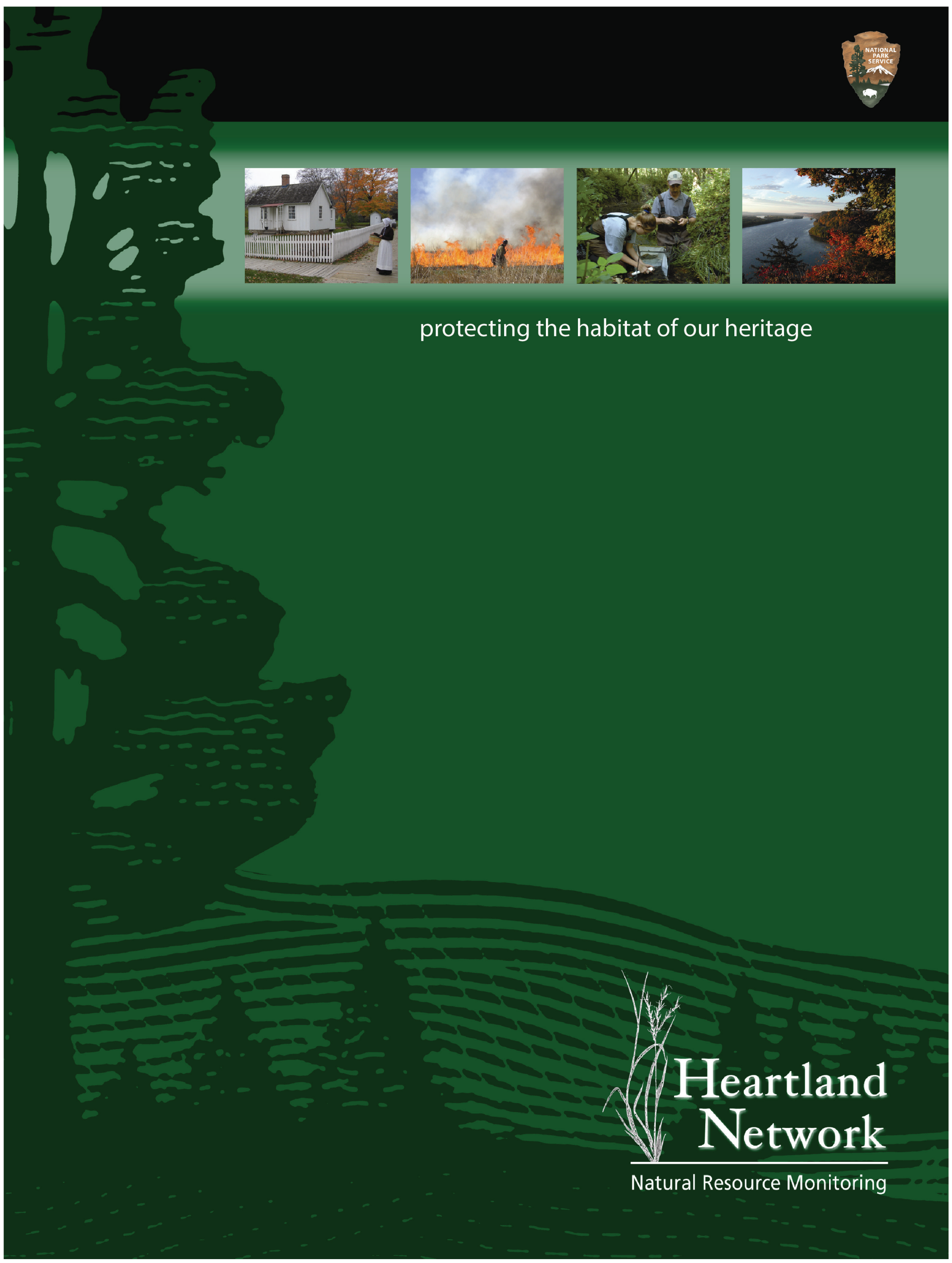
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri, Version 2.0

Natural Resource Report NPS/HTLN/NRR—2018/1633



ON THE COVER
From left to right: Herbert Hoover's birthplace cottage at Herbert Hoover National Historic Site, prescribed burn at Tallgrass Prairie National Preserve, aquatic invertebrate sampling at George Washington Carver National Monument, and Mississippi River at Effigy Mounds National Monument.
Photography by NPS.

Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri, Version 2.0

Natural Resource Report NPS/HTLN/NRR—2018/1633

Hope R. Dodd,[1] James C. Petersen,[2] B. G. Justus,[2] David E. Bowles,[1] Gareth Rowell,[1] Lloyd Morrison,[1] Janice A. Hinsey,[1] Jeffrey M. Williams[1]

[1]National Park Service
Heartland I&M Network
Wilson's Creek National Battlefield
6424 West Farm Road 182
Republic, Missouri 65738

[2]U. S. Geological Survey
Lower Mississippi-Gulf Water Science Center
401 Hardin Road
Little Rock, Arkansas 72211

Editing and Design by

Tani Hubbard

National Park Service &
Northern Rockies Conservation Cooperative
12661 E. Broadway Blvd.
Tucson, AZ 85748

May 2018

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information. Peer review was conducted by two independent U.S. Geological Survey scientists, the Regional I&M Network manager, and an outside agency (non-NPS) reviewer.

This report is available from Heartland I&M Network website, and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Dodd, H. R., J. C. Petersen, B. G. Justus, D. E. Bowles, L. W. Morrison, G. A. Rowell, J. A. Hinsey, and J. M. Williams. 2018. Methods for monitoring fish communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri, Version 2.0. Natural Resource Report NPS/HTLN/NRR—2018/1633. National Park Service, Fort Collins, Colorado.

NPS 173/145004, 614/145004, May 2018

Contents

Figures

Tables

Appendices

Abstract

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

The protocol includes (1) a protocol narrative, (2) supplemental information helpful for implementation of the protocol (in appendices), and (3) standard operating procedures published as separate stand-alone documents. The protocol narrative provides background information pertaining to 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, measurement of 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 (USGS) National Water Quality Assessment (NAWQA) program and the NPS Heartland I&M Network (HTLN) program. Supplemental information that would be helpful for implementing the protocol is included in the appendices of this narrative. This information includes information on fish species known or suspected to occur in the parks, sample sites, sample design, fish species traits, and index of biotic integrity metrics.

Acknowledgments

We would like to thank the staff at BUFF and OZAR for their review of the original protocol (Version 1.0, Petersen et al. 2008) and for their advice, council, and review of protocol revisions presented in DeBacker et al. (2012) which are incorporated in this protocol (Version 2.0). We particularly want to thank Victoria Grant and Mike Gossett from OZAR and Faron Usrey from BUFF. We would also like to acknowledge Tyler Cribbs from HTLN and the many interns, technicians, and volunteers who assisted with the collection of data used to reevaluate the original protocol. Thanks also to the peer reviewers of this protocol version (Version 2.0).

Acronyms

AGFC	Arkansas Game and Fish Commission
BUFF	Buffalo National River
DOI	Department of the Interior
DOQQ	Digital Ortho-quarter Quadrangles
DRQ	Digital Raster Graphic
EMAP	Environmental Monitoring and Assessment Program (EPA)
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
GRTS	General Random Tessellation Stratified method
HTLN	Heartland Inventory and Monitoring Network
IBI	Index of Biological Integrity
I&M	Inventory and Monitoring
IMD	Inventory and Monitoring Division (NPS)
IRMA	Integrated Resource Management Applications (NPS)
MDC	Missouri Department of Conservation
MORAP	Missouri Resource Assessment Partnership
MWSW	Mean Wetted Stream Width
NAWQA	National Water Quality Assessment program
NHD	National Hydrography Dataset
NPS	National Park Service
OZAR	Ozark National Scenic Riverways
QA/QC	Quality Assurance/Quality Control
RBPs	Rapid Bioassessment Protocols (EPA)
SOP	Standard Operating Procedure
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VST	Valley Segment Type

Protocol Revision

The Protocol Narrative is a general overview on the background and justification for the monitoring project and an overview of sampling design and methodology. Revisions to this Protocol Narrative may be necessary for several reasons, such as changes in temporal design (how often sites are visited) or spatial design (what sites are visited). However, changes to the Narrative will be infrequent. Documentation of protocol revisions is mandatory for maintaining consistency in data collection and analysis between the earlier and the revised version. The purpose for publishing the Protocol Narrative separately from the Standard Operating Procedures (SOPs) is to organize the protocol such that minor changes to SOPs do not require a revision of the entire protocol. SOPs contain more detailed information on completing tasks required for monitoring and may need to be revised more frequently than the Protocol Narrative (see SOP 12 for details on revising SOPs). Therefore, revisions to SOPs will not require revision of the Protocol Narrative unless major changes are made that affect study design or methodology.

All versions of the Protocol Narrative and SOPs must be archived in a protocol library on NPS IRMA Data Store (https://irma.nps.gov/Portal). A history log of changes to the Protocol Narrative will be maintained under this Protocol Revision section. 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 Narrative will increase by 0.1 for minor revisions and by 1.0 for major revisions. Minor changes will require internal review by HTLN staff, and major revisions will require an outside review by regional NPS staff and experts from other agencies familiar with fish community monitoring.

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 that may require changes in database design or analytical procedures.

Protocol Narrative Revision Log

Revision Recommendations based on HTLN start-up review

In August 2008, a start-up review was conducted for the HTLN. Several recommendations were made by the review panel regarding aquatic vital signs monitoring (Fancy et al. 2008). The network recognized that the level of monitoring (number and scope of vital signs) described in the vital signs monitoring plan (DeBacker et al. 2005) was too ambitious with current staffing and funding levels. The review panel agreed that the network was operating on a "razor-thin margin" with little opportunity for making adjustments in the event of staff turnover, equipment failures, poor weather, or other events that must be expected with any long-term monitoring program. The review panel concurred with the network's efforts to trim costs and make field efforts more efficient. Several measures to reduce the work load and make the program sustainable were recommended. For aquatic vital signs, the following recommendations were made:

- Do not implement the geomorphic vital signs protocol that was delivered by a contractor and seems to be impractical. Instead, incorporate a few simple geomorphic measures into the aquatic macroinvertebrate and/or fish protocols
- Defer the monitoring of Hellbenders by network staff given the rareness and difficulty of obtaining adequate data, and the difficulty in interpreting the monitoring results (very low potential benefit considering the cost and difficulty of monitoring this very rare species)
- Evaluate staffing for the aquatics program, which seems to be stretched too thin and is behind schedule on getting some of the routine reports out. The network might also want to consider cutting back on the sample size or number of measures for some of the aquatics protocols until additional funding or staff can be found.

Based on the HTLN start-up review recommendations, HTLN staff conducted a thorough assessment of alternatives for reaching sustainable operations. DeBacker et al. (2012) described the results of our assessments and recommended specific changes to the revisit design and some minor field method and analytical adjustments. This document was reviewed by park staff at OZAR and BUFF and by non-NPS reviewers. The final report was approved for publication by the Heartland Board of Directors and Midwest Region I&M Program Manager on August 17, 2012. Changes described below detail revisions to Version 1.0 of the Protocol Narrative. The new version is Version 2.0.

Protocol revision table.

Version #	Date	Author	Change Description and Reason	References (if appropriate)	New Version #
1.0	November 2016	Dodd	Spatial Design section: Tributary sites changed from randomly selected to targeted tributaries of interest to the parks. Total number of tributaries sampled reduced.	Fancy et al. 2008; DeBacker et al. 2012	2.0
	November 2016	Dodd	Temporal Design: New revisit design for mainstem river and tributaries at BUFF and OZAR. Increase in frequency of sampling each tributary.	Fancy et al. 2008; DeBacker et al. 2012	2.0
	March 2016	Rowell and Dodd	Data Management section: Section updated to reflect changes in I&M Division (IMD) policy and revision of database structure.	Frakes et al. 2015; NPS 2016	2.0
	June 2016	Morrison and Dodd	Analysis and Reporting section: Added more information on trend analyses to be used. Included use of concise reports for reporting/updating.	–	2.0
	December 2016	Dodd	Personnel Requirements and Training section: Added detail on number of crew members, experience, and training needed to safely and effectively collect data.	Fancy et al. 2008	2.0
	December 2016	Dodd	Startup Costs and Budget Consideration section: Edited costs and budgets to reflect current inflation and salaries.	Fancy et al. 2008	2.0
	Jan 2017	Dodd	Protocol Revision section: Added information on separate publication of Narrative and SOPs. Clarified versioning number for narrative revision. Added Narrative Revision Log section.	IMD guidance	2.0

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 (NPS) in the Ozark Plateaus physiographic province (Figure 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 this report.

