildlife Management, v. 63, p. 763-772.

Jongman, R.H.G., ter Braak, C.J.F., and van Tongeren, O.F.R., 1995, Data analysis in community and landscape ecology: Cambridge, Cambridge University Press, 299 p.

Justus B.G., 2003, An index of ecological integrity for the Mississippi Alluvial Plain Ecoregion: Index development and relations to selected landscape variables. U.S. Geological Survey Water-Resources Investigations Report 03–4110, 32 p.

Karr J.R., 1981, Assessment of biotic integrity using fish communities: Fisheries, v. 6, p. 21–27.

Kirk, R. E., 1996, Practical significance: A concept whose time has come: Educational and Psychological Measurement, v. 56, p.746-759.

Kocovsky, P.M., Gowan, C.G., Fausch, K.D., and Riley, S.C., 1997, Spinal injury rates in three wild trout populations in Colorado after eight years of backpack electrofishing: North American Journal of Fisheries Management, v. 17, p. 308-313

Mack, R.N., 1986, Writing with precision, clarity, and economy: Bulletin of Ecological Society of America, v. 67, p. 31-35.

Manly, B. F. J., 2001, Statistics for environmental science and management: Boca Raton, Florida, Chapman & Hall/CRC, 326 p.

Mardia, K. V., 1971, The effect of nonnormality on some multivariate tests and robustness to nonnormality in the linear model: Biometrika v. 58, p. 105-121.

Master, L.L, Flack, S.R., and Stein, B.A., eds., 1998, Rivers of life: Critical watersheds for protecting freshwater biodiversity: Arlington, Va., The Nature Conservancy, 71 p.

Matthews, W.J., 1986, Fish faunal structure in an Ozark stream—Stability, persistence and a catastrophic flood: Copeia, v. 1986, p. 388–397.

McBean, E. A. and Rovers, F.A., 1998, Statistical procedures for analysis of environmental monitoring data and risk assessment: Upper Saddle River, New Jersey, Prentice Hall PTR, 320 p.

McCormick, F.H., and Hughes, R.M., 1998, Aquatic vertebrates in Lazorchak, J.M., Klemm, D.J., and Peck, D.V., eds., Environmental Monitoring and Assessment Program—Surface waters: Field operations and methods for measuring the ecological condition of wadeable streams: U.S. Environmental Protection Agency Report, EPA 620–R–94–004F, [variously paginated].

McCormick, F.H., and Hughes, R.M., 2000, Aquatic vertebrates in Lazorchak, J.M., Hill, B.H., Averill, D.K., Peck, D.V., and Klemm, D.J., eds., Environmental Monitoring and Assessment Program—Surface waters: Field operations and methods for measuring the ecological condition of nonwadeable streams: U.S. Environmental Protection Agency Report, EPA 620–R–00–007, [variously paginated].

McDonald, Trent, 2004, Ecological survey recommendations for the Buffalo National River and Ozark National Scenic Riverways Parks: West, Inc. 15 p.

McMichael, G.A., Fritts, A.L., and Pearsons, T.N., 1998, Electrofishing injury to stream salmonids; Injury assessment at the sample, reach, and stream scales: North American Journal of Fisheries Management, v. 18, p. 894–904.

Meador, M.R., Cuffney, T.F., and Gurtz, M.E., 1993, Methods for sampling fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-104, 40 p.

Meador, M.R, and McIntyre, J.P., 2003, Effects of electrofishing gear type on spatial and temporal variability in fish community sampling: Transactions of the American Fisheries Society, v. 132, p. 709-716.

Meador, M.R, McIntyre, J.P., and Pollock, K.H., 2003, Assessing the efficacy of single-pass backpack electrofishing to characterize fish community structure: Transactions of the American Fisheries Society, v. 132, p. 39-46.

Mettee, M.F., O'Neil, P.E., and Pierson, J.M., 1996, Fishes of Alabama and the Mobile Basin: Birmingham, Alabama, Oxmoor House, Inc., 820 p.

Moix, M.W., and Galloway, J.M., 2005, Base flow, water quality, and streamflow gain and loss of the Buffalo River, Arkansas, and selected tributaries, July and August, 2003: U.S. Geological Survey Scientific Investigations Report 2004-5274, 36 p.

Montgomery, D. C., 2001, Introduction to statistical quality control: New York, John Wiley & Sons, Inc., 776 p.

Morrison, L.W., 2007, Assessing the reliability of ecological monitoring data: Power analysis and alternative approaches: Natural Areas Journal, v. 27, p. 83-91.

Morrison, L.W., in press, The use of control charts to interpret environmental monitoring data: Natural Areas Journal.

Mott, D.N., and Luraas, Jessica, 2004, Water resources management plan, Buffalo National River, Arkansas: Buffalo National River, Harrison, Arkansas, 144 p.

Moulton, S.R., II, Kennen, J.G., Goldstein, R.M., and Hambrook, J.A., 2002, Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 02-150, 75 p.

Nakagawa, S. and Foster, T.M., 2004, The case against retrospective power analyses with an introduction to power analysis: Acta Ethologica v. 7, p. 103-108.

National Park Service, 2005, Ozark National Scenic Riverways, nature and science, fish: accessed May 10, 2005 at URL http://www.nps.gov/ozar/pphtml/subanimals4.html.

National Park Service, 2006, Inventory and Monitoring Natural Resource Database Template Version 3.1 documentation: Fort Collins, Colorado, Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, 28 p.

National Park Service/Water Resources Division, 2007a, Vital signs long-term monitoring projects: Part C draft guidance on WRD required and other field parameter measurements, general monitoring methods and some design considerations in preparation of a detailed study plan, accessed April 27, 2007 at URL http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartC.pdf

National Park Service, 2007b, Vital signs water-quality data management and archiving, accessed on April 27, 2007 at URL http://www.nature.nps.gov/water/infoanddata/index.cfm.

Nelson, J.S., Crossman, E.J., Espinoza-Perez, Hector, Findley, L.T., Gilbert, C.R., Lea, R.N., and Williams, J.D., 2004, Common and scientific names of fishes from the United States, Canada, and Mexico: Bethesda, Md., American Fisheries Society, Special Publication 29, 386 p.

Nielsen, L.A., and Johnson, D.L., 1983, Fisheries techniques: Bethesda, Md., American Fisheries Society, 468 p.

Olsen, T., Hayden, B.P., Ellison, A.M., Oehlert, G.W., and Esterby, S.R., 1997, Ecological resource monitoring: Change and trend detection workshop report: Bulletin of the Ecological Society of America v. 78, p. 11-13.

Olson, C. L., 1974, Comparative robustness of six tests in multivariate analysis of variance: Journal of the American Statistical Association, v. 69, p. 894-908.

Page, L. M. and Burr, B.M., 1991, A field guide to freshwater fishes: North America north of Mexico: Boston, Houghton Mifflin Company, 432 p.

Panfil, M.S., and Jacobson, R.B., 2001, Relations among geology, physiography, land use, and stream habitat conditions in the Buffalo and Current River Systems, Missouri and Arkansas: Biological Science Report 2001-0005, 112 p.

Petersen, J.C., 1998, Water-quality assessment of the Ozark Pla¬teaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—Fish communities in streams of the Ozark Plateaus and their relations to selected environmental factors: U.S. Geological Survey Water-Resources Investigations Report 98-4155, 32 p.

Petersen, J.C., Adamski, J.C., Bell, R.W., Davis, J.V., Femmer, S.R., Freiwald, D.A., and Joseph, R.L., 1998, Water quality in the Ozark Plateaus, Arkansas, Kansas, Missouri, and Oklahoma, 1992—95: U.S. Geological Survey Circular 1158, 33 p.

Petersen, J.C., 2004, Fish communities of the Buffalo River Basin and nearby basins of Arkansas and their relation to selected environmental factors, 2001-2004: U.S. Geological Survey Scientific Investigations Report 2004-5119, 93 p.

Petersen, J.C., 2005, Fishes of Buffalo National River: U.S. Geological Survey Scientific Investigations Map 2005-2908, 1 sheet.

Petersen, J.C. and Justus, B.J., 2005, The fishes of Buffalo National River, 2001-2003: U.S. Geological Survey Scientific Investigations Report 2005-5130, 37 p.

Pettersson, M., 1998, Monitoring a freshwater fish population: Statistical surveillance of biodiversity: Environmetrics, v. 9, p. 139-150.

Pflieger, W.L., 1997, The fishes of Missouri: Missouri Department of Conservation, 372 p.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., Hughes, R.M., 1989, Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish: Office of Water Regulations and Standards, U.S. Environmental Protection Agency, EPA 440-4-89-001, Washington, D.C., [variously paginated].

Pusey, B. J., Kennard, M.J., Arthur, J.M., and Arthington, A.H., 1998, Quantitative sampling of stream fish assemblages: Single- vs. multiple-pass electrofishing: Australian Journal of Ecology v. 23, p. 365–374.

Rabeni, C.F., Sarver, R.J., Wang, Ning, Wallace, G.S., Weiland, Mark, and Peterson, J.T., 1997, Development of regionally based biological criteria for streams of Missouri: Columbia, Mo., Missouri Cooperative Fish and Wildlife Research Unit, a report to the Missouri Department of Natural Resources, 273 p.

Rohde, F. C., Arndt, R.G., Lindquist, D.G., and Parnel, J.F., 1994, Freshwater fishes of the Carolinas, Virginia, Maryland, and Delaware: Chapel Hill, North Carolina, University of North Carolina Press, 228 p.

Robison, H.W., and Buchanan, T.M., 1988, Fishes of Arkansas: Fayetteville, Arkansas, University of Arkansas Press, 536 p.