The purpose of this report is to provide a protocol (hereafter called the Ozark Rivers Fish Community Protocol, Version 2.0) that will be used by the NPS Heartland I&M Network (HTLN) 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. The original Ozark Rivers Fish Community Protocol, Version 1.0 (Petersen et al. 2008) was prepared by the U.S. Geological Survey (USGS) with assistance from HTLN. The protocol outlined in this report (Version 2.0) is a modification of the original Petersen et al. 2008 protocol based on recommendations published in a five-year protocol/data review report (DeBacker et al. 2012). 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 NPS 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) supplemental information helpful for implementation of the protocol (see Appendices 1-9), and (3) several Standard Operating Procedures (SOPs) that are published separately from the narrative (see Appendix 10 for list of SOPs).

The Protocol Narrative provides background information about the protocol such as the rationale for 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, Version 2.0 (i.e. measurable objectives, sampling design, field methodology, data analysis and reporting, personnel requirements, training procedures, and operational requirements) and summarizes the history of decision making that accompanied protocol development. Supplemental information includes species lists, sample site lists, and comparison of this protocol to other fish community sampling protocols (see Appendices 1-9).

The SOPs cover preparation, training, reach selection, water-quality sampling, fish community sampling, physical habitat collection, measurement of stream discharge, equipment maintenance/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 National Water Quality Assessment (NAWQA) program and the HTLN program. All SOPs provide information that can be used to maximize the accuracy, representativeness, and completeness of the fish community data (see Appendix 10 for a list of SOPs).

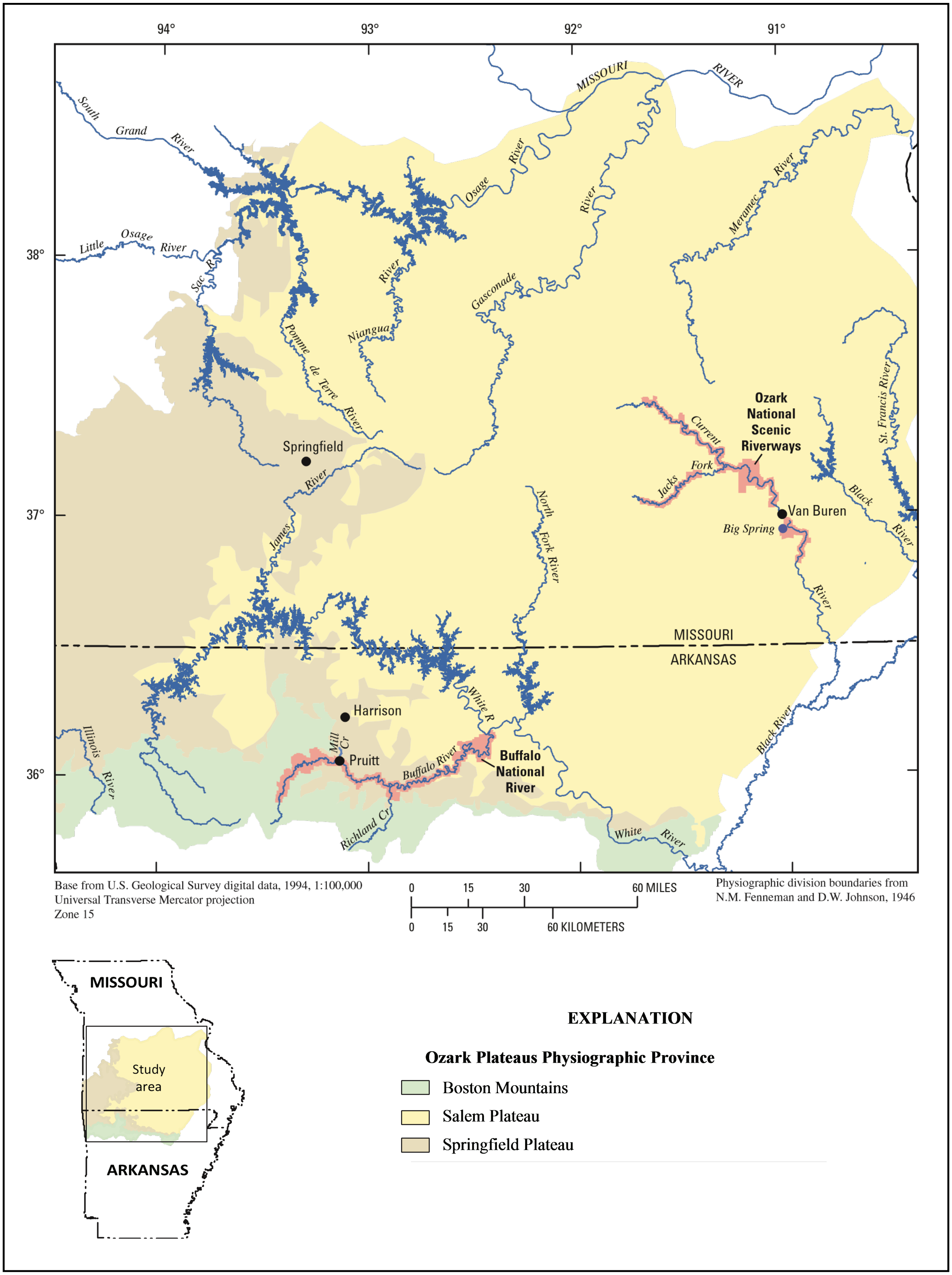


Figure 1. Location of Buffalo National River and Ozark National Scenic Riverways.

Protocol Narrative

Background and Objectives

The extents of BUFF and OZAR (Figure 1) are limited to relatively narrow bands along much of the Buffalo River (BUFF) and the Jacks Fork and Current River (OZAR). 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 et al. 1997; Davis and Bell 1998; Petersen et al. 1998; Mott and Luraas 2004). Both parks are in the Springfield or Salem Plateau physiographic provinces, which are typified by limestone and dolomite geologic formations. Karst features, such as sinkholes, caves, springs, and sections of streams that interact with groundwater 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 province, 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 streamflow, and some sections of the Buffalo River become dry during the summer because of a lack of substantial spring flows and losing reaches of stream (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 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 those of 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), Petersen (2005), and Dodd (2009a) reported 77 species of fish from BUFF, and 121 species of fish have been reported to occur in or near OZAR (Michael Williams and Victoria Grant, National Park Service, written communication [NPS 2006]; Dodd 2009b; Dodd 2013; Appendices 1 and 2). Some of these species are endemic 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 et al. 1998).

Since some fish species, including several darters, minnows, and madtoms, are considered intolerant of habitat alterations (Robison and Buchanan 1988; Pflieger 1997; Dauwalter et al. 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 this protocol are related to monitoring (1) temporal changes in fish communities and (2) relations between the fish communities and environmental factors. This monitoring information 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 (e.g. species richness, percent tolerant individuals, percent invertivores, and percent omnivores) that can be used to calculate multi-metric indices (Karr 1981; Hoefs 1989; Dauwalter et al. 2003; Dauwalter and Pert 2004), and (2) to estimate the spatial and temporal variability of fish community metric values and indices among collection sites, and determine relations between metrics and indices with various environmental variables (e.g. stream size, riparian characteristics, substrate characteristics, water quality, and land use).

Sampling Design

Efficient sampling for environmental factors of interest (through space and time) is a necessary component of any long-term monitoring program. The 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 et al. 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 NPS jurisdictional boundaries at BUFF and OZAR.

The sample unit has been defined to accommodate the field protocols for all aquatic vital signs (fish, aquatic invertebrates, metal contaminants, etc.). 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 distance associated with pool-riffle sequences increases. A key characteristic of this overall spatial 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 (stretches) remain fixed and are used by all studies under the unified monitoring design.

Two different categories of stretch length were established. In the tributaries and upper mainstem, stretch lengths were 1 to 2 km. In the lower mainstem, stretch lengths were 3 to 5 km. Within categories, stretch length was not fixed, but varied 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), which is based on gradient, streamflow, temperature, geology, soil texture, valley wall interaction (a surrogate for potential bluff pool habitat), stream size discrepancy, and channel type. Stretches in the tributaries were delimited by the floodplain 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.

For both parks, the initial sample frame of stretches (a finite list of sample units used to select site locations; statistical inferences can only be made to sample units that are part of the frame) 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). These datasets 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 (EPA). The coverage included arcs representing the centerlines of wide streams, as well as the segments of single line streams. An ArcInfo 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. 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 and removed from the sampling frame due to the potential interaction with the mainstem (see Selection of Tributaries section below for more details).

The sample frames 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 (see Selection of Sample Stretches section below). 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 (i.e., 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 three rivers.

Selection of Sample Stretches

In the original Ozark Rivers Fish Community Protocol, Version 1.0 (Petersen et al. 2008), it was deemed desirable that sample sites for both the mainstem and the tributaries be randomly selected and spatially balanced throughout the park. Spatial balance was important because (1) responses are typically known to be spatially autocorrelated (units close to one another tend to yield correlated responses), and (2) parkwide inferences were 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 (Stevens and Olsen 1999; Stevens and Olsen 2004) was employed to select random and spatially balanced mainstem and tributary stretches for sampling. 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. Additionally, because GRTS samples are not evenly spaced, it is not possible for sample locations to be in phase with a cyclic response.

The S-Draw program developed by Trent McDonald (www.west-inc.com) was used to draw the GRTS stretches in the original protocol (Version 1.0, Petersen et al. 2008), and mainstem sites were weighted by stretch length. Several options in S-Draw were employed: (1) the hierarchical structure was randomized, (2) the reverse hierarchical ordering option was employed which assures that any contiguous set of stretches will be spatially balanced (Stevens and Olsen 2004), and (3) a random number seed generated from the system clock was used. All GRTS draws were "oversampled," in that more sites were selected and ordered than would be sampled, allowing for addition of sites in the future (if budget allows) without decreasing the degree of spatial balance and providing flexibility to not sample certain sites if an issue arises deeming the sample site inappropriate.

Selection of Mainstem Stretches

For drawing mainstem stretches, a greater degree of control was desired at OZAR 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 also 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 flow, 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 stretches to sample using GRTS.

The Buffalo River 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 of possible sample stretches. 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 stretches in the sample frame were selected and ordered for OZAR (64 mainstem stretches) and BUFF (37 mainstem stretches). In the original Ozark Rivers Fish Community Protocol, Version 1.0 (Petersen et al. 2008), only the first nine stretches at OZAR (three in both the upper and lower Current River and three in the Jacks Fork) and the first six stretches at BUFF (three both in the upper and lower Buffalo River) that were selected in the GRTS process were sampled due to limited budget and personnel precluding more sample sites (Appendix 3). In Version 2.0, we will continue to sample these same randomly selected and spatially balanced mainstem sites in order to make inferences to the entire mainstem river within each park (Table 1a, b).

Selection of Tributaries

In the original Ozark Rivers Fish Community Protocol, Version 1.0 (Petersen et al. 2008), tributaries were randomly selected and spatially balanced across each park using GRTS. Prior to selecting these sample stretches for tributaries, all floodplain stretches were removed because those portions of the tributaries within the floodplain of the mainstem are likely to be more variable and less representative of the tributary due to intermittent backwater inundation. The distance between the most downstream stretch and the confluence with the mainstem may 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 was limited by park boundaries. Because the downstream tributary stretches were separated from the mainstem by the width of the mainstem flood plain, the influence of the mainstem on tributary fish communities was reduced.