Ross, S.T., 2001, The inland fishes of Mississippi: Oxford, Mississippi, University of Mississippi Press, 736 p.

Rowell, G. A., Williams, M.H., and DeBacker, M.D., 2005, Data management plan: Heartland I&M Network and Prairie Cluster Prototype Monitoring Program: Wilson's Creek National Battlefield, Republic, Mo., 64 p.

Shaver, J. P., 1993,. What statistical significance testing is, and what it is not: Journal of Experimental Education, v. 61, p. 293-316.

Simon T.P., 1999, Assessing the sustainability and biological integrity of water resources using fish communities: Boca Raton, Florida., CRC Press, Inc., 671 p.

Simonson, T.D, and Lyons, John, 1995, Comparison of catch per effort and removal procedures for sampling stream fish assemblages: North American Journal of Fisheries Management, v. 15, no. 2, p. 419-427.

Scott, W.B. and Crossman, E.J., 1973, Freshwater fishes of Canada: Ottawa, Fisheries Research Board of Canada, Bulletin 184, 966 p.

Smith, S.B., Donahue, A.P., Lipkin, R.J., Blazer, V.S., Schmitt, C.J., and Goede, R.W., 2002, Illustrated field guide for assessing external and internal anomalies in fish: U.S. Geological Survey Information and Technology Report 2002-0007, 46 p.

Steidl, R. J., Hayes, J.P., and E. Schauber, E., 1997, Statistical power analysis in wildlife research: Journal of Wildlife Research, v. 61, p. 270-279.

Stevens, D. L., Jr. and Olsen, A.R., 1999, Spatially restricted surveys over time for aquatic resources: Journal of Agricultural, Biological, and Environmental Statistics, v. 4, p. 415-428.

Stevens, D.L, and Olson, A.R., 2004, Spatially balanced sampling of natural resources: Journal of the American Statistical Association, v. 99, p. 262-278

Stoehr, A. M., 1999, Are significance thresholds appropriate for the study of animal behaviour? Animal Behaviour, v. 57, p. F22-F25.

Strunk, W. Jr., and White, E.B., 2000, The elements of style (4th Edition): New York, Macmillan, 43 p.

Taylor, L. R., 1961, Aggregation, variance, and the mean: Nature, v. 189, p. 732-735.

Timm, N.H., 2002, Applied multivariate analysis: University of Pittsburgh Press, 693 p.

Utts, J., 1988, Successful replication verses statistical significance: The Journal of Parapsychology v. 52, p. 305-320.

Vineyard, J.D., and Feder, G.L., 1974, Springs of Missouri with sections on Fauna and flora, by W.L. Pflieger and R.G. Lipscomb: Rolla, Missouri Department of Geology and Land Survey Water Resources Report 29, 212 p., (reprinted 1982).

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments

Walsh, S.J., and Meador, M.R., 1998, Guidelines for quality assurance and quality control of fish taxonomic data collected as part of the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 98-4239, 33 p.

Wiley, M.L., and Tsai, Chu-Fa, 1983, The relative efficiencies of electrofishing vs. seines in Piedmont streams of Maryland: North American Journal of Fisheries Management, v. 3, p. 243–253.

Williams, W.T., and Gillard, P., 1971, Pattern analysis of a grazing experiment: Australian Journal of Agricultural Research, v. 22, p. 245-260.

Yoccoz, N. G., 1991, Use, overuse, and misuse of significance tests in evolutionary biology and ecology: Bulletin of the Ecological Society of America: v. 72, p. 106-111.

Appendixes 1-20

Appendix 1. Fish species collected within Buffalo National River.

[From Petersen and Justus (2005)]

Common name	Scientific name
American brook lamprey	*Lampetra appendix*
American eel	*Anguilla rostrata*
Arkansas saddled darter	*Etheostoma euzonum*
Banded darter	*Etheostoma zonale*
Banded sculpin	*Cottus carolinae*
Bigeye chub	*Hybopsis amblops*
Bigeye shiner	*Notropis boops*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Black redhorse	*Moxostoma duquesnei*
Blackside darter	*Percina maculata*
Blackspotted topminnow	*Fundulus olivaceus*
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Brook silverside	*Labidesthes sicculus*
Brown trout	*Salmo trutta*
Carmine shiner	*Notropis percobromus*
Central stoneroller	*Campostoma anomalum*
Channel catfish	*Ictalurus punctatus*
Checkered madtom	*Noturus flavater*
Chestnut lamprey	*Ichthyomyzon castaneus*
Common carp	*Cyprinus carpio*
Creek chub	*Semotilus atromaculatus*
Duskystripe shiner	*Luxilus pilsbryi*
Flathead catfish	*Pylodictis olivaris*
Freshwater drum	*Aplodinotus grunniens*
Gilt darter	*Percina evides*
Gizzard shad	*Dorosoma cepedianum*
Golden redhorse	*Moxostoma erythrurum*
Green sunfish	*Lepomis cyanellus*
Greenside darter	*Etheostoma blennioides*
Highfin carpsucker	*Carpiodes velifer*
Hornyhead chub	*Nocomis biguttatus*
Largemouth bass	*Micropterus salmoides*
Largescale stoneroller	*Campostoma oligolepus*
Least brook lamprey	*Lampetra aepyptera*
Logperch	*Percina caprodes*
Longear sunfish	*Lepomis megalotis*
Longnose gar	*Lepisosteus platostomus*
Northern hog sucker	*Hypentelium nigricans*
Northern studfish	*Fundulus catenatus*

Appendix 1. Fish species collected within Buffalo National River.—Continued

[From Petersen and Justus (2005)]

Common name	Scientific name
Orangethroat darter	*Etheostoma spectabile*
Ozark bass	*Ambloplites constellatus*
Ozark chub	*Erimystax harryi*
Ozark madtom	*Noturus albater*
Ozark minnow	*Notropis nubilus*
Ozark sculpin	*Cottus hypselurus*
Ozark shiner	*Notropis ozarcanus*
Pealip redhorse[1]	*Moxostoma pisolabrum*
Quillback	*Carpiodes cyprinus*
Rainbow darter	*Etheostoma caeruleum*
Rainbow trout	*Oncorhynchus mykiss*
Redear sunfish	*Lepomis microlophus*
Redspotted sunfish	*Lepomis miniatus*
River carpsucker	*Carpiodes carpio*
River redhorse	*Moxostoma carinatum*
Slender madtom	*Noturus exilis*
Smallmouth bass	*Micropterus dolomieu*
Southern redbelly dace	*Phoxinus erythrogaster*
Speckled darter	*Etheostoma stigmaeum*
Spotted bass	*Micropterus punctulatus*
Spotted sucker	*Minytrema melanops*
Steelcolor shiner	*Cyprinella whipplei*
Stippled darter	*Etheostoma punctulatum*
Striped shiner	*Luxilus chrysocephalus*
Telescope shiner	*Notropis telescopus*
Walleye	*Sander vitreus*
Warmouth	*Lepomis gulosus*
Wedgespot shiner	*Notropis greenei*
White bass	*Morone chrysops*
White sucker	*Catostomus commersoni*
Whitetail shiner	*Cyprinella galactura*
Yellow bullhead	*Ameiurus natalis*
Yoke darter	*Etheostoma juliae*

[1] Formerly was shorthead redhorse (*Moxostoma macrolepidotum*)

Appendix 2. Fish species collected or suspected of occurring within Ozark National Scenic Riverways.

[Michael Williams and Victoria Grant, National Park Service, written commun., 2006]

Common name	Scientific name
American brook lamprey	*Lampetra appendix*
American eel	*Anguilla rostrata*
Arkansas saddled darter	*Etheostoma euzonum*
Banded darter	*Etheostoma zonale*
Banded sculpin	*Cottus carolinae*
Bigeye chub	*Hybopsis amblops*
Bigeye shiner	*Notropis boops*
Bigmouth buffalo	*Ictiobus cyprinellus*
Black buffalo	*Ictiobus niger*
Black bullhead	*Ameiurus melas*
Black crappie	*Pomoxis nigromaculatus*
Black redhorse	*Moxostoma duquesnei*
Blackside darter	*Percina maculata*
Blackspotted topminnow	*Fundulus olivaceus*
Blacktail shiner	*Cyprinella venusta*
Bleeding shiner	*Luxilus zonatus*
Blue sucker	*Cycleptus elongatus*
Bluegill	*Lepomis macrochirus*
Bluntnose minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brindled madtom	*Noturus miurus*
Brook silverside	*Labidesthes sicculus*
Brown trout	*Salmo trutta*
Carmine shiner	*Notropis percobromus*
Central stoneroller	*Campostoma anomalum*
Chain pickerel	*Esox niger*
Channel catfish	*Ictalurus punctatus*
Checkered madtom	*Noturus flavater*
Chestnut lamprey	*Ichthyomyzon castaneus*
Common carp	*Cyprinus carpio*
Creek chub	*Semotilus atromaculatus*
Creek chubsucker	*Erimyzon oblongus*
Current darter	*Etheostoma uniporum*
Cypress darter	*Etheostoma proeliare*
Emerald shiner	*Notropis atherinoides*
Fantail darter	*Etheostoma flabellare*
Fathead minnow	*Pimephales promelas*
Flathead catfish	*Pylodictis olivaris*
Flier	*Centrarchus macropterus*
Freckled madtom	*Noturus nocturnus*

Appendix 2. Fish species collected or suspected of occurring within Ozark National Scenic Riverways.—Continued

[Michael Williams and Victoria Grant, National Park Service, written commun., 2006]