A number of tributaries, although indicated as perennial on 7.5-minute topographic USGS maps, drained relatively small water basins and, according to park personnel, often had little to no flowing water. Thus, the sample frame used for the original selection of tributaries (in Version 1.0) 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.

Since most of these tributaries were relatively small, it was determined that a representative sample 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 m in Version 1.0 of the protocol. Reconnaissance surveys were conducted of selected tributaries that, based on a

Table 1a. Mainstem and tributary sites sampled under this protocol (Version 2.0) for monitoring fish communities at Buffalo National River.

Stretch ID	Reach ID	River Basin	Site Type[a]	Site No.	Tributary Name	Panel No.[b]	County	Lower Stretch UTM[c] Easting	Lower Stretch UTM[c] Northing	Lower Sample Reach UTM[c] Easting	Lower Sample Reach UTM[c] Northing	Reach Length (m)
24	BUFFM01	Buffalo	M	01	–	Biennial	Newton	464088.50	3981659.30	464259.027	3981461.484	290
55	BUFFM02	Buffalo	M	02	–	Biennial	Newton	490340.90	3987599.90	490387.376	3987727.621	440
59	BUFFM03	Buffalo	M	03	–	Biennial	Newton	499985.28	3983483.70	499922.291	3983702.401	600
69	BUFFM04	Buffalo	M	04	–	Biennial	Searcy	520484.74	3981679.66	520396.874	3981741.881	620
73	BUFFM05	Buffalo	M	05	–	Biennial	Searcy	529619.95	3984878.60	529076.108	3984910.528	560
87	BUFFM06	Buffalo	M	06	–	Biennial	Marion	545997.97	3995359.40	545843.897	3995174.566	726
646	BUFFT07	Buffalo	T	07	Mill	Biennial	Newton	487979.09	3990501.25	487933.175	3990589.489	180
383	BUFFT15	Buffalo	T	15	Davis	Biennial	Newton	504216.16	3984923.25	504131.918	3985033.521	200
378	BUFFT19	Buffalo	T	19	Calf	Biennial	Searcy	520463.22	3981045.50	520457.523	3981019.421	165
472	BUFFT20	Buffalo	T	20	Bear	Biennial	Searcy	526905.38	3983413.50	526899.046	3983227.746	450
476	BUFFT27	Buffalo	T	27	Clabber	1	Marion	540925.44	3998147.75	540821.629	3998527.103	180
603	BUFFT30	Buffalo	T	30	Middle	1	Marion	551428.31	3993556.50	551487.935	3993528.202	150
623	BUFFT31	Buffalo	T	31	Leatherwood	1	Marion	551307.69	3996258.00	551410.833	3996233.100	150
462	BUFFT05	Buffalo	T	05	Cecil	2	Newton	479905.44	3992743.25	479870.761	3992741.028	232
420	BUFFT09	Buffalo	T	09	Little Buffalo	2	Newton	490340.91	3987600.00	490169.939	3987680.937	260
574	BUFFT23	Buffalo	T	23	Water	2	Searcy	538186.50	3989492.75	537965.089	3989702.352	150

[a] M = Mainstem; T = Tributary

[b] Panel No. describes how often a site is sampled; Panels 1 and 2 are sampled every four years.

[c] UTM is Universal Transverse Mercator coordinates (zone 15), horizontal datum is North American Datum 1983.

Table 1b. Mainstem and tributary sites sampled under this protocol (Version 2.0) for monitoring fish communities at Ozark National Scenic Riverways.

Stretch ID	Reach ID	River Basin	Site Type[a]	Site No.	Tributary Name	Panel No.[b]	County	Lower Stretch UTM[c] Easting	Lower Stretch UTM[c] Northing	Lower Sample Reach UTM[c] Easting	Lower Sample Reach UTM[c] Northing	Reach Length (m)
14	CURRM01	Current	M	01	–	Biennial	Shannon	623336.28	4141730.82	623330.810	4141819.358	342
35	CURRM02	Current	M	02	–	Biennial	Shannon	637468.41	4131822.17	637113.180	4131465.688	450
42	CURRM03	Current	M	03	–	Biennial	Shannon	643252.57	4126300.08	642631.838	4126422.535	660
67	CURRM04	Current	M	04	–	Biennial	Shannon	661785.40	4111783.86	662104.165	4112724.645	702
71	CURRM05	Current	M	05	–	Biennial	Shannon	666195.85	4111128.94	666087.431	4111411.528	1000
97	CURRM06	Current	M	06	–	Biennial	Carter	684220.63	4078321.12	685209.621	4079792.188	1000
105	JACKM01	Jacks Fork	M	01	–	Biennial	Shannon	619895.88	4101117.92	619901.956	4101344.874	290
114	JACKM02	Jacks Fork	M	02	–	Biennial	Shannon	627768.31	4102604.03	627579.024	4102191.921	286
123	JACKM03	Jacks Fork	M	03	–	Biennial	Shannon	633244.58	4108431.69	633452.088	4108220.025	320
463	CURRT14	Current	T	14	Sinking	Biennial	Shannon	640511.35	4129644.43	640779.257	4129682.694	500
699	JACKT03	Jacks Fork	T	03	Shawnee	Biennial	Shannon	650824.38	4115207.50	650814.727	4115153.041	150
917	CURRT06	Current	T	06	Blair	1	Shannon	659132.19	4116340.75	658985.647	4116351.733	150
734	CURRT15	Current	T	15	Big West	1	Shannon	623266.41	4141724.36	623206.262	4141756.210	150
657	CURRT08	Current	T	08	Rocky	2	Shannon	661958.31	4110833.50	661931.524	4110852.285	348
856	CURRT16	Current	T	16	Big East	2	Shannon	648435.63	4129644.43	648341.558	4123747.999	150

[a] M = Mainstem; T = Tributary

[b] Panel No. describes how often a site is sampled; Panels 1 and 2 are sampled every four years.

[c] UTM is Universal Transverse Mercator coordinates (zone 15), horizontal datum is North American Datum 1983.

study of maps and consultation with park staff, may have been too far in the flood plain of the mainstem, or may have had insufficient flow.

At BUFF, an initial set of 37 tributaries satisfied the above criteria. Reconnaissance resulted in adjustment of the floodplain criteria for two tributaries and elimination of one tributary because of insufficient flow. Ultimately, a total of 34 tributary stretches satisfied the selection criteria and constituted the original sample frame at BUFF. 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. A total of 16 tributary stretches met the selection criteria at OZAR, and constituted the original sample frame. In the sample design established in Version 1.0 (Petersen et al. 2008), 30 tributary stretches at BUFF and 15 at OZAR were selected for sampling on a 5-year rotation (Appendix 3). This spatial design was used in 2005-2010 to obtain baseline information at a large number of tributaries.

Based on recommendations from the 2008 HTLN start-up review, staff from the Inventory and Monitoring Division (IMD), park superintendents, and resource managers agreed that HTLN productivity was high with a relatively small staff, but that HTLN was operating on a “razor-thin margin” (Fancy et al. 2008). In 2011, an ad-hoc committee of OZAR and BUFF resource managers and HTLN staff reviewed the original aquatic invertebrate (Bowles et al. 2007) and fish protocols (Petersen et al. 2008) for BUFF and OZAR to determine how to scale back monitoring yet provide park managers with the data needed to make informed management decisions. After analysis of the baseline datasets at OZAR and BUFF and committee discussions regarding workload sustainability and data needs for tributaries, it was agreed that a small number of targeted tributaries would be sampled on a shorter rotation rather than sampling a large number of randomly selected tributaries on a longer rotation (DeBacker et al. 2012).

This would provide park managers information on tributaries of interest in a timely manner in order to modify/implement management strategies to protect or conserve the resources of these tributaries. For BUFF, the 10 targeted tributaries selected for sampling in Version 2.0 (see Table 1a) were a subset of tributaries sampled under Version 1.0 of the protocol (see Appendix 3 for original list). For OZAR, six targeted tributaries were selected for sampling in Version 2.0 (Table 1b). Three of these targeted tributaries were in the original sample set of tributaries selected in Version 1.0 of the protocol (Shawnee, Blair, and Rocky Creeks; see Appendix 3). Three of the tributaries had not been sampled in Version 1.0 and were selected by park staff due to water quality or sediment issues (Sinking, Big West, and Big East Creeks; Table 1b).

Establishing Sample Reaches

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

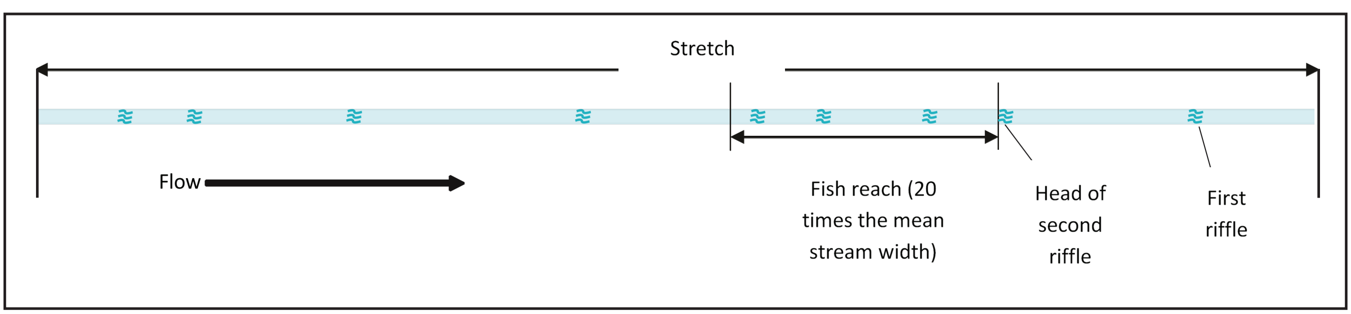


Figure 2. Hypothetical reach location within a stretch.

Temporal Design

In the original Ozark Rivers Fish Community Protocol, Version 1.0 (Petersen et al. 2008), mainstem sites were sampled annually and tributaries were sampled on a five-year rotation due to the large number of tributaries selected for sampling (see Appendix 3). Based on data analysis of the mainstem and tributary datasets from the first five years of collection at OZAR and BUFF and ad-hoc committee discussions on HTLN staff workload, it was deemed appropriate and necessary to place both parks on a biennial rotation (DeBacker et al. 2012).

BUFF is sampled during odd numbered years with all six mainstem sites and four targeted tributaries sampled each time the park is visited (Table 1a and 2). The remaining six targeted tributaries are on two alternating panels such that each stream in a panel is sampled once every four years. During each visit at BUFF, 13 sites are sampled: six mainstem, four biennial tributaries, and three panel tributaries (Table 2).

OZAR is sampled during even numbered years with all nine mainstem sites and two targeted tributaries sampled each time the park is visited (Table 1b and 2). The remaining four targeted tributaries are on two alternating panels where each stream panel is sampled once every four years. During each visit to OZAR, 13 sites are sampled: nine mainstem, two biennial tributaries, and two panel tributaries.

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 and under similar water levels and temperature 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 can cause high variability in assemblage composition and structure within a stream, fish monitoring is conducted once a year during early summer to early fall (May 15 - October 31) when communities are more stable. Sites at BUFF are sampled in May/June because of the potential drying of the upper mainstem and small tributaries in late summer and fall. At OZAR, sites are sampled in September/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) are 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 (4-6 weeks) to reduce seasonal effects. Sampling outside the 6-week sampling period could introduce variability due to seasonal changes in temperature or flow rather than demonstrating

Table 2. New revisit design for monitoring fish communities at Buffalo National River (BUFF) and Ozark National Scenic Riverways (OZAR).