Common name	Scientific name
Freshwater drum	*Aplodinotus grunniens*
Gilt darter	*Percina evides*
Gizzard shad	*Dorosoma cepedianum*
Golden redhorse	*Moxostoma erythrurum*
Golden shiner	*Notemigonus crysoleucas*
Goldeye	*Hiodon alosoides*
Goldfish	*Carassius auratus*
Gravel chub	*Erimystax x-punctatus*
Green sunfish	*Lepomis cyanellus*
Greenside darter	*Etheostoma blennioides*
Highfin carpsucker	*Carpiodes velifer*
Hornyhead chub	*Nocomis biguttatus*
Johnny darter	*Etheostoma nigrum*
Lake chubsucker	*Erimyzon sucetta*
Largemouth bass	*Micropterus salmoides*
Largescale stoneroller	*Campostoma oligolepis*
Least brook lamprey	*Lampetra aepyptera*
Logperch	*Percina caprodes*
Longear sunfish	*Lepomis megalotis*
Longnose gar	*Lepisosteus osseus*
Mississippi silvery minnow	*Hybognathus nuchalis*
Mooneye	*Hiodon tergisus*
Mountain madtom	*Noturus eleutherus*
Mud darter	*Etheostoma asprigene*
Northern hog sucker	*Hypentelium nigricans*
Northern studfish	*Fundulus catenatus*
Orangespotted sunfish	*Lepomis humilis*
Ozark chub	*Erimystax harryi*
Ozark madtom	*Noturus albater*
Ozark minnow	*Notropis nubilus*
Ozark sculpin	*Cottus hypselurus*
Ozark shiner	*Notropis ozarcanus*
Paddlefish	*Polyodon spathula*
Pealip redhorse[1]	*Moxostoma pisolabrum*
Pirate perch	*Aphredoderus sayanus*
Pugnose minnow	*Opsopoeodus emiliae*
Rainbow darter	*Etheostoma caeruleum*
Rainbow trout	*Oncorhynchus mykiss*
Redear sunfish	*Lepomis microlophus*
Redfin pickerel	*Esox americanus*

Appendix 2. Fish species collected or suspected of occurring within Ozark National Scenic Riverways.—Continued

[Michael Williams and Victoria Grant, National Park Service, written commun., 2006]

Common name	Scientific name
Redfin shiner	*Lythrurus umbratilis*
Redspotted sunfish	*Lepomis miniatus*
Ribbon shiner	*Lythrurus fumeus*
River carpsucker	*Carpiodes carpio*
River redhorse	*Moxostoma carinatum*
Sauger	*Sander canadensis*
Shadow bass	*Ambloplites ariommus*
Shortnose gar	*Lepisosteus platostomus*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*
Silver redhorse	*Moxostoma anisurum*
Skipjack herring	*Alosa chrysochloris*
Slender madtom	*Noturus exilis*
Smallmouth bass	*Micropterus dolomieu*
Smallmouth buffalo	*Ictiobus bubalus*
Southern cavefish	*Typhlichthys subterraneus*
Southern redbelly dace	*Phoxinus erythrogaster*
Speckled darter	*Etheostoma stigmaeum*
Spotted bass	*Micropterus punctulatus*
Spotted gar	*Lepisosteus oculatus*
Spotted sucker	*Minytrema melanops*
Stargazing darter	*Percina uranidea*
Steelcolor shiner	*Cyprinella whipplei*
Stippled darter	*Etheostoma punctulatum*
Striped shiner	*Luxilus chrysocephalus*
Suckermouth minnow	*Phenacobius mirabilis*
Tadpole madtom	*Noturus gyrinus*
Telescope shiner	*Notropis telescopus*
Threadfin shad	*Dorosoma petenense*
Walleye	*Sander vitreus*
Warmouth	*Lepomis gulosus*
Wedgespot shiner	*Notropis greenei*
Weed shiner	*Notropis texanus*
Western mosquitofish	*Gambusia affinis*
White bass	*Morone chrysops*
White crappie	*Pomoxis annularis*
White sucker	*Catostomus commersoni*
Whitetail shiner	*Cyprinella galactura*
Yellow bullhead	*Ameiurus natalis*
Yellow perch	*Perca flavescens*

[1] Formerly was shorthead redhorse (*Moxostoma macrolepidotum*).

Appendix 3. Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified method for monitoring fish communities at Buffalo National River and Ozark National Scenic Riverways.

[UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983; BT, boat; BP backpack; BA, barge]

Stretch	Reach identification code	River basin	Site type	Site/ tributary number	Tributary name	Panel number (year)	County	UTM easting	UTM northing	Electrofishing gear used	Percent effort by gear
Buffalo National River											
24	BUFFM01	Buffalo	Mainstem	01		Annual	Newton	464088.50	3981659.30	BT, BP	70, 30
55	BUFFM02	Buffalo	Mainstem	02		Annual	Newton	490340.90	3987599.90	BT, BP	40, 60
59	BUFFM03	Buffalo	Mainstem	03		Annual	Newton	499985.28	3983483.70	BT, BP	90, 10
69	BUFFM04	Buffalo	Mainstem	04		Annual	Searcy	520484.74	3981679.66	BT, BA	60, 40
73	BUFFM05	Buffalo	Mainstem	05		Annual	Searcy	529619.95	3984878.60	BT, BP	40, 60
87	BUFFM06	Buffalo	Mainstem	06		Annual	Marion	545997.97	3995359.40	BT, BP	60, 40
640	BUFFT03	Buffalo	Tributary	03	Whiteley	1	Newton	463933.84	3982976.75	BP	100
420	BUFFT09	Buffalo	Tributary	09	Little Buffalo	1	Newton	490340.91	3987600.00	BT, BP	20 ,80
300	BUFFT22	Buffalo	Tributary	22	Spring	1	Searcy	536995.44	3986311.00	BP	100
649	BUFFT24	Buffalo	Tributary	24	Hickory	1	Marion	540092.81	3992069.50	BP	100
603	BUFFT30	Buffalo	Tributary	30	Middle	1	Marion	551428.31	3993556.50	BP	100
623	BUFFT31	Buffalo	Tributary	31	Leatherwood	1	Marion	551307.69	3996258.00	BP	100
462	BUFFT05	Buffalo	Tributary	05	Cecil	2	Newton	479905.44	3992743.25	BP	100
646	BUFFT07	Buffalo	Tributary	07	Mill	2	Newton	487979.09	3990501.25	BA	100
242	BUFFT12	Buffalo	Tributary	12	Sheldon Branch	2	Newton	492781.88	3983234.50	BP	100
241	BUFFT21	Buffalo	Tributary	21	Brush	2	Searcy	527984.75	3983963.00	BP	100
238	BUFFT25	Buffalo	Tributary	25	Little Panther	2	Marion	540006.31	3993475.25	BP	100
390	BUFFT33	Buffalo	Tributary	33	Stewart	2	Marion	552646.50	4000976.50	BP	100
441	BUFFT04	Buffalo	Tributary	04	Sneeds	3	Newton	472172.12	3990497.25	BP	100
244	BUFFT13	Buffalo	Tributary	13	Big	3	Newton	495709.59	3981030.75	BA, BP	80, 20
383	BUFFT15	Buffalo	Tributary	15	Davis	3	Newton	504216.16	3984923.25	BA, BP	80, 20
225	BUFFT16	Buffalo	Tributary	16	Mill Branch	3	Newton	504310.34	3984978.25	BP	100
378	BUFFT19	Buffalo	Tributary	19	Calf	3	Searcy	520463.22	3981045.50	BA, BP	80, 20

Appendix 3. Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified method for monitoring fish communities at Buffalo National River and Ozark National Scenic Riverways.—Continued

[UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983; BT, boat; BP backpack; BA, barge]

Stretch	Reach identification code	River basin	Site type	Site/ tributary number	Tributary name	Panel number (year)	County	UTM easting	UTM northing	Electrofishing gear used	Percent effort by gear
484	BUFFT28	Buffalo	Tributary	28	Boat	3	Marion	543933.19	3998512.25	BP	100
279	BUFFT01	Buffalo	Tributary	01	Smith	4	Newton	464098.72	3978179.75	BP	100
403	BUFFT06	Buffalo	Tributary	06	Glade	4	Newton	481332.88	3992648.50	BP	100
638	BUFFT10	Buffalo	Tributary	10	Wells	4	Newton	490814.66	3986624.00	BP	100
317	BUFFT11	Buffalo	Tributary	11	Rock	4	Newton	492478.22	3984111.00	BP	100
472	BUFFT20	Buffalo	Tributary	20	Bear	4	Searcy	526905.38	3983413.50	BT, BA, BP	20, 60, 20
574	BUFFT23	Buffalo	Tributary	23	Water	4	Searcy	538186.50	3989492.75	BA, BP	80, 20
229	BUFFT08	Buffalo	Tributary	08	Vanishing	5	Newton	489406.03	3989463.00	BP	100
367	BUFFT14	Buffalo	Tributary	14	Lick	5	Newton	499899.69	3983426.50	BP	100
304	BUFFT17	Buffalo	Tributary	17	Richland	5	Searcy	509734.38	3975988.00	BA, BP	80, 20
476	BUFFT27	Buffalo	Tributary	27	Clabber	5	Marion	540925.44	3998147.75	BA, BP	80, 20
366	BUFFT29	Buffalo	Tributary	29	Big	5	Marion	547400.69	3992751.25	BA, BP	80, 20
275	BUFFT32	Buffalo	Tributary	32	Cow	5	Marion	551138.19	3998892.75	BP	100
232	BUFFT18	Buffalo	Tributary	18	Slay Branch	Alternate	Searcy	514572.59	3979212.00	BP	100
694	BUFFT26	Buffalo	Tributary	26	Rush	Alternate	Marion	540617.75	39978810.50	BP	100
Ozark National Scenic Riverways											
14	CURRM01	Current	Mainstem	01		Annual	Shannon	623336.28	4141730.82	BA	100
35	CURRM02	Current	Mainstem	02		Annual	Shannon	637468.41	4131822.17	BT, BP	70, 30
42	CURRM03	Current	Mainstem	03		Annual	Shannon	643252.57	4126300.08	BT, BP	75, 25
67	CURRM04	Current	Mainstem	04		Annual	Shannon	661785.40	4111783.86	BT, BP	80, 20
71	CURRM05	Current	Mainstem	05		Annual	Shannon	666195.85	4111128.94	BT, BP	90, 10
97	CURRM06	Current	Mainstem	06		Annual	Carter	684220.63	4078321.12	BT, BP	90, 10
105	JACKM01	Jacks Fork	Mainstem	01		Annual	Shannon	619895.88	4101117.92	BT, BP	85, 15
114	JACKM02	Jacks Fork	Mainstem	02		Annual	Shannon	627768.31	4102604.03	BT, BP	80, 15, 5

Appendix 3. Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified method for monitoring fish communities at Buffalo National River and Ozark National Scenic Riverways.—Continued

[UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983; BT, boat; BP backpack; BA, barge]

Stretch	Reach identification code	River basin	Site type	Site/ tributary number	Tributary name	Panel number (year)	County	UTM easting	UTM northing	Electro-fishing gear used	Percent effort by gear
123	JACKM03	Jacks Fork	Mainstem	03		Annual	Shannon	633244.58	4108431.69	BA	100
907	JACKT01	Jacks Fork	Tributary	01	Flat Rock Hollow	1	Shannon	627068.19	4101683.25	BP	100
657	CURRT08	Current	Tributary	08	Rocky	1	Shannon	661958.31	4110833.50	BA, BP	90, 10
685	CURRT13	Current	Tributary	13	Mill	1	Carter	672241.31	4100790.25	BP	100
542	JACKT02	Jacks Fork	Tributary	02	Water Branch	2	Shannon	639856.63	4114033.50	BP	100
850	CURRT02	Current	Tributary	02	Sutton	2	Shannon	649132.00	4118740.25	BP	100
930	CURRT11	Current	Tributary	11	Chilton	2	Carter	673293.31	4103594.50	BP	100
494	CURRT07	Current	Tributary	07	Powder Mill	3	Shannon	662035.12	4116885.50	BP	100
695	CURRT09	Current	Tributary	09	Carr	3	Shannon	666007.31	4111876.50	BP	100
711	CURRT10	Current	Tributary	10	Thorny	3	Shannon	666068.69	4111169.25	BP	100
699	JACKT03	Jacks Fork	Tributary	03	Shawnee	4	Shannon	650824.38	4115207.50	BP	100
819	CURRT01	Current	Tributary	01	Shafer Spring	4	Dent	622056.00	4144309.50	BP	100
576	CURRT03	Current	Tributary	03	Thompson	4	Shannon	652336.88	4117663.00	BP	100
920	CURRT04	Current	Tributary	04	Prairie Hollow	5	Shannon	654127.81	4116782.50	BP	100
917	CURRT06	Current	Tributary	06	Blair	5	Shannon	659132.19	4116340.75	BP	100
950	CURRT12	Current	Tributary	12	Rogers	5	Carter	672338.69	4102176.50	BP	100
473	CURRT05	Current	Tributary	05	Thorny Hollow	Alternate	Shannon	657045.31	4115739.25	BP	100

Appendix 4. Comparison of selected characteristics of the NAWQA, EMAP, and RBP protocols and the Ozark Rivers Fish Community protocol.

[NAWQA = National Water-Quality Assessment program; EMAP = Environmental Montoring and Assessment Program; RBP = Rapid Bioassessment Protocol; X = times; GRTS = generalized random tesselation stratified sampling]

Characteristic	NAWQA	EMAP	RBP	Ozark Rivers Fish Community Protocol
Reach length minimum and maximum (meters)	150-1,000	150 (minimum)	Variable	150-1,000
Reach length relative to mean wetted channel width	20X	40X (wadeable streams), (40 to 100X for non-wadeable)	Variable	20X
Time limit (hours)	None specified	0.75 to 3	Not specified	None specified
Number of electrofishing passes	2	1	1	Wadeable, 1; non-wadeable, 2
Electrofishing gear	Backpack, barge, or boat as appropriate	Backpack or boat as appropriate	Backpack or barge as appropriate	Backpack, barge, or boat as appropriate
Block nets	No	Optional	Optional	No
Seining	Optional (electrofishing and one or more other methods used)	Optional	No	Standard and kick seine
Length-weight measurements	30 per species	30 per species	Optional, not required	30 per species
Recording of anomalies	Yes	Yes	Yes	Yes
Selection of reach location (general)	Professional judgment	Randomized, systematic design	Professional judgment	GRTS
Selection of reach boundary	Relative to riffle, run, pool[1]	Randomized, systematic design	Professional judgment	Bottom of reach is top of second riffle upstream from bottom of stream area selected by GRTS
Other	--	Option to subsample between transects (wadeable streams)	Fish less than 20 millimeters total length not included	--
Other	--	Subsampled between transects (non-wadeable streams)	Several potential metrics listed	--

[1]One-half of mean wetted channel width downstream or upstream from a riffle, run, or pool boundary. Generally selected to include multiple runs, riffles, and pools.

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

				Habitat preference				Spawning preference			
Common name	Scientific name	References	Tole-rance	Riffle	Pool	Run or main channel	Back-water	Broad-caster	Simple nester	Com-plex nester	Migra-tory
American brook lamprey (ammocoete)	*Lampetra appendix*	a, g	Unk		X		X				
American brook lamprey adult	*Lampetra appendix*	a, b, c, g	I	X					X		X
American eel	*Anguilla rostrata*	b, g, j	M-T		X		X				
Arkansas saddled darter	*Etheostoma euzonum*	g	Unk	X							
Banded darter	*Etheostoma zonale*	b, c, d, g	I	X				X			
Banded sculpin	*Cottus carolinae*	b, d, g	M	X						X	
Bigeye chub	*Hybopsis amblops*	b, d, g	I-M		X	X		X			
Bigeye shiner	*Notropis boops*	d, g, i	I		X			X			
Bigmouth buffalo	*Ictiobus cyprinellus*	c, g, h	M		X	X	X	X			
Black buffalo	*Ictiobus niger*	c, g, h	M-I		X		X	X			
Black bullhead	*Ameiurus melas*	a, b, c, g	M-T		X		X			X	
Black crappie	*Pomoxis nigromaculatus*	a, b, c, g	M		X		X			X	
Black redhorse	*Moxostoma duquesnei*	b, c, d, g	I			X		X			X
Blackside darter	*Percina maculata*	a, b, c, g	M		X			X			X
Blackspotted topminnow	*Fundulus olivaceus*	d, g, h	M		X		X	X			
Blacktail shiner	*Cyprinella venusta*	d, g, h	Unk			X			X		
Bleeding shiner	*Luxilus zonatus*	g, j, k	Unk								
Bluegill	*Lepomis macrochirus*	a, b, c, g	M-T		X					X	
Blue sucker	*Cycleptus elongatus*	c, d, g	I			X		X			X
Bluntnose minnow	*Pimephales notatus*	b, c, d, g	T		X		X			X	
Brindled madtom	*Noturus miurus*	d, g, h	I-M		X					X	
Brook silverside	*Labidesthes sicculus*	b, c, g	M-I		X			X			
Brown trout	*Salmo trutta*	c, g	M-I		X				X		X
Carmine shiner (traits from rosyface shiner)	*Notropis percobromus*	a, c, d, g	I		X	X			X		
Central stoneroller	*Campostoma anomalum*	b, c, d, g	M-T	X	X	X			X		X
Chain pickerel	*Esox niger*	b, d, g	M		X			X			
Channel catfish	*Ictalurus punctatus*	b, c, g	M		X	X				X	
Checkered madtom	*Noturus flavater*	g, j, k	Unk								
Chestnut lamprey adult	*Ichthyomyzon castaneus*	a, c, g, k	M			X			X		
Common carp	*Cyprinus carpio*	b, c, g	T		X			X			
Creek chub	*Semotilus atromaculatus*	b, c, d, g	T		X				X		