Park	Sites	Rotation	% of Effort	Year										
				1	2	3	4	5	6	7	8	9	10	11
BUFF	6 Mainstem	Biennial	46	X	–	X	–	X	–	X	–	X	–	X
	4 Tributaries	Biennial	31	X	–	X	–	X	–	X	–	X	–	X
	3 Tributaries	Panel 1	23	X	–	–	–	X	–	–	–	X	–	
	3 Tributaries	Panel 2	23	–	–	X	–	–	–	X	–	–	–	X
OZAR	9 Mainstem	Biennial	70	–	X	–	X	–	X	–	X	–	X	–
	2 Tributaries	Biennial	15	–	X	–	X	–	X	–	X	–	X	–
	2 Tributaries	Panel 1	15	–	X	–	–	–	X	–	–	–	X	–
	2 Tributaries	Panel 2	15	–		–	X	–	–	–	X	–	–	–

Table 3. Mean discharge levels for conducting fish sampling at Buffalo National River (BUFF) and Ozark National Scenic Riverways (OZAR). Data obtained from USGS streamgages (https://waterwatch.usgs.gov).

Park	USGS Station Name	USGS Gage Number	Mean Discharge (m^3/s)
BUFF	Boxley	07055646	55
	Ponca	07055660	138
	Pruitt	07055680	213
	St Joe	07056000	378
	Harriett	07056700	630
OZAR	Montauk	07064440	79
	Akers	07064533	217
	Van Buren	07067000	1,031
	Mountain View	07065200	68
	Alley	07065495	100

true changes in the fish assemblages; and therefore, sampling outside the 6-week time frame should not be conducted. See Table 3 for mean discharge levels for sampling at BUFF and OZAR. Following a large, natural disturbance such as a flood, at least two 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 Ozark Rivers Fish Community Protocol narrative and SOPs and begin planning for the field activities. Early review of SOP 1 (preparation) and SOP 2 (training) are particularly important because of the 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 eight or more hours is typical.

Sampling location was determined by random selection of sampling stretches, wetted stream width, and relation of riffle location to downstream end of the sampling stretch (see Establishing Sample Reaches or SOP 3 for details). At each reach, water-quality (SOP 4), fish community (SOP 5), habitat data (SOP 6), and discharge data (SOP 7) are collected (Figure 3).

Fish communities are 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 are 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 and may be used 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 et al. (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 et al. 1997; Meador and McIntyre 2003) suggest that data collected using different gear, or different combinations of multiple gear types, will be affected by gear type.

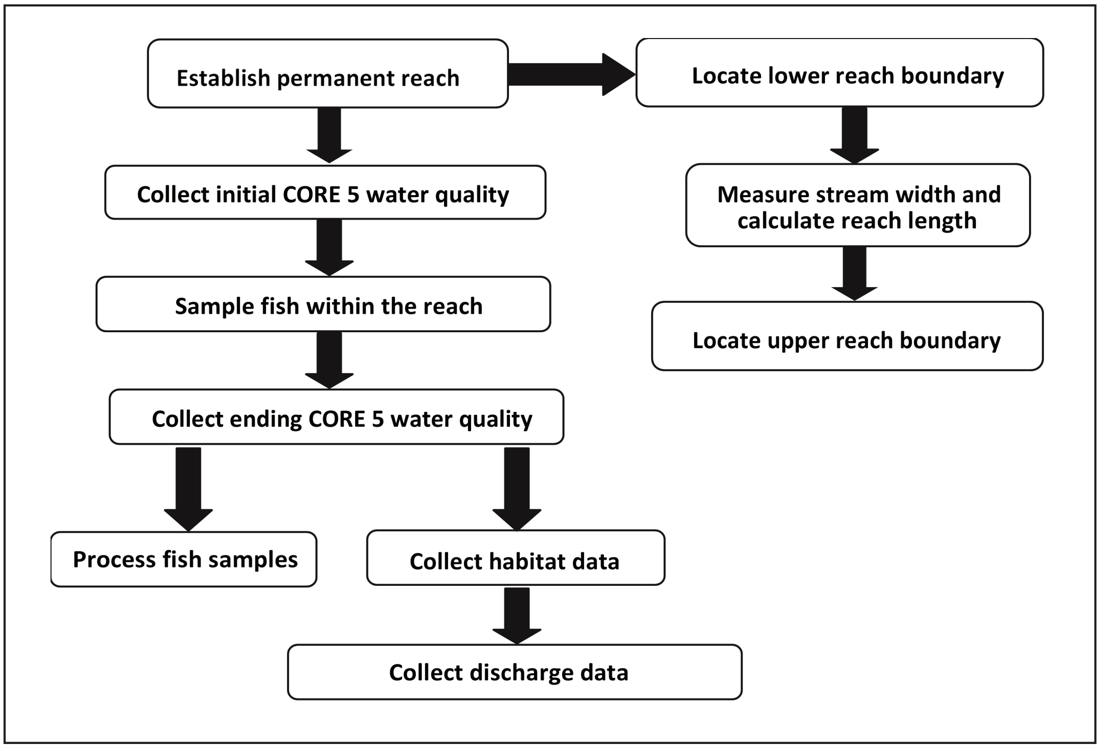


Figure 3. Flow diagram for fish, water quality, and habitat data collection.

Therefore, it is imperative that gear type used and sampling effort at a site be consistent across years. 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 and/or kick seines. 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, side channel, backwater). 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 for details).

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 type. 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 and water quality measurements (see SOP 4) are collected in conjunction with fish sampling.

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 EPA—the Rapid Bioassessment Protocols (RBPs; Barbour et al. 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 protocol developed for the NAWQA program (Moulton et al. 2002). The EMAP and NAWQA 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). The NAWQA protocol or similar methods have been used at several sites at BUFF (Petersen 1998 and 2004) and OZAR (Petersen 1998).

This Ozark Rivers Fish Community Protocol,Version 2.0 is based on the NAWQA approach with selected procedures largely following the NAWQA protocol. 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 RBPs and EMAP 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).

Version 2.0 is similar to the NAWQA protocol 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 on the mainstem of each river 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 mainstem 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 difference in electrofishing procedures between Version 2.0 and the NAWQA protocol is the electrofishing effort used. For Version 2.0, fish communities of wadeable streams are sampled using single pass electrofishing, while the NAWQA protocol specifies that two passes be used (Appendix 4). Single pass electrofishing corresponds with methods described in the RBPs (Barbour et al. 1999) and EMAP protocols (McCormick and Hughes 1998 and 2000). The advantage of single pass electrofishing is that a site can be sampled using fewer man-hours at reduced cost; however, this approach has potential limitations. A study by Meador et al. (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% 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% and ranged from 40-100%. However, Meador et al. (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 et al. (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. They 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 et al. (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 RBPs and EMAP protocols are also 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 RBPs, 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 RBPs are not designed for nonwadeable streams.

Other differences are that block nets are sometimes used at the ends of the reach and seining is not required in the RBPs and EMAP protocols. 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 et al. 1998; Moulton et al. 2002), which specifies reach lengths of approximately 20 times 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 et al. (2003) developed their Index of Biotic Integrity (IBI) for wadeable Ozark Highlands streams in Arkansas for a reach length of 51 times 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 Integrated Resource Management Applications (IRMA) Data Store System. Sensitve data, such as locations or numbers of threatened or endangered species, that are stored in the database or listed in the protocol are restricted to project leaders within NPS IRMA Data Store System. Protocols and databases that do not contain sensitive data are made available to the public.

Analysis and Reporting

Analysis

In any long-term monitoring program, a consistent methodology and careful implementation of field sampling techniques are critical in obtaining comparable data. Thus the procedures for data collection must be specified and followed exactly. In contrast, data analysis techniques do not need to be specified in as great detail. Many different analyses methods are available, and are documented in great detail in texts and literature. Moreover, new methods are developed over time. Thus, absolute and detailed specification of data analysis techniques is not necessary or desirable. Due to the complexity of higher-level analyses, many options are available and step-by-step instructions will not be sufficient; a competent analyst will always need to be consulted. Thus descriptions of various data analysis options are presented here and in SOP 10 (data analysis), realizing that the most appropriate techniques will vary over time as sample sizes increase and that the details of any analysis can be found in the relevant texts or literature.

The data analysis process 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. The primary audience for brief data summaries of short-term datasets (less than 5 years) or data updates of longer-term datasets (addition of 1 or 2 data points to a dataset that has more than 5 years of data) will consist of park resource managers, superintendents, interpretive staff and potentially park visitors. More in-depth data summaries or trend reports of longer-term datasets (more than 5 years) will target park resource managers and superintendents and outside agency partners as the primary audience.

Additionally, protocols such as this one provide large amounts of data on many different types of variables. Thus, to the extent possible, it is important that core data analyses 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. The type and magnitude of variability or uncertainty associated with the results should be measurable, allowing thresholds to be established for potential management action. In addition to core analyses described in this protocol, future resource questions posed by park staff may warrant issue-specific analyses of certain fish or habitat parameters (DeBacker et al. 2012).

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). Thus, we do not advocate a Bayesian approach.

The interest of this monitoring program is not whether fish communities are changing, but rather in the magnitude or direction of the change, and whether it represents something biologically important. When conducting hypothesis testing, concern should be placed on whether the data support meaningful scientific hypotheses that are biologically significant (Kirk 1996; Hoenig and Heisey 2001). Depending on the characteristics of the ecological data being analyzed (i.e. normal distribution, data independence, etc.), parametric (e.g. linear regression, univariate control charts) and non-parametric (e.g. Mann-Kendall; Mann 1945; Kendall 1975) tests may be warranted to detect a directional change or an abrupt change in the fish community due to changes in park management strategies or changes in adjacent land use.

Estimation of biological characteristics or metrics (hereafter referred to as "metric estimation") is a straightforward method that can provide more information than hypothesis testing (Steidl et al. 1997; Gerard et al. 1998; Johnson 1999; Anderson et al. 2000 and 2001; Colegrave and Ruxton 2003; Nakagawa and Foster 2004). Metric estimation emphasizes the magnitude of effects and the biological significance of the results (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 et al. 1997). Thus, most of the data analysis suggested in this protocol will take the form of metric estimation.

Metrics 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 calculation of multiple metric biological indexes (Plafkin et al. 1989; Hughes and Oberdorff 1998; Barbour et al. 1999; Simon 1999). 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 et al. 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 by the scoring and summing of individual metrics (Appendices 6-9). A standardized scoring criteria is developed for specific regions or watersheds. This index is used as an indicator of overall stream quality, enabling investigators to compare conditions at multiple sites across a region/watershed or at a single site across time (Karr 1981; Barbour et al. 1999; Simon 1999). IBIs have been created for Ozark Highland streams (see Appendices 7-9; Hoefs 1989; Dauwalter et al. 2003; and Matt Combes, Missouri Department of Conservation, written comm., 2006) and three ecoregions in Arkansas (Hlass et al. 1998; Dauwalter et al. 2003; Justus 2003; Dauwalter and Jackson 2004). 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 et al. 1999; Simon 1999).

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 et al. 1995; Petersen 1998; Everitt and Dunn 2001; Timm 2002; Petersen 2004). Multivariate techniques differ from univariate or bivariate analyses in that the former techniques are generally more descriptive and generate hypotheses from the biological data rather than attempt to disprove a null hypothesis, and the effectiveness improves as the number of variables increases (Williams and Gillard 1971). Two multivariate techniques commonly used to analyze community data include ordination and classification (Gauch 1982; Jongman et al. 1995; Everitt and Dunn 2001; McCune and Grace 2002; Timm 2002).

Control charts can also 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 et al. 1992; Gyrna 2001; Montgomery 2001; Morrison 2008). Control charts may be univariate or multivariate, and can be used for different types of variables (i.e., metrics, count, or frequency data). 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 Inventory and Monitoring Program (Atkinson et al. 2003). Control charts contain control limit(s) 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 using a desired confidence interval around the data, a desired management goal, or a regulatory threshold for the metric of interest.