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**References**	**Tole-rance**	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Com-plex nester**	**Migra-tory**
Creek chubsucker	*Erimyzon oblongus*	b, c, d, g	M-T-I		X			X			X
Current darter (traits from orangethroat darter)	*Etheostoma uniporum*	d, g, k	M		X	X			X		
Cypress darter	*Etheostoma proeliare*	d, g, h	M		X		X		X		
Duskystripe shiner	*Luxilus pilsbryi*	g, j, k	Unk		X	X					
Emerald shiner	*Notropis atherinoides*	b, c, d, g	M		X	X		X			
Fantail darter	*Etheostoma flabellare*	b, c, d, g	M	X						X	
Fathead minnow	*Pimephales promelas*	b, c, g	T		X					X	
Flathead catfish	*Pylodictis olivaris*	b, c, g	M		X					X	
Flier	*Centrarchus macropterus*	b, d, g, i	M		X		X			X	
Freckled madtom	*Noturus nocturnus*	d, g, h	M-I	X		X				X	
Freshwater drum	*Aplodinotus grunniens*	b, g	M		X		X	X			
Goldfish	*Carassius auratus*	c, g, i	T		X		X	X			
Gilt darter	*Percina evides*	b, c, g	I	X				X			
Gizzard shad	*Dorosoma cepedianum*	b, c, d, g	M-T		X	X		X			
Golden redhorse	*Moxostoma erythrurum*	a, b, c, d, g	M-I		X			X			X
Golden shiner	*Notemigonus crysoleucas*	b, c, d, g	T		X		X	X			
Goldeye	*Hiodon alosoides*	a, c, g	I		X		X	X			
Gravel chub	*Erimystax x-punctatus*	c, g, j	M-I	X		X		X			
Green sunfish	*Lepomis cyanellus*	a, b, c, g	T-M		X		X			X	
Greenside darter	*Etheostoma blennioides*	b, d, g	M-I	X					X		
Highfin carpsucker	*Carpiodes velifer*	c, d, g	I-M		X		X	X			X
Horneyhead chub	*Nocomis biguttatus*	a, c, g	I-M	X	X				X		
Johnny darter	*Etheostoma nigrum*	b, c, d, g	M		X					X	
Lake chubsucker	*Erimyzon sucetta*	b, d, g	M		X		X	X			
Largemouth bass	*Micropterus salmoides*	a, b, c, g	M-T		X		X			X	
Largescale stoneroller	*Campostoma oligolepis*	c, g, h, k	M	X		X			X		X
Least brook lamprey adult	*Lampetra aepyptera*	b, g, j, k	M-I	X					X		
Least brook lamprey ammocoete	*Lampetra aepyptera*	g	Unk		X		X				
Logperch	*Percina caprodes*	b, c, g, j	M					X			
Longear sunfish	*Lepomis megalotis*	b, g, h	I-M		X					X	
Longnose gar	*Lepisosteus osseus*	a, c, g	M		X		X	X			
Mississippi silvery minnow	*Hybognathus nuchalis*	c, d, g	M-I		X		X	X			

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

				Habitat preference				Spawning preference			
Common name	Scientific name	References	Tolerance	Riffle	Pool	Run or main channel	Backwater	Broadcaster	Simple nester	Complex nester	Migratory
Mooneye	*Hiodon tergisus*	c, g, i	I		X		X	X			
Mountain madtom	*Noturus eleutherus*	b, d, g, k	I	X		X				X	
Mud darter	*Etheostoma asprigene*	d, g, i	M			X				X	
Northern hog sucker	*Hypentelium nigricans*	a, c, d, g	I-M	X		X		X			
Northern studfish	*Fundulus catenatus*	b, d, g, i	I				X	X			
Orangespotted sunfish	*Lepomis humilis*	c, d, g	M		X					X	
Orangethroat darter	*Etheostoma spectabile*	d, g, k	M		X	X			X		
Ozark bass	*Ambloplites constellatus*	b, g, l	Unk		X					X	
Ozark chub (traits from streamline chub)	*Erimystax harryi*	b, d, g	I		X	X		X			
Ozark madtom	*Noturus albater*	g, j, k	Unk	X	X						
Ozark minnow	*Notropis nubilus*	c, g, j	I		X		X		X		
Ozark sculpin	*Cottus hypselurus*	g, j, k	Unk	X							
Ozark shiner	*Notropis ozarcanus*	g, k	Unk		X	X					
Paddlefish	*Polyodon spathula*	b, g, h	I			X		X			X
Pealip redhorse (traits from shorthead redhorse)	*Moxostoma pisolabrum*	b, c, d, g	M	X	X	X		X			X
Pirate perch	*Aphredoderus sayanus*	b, c, d, g	M		X		X			X	
Pugnose minnow	*Opsopoeodus emiliae*	a, d, g, k	I				X			X	
Quillback	*Carpiodes cyprinus*	b, c, g	M-T		X		X	X			X
Rainbow darter	*Etheostoma caeruleum*	a, b, c, d, g	M-I	X	X				X		
Rainbow trout	*Oncorhynchus mykiss*	a, c, g	M-I	X	X				X		X
Redear sunfish	*Lepomis microlophus*	b, g, h	M		X		X			X	
Redfin pickerel	*Esox americanus*	a, c, g	M		X			X			
Redfin shiner	*Lythrurus umbratilis*	c, d, g	M-T		X				X		
Redspotted sunfish	*Lepomis miniatus*	d, g, h	Unk		X					X	
Ribbon shiner	*Lythrurus fumeus*	not listed	M								
River carpsucker	*Carpiodes carpio*	c, g, h	M		X		X	X			
River redhorse	*Moxostoma carinatum*	b, c, d, g	I		X	X			X		
Sauger	*Sander canadensis*	b, c, g	M		X	X	X	X			X
Shadow bass	*Ambloplites ariommus*	b, g, l	Unk		X					X	
Shortnose gar	*Lepisosteus platostomus*	c, d, g	M		X			X			
Shovelnose sturgeon	*Scaphirhyncus platorynchus*	c, d, g	M			X		X			
Silver redhorse	*Moxostoma anisurum*	b, c, d, g	M		X			X			X

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

				Habitat preference				Spawning preference			
Common name	Scientific name	References	Tole-rance	Riffle	Pool	Run or main channel	Back-water	Broad-caster	Simple nester	Com-plex nester	Migra-tory
Skipjack herring	*Alosa chrysochloris*	c, g, h	M			X		X			X
Slender madtom	*Noturus exilis*	c, d, g, i	I	X	X	X				X	
Smallmouth bass	*Micropterus dolomieu*	a, b, c, g	M-I		X	X				X	
Smallmouth buffalo	*Ictiobus bubalus*	c, d, g	M-I		X	X	X	X			
Southern cavefish	*Typhlichthys subterraneus*	not listed	Unk								
Southern redbelly dace	*Phoxinus erythrogaster*	c, d, g	M-I		X			X			
Speckled darter	*Etheostoma stigmaeum*	b, d, g	Unk		X	X			X		
Spotted bass	*Micropterus punctulatus*	b, d, g	M		X	X				X	
Spotted gar	*Lepisosteus oculatus*	d, g, i	M		X		X	X			
Spotted sucker	*Minytrema melanops*	c, d, g	M-I		X			X			
Stargarzing darter	*Percina uranidea*	b, d, g	I			X					
Steelcolor shiner	*Cyprinella whipplei*	b, d, g	M-I		X	X			X		
Stippled darter	*Etheostoma punctulatum*	g, j, k	Unk		X						
Striped shiner	*Luxilus chrysocephalus*	b, c, d, g	M-T		X		X		X		
Suckermouth minnow	*Phenacobius mirabilis*	b, c, d, g	M	X		X		X			X
Tadpole madtom	*Noturus gyrinus*	b, c, g, i	M-I		X		X			X	
Telescope shiner	*Notropis telescopus*	b, d, g	Unk		X	X					
Threadfin shad	*Dorosoma petenense*	b, d, g, h	M					X			
Walleye	*Sander vitreus*	b, c, g	M		X	X	X	X			X
Warmouth	*Lepomis gulosus*	b, d, g	M		X		X			X	
Wedgespot shiner	*Notropis greenei*	g, j	Unk		X	X					
Weed shiner	*Notropis texanus*	c, d, g	I		X	X		X			
Western mosquitofish	*Gambusia affinis*	d, g, i	M-T				X				
White bass	*Morone chrysops*	b, c, g	M-T		X			X			X
White crappie	*Pomoxis annularis*	b, c, g	M-T		X		X			X	
White sucker	*Catostomus commersoni*	b, c, d, g	T	X	X			X			X
Whitetail shiner	*Cyprinella galuctura*	b, d, g	Unk			X			X		
Yellow bullhead	*Ameiurus natalis*	a, b, c, g	T-M		X		X			X	
Yellow perch	*Perca flavescens*	a, b, c, g	M		X		X	X			
Yoke darter	*Etheostoma juliae*	g, j, k	Unk	X							

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

		Substrate preference					Trophic status				
Common name	Scientific name	Cobble/ rubble/ (rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vege- tation	Herbi- vore	Plank- tivore	Detri- tivore	Inver- tivore	Carni- vore
American brook lamprey (ammocoete)	*Lampetra appendix*				X		X				
American brook lamprey adult	*Lampetra appendix*	X	X	X							
American eel	*Anguilla rostrata*									X	X
Arkansas saddled darter	*Etheostoma euzonum*	X	X								
Banded darter	*Etheostoma zonale*		X							X	
Banded sculpin	*Cottus carolinae*	X	X							X	
Bigeye chub	*Hybopsis amblops*		X	X						X	
Bigeye shiner	*Notropis boops*	X								X	
Bigmouth buffalo	*Ictiobus cyprinellus*				X					X	
Black buffalo	*Ictiobus niger*										
Black bullhead	*Ameiurus melas*			X	X					X	X
Black crappie	*Pomoxis nigromaculatus*			X	X	X				X	X
Black redhorse	*Moxostoma duquesnei*	X	X	X						X	
Blackside darter	*Percina maculata*		X	X						X	
Blackspotted topminnow	*Fundulus olivaceus*		X	X			X			X	
Blacktail shiner	*Cyprinella venusta*			X						X	
Bleeding shiner	*Luxilus zonatus*	X								X	
Bluegill	*Lepomis macrochirus*					X				X	
Blue sucker	*Cycleptus elongatus*		X	X			X			X	
Bluntnose minnow	*Pimephales notatus*		X	X	X				X		
Brindled madtom	*Noturus miurus*		X	X	X					X	
Brook silverside	*Labidesthes sicculus*							X		X	
Brown trout	*Salmo trutta*	X								X	X
Carmine shiner (traits from rosyface shiner)	*Notropis percobromus*	X	X				X		X	X	
Central stoneroller	*Campostoma anomalum*	X					X				
Chain pickerel	*Esox niger*					X					X
Channel catfish	*Ictalurus punctatus*	X		X	X					X	X
Checkered madtom	*Noturus flavater*										
Chestnut lamprey adult	*Ichthyomyzon castaneus*	X	X								X
Common carp	*Cyprinus carpio*					X			X	X	
Creek chub	*Semotilus atromaculatus*	X		X						X	X

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

		Substrate preference					Trophic status				
Common name	**Scientific name**	**Cobble/ rubble/ (rocky)**	**Gravel**	**Sand**	**Mud (silt, clay detritus)**	**Vege- tation**	**Herbi- vore**	**Plank- tivore**	**Detri- tivore**	**Inver- tivore**	**Carni- vore**
Creek chubsucker	*Erimyzon oblongus*		X	X		X				X	
Current darter (traits from orangethroat darter)	*Etheostoma uniporum*		X							X	
Cypress darter	*Etheostoma proeliare*				X	X				X	
Duskystripe shiner	*Luxilus pilsbryi*	X								X	
Emerald shiner	*Notropis atherinoides*			X				X			
Fantail darter	*Etheostoma flabellare*	X	X							X	
Fathead minnow	*Pimephales promelas*			X	X				X	X	
Flathead catfish	*Pylodictis olivaris*									X	X
Flier	*Centrarchus macropterus*				X					X	
Freckled madtom	*Noturus nocturnus*		X	X						X	
Freshwater drum	*Aplodinotus grunniens*									X	X
Goldfish	*Carassius auratus*				X	X	X			X	
Gilt darter	*Percina evides*	X								X	
Gizzard shad	*Dorosoma cepedianum*						X				
Golden redhorse	*Moxostoma erythrurum*									X	
Golden shiner	*Notemigonus crysoleucas*						X			X	
Goldeye	*Hiodon alosoides*									X	
Gravel chub	*Erimystax x-punctatus*		X				X				
Green sunfish	*Lepomis cyanellus*					X				X	X
Greenside darter	*Etheostoma blennioides*	X								X	
Highfin carpsucker	*Carpiodes velifer*		X	X					X		
Horneyhead chub	*Nocomis biguttatus*	X	X				X			X	
Johnny darter	*Etheostoma nigrum*			X	X					X	
Lake chubsucker	*Erimyzon sucetta*			X	X		X			X	
Largemouth bass	*Micropterus salmoides*			X	X	X				X	X
Largescale stoneroller	*Campostoma oligolepis*	X					X				
Least brook lamprey adult	*Lampetra aepyptera*		X	X							
Least brook lamprey ammocoete	*Lampetra aepyptera*				X		X				
Logperch	*Percina caprodes*		X	X							
Longear sunfish	*Lepomis megalotis*	X		X		X				X	
Longnose gar	*Lepisosteus osseus*					X					X
Mississippi silvery minnow	*Hybognathus nuchalis*			X					X		

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

		Substrate preference					Trophic status				
Common name	Scientific name	Cobble/ rubble/ (rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vege- tation	Herbi- vore	Plank- tivore	Detri- tivore	Inver- tivore	Carni- vore
Mooneye	*Hiodon tergisus*									X	
Mountain madtom	*Noturus eleutherus*	X	X							X	
Mud darter	*Etheostoma asprigene*		X	X						X	
Northern hog sucker	*Hypentelium nigricans*	X	X				X			X	
Northern studfish	*Fundulus catenatus*			X						X	
Orangespotted sunfish	*Lepomis humilis*					X				X	
Orangethroat darter	*Etheostoma spectabile*		X							X	
Ozark bass	*Ambloplites constellatus*	X								X	X
Ozark chub (traits from streamline chub)	*Erimystax harryi*	X	X								
Ozark madtom	*Noturus albater*	X								X	
Ozark minnow	*Notropis nubilus*	X	X				X				
Ozark sculpin	*Cottus hypselurus*		X			X				X	
Ozark shiner	*Notropis ozarcanus*	X		X						X	
Paddlefish	*Polyodon spathula*							X		X	
Pealip redhorse (traits from shorthead redhorse)	*Moxostoma pisolabrum*		X							X	
Pirate perch	*Aphredoderus sayanus*				X	X				X	X
Pugnose minnow	*Opsopoeodus emiliae*					X		X	X		
Quillback	*Carpiodes cyprinus*		X	X					X	X	
Rainbow darter	*Etheostoma caeruleum*	X	X							X	
Rainbow trout	*Oncorhynchus mykiss*		X							X	X
Redear sunfish	*Lepomis microlophus*			X	X					X	
Redfin pickerel	*Esox americanus*					X				X	X
Redfin shiner	*Lythrurus umbratilis*				X						
Redspotted sunfish	*Lepomis miniatus*			X	X					X	
Ribbon shiner	*Lythrurus fumeus*										
River carpsucker	*Carpiodes carpio*			X	X		X	X			
River redhorse	*Moxostoma carinatum*	X	X							X	
Sauger	*Sander canadensis*		X	X	X					X	X
Shadow bass	*Ambloplites ariommus*		X	X	X					X	X
Shortnose gar	*Lepisosteus platostomus*										X
Shovelnose sturgeon	*Scaphirhyncus platorynchus*		X	X						X	
Silver redhorse	*Moxostoma anisurum*									X	

Appendix 5. Fish species known to occur in Buffalo National River and Ozark National Scenic Riverways classified by tolerance and by habitat, spawning, substrate, and trophic preference.—Continued

[modified from Goldsteain and Meader (2004); tolerance values are from Barbour and others (1999); Unk is unknown; I is intolerant, M is moderate tolerance, T is tolerant, first tolerance value is greatest consensus]

Common name	Scientific name	Substrate preference					Trophic status				
		Cobble/ rubble/ (rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vege-tation	Herbi-vore	Plank-tivore	Detri-tivore	Inver-tivore	Carni-vore
Skipjack herring	*Alosa chrysochloris*		X	X				X			
Slender madtom	*Noturus exilis*		X						X	X	
Smallmouth bass	*Micropterus dolomieu*		X							X	X
Smallmouth buffalo	*Ictiobus bubalus*						X			X	
Southern cavefish	*Typhlichthys subterraneus*										
Southern redbelly dace	*Phoxinus erythrogaster*		X					X			
Speckled darter	*Etheostoma stigmaeum*		X	X							
Spotted bass	*Micropterus punctulatus*		X							X	X
Spotted gar	*Lepisosteus oculatus*										X
Spotted sucker	*Minytrema melanops*			X	X					X	
Stargarzing darter	*Percina uranidea*		X							X	
Steelcolor shiner	*Cyprinella whipplei*	X		X						X	
Stippled darter	*Etheostoma punctulatum*	X								X	
Striped shiner	*Luxilus chrysocephalus*		X	X						X	
Suckermouth minnow	*Phenacobius mirabilis*	X	X	X						X	
Tadpole madtom	*Noturus gyrinus*	X			X			X		X	
Telescope shiner	*Notropis telescopus*	X								X	
Threadfin shad	*Dorosoma petenense*							X			
Walleye	*Sander vitreus*									X	X
Warmouth	*Lepomis gulosus*				X	X				X	X
Wedgespot shiner	*Notropis greenei*	X	X	X							
Weed shiner	*Notropis texanus*			X		X			X		
Western mosquitofish	*Gambusia affinis*									X	
White bass	*Morone chrysops*									X	X
White crappie	*Pomoxis annularis*			X	X					X	X
White sucker	*Catostomus commersoni*	X	X				X		X		
Whitetail shiner	*Cyprinella galuctura*	X								X	
Yellow bullhead	*Ameiurus natalis*			X	X	X				X	X
Yellow perch	*Perca flavescens*					X				X	X
Yoke darter	*Etheostoma juliae*	X								X	

Appendix 6. Metrics used in an index of biotic integrity for midwestern streams.

[From Karr (1981)]

Metric classification	Metric description
Richness	
	Total number of fish species
	Number and identity of darter species[1]
	Number and identity of sunfish species
	Number and identity of sucker species[1]
Tolerance	
	Proportion of individuals as green sunfish
	Number and identity of intolerant species
Trophic	
	Proportion of individuals as omnivores
	Proportion of individuals as invertivorous cyprinids[1]
	Proportion of individuals as piscivores
Density	
	Number of individuals in sample
Incidence of disease/hybridization	
	Proportion of individuals as hybrids
	Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

[1]This metric could also be classified under "Tolerance". In the Ozarks these groups generally represent intolerant species.

Appendix 7. Metrics modified from the original index of biotic integrity (Karr, 1981) for use on the Current River in southeastern Missouri.

[From Hoefs (1989)]

Metric classification	Metric description
Richness	
	Total number of fish species
	Number and identity of sunfish and water-column cyprinid species
	Number and identity of sucker and minnow species[1]
	Number and identity of darter, sculpin, and round bodied sucker species[1]
Tolerance	
	Proportion of individuals as green sunfish
	Number and identity of intolerant species
Trophic	
	Proportion of individuals as omnivores
	Proportion of individuals as invertivorous cyprinids[1]
	Proportion of individuals as piscivores
Spawning preference	
	Proportion of individuals as lithophilic spawners[1]

[1] This metric could also be classified under "Tolerance." In the Ozarks these groups generally represent intolerant species.

Appendix 8. Metrics modified from the original index of biotic integrity (Karr, 1981) for use in Missouri streams by the Missouri Department of Conservation.