A formal power analysis for this protocol was not conducted for three reasons (Morrison 2007). First, 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 and staff size, 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. Secondly, 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. Lastly, most data analyses will take the form of metric estimation, rather than null hypothesis significance testing. When estimating metrics, there is no associated statistical power and alternative approaches to measuring the variability or uncertainty in the data will be employed, when applicable.

The primary approach to organizing and analyzing data will consist of metric estimation combined with trend analysis (parametric or non-parametric), the use of control charts, and multivariate techniques such as ordination or classification. However, the use of other statistical methods can not be 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. Specific resource questions by park staff may require use of hypothesis testing using either parametric or non-parametric tests depending on the normality and the independence of the dataset analyzed. Tests for normality and spatial or temporal autocorrelation should be performed to determine the validity of using parametric tests. Employing multiple analytic approaches will provide multiple lines of evidence on trends or patterns in fish communities within the park, increasing the validity and confidence of study conclusions. A detailed summary of calculated metrics and data analysis techniques are given in SOP 10.

Reporting

Results from fish community monitoring will be distributed to park superintendents and resource management staff and State agencies after each visit to the parks. The purpose of these summary reports will be to update general findings and status of the fish community, and they will be concise documents that consist of species catch data, metric calculations, and/or habitat summaries. These reports will not deviate substantially from year to year in terms of structure or analyses used (see SOP 11). Scientific collection permits required in Arkansas and Missouri will be renewed annually. As part of the permit process, a report of the collection activities will be sent to the Arkansas Game and Fish Commission (AGFC) and the Missouri Department of Conservation (MDC).

More extensive reports containing trend analysis and detailed explanations of findings will be completed on longer-term datasets (>5 years). The purpose of these reports will be 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. Trend reports will be sent to park superintendents and resource management staff, and external scientists outside HTLN or NPS. A copy of summary reports and comprehensive trend reports will be stored on NPS IRMA Data Store (https://irma.nps.gov/Portal).

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, stream size, 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). Smaller sites require 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 protocol and the potential difficulties in accessing random sites, fish community monitoring will require a minimum crew of six each year. The crew will be made up of at least one HTLN staff member (fisheries biologist or aquatic ecologist) who has experience leading and training a field crew and familiarity with site locations and the fish and habitat SOPs. The crew will be made up of at least two technicians who are familiar with electrofishing and motorboat use and three seasonal technicians/interns (see SOP 2 for specific qualifications of crew members). For safety of the crew, at least two members of the crew (HTLN fisheries biologist or aquatic ecologist and one other technician) must have successfully completed the U.S. Fish & Wildlife Service (USFWS) electrofishing course and the Department of the Interior (DOI) motorboat operator course.

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. For the field crew, the fisheries biologist (project manager) and aquatic ecologist(s) will remain relatively consistent from year to year. The project manager is responsible for implementing the monitoring protocol and is responsible for ensuring that, with assistance from the aquatic ecologist(s), all crewmembers are trained. 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.

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 (fisheries biologist) will be responsible for ensuring 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

Thirteen 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 or conditions, such as thunderstorms or high water. 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 with a fume hood; 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 (see SOP 8 for guidance on equipment storage)

Startup Costs and Budget Considerations

Startup costs and annual budgets are important considerations for any monitoring program. Annual costs (in 2016 dollars) for conducting monitoring are summarized in Table 4. Many network staff including the HTLN project leader, quantitative ecologist, and network program manager play a role in this monitoring effort and their contributions are accounted for in each salary line item. Expenses for fieldwork are based on a minimum crew of six 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 costs for field equipment include the purchase of a boat electrofishing unit, two backpack electrofishing units, a towed barge unit, boat motors, and various field equipment (such as waders, nets, and gloves). Some of the items included under field equipment are for longer-term use (more than 5 years) and will only need to be purchased occasionally (such as boat electrofishing unit or 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 4. Estimated annual costs for salaries, equipment, supplies, travel, and other expenditures.

Expense categories	Estimated cost (as of 2016)
Salary	$110,700
Field/office equipment	$1,900
Supplies	$1,300
Computer hardware and software	$1,100
Fieldwork travel	$4,000
Vehicle lease	$2,500
Overhead to Missouri State University	$700
Administrative support to Wilson's Creek National Battlefield	$1,700
Laboratory fees	$2,800
Total	**$126,700**

Literature Cited

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

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

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

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

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 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].

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

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

Bell, R. W., J. V. Davis, S. F. Femmer, and R. L. Joseph. 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.

Bowles, D. E., J. A. Luraas, L. W. Morrison, H. R. Dodd, M. H. Williams, G. A. Rowell, M. D. DeBacker, J. A. Hinsey, F. D. Usrey, J. L. Haack. 2007. Protocol for Monitoring Aquatic Invertebrates at Ozark National Scenic Riverways, Missouri, and Buffalo National River, Arkansas. Natural Resource Report NPS/HTLN/NRR—2007/009. National Park Service, Fort Collins, Colorado.

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

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

Dauwalter, D. C., E. J. Pert, and W. E. Keith. 2003. An index of biotic integrity for fish assemblages in Ozark Highland Streams of Arkansas. Southeastern Naturalist 2: 447468.

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

Davis, J. V., and R. W. Bell. 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.

DeBacker, M. D., C. C. Young (editor), P. Adams, L. Morrison, D. Peitz, G. A. Rowell, M. Williams, and D. Bowles. 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. https://science.nature.nps.gov/im/monitor/plans/HTLN_MonitoringPlan.pdf

DeBacker, M. D., D. E. Bowles, H. R. Dodd, and L. W. Morrison. 2012. Five-year review and recommendations for revision of aquatic sampling protocols at Buffalo National River and Ozark National Scenic Riverways. Natural Resource Report NPS/HTLN/NRR – 2012/563. National Park Service, Fort Collins, Colorado.

Dodd, H. R. 2009a. Fish community monitoring at Buffalo National River: 2006-2007 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/185. National Park Service, Fort Collins, Colorado.

Dodd, H. R. 2009b. Fish community monitoring at Ozark National Scenic Riverways: 2005-2007 status report. Natural Resource Technical Report NPS/HTLN/NRTR—2009/224. National Park Service, Fort Collins, Colorado.

Dodd, H. R. 2013. Fish community monitoring at Ozark National Scenic Riverways: 2005-2010 summary report. Natural Resource Data Series NPS/HTLN/NRDS—2013/599. National Park Service, Fort Collins, Colorado.

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

Everitt, B. S., and G. Dunn. 2001. Applied multivariate data analysis, 2nd edition. 342 p.

Fancy, S., M. DeBacker, D. Bowles. 2008. Three-year start-up review of Heartland I&M Network report and recommendations from review panel, August 19-21, 2008, Unpublished report.

Fitzpatrick, F. A., I. R. Waite, P. J. D'Arconte, M. R. Meador, M. A. Maupin, and M. E. Gurtz. 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.

Frakes, B., S. Kingston, and M. Beer. 2015. Inventory and Monitoring Division database standards: September 11, 2015. Natural Resource Report NPS/NRSS/NRR—2015/1035. National Park Service, Fort Collins, Colorado.

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

Gerard, P. D., D. R. Smith, and G. Weerakkody. 1998. Limits of retrospective power analysis. Journal of Wildlife Management 62: 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 133: 971-983.

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

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

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., W. L. Fisher, and D. J. Turton. 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 13(2): 181-192.

Hoefs, N. J. 1989. Applying the index of biotic integrity to resource inventory in the Current River Basin, Missouri. Thesis. Colorado State University, Fort Collins, Colorado.

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

Hughes, R. M., and T. Oberdorff. 1998. Applications of IBI concepts and metrics to waters outside the United States and Canada. Pages 79-93 *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 N. M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

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

Jongman, R. H. G., C. J. F. ter Braak, and O. F. R. van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge. 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 6: 21–27.

Kendall, M. G. 1975. Rank correlation methods, 4th edition. Charles Griffin, London.

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

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

Mann, H. B. 1945. Non-parametric tests against trend. Econometrica 13:163-171.

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

McBean, E. A., and F. A. Rovers. 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 R. M. Hughes. 1998. Aquatic vertebrates. *In* Lazorchak, J. M., D. J. Klemm, and D. V. Peck, 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 R. M. Hughes. 2000. Aquatic vertebrates. *In* Lazorchak, J. M., B. H. Hill, D. K. Averill, D. V. Peck, , and D. J. Klemm, 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].

McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Oregon.

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

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

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

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

Moix, M. W., and J. M. Galloway. 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. John Wiley & Sons. Inc. New York. 776 p.

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

Morrison, L. W. 2008. The use of control charts to interpret environmental monitoring data. Natural Areas Journal 2: 66-73.

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

Moulton, S. R., II, J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 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 T. M. Foster. 2004. The case against retrospective power analyses with an introduction to power analysis. Acta Ethologica 7: 103-108.

National Park Service (NPS). 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. (NPS) 2016. Certification guidelines for inventory and monitoring data products. National Park Service, Inventory and Monitoring Division, Fort Collins, Colorado.

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

Page, L. M., and B. M. Burr. 1991. A field guide to freshwater fishes: North America north of Mexico. The Peterson Field Guide Series, Houghton Mifflin Company, Boston, Massachusetts.

Page, L. M., H. Espinosa-Perez, L. T. Findley, C. R. Gilbert, R. N. Lea, N. E. Mandrak, R. L. Mayden, and J. S. Nelson. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico. 7th edition. American Fisheries Society, Special Publication 34. Bethesda, Maryland.

Panfil, M. S., and R. B Jacobson. 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 Plateaus 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., J. C. Adamski, R. W. Bell, J. V. Davis, S. R. Femmer, D. A. Freiwald, and R. L. Joseph. 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 20052908.

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

Petersen, J. C., B. G. Justus, H. R. Dodd, D. E. Bowles, L. W. Morrison, M. H. Williams, G. A. Rowell. 2008. Methods for monitoring fish communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1.0. U.S. Geological Survey, Little Rock, AR. Open-File Report 2007-1302.

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

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

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 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., M. J. Kennard, J. M. Arthur, and A. H. Arthington. 1998. Quantitative sampling of stream fish assemblages: Single- vs. multiple-pass electrofishing. Australian Journal of Ecology 23: 365–374.

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

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

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

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

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

Shaver, J. P. 1993. What statistical significance testing is, and what it is not. Journal of Experimental Education 61: 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 J. Lyons. 1995. Comparison of catch per effort and removal procedures for sampling stream fish assemblages. North American Journal of Fisheries Management 15(2): 419-427.

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

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

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

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

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 52: 305-320.

Vineyard, J. D., and F. L. Feder. 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. Rolla, Missouri. 212 p. (reprinted 1982).

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

Appendix 1. Buffalo National River Fish Species Collected

Table A-1. Fish species collected within Buffalo National River. List is combined from Petersen and Justus (2005) and Dodd (2009a).

Common name	Scientific name
American brook lamprey	*Lethenteron appendix*[a]
American eel	*Anguilla rostrata*
Arkansas saddled darter	*Etheostoma euzonum*
Autumn darter[b]	*Etheostoma autmnale*
Banded darter	*Etheostoma zonale*
Banded sculpin	*Cottus carolinae*
Bigeye chub	*Hybopsis amblops*[c]
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*

[a] Formerly *Lampetra appendix*

[b] Species split from Stippled darter (*E. punctulatum*)

[c] Formerly *Notropis amblops*

Table A-1 (continued). Fish species collected within Buffalo National River. List is combined from Petersen and Justus (2005) and Dodd (2009a).

Common name	Scientific name
Gizzard shad	*Dorosoma cepedianum*
Golden redhorse	*Moxostoma erythrurum*
Golden shiner	*Notemigonus crysoleucas*
Green sunfish	*Lepomis cyanellus*
Greenside darter	*Etheostoma blennioides*
Highfin carpsucker	*Carpiodes velifer*
Hornyhead chub	*Nocomis biguttatus*
Knobfin sculpin[d]	*Cottus immaculatus*
Largemouth bass	*Micropterus salmoides*
Largescale stoneroller	*Campostoma oligolepus*
Common name	*Scientific name*
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*
Orangespotted sunfish	*Lepomis humilis*
Orangethroat darter	*Etheostoma spectabile*
Ozark bass	*Ambloplites constellatus*
Ozark chub	*Erimystax harryi*
Ozark madtom	*Noturus albater*
Ozark minnow	*Notropis nubilus*
Ozark shiner	*Notropis ozarcanus*
Pealip redhorse	*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*

[d] Species split from Ozark sculpin (*C. hypselurus*)

Table A-1 (continued). Fish species collected within Buffalo National River. List is combined from Petersen and Justus (2005) and Dodd (2009a).

Common name	Scientific name
Smallmouth bass	*Micropterus dolomieu*
Southern redbelly dace	*Chrosomus erythrogaster*[e]
Speckled darter	*Etheostoma stigmaeum*
Spotted bass	*Micropterus punctulatus*
Spotted sucker	*Minytrema melanops*
Steelcolor shiner	*Cyprinella whipplei*
Striped shiner	*Luxilus chrysocephalus*
Telescope shiner	*Notropis telescopus*
Walleye	*Sander vitreus*
Warmouth	*Lepomis gulosus*
Wedgespot shiner	*Notropis greenei*
Western mosquitofish	*Gambusia affinis*
White bass	*Morone chrysops*
White sucker	*Catostomus commersonii*[f]
Whitetail shiner	*Cyprinella galactura*
Yellow bullhead	*Ameiurus natalis*
Yoke darter	*Etheostoma juliae*

[e] Formerly *Phoxinus erythrogaster*

[f] Formerly spelled *Catostomus commersoni*

Appendix 2. Ozark National Scenic Riverways Fish Species Collected or Suspected of Occurring

Table A-2. Fish species collected or suspected of occurring within Ozark National Scenic Riverways. List is combined from Michael Williams and Victoria Grant, National Park Service, written communication (NPS 2006), Dodd (2009b) and Dodd (2013).

Common name	Scientific name
American brook lamprey	*Lethenteron appendix*[a]
American eel	*Anguilla rostrata*
Autumn darter[b]	*Etheostoma autmnale*
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*
Black River madtom[c]	*Noturus maydeni*
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*

[a] Formerly *Lampetra appendix*

[b] Species split from Stippled darter (*E. punctulatum*)

[c] Species split from Ozark madtom (*N. albater*)

Table A-2 (continued). Fish species collected or suspected of occurring within Ozark National Scenic Riverways. List is combined from Michael Williams and Victoria Grant, National Park Service, written communication (NPS 2006), Dodd (2009b) and Dodd (2013).

Common name	Scientific name
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*
Current River Saddled darter	*Etheostoma euzonum erizonum*
Cypress darter	*Etheostoma proeliare*
Emerald shiner	*Notropis atherinoides*
Fantail darter	*Etheostoma flabellare*
Fathead minnow	*Pimephales promelas*
Common name	*Scientific name*
Flathead catfish	*Pylodictis olivaris*
Flier	*Centrarchus macropterus*
Freckled madtom	*Noturus nocturnus*
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*
Knobfin sculpin[d]	*Cottus immaculatus*
Lake chubsucker	*Erimyzon sucetta*
Largemouth bass	*Micropterus salmoides*

[d] Species split from Ozark sculpin (*C. hypselurus*)

Table A-2 (continued). Fish species collected or suspected of occurring within Ozark National Scenic Riverways. List is combined from Michael Williams and Victoria Grant, National Park Service, written communication (NPS 2006), Dodd (2009b) and Dodd (2013).

Common name	Scientific name
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 minnow	*Notropis nubilus*
Ozark shiner	*Notropis ozarcanus*
Paddlefish	*Polyodon spathula*
Pealip redhorse	*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*
Redfin shiner	*Lythrurus umbratilis*
Common name	*Scientific name*
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*

Table A-2 (continued). Fish species collected or suspected of occurring within Ozark National Scenic Riverways. List is combined from Michael Williams and Victoria Grant, National Park Service, written communication (NPS 2006), Dodd (2009b) and Dodd (2013).

Common name	Scientific name
Silver redhorse	*Moxostoma anisurum*
Skipjack herring	*Alosa chrysochloris*
Slender madtom	*Noturus exilis*
Smallmouth bass	*Micropterus dolomieu*
Smallmouth buffalo	*Ictiobus bubalus*
Southern brook lamprey	*Ichthyomyzon gagei*
Southern cavefish	*Typhlichthys subterraneus*
Southern redbelly dace	*Chrosomus erythrogaster*[e]
Speckled darter	*Etheostoma stigmaeum*
Spotted bass	*Micropterus punctulatus*
Spotted gar	*Lepisosteus oculatus*
Spotted sucker	*Minytrema melanops*
Stargazing darter	*Percina uranidea*
Steelcolor shiner	*Cyprinella whipplei*
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 creek chubsucker[f]	*Erimyzon claviformis*
Western mosquitofish	*Gambusia affinis*
White bass	*Morone chrysops*
White crappie	*Pomoxis annularis*
White sucker	*Catostomus commersonii*[g]
Whitetail shiner	*Cyprinella galactura*
Yellow bullhead	*Ameiurus natalis*
Yellow perch	*Perca flavescens*

[e] Formerly Phoxinus erythrogaster

[f] Species split from Creek chubsucker (E. oblongus)

[g] Formerly spelled Catostomus commersoni.

Appendix 3. 2005–2010 Monitored Mainstem and Tributary Sites Selected by the Generalized Random Tessellation Stratified Method

Table A-3a. Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified (GRTS) method and monitored for fish communities at Buffalo National River from 2005-2010 under Petersen et al. 2008 (version 1.0) protocol.

Stretch ID	Reach ID	River basin	Site type	Site or tributary number	Tributary name	Panel number[a] (year)	County	Lower stretch UTM[b] Easting	Lower stretch UTM[b] Northing	Gear Used[c]	% Effort by Gear
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	Panther	2	Marion	540006.31	3993475.25	BP	100

[a] Panel No. describes how often a site is sampled. Panels 1-5 were sampled once every five years.

[b] UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983.

[c] BT = boat, BP = backpack, BA = barge

Table A-3a (continued). Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified (GRTS) method and monitored for fish communities at Buffalo National River from 2005-2010 under Petersen et al. 2008 (version 1.0) protocol.

Stretch ID	Reach ID	River basin	Site type	Site or tributary number	Tributary name	Panel number[a] (year)	County	Lower stretch UTM[b] Easting	Lower stretch UTM[b] Northing	Gear Used[c]	% Effort by Gear
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
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	Alt	Searcy	514572.59	3979212.00	BP	100
694	BUFFT26	Buffalo	Tributary	26	Rush	Alt	Marion	540617.75	39978810.50	BP	100

[a] Panel No. describes how often a site is sampled. Panels 1-5 were sampled once every five years.

[b] UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983.

[c] BT = boat, BP = backpack, BA = barge

Table A-3b. Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified (GRTS) method and monitored for fish communities at Ozark National Scenic Riverways from 2005-2010 under Petersen et al. 2008 (version 1.0) protocol.

Stretch ID	Reach ID	River basin	Site type	Site or tributary number	Tributary name	Panel number[a] (year)	County	Lower stretch UTM[b] Easting	Lower stretch UTM[b] Northing	Gear Used[c]	% Effort by Gear
14	CURRM01	Current	Mainstem	01	–	Annual	Shannon	623336.28	4141730.82	BT, BP	75, 25
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	75, 25
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[d]	85, 15
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

[a] Panel No. describes how often a site is sampled. Panels 1-5 were sampled once every five years.

[b] UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983.

[c] BT = boat, BP = backpack, BA = barge

[d] Denotes seine is used at this site in backwater area.

Table A-3b (continued). Mainstem and tributary sites selected by the Generalized Random Tessellation Stratified (GRTS) method and monitored for fish communities at Ozark National Scenic Riverways from 2005-2010 under Petersen et al. 2008 (version 1.0) protocol.

Stretch ID	Reach ID	River basin	Site type	Site or tributary number	Tributary name	Panel number[a] (year)	County	Lower stretch UTM[b] Easting	Lower stretch UTM[b] Northing	Gear Used[c]	% Effort by Gear
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

[a] Panel No. describes how often a site is sampled. Panels 1-5 were sampled once every five years.

[b] UTM is Universal Transverse Mercator coordinates (zone 15); horizontal datum is North American Datum of 1983.

[c] BT = boat, BP = backpack, BA = barge

Appendix 4. Comparison of Fish Monitoring Protocols

Table A-4. Comparison of selected protocol characteristics from the National Water Quality Assessment program (NAWQA), Environmental Monitoring and Assessment Program (EMAP), and Rapid Bioassessment Protocols (RBPs) with the Ozark Rivers Fish Community Protocol, version 2.0 protocol. X = times.

Characteristic	NAWQA	EMAP	RBP	Ozark Rivers Fish Community Protocol, V. 2.0	Reference to Protocol Narrative Section
Reach length minimum and maximum (meters)	150-1,000	150 (minimum)	Variable	150-1,000	Field Methods and Rationale
Reach length relative to mean wetted channel width	20X	40X (wadeable streams), 40 to 100X (nonwadeable streams)	Variable	20X	Establishing Sample Reaches, Figure 2
Time limit (hours)	None specified	0.75 to 3	Not specified	None specified	Field Methods and Rationale
Number of electrofishing passes	2	1	1	Wadeable, 1; non-wadeable, 2	Field Methods and Rationale
Electrofishing gear	Backpack, barge, or boat as appropriate	Backpack or boat as appropriate	Backpack or barge as appropriate	Backpack, barge, or boat as appropriate	Field Methods and Rationale
Block nets	No	Optional	Optional	No	Field Methods and Rationale
Seining	Optional (electrofishing and one or more other methods used)	Optional	No	Standard and kick seine, optional	Field Methods and Rationale
Length-weight measurements	30 per species	30 per species	Optional, not required	30 per species	Field Methods and Rationale
Recording of anomalies	Yes	Yes	Yes	Yes	Field Methods and Rationale
Selection of reach location (general)	Professional judgment	Randomized, systematic design	Professional judgment	GRTS (generalizeed random tessellation stratified sampling)	Selection of Sample Stretches; Field Methods and Rationale
Selection of reach boundary	Relative to riffle, run, pool[a]	Randomized, systematic design	Professional judgment	Bottom of reach is top of second riffle upstream from bottom of stretch	Establishing Sample Reaches, Figure 2
Other	–	Option to subsample between transects (wadeable streams)	Fish less than 20 miimeters total length not included	–	–
Other	–	Subsampled between transects (non-wadeable streams)	Several potential metrics listed	–	–

[a] 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, Tolerance, Habitat, Spawning, Substrate, and Trophic Preference

Table A-5a. Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

Common name	Scientific name	Refs.[a]	Tolerance[b]	Habitat preference				Spawning preference			
				Riffle	Pool	Run or main channel	Back-water	Broad-caster	Simple nester	Complex nester	Migratory
American brook lamprey (ammocoete)	*Lethenteron appendix*	1, 5	Unk	–	X	–	X	–	–	–	–
American brook lamprey adult	*Lethenteron appendix*	1, 2, 3, 5	I	X	–	–	–	–	X	–	X
American eel	*Anguilla rostrata*	2, 5, 8	M-T	–	X	–	X	–	–	–	–
Arkansas saddled darter	*Etheostoma euzonum*	5	Unk	X	–	–	–	–	–	–	–
Autumn darter (traits from Stippled darter)	*Etheostoma autmnale*	5, 8, 9	Unk	–	X	–	–	–	–	–	–
Banded darter	*Etheostoma zonale*	2, 3, 4, 5	I	X	–	–	–	X	–	–	–
Banded sculpin	*Cottus carolinae*	2, 4, 5	M	X	–	–	–	–	–	X	–
Bigeye chub	*Hybopsis amblops*	2, 4, 5	I-M	–	X	X	–	X	–	–	–
Bigeye shiner	*Notropis boops*	4, 5, 7	I	–	X	–	–	X	–	–	–
Bigmouth buffalo	*Ictiobus cyprinellus*	3, 5, 6	M	–	X	X	X	X	–	–	–
Black buffalo	*Ictiobus niger*	3, 5, 6	M-I	–	X	–	X	X	–	–	–
Black bullhead	*Ameiurus melas*	1, 2, 3, 5	M-T	–	X	–	X	–	–	X	–
Black crappie	*Pomoxis nigromaculatus*	1, 2, 3, 5	M	–	X	–	X	–	–	X	–
Black redhorse	*Moxostoma duquesnei*	2, 3, 4, 5	I	–	–	X	–	X	–	–	X
Black River madtom (traits from Ozark madtom)	*Noturus maydeni*	5, 8, 9	Unk	X	X	–	–	–	–	–	–
Blackside darter	*Percina maculata*	1, 2, 3, 5	M	–	X	–	–	X	–	–	X

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**Refs.**[a]	**Tolerance**[b]	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Complex nester**	**Migratory**
Blackspotted topminnow	*Fundulus olivaceus*	4, 5, 6	M	–	X	–	X	X	–	–	–
Blacktail shiner	*Cyprinella venusta*	4, 5, 6	Unk	–	–	X	–	–	X	–	–
Bleeding shiner	*Luxilus zonatus*	5, 8, 9	Unk	–	–	–	–	–	–	–	–
Bluegill	*Lepomis macrochirus*	1, 2, 3, 5	M-T	–	X	–	–	–	–	X	–
Blue sucker	*Cycleptus elongatus*	3, 4, 5	I	–	–	X	–	X	–	–	X
Bluntnose minnow	*Pimephales notatus*	2, 3, 4, 5	T	–	X	–	X	–	–	X	–
Brindled madtom	*Noturus miurus*	4, 5, 6	I-M	–	X	–	–	–	–	X	–
Brook silverside	*Labidesthes sicculus*	2, 3, 5	M-I	–	X	–	–	X	–	–	–
Brown trout	*Salmo trutta*	3, 5	M-I	–	X	–	–	–	X	–	X
Carmine shiner (traits from Rosyface shiner)	*Notropis percobromus*	1, 3, 4, 5	I	–	X	X	–	–	X	–	–
Central stoneroller	*Campostoma anomalum*	2, 3, 4, 5	M-T	X	X	X	–	–	X	–	X
Chain pickerel	*Esox niger*	2, 4, 5	M	–	X	–	–	X	–	–	–
Channel catfish	*Ictalurus punctatus*	2, 3, 5	M	–	X	X	–	–	–	X	–
Checkered madtom	*Noturus flavater*	5, 8, 9	Unk	–	–	–	–	–	–	–	–
Chestnut lamprey adult	*Ichthyomyzon castaneus*	1, 3, 5, 9	M	–	–	X	–	–	X	–	–
Common carp	*Cyprinus carpio*	2, 3, 5	T	–	X	–	–	X	–	–	–
Creek chub	*Semotilus atromaculatus*	2, 3, 4, 5	T	–	X	–	–	–	X	–	–
Current darter (traits from orangethroat darter)	*Etheostoma uniporum*	4, 5, 9	M	–	X	X	–	–	X	–	–
Cypress darter	*Etheostoma proeliare*	4, 5, 6	M	–	X	–	X	–	X	–	–
Duskystripe shiner	*Luxilus pilsbryi*	5, 8, 9	Unk	–	X	X	–	–	–	–	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**Refs.[a]**	**Tolerance[b]**	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Complex nester**	**Migratory**
Emerald shiner	*Notropis atherinoides*	2, 3, 4, 5	M	–	X	X	–	X	–	–	–
Fantail darter	*Etheostoma flabellare*	2, 3, 4, 5	M	X	–	–	–	–	–	X	–
Fathead minnow	*Pimephales promelas*	2, 3, 5	T	–	X	–	–	–	–	X	–
Flathead catfish	*Pylodictis olivaris*	2, 3, 5	M	–	X	–	–	–	–	X	–
Flier	*Centrarchus macropterus*	2, 4, 5, 7	M	–	X	–	X	–	–	X	–
Freckled madtom	*Noturus nocturnus*	4, 5, 6	M-I	X	–	X	–	–	–	X	–
Freshwater drum	*Aplodinotus grunniens*	2, 5	M	–	X	–	X	X	–	–	–
Goldfish	*Carassius auratus*	3, 5, 7	T	–	X	–	X	X	–	–	–
Gilt darter	*Percina evides*	2, 3, 5	I	X	–	–	–	X	–	–	–
Gizzard shad	*Dorosoma cepedianum*	2, 3, 4, 5	M-T	–	X	X	–	X	–	–	–
Golden redhorse	*Moxostoma erythrurum*	1, 2, 3, 4, 5	M-I	–	X	–	–	X	–	–	X
Golden shiner	*Notemigonus crysoleucas*	2, 3, 4, 5	T	–	X	–	X	X	–	–	–
Goldeye	*Hiodon alosoides*	1, 3, 5	I	–	X	–	X	X	–	–	–
Gravel chub	*Erimystax x-punctatus*	3, 5, 8	M-I	X	–	X	–	X	–	–	–
Green sunfish	*Lepomis cyanellus*	1, 2, 3, 5	T-M	–	X	–	X	–	–	X	–
Greenside darter	*Etheostoma blennioides*	2, 4, 5	M-I	X	–	–	–	–	X	–	–
Highfin carpsucker	*Carpiodes velifer*	3, 4, 5	I-M	–	X	–	X	X	–	–	X
Horneyhead chub	*Nocomis biguttatus*	1, 3, 5	I-M	X	X	–	–	–	X	–	–
Johnny darter	*Etheostoma nigrum*	2, 3, 4, 5	M	–	X	–	–	–	–	X	–
Knobfin sculpin (traits from Ozark sculpin)	*Cottus immaculatus*	5, 8, 9	Unk	X	–	–	–	–	–	–	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**Refs.[a]**	**Tolerance[b]**	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Complex nester**	**Migratory**
Lake chubsucker	*Erimyzon sucetta*	2, 4, 5	M	–	X	–	X	X	–	–	–
Largemouth bass	*Micropterus salmoides*	1, 2, 3, 5	M-T	–	X	–	X	–	–	X	–
Largescale stoneroller	*Campostoma oligolepis*	3, 5, 6, 9	M	X	–	X	–	–	X	–	X
Least brook lamprey adult	*Lampetra aepyptera*	2, 5, 8, 9	M-I	X	–	–	–	–	X	–	–
Least brook lamprey ammocoete	*Lampetra aepyptera*	5	Unk	–	X	–	X	–	–	–	–
Logperch	*Percina caprodes*	2, 3, 5, 8	M	–	–	–	–	X	–	–	–
Longear sunfish	*Lepomis megalotis*	2, 5, 6	I-M	–	X	–	–	–	–	X	–
Longnose gar	*Lepisosteus osseus*	1, 3, 5	M	–	X	–	X	X	–	–	–
Mississippi silvery minnow	*Hybognathus nuchalis*	3, 4, 5	M-I	–	X	–	X	X	–	–	–
Mooneye	*Hiodon tergisus*	3, 5, 7	I	–	X	–	X	X	–	–	–
Mountain madtom	*Noturus eleutherus*	2, 4, 5, 9	I	X	–	X	–	–	–	X	–
Mud darter	*Etheostoma asprigene*	4, 5, 7	M	–	–	X	–	–	–	X	–
Northern hog sucker	*Hypentelium nigricans*	1, 3, 4, 5	I-M	X	–	X	–	X	–	–	–
Northern studfish	*Fundulus catenatus*	2, 4, 5, 7	I	–	–	–	X	X	–	–	–
Orangespotted sunfish	*Lepomis humilis*	3, 4, 5	M	–	X	–	–	–	–	X	–
Orangethroat darter	*Etheostoma spectabile*	4, 5, 9	M	–	X	X	–	–	X	–	–
Ozark bass	*Ambloplites constellatus*	2, 5, 10	Unk	–	X	–	–	–	–	X	–
Ozark chub (traits from Streamline chub)	*Erimystax harryi*	2, 4, 5	I	–	X	X	–	X	–	–	–
Ozark madtom	*Noturus albater*	5, 8, 9	Unk	X	X	–	–	–	–	–	–
Ozark minnow	*Notropis nubilus*	3, 5, 8	I	–	X	–	X	–	X	–	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

Common name	Scientific name	Refs.[a]	Tolerance[b]	Habitat preference				Spawning preference			
				Riffle	Pool	Run or main channel	Back-water	Broad-caster	Simple nester	Complex nester	Migratory
Ozark shiner	*Notropis ozarcanus*	5, 9	Unk	–	X	X	0	–	–	–	–
Paddlefish	*Polyodon spathula*	2, 5, 6	I	–	–	X	–	X	–	–	X
Pealip redhorse (traits from Shorthead redhorse)	*Moxostoma pisolabrum*	2, 3, 4, 5	M	X	X	X	–	X	–	–	X
Pirate perch	*Aphredoderus sayanus*	2, 3, 4, 5	M	–	X	–	X	–	–	X	–
Pugnose minnow	*Opsopoeodus emiliae*	1, 4, 5, 9	I	–	–	–	X	–	–	X	–
Quillback	*Carpiodes cyprinus*	2, 3, 5	M-T	–	X	–	X	X	–	–	X
Rainbow darter	*Etheostoma caeruleum*	1, 2, 3, 4, 5	M-I	X	X	–	–	–	X	–	–
Rainbow trout	*Oncorhynchus mykiss*	1, 3, 5	M-I	X	X	–	–	–	X	–	X
Redear sunfish	*Lepomis microlophus*	2, 5, 6	M	–	X	–	X	–	–	X	–
Redfin pickerel	*Esox americanus*	1, 3, 5	M	–	X	–	–	X	–	–	–
Redfin shiner	*Lythrurus umbratilis*	3, 4, 5	M-T	–	X	–	–	–	X	–	–
Redspotted sunfish	*Lepomis miniatus*	4, 5, 6	Unk	–	X	–	–	–	–	X	–
Ribbon shiner	*Lythrurus fumeus*	not listed	M	–	–	–	–	–	–	–	–
River carpsucker	*Carpiodes carpio*	3, 5, 6	M	–	X	–	X	X	–	–	–
River redhorse	*Moxostoma carinatum*	2, 3, 4, 5	I	–	X	X	–	–	X	–	–
Sauger	*Sander canadensis*	2, 3, 5	M	–	X	X	X	X	–	–	X
Shadow bass	*Ambloplites ariommus*	2, 5, 10	Unk	–	X	–	–	–	–	X	–
Shortnose gar	*Lepisosteus platostomus*	3, 4, 5	M	–	X	–	–	X	–	–	–
Shovelnose sturgeon	*Scaphirhyncus platorynchus*	3, 4, 5	M	–	–	X	–	X	–	–	–
Silver redhorse	*Moxostoma anisurum*	2, 3, 4, 5	M	–	X	–	–	X	–	–	X

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**Refs.[a]**	**Tolerance[b]**	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Complex nester**	**Migratory**
Skipjack herring	*Alosa chrysochloris*	3, 5, 6	M	–	–	X	–	X	–	–	X
Slender madtom	*Noturus exilis*	3, 4, 5, 7	I	X	X	X	–	–	–	X	–
Smallmouth bass	*Micropterus dolomieu*	1, 2, 3, 5	M-I	–	X	X	–	–	–	X	–
Smallmouth buffalo	*Ictiobus bubalus*	3, 4, 5	M-I	–	X	X	X	X	–	–	–
Southern brook lamprey adult	*Ichthyomyzon gagei*	2, 5, 8, 9	I	X	–	–	–	–	X	–	–
Southern brook lamprey ammocoete	*Ichthyomyzon gagei*	5	Unk	–	X	–	X	–	–	–	–
Southern cavefish	*Typhlichthys subterraneus*	not listed	Unk	–	–	–	–	–	–	–	–
Southern redbelly dace	*Chrosomus erythrogaster*	3, 4, 5	M-I	–	X	–	–	X	–	–	–
Speckled darter	*Etheostoma stigmaeum*	2, 4, 5	Unk	–	X	X	–	–	X	–	–
Spotted bass	*Micropterus punctulatus*	2, 4, 5	M	–	X	X	–	–	–	X	–
Spotted gar	*Lepisosteus oculatus*	4, 5, 7	M	–	X	–	X	X	–	–	–
Spotted sucker	*Minytrema melanops*	3, 4, 5	M-I	–	X	–	–	X	–	–	–
Stargarzing darter	*Percina uranidea*	2, 4, 5	I	–	–	X	–	–	–	–	–
Steelcolor shiner	*Cyprinella whipplei*	2, 4, 5	M-I	–	X	X	–	–	X	–	–
Stippled darter	*Etheostoma punctulatum*	5, 8, 9	Unk	–	X	–	–	–	–	–	–
Striped shiner	*Luxilus chrysocephalus*	2, 3, 4, 5	M-T	–	X	–	X	–	X	–	–
Suckermouth minnow	*Phenacobius mirabilis*	2, 3, 4, 5	M	X	–	X	–	X	–	–	X
Tadpole madtom	*Noturus gyrinus*	2, 3, 5, 7	M-I	–	X	–	X	–	–	X	–
Telescope shiner	*Notropis telescopus*	2, 4, 5	Unk	–	X	X	–	–	–	–	–
Threadfin shad	*Dorosoma petenense*	2, 4, 5, 6	M	–	–	–	–	X	–	–	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5a (continued). Habitat and spawning preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Habitat preference				Spawning preference			
Common name	**Scientific name**	**Refs.[a]**	**Tolerance[b]**	**Riffle**	**Pool**	**Run or main channel**	**Back-water**	**Broad-caster**	**Simple nester**	**Complex nester**	**Migratory**
Walleye	*Sander vitreus*	2, 3, 5	M	–	X	X	X	X	–	–	X
Warmouth	*Lepomis gulosus*	2, 4, 5	M	–	X	–	X	–	–	X	–
Wedgespot shiner	*Notropis greenei*	5, 8	Unk	–	X	X	–	–	–	–	–
Weed shiner	*Notropis texanus*	3, 4, 5	I	–	X	X	–	X	–	–	–
Western creek chub-sucker (traits from Eastern creek chubsucker)	*Erimyzon claviformis*	2, 3, 4, 5	M-T-I	–	X	–	–	X	–	–	X
Western mosquitofish	*Gambusia affinis*	4, 5, 7	M-T	–	–	–	X	–	–	–	–
White bass	*Morone chrysops*	2, 3, 5	M-T	–	X	–	–	X	–	–	X
White crappie	*Pomoxis annularis*	2, 3, 5	M-T	–	X	–	X	–	–	X	–
White sucker	*Catostomus commersonii*	2, 3, 4, 5	T	X	X	–	–	X	–	–	X
Whitetail shiner	*Cyprinella galuctura*	2, 4, 5	Unk	–	–	X	–	–	X	–	–
Yellow bullhead	*Ameiurus natalis*	1, 2, 3, 5	T-M	–	X	–	X	–	–	X	–
Yellow perch	*Perca flavescens*	1, 2, 3, 5	M	–	X	–	X	X	–	–	–
Yoke darter	*Etheostoma juliae*	5, 8, 9	Unk	X	–	–	–	–	–	–	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b. Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Substrate preference					Trophic status				
Common name	**Scientific name**	**Refs.[a]**	**Tolerance[b]**	**Cobble/ rubble/ (rocky)**	**Gravel**	**Sand**	**Mud (silt, clay detritus)**	**Vegetation**	**Herbivore**	**Planktivore**	**Detritivore**	**Invertivore**	**Carnivore**
American brook lamprey (ammocoete)	*Lethenteron appendix*	1, 5	Unk	–	–	–	X	–	X	–	–	–	–
American brook lamprey adult	*Lethenteron appendix*	1, 2, 3, 5	I	X	X	X	–	–	–	–	–	–	–
American eel	*Anguilla rostrata*	2, 5, 8	M-T	–	–	–	–	–	–	–	–	X	X
Arkansas saddled darter	*Etheostoma euzonum*	5	Unk	X	X	–	–	–	–	–	–	–	–
Autumn darter (traits from Stippled darter)	*Etheostoma autmnale*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–
Banded darter	*Etheostoma zonale*	2, 3, 4, 5	I	–	X	–	–	–	–	–	–	X	–
Banded sculpin	*Cottus carolinae*	2, 4, 5	M	X	X	–	–	–	–	–	–	X	–
Bigeye chub	*Hybopsis amblops*	2, 4, 5	I-M	–	X	X	–	–	–	–	–	X	–
Bigeye shiner	*Notropis boops*	4, 5, 7	I	X	–	–	–	–	–	–	–	X	–
Bigmouth buffalo	*Ictiobus cyprinellus*	3, 5, 6	M	–	–	–	X	–	–	–	–	X	–
Black buffalo	*Ictiobus niger*	3, 5, 6	M-I	–	–	–	–	–	–	–	–	–	–
Black bullhead	*Ameiurus melas*	1, 2, 3, 5	M-T	–	–	X	X	–	–	–	–	X	X
Black crappie	*Pomoxis nigromaculatus*	1, 2, 3, 5	M	–	–	X	X	X	–	–	–	X	X
Black redhorse	*Moxostoma duquesnei*	2, 3, 4, 5	I	X	X	X	–	–	–	–	–	X	–
Black River madtom (traits from Ozark madtom)	*Noturus maydeni*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–
Blackside darter	*Percina maculata*	1, 2, 3, 5	M	–	X	X	–	–	–	–	–	X	–
Blackspotted topminnow	*Fundulus olivaceus*	4, 5, 6	M	–	X	X	–	–	X	–	–	X	–
Blacktail shiner	*Cyprinella venusta*	4, 5, 6	Unk	–	–	X	–	–	–	–	–	X	–
Bleeding shiner	*Luxilus zonatus*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Substrate preference					Trophic status				
Common name	**Scientific name**	**Refs.[a]**	**Toler-ance[b]**	**Cob-ble/ rubble/ (rocky)**	**Gravel**	**Sand**	**Mud (silt, clay detritus)**	**Vege-tation**	**Herbi-vore**	**Plank-tivore**	**Detriti-vore**	**Inverti-vore**	**Carni-vore**
Bluegill	*Lepomis macrochirus*	1, 2, 3, 5	M-T	–	–	–	–	X	–	–	–	X	–
Blue sucker	*Cycleptus elongatus*	3, 4, 5	I	–	X	X	–	–	X	–	–	X	–
Bluntnose minnow	*Pimephales notatus*	2, 3, 4, 5	T	–	X	X	X	–	–	–	X	–	–
Brindled madtom	*Noturus miurus*	4, 5, 6	I-M	–	X	X	X	–	–	–	–	X	–
Brook silverside	*Labidesthes sicculus*	2, 3, 5	M-I	–	–	–	–	–	–	X	–	X	–
Brown trout	*Salmo trutta*	3, 5	M-I	X	–	–	–	–	–	–	–	X	X
Carmine shiner (traits from Rosyface shiner)	*Notropis percobromus*	1, 3, 4, 5	I	X	X	–	–	–	X	–	X	X	–
Central stoneroller	*Campostoma anomalum*	2, 3, 4, 5	M-T	X	–	–	–	–	X	–	–	–	–
Chain pickerel	*Esox niger*	2, 4, 5	M	–	–	–	–	X	–	–	–	–	X
Channel catfish	*Ictalurus punctatus*	2, 3, 5	M	X	–	X	X	–	–	–	–	X	X
Checkered madtom	*Noturus flavater*	5, 8, 9	Unk	–	–	–	–	–	–	–	–	–	–
Chestnut lamprey adult	*Ichthyomyzon castaneus*	1, 3, 5, 9	M	X	X	–	–	–	–	–	–	–	X
Common carp	*Cyprinus carpio*	2, 3, 5	T	–	–	–	–	X	–	–	X	X	–
Creek chub	*Semotilus atromaculatus*	2, 3, 4, 5	T	X	–	X	–	–	–	–	–	X	X
Current darter (traits from orangethroat darter)	*Etheostoma uniporum*	4, 5, 9	M	–	X	–	–	–	–	–	–	X	–
Cypress darter	*Etheostoma proeliare*	4, 5, 6	M	–	–	–	X	X	–	–	–	X	–
Duskystripe shiner	*Luxilus pilsbryi*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–
Emerald shiner	*Notropis atherinoides*	2, 3, 4, 5	M	–	–	X	–	–	–	X	–	–	–
Fantail darter	*Etheostoma flabellare*	2, 3, 4, 5	M	X	X	–	–	–	–	–	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Substrate preference					Trophic status				
Common name	Scientific name	Refs.[a]	Tolerance[b]	Cobble/ rubble/ (rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vegetation	Herbivore	Planktivore	Detritivore	Invertivore	Carnivore
Fathead minnow	*Pimephales promelas*	2, 3, 5	T	–	–	X	X	–	–	–	X	X	–
Flathead catfish	*Pylodictis olivaris*	2, 3, 5	M	–	–	–	–	–	–	–	–	X	X
Flier	*Centrarchus macropterus*	2, 4, 5, 7	M	–	–	–	X	–	–	–	–	X	–
Freckled madtom	*Noturus nocturnus*	4, 5, 6	M-I	–	X	X	–	–	–	–	–	X	–
Freshwater drum	*Aplodinotus grunniens*	2, 5	M	–	–	–	–	–	–	–	–	X	X
Goldfish	*Carassius auratus*	3, 5, 7	T	–	–	–	X	X	X	–	–	X	–
Gilt darter	*Percina evides*	2, 3, 5	I	X	–	–	–	–	–	–	–	X	–
Gizzard shad	*Dorosoma cepedianum*	2, 3, 4, 5	M-T	–	–	–	–	–	X	–	–	–	–
Golden redhorse	*Moxostoma erythrurum*	1, 2, 3, 4, 5	M-I	–	–	–	–	–	–	–	–	X	–
Golden shiner	*Notemigonus crysoleucas*	2, 3, 4, 5	T	–	–	–	–	–	X	–	–	X	–
Goldeye	*Hiodon alosoides*	1, 3, 5	I	–	–	–	–	–	–	–	–	X	–
Gravel chub	*Erimystax x-punctatus*	3, 5, 8	M-I	–	X	–	–	–	X	–	–	–	–
Green sunfish	*Lepomis cyanellus*	1, 2, 3, 5	T-M	–	–	–	–	X	–	–	–	X	X
Greenside darter	*Etheostoma blennioides*	2, 4, 5	M-I	X	–	–	–	–	–	–	–	X	–
Highfin carpsucker	*Carpiodes velifer*	3, 4, 5	I-M	–	X	X	–	–	–	–	X	–	–
Horneyhead chub	*Nocomis biguttatus*	1, 3, 5	I-M	X	X	–	–	–	X	–	–	X	–
Johnny darter	*Etheostoma nigrum*	2, 3, 4, 5	M	–	–	X	X	–	–	–	–	X	–
Knobfin sculpin (traits from Ozark sculpin)	*Cottus immaculatus*	5, 8, 9	Unk	–	X	–	–	X	–	–	–	X	–
Lake chubsucker	*Erimyzon sucetta*	2, 4, 5	M	–	–	X	X	–	X	–	–	X	–
Largemouth bass	*Micropterus salmoides*	1, 2, 3, 5	M-T	–	–	X	X	X	–	–	–	X	X

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

Common name	Scientific name	Refs.[a]	Tolerance[b]	Substrate preference					Trophic status				
				Cobble/rubble/(rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vegetation	Herbivore