[From Matt Combes, Missouri Department of Conservation, written commun., 2004]

Metric classification	Metric description
Richness	
	Number of native taxa
	Number of native minnow taxa[1]
	Number of native centarchid taxa
	Number of native watercolumn taxa
	Number of benthic taxa[1]
	Number of native longlived taxa[1]
Density	
	Catch per unit effort for native individuals
Tolerance	
	Percent of tolerant taxa
Trophic	
	Percent omnivore/herbivore
	Percent carnivore
	Percent invertivore

[1]This metric could also be classified under “Tolerance”. In the Ozarks these groups generally represent tolerant species.

Appendix 9. Metrics selected for an index of biotic integrity for wadeable streams in the Ozark Highlands.

[From Dauwalter and others (2003)]

Metric classification	Metric description
Tolerance	
	Number of darter, sculpin, and madtom species[1]
	Percent green sunfish, bluegill, yellow bullhead, and channel catfish[2]
Trophic	
	Percent (of individuals) as algivorous/herbivorous, invertivorous, and piscivorous
	Percent invertivores[3]
	Percent top carnivores
Spawning preference	
	Number of lithophilic species[3]
Incidence of disease/hybridization	
	Percent of fish with black spot or anomaly

[1] This metric could also be classified under “Taxa Richness.” However, in the Ozarks these groups generally represent intolerant species.

[2] This metric could also be classified under “Taxa Richness.” However, in the Ozarks these groups generally represent intolerant species.

[3] This metric could also be classified under “Tolerance.” In the Ozarks these groups generally represent intolerant species.

Appendix 10. Equipment necessary for attended water-quality measurements.

[ºC, degrees Celsius; FS, full scale; NIST, National Institute of Standards and Technology: µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; cm, centimeters; mL, milliliters; ≥, greater than or equal to; %, percent; DO, dissolved oxygen]

pH, Specific Conductance, and Water Temperature

YSI® Model 63 pH, Conductivity, Temperature & Salinity Meter

Meter requirements for pH and conductivity (preferred)*

Battery powered with automatic temperature compensation (25ºC, range -5°C to 45ºC) and slope compensation.
Display: to 0.01 pH units, 0.1 µS/cm
Range: 0 to 14 pH units, 0 to 499 µS/cm
Resolution: 0.01 pH units, 0.1 µS/cm
Stabilization Criteria: ±0.1 pH units, ±0.5% FS
(variability/repeatability should be within the value shown)

*these specifications may differ for specific instruments but should be close to these values

YSI Model 63, Operations Manual, YSI Incorporated, December 2001**
Factory calibrated thermometer (liquid in glass or digital) traceable to NIST (not for field use) with a calibration point at 20°C, instrument accuracy: 0.1ºC
pH probe (gel filled probe is recommended for field use) and stand for probe
buffer solutions at pH 4, 7, 10 and pH probe storage solution and cap
Specific conductance standard within range of expected values (100-µS/cm to 1,000-µS/cm).
100-mL graduated cylinder and plastic beakers, assorted sizes

Dissolved Oxygen

YSI® Model 55 Dissolved Oxygen Meter

Meter requirements (preferred*):

Temperature readout display, temperature/pressure compensated
Operating range at least -5ºC to 45ºC
Measure concentrations ≥ 1 to 20-mg/L
Minimum scale readability preferred 0.05-mg/L
Instrument accuracy within 5% of actual value

*these specifications may differ for specific instruments but should be close to these values
YSI Model 55 Operations Manual, YSI Incorporated, August 1997 **.
(contains Oxygen solubility chart)
DO sensor membrane replacement kit (O-rings, membrane, filling solution)
Pocket altimeter-barometer (for Dissolved Oxygen calibration)
Calibration chamber

Turbidity and Air Temperature

Turbidity tube, 120 cm capacity (available from Wildlife Supply Company, www.wildco.com)

- Liquid-in-glass thermometer or digital thermometer for air temperature

General equipment/supplies

- Large container or plastic box for water bath, to hold 1 gallon of water
- Box filled with packing insulation
- Deionized water at room temperature and squeeze bottle
- Extra batteries
- Small soft brush
- Lint-free paper tissues
- Log books for recording calibrations, maintenance, and repair
- Data sheets on waterproof paper (see Appendix 13)

**All YSI manuals are available on-ling at: http://www.ysi.com

Appendix 11. Equipment necessary for unattended water-quality measurements.

- YSI 6920
- YSI 6600
- YSI 650 Display/Logger
- YSI 6091 Field cable
- YSI 6095B “Y” cable with DB-9 adapter (connects personal computer to field cable)
- Specific probes
    - YSI 6136 Turbidity Probe
    - YSI 6552 Dissolved-Oxygen Probe
    - YSI 6560 Conductivity/Temperature Probe
    - YSI 6561 pH probe
- Dissolved-oxygen sensor membrane replacement kit (O-rings, membrane, filling solution)
- Extra batteries, membranes, and filling solution
- Deionized water
- Calibration chamber
- Low dissolved-oxygen solution (~ 1 gram of anhydrous sodium sulfite and a few crystals of cobaltous chloride dissolved in 1 liter of distilled water (with little or no head space), prepared fresh before each use
- Probe guard
- Hydrolab
- YSI Environmental Operations Manual for YSI 6920 and YSI 6600 data sondes, YSI Incorporated, January 2002 located at http://www.ysi.com
- Log book for recording repairs, maintenance, and calibrations
- Data sheets on waterproof paper

Appendix 12. Equipment necessary for conducting fish monitoring at Buffalo National River and Ozark National Scenic Riverways.

General Equipment

Waders
Rain gear
Polarized glasses
Hats
Maps
Flagging
Stop watch
Collecting permits
Field guides
Camera
Tool box - hammer, wrench, pliers, screwdrivers
Volt/ohm meter
Electric winch
Flashlight
Wader repair kit
Battery charger for rechargeable batteries
Park radio and charger
Cell phone
Directions to hospital
First aide kit
Bug spray
Sun screen

Fish Sampling - Tributary and Shallow River

Backpack electrofishing unit
  backpack
  anode
  cathode
  batteries
  battery charger
Towed barge electrofishing unit
  barge
  generator
  pulse box
  anodes
  cathodes
  gas can with gas
  oil
Seine
Buckets
Tub for larger fish
Aerators (2)
  Batteries (rechargeable)
Dip nets
Electrofishing gloves

Fish Sampling - Deep River

Electrofishing unit boat w/ long handled dip-nets
  generator
  pulse box and cradle
  boom and cords
Seine
Canoe with paddles
Outboard motor and gas can
Gas can for generator
Extra motor oil
Personal floatation devices
Large tub or live well
Electrofishing gloves

Fish Processing Equipment

Flow through tank or instream pen for large fish
Aquarium nets
1 gallon jugs and 5 gallon buckets with lids
Knives, scalpel, scissors
Clipboard - pens, pencils, waterproof markers
Waterproof paper
Data sheets -Fish Sheet 2
Measuring board
Hanging scales
Weighing balance
  small scales and batteries (rechargeable)
  large scales and batteries (rechargeable)
Plastic container for balance
100 percent buffered formalin (37 percent buffered formaldehyde)
Tags for jars

Appendix 13. Equipment necessary to collect physical habitat data.

- Flow meter with wading rod
  - Batteries
- Digital depth sounder (to collect depth in large pools)
- Tape measure (100 meters)
- Range finder
  - 9-volt battery
- Survey rod (in meters)
- Heavy rope - 50 to 100 meters
- Clipboard with data forms
  - Instream habitat form
  - Fish cover form
  - Bank measurement form
- Instruction manuals for flow meter, range finder, and depth sounder
- Personal floatation devices

Appendix 14. Equipment necessary for collecting discharge data.

[°C, degrees Celsius]

FLO-MATE Model 2000 (Marsh-McBirney) velocity meter

Accuracy of ±2 percent operates in temperatures between 0 °C and 72 °C.

Tape measure (in increments of feet and/or meters)

Stakes for mounting tape measure if necessary

Top-setting wading rod (in increments of feet or meters)*

3-5 gallon bucket

Extra batteries (D alkaline)

Carrying case

Log book

Data sheets on waterproof paper

Instruction Manual for the Flo-Mate model 2000 portable flowmeter.

Marsh-McBirney Inc., Frederick, Maryland 21704-9452

**Standard wading rods come in both metric and English standard units.*

Discharge measurements are generally recorded in English units as cubic feet per second.

Whatever units are used, ensure that there is consistency between the settings on the velocity meter, the wading rod, and the tape measure and that the units are clearly recorded on the data sheet.

Appendix 15. Fish community field forms for recording environmental conditions and reach location.

Fish Community Field Data Sheet 1 Page ___ of ___

Reach ID:________________ Date:___________ Reach Length(m):_______ Stretch #:_____
Recorder:______________ Reach Description: ____________________________________
____
____

Weather Conditions: Cloud cover:_______% Wind: *Calm* *Light* *Moderate* *Gusty*
Precipitation: *None* *Rain* *Sleet* *Snow* Intensity: *N/A* *Light* *Moderate* *Heavy*
Other Weather:____

Reach Data:
Fish Reach Coordinates: Lower UTM Coordinates ________________ ______________
Upper UTM Coordinates ________________ ______________

Discharge (m^3/s):__________ (record points on Discharge datasheet & transfer total discharge here)

Beginning Measurements:

Time	
Water Temperature (°C)	
Air Temperature (°C)	
pH	
Specific Conductance (µS/cm)	
Conductivity (µS/cm)	
Dissolved Oxygen (mg/L)	

Ending Measurements:

Time	
Water Temperature (°C)	
Air Temperature (°C)	
pH	
Specific Conductance (µS/cm)	
Conductivity (µS/cm)	
Dissolved Oxygen (mg/L)	

Additional Comments:____
____
____
____

	Date	Initials
Data Entered		
Data Verified		

Appendix 16. Fish community field forms for recording individual fish data.

page ___ of ___

Fish Community Data Sheet 2

Reach ID:____________ Date: ____________ IDed by: ____________ Recorder: ____________

Gear: *Backpack Barge Boat Seine* Habitat: *Main Channel Backwater/Side Channel Other* ____________

Effort (sec.): _________ No. Seine Hauls: _________ Seine Reach Length (m): _________ Crew: *Shocker(s):* _______
Boat/Barge: _______
Netter(s): _________

Anomalies: D = deformities, E = Eroded fins, L = lesions, T = tumors, B = blacksport

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Species:				
TL (mm)	Wt (g)	Anom	Vchrd	Cmts
			Species Count:	

Appendix 17. Data sheet for collecting instream habitat data.

Instream Habitat Assessment Form **Page ____ of ____**

Reach ID: Stretch No: Date: Crew:

Reach Length: Transect Spacing Interval (reach length / 10): Channel : Main Side Backwater

Trans	Channel Unit	Pool Form	Width (m)	Depth (cm)	Velocity (m/sec)	Dominant ** Substrate	Embeddedness	Canopy Cover
1*				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
2				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
3				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
4				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
5				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
6				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
7				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
8				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
9				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
10				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt
11				Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt	Lt Ctr Rt

CHANNEL UNIT CODES		POOL FORM CODES		Embeddedness & Canopy Cover
GL	Glide	**B**	Backwater Pool	0 = Absent (0%)
RI	Riffle	**F**	Bluff Pool	1 = Sparse (<10%)
RU	Run/Race	**I**	Impoundment	2 = Moderate (10-40%)
PO	Pool	**L**	Lateral Pool	3 = Heavy (40-75%)
RRX	Riffle-Run complex	**M**	Mid-Channel Pool	4 = Very Heavy (>75%)
PGX	Pool-Glide complex	**O**	Obstruction Pool	**(Canopy within 1m on each side of transect)**

Transects are equally spaced as determined by dividing the reach length by 10.

***Transect 1 is located at the downstream end of the reach; Transect 11 is located at the upstream end of the reach**

**** Dominate substrate is average substrate within a 10 cm diameter circle around the point where depth is taken**

Appendix 17 Continued.

Embeddedness is assessed within a 10 cm diameter circle around point

Channel Unit Types

Riffle An area of the stream with steepest slope and shallowest depth, often rocky substrate, and swift current.
Thalweg is usually poorly defined.

Run Differ from riffles in that depth of flow is typically greater and slope of the bed is less than that of riffles.
Runs will often have a well defined thalweg.
Runs sometimes are referred to as races.

Glide Normally located immediately downstream from pools and upstream from riffles.
The slope of the channel bed through a glide is negative while the slope of the water surface is positive.
The head of the glide can be difficult to identify. Use these characteristics to help locate the head of the glide:

- the location of increased flow velocity coming out of the pool
- the location at which the steeply sloped bed rising out of the pool decreases to a lesser gradient
- the location at which the thalweg coming out of the pool becomes less defined and fades completely
- the location at which elevation is approximately the same elevation as the tail of the run.

Pool. Has a relatively slow current and is usually found at stream channel bends, upstream from riffles, or on the downstream side of obstructions such as boulders or fallen trees.
The stream bottom in a pool is often bowl shaped and represents the deepest locations of the reach.
Water-surface slope of pools at below bankfull flows is zero.

For pools, indicate the pool form type.

Riffle/Run Complex This code is recorded when a portion of the channel is a riffle habitat (shallow, fast turbulent flow, large substrate) and the other portion is run habitat (deeper and fast but not turbulent flow).
This type of habitat unit is typically formed by instream gravel bars.

Pool/Glide Complex This code is recorded when a pool is transitioning into a glide.
Because the head of a glide is difficult to identify, use this code if unsure about the exact location of the glide.

Appendix 18. Data sheets for collecting fish cover data

Fish Cover Form **Page ____ of ____**

Reach ID: Stretch No.: Date: Crew:

Reach Length: Transect Spacing Interval: Channel: Main Side Backwater

		Fish Cover*										
Trans.		**Circle all cover types present.**										Comment
1	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
2	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
3	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
4	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
5	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
6	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
7	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
8	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
9	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
10	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
11	Lt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	
	Ctr	FA	HY	BO	AR							
	Rt	FA	HY	BO	AR	SWD	LWD	T/R	OV	UC	BL	

Fish Cover Types*

FA = Filamentous Algae
HY = Hydrophytes & Mosses
BO = Boulders
AR = Artificial
SWD = Small Woody Debris
LWD = Large Woody Debris
T/R = Trees/Roots
OV = Overhanging Vegetation
UC = Undercut bank
BL = Bluff within 5 m of water

Additional comments:

FA, HY, BO, AR are assessed within a 10-cm diameter circle around each point on transect
SWD is < 10 cm in diameter at largest end; LWD is >10 cm at largest end
SWD & LWD assessed on a 1-m belt along transect on left and right side of center channel
T/R, OV, UC, BL are assessed within 1 m on either side of transect along bank

10 cm or 0.1 m

Appendix 19. Data sheets for collecting bank measurement data.

Bank Measurment Form

Reach ID: Stretch No: Date: Crew:

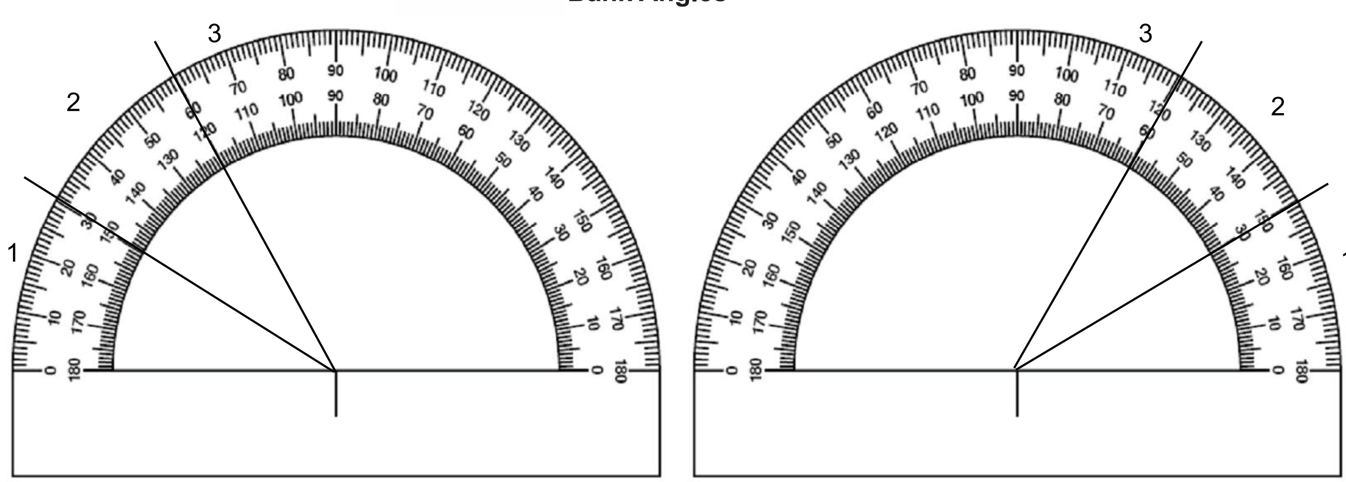
Reach Length: Transect Spacing Interval: Channel: Main Side Backwater

		Bank Stability				Bank Cover*					
Trans.		Angle	Veg	Height	Sub	Circle Dominant (>50%) Cover					Comment
1	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
2	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
3	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
4	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
5	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
6	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
7	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
8	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
9	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
10	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	
11	Lt					TR	SH	GR	BA	AR	
	Rt					TR	SH	GR	BA	AR	

***Bank cover is assessed within 1 m on each side of transect and 10 m up the bank from wetted edge**

Bank Angle, Degrees	Vegetative Cover (%)	Height (m)	Substrate	Bank Cover Types*
1 = 0 - 30	1 = >80	1 = 0-1	1 = Bedrock/Artificial	TR = Large trees (> 3 in. dbh)
2 = 31-60	2 = 50-80	2 = 1.1-2	2 = Boulder/Cobble	SH = Small trees and shrubs
3 = >60	3 = 20-49	3 = 2.1-3	5 = Silt	GR = Grass and Forbes
	4 = <20	4 = 3.1-4	8 = Sand	BA = Bare rock/sediment
		5 = >4	10 = Gravel/Sand	AR = Artificial

Bank Angles



Appendix 20. Data sheet for collecting discharge data.

Discharge

Park: ____________________ **Stream name:** ____________________ **Reach ID** ____________________

Date: ____________________ **Time:** ___________________________ **Crew Initials:** ________________

Stream width: _____________ **ft or m** **Meter used:** _______________________________________

Interval	Tap Measure Reading	Interval Width *ft or meters*	Depth *ft or meters*	Velocity *ft/s or m/s*
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Notes:

Publishing support provided by:
Lafayette and Rolla Publishing Service Centers

For more information concerning the research described in the report:

U.S. Geological Survey
Arkansas Water Science Center
401 Hardin Road
Little Rock, AR 72211-3528
(501) 228-3600

http://ar.water.usgs.gov

Petersen and others—**Methods for Monitoring Fish Communities** —Open-File Report 2007–1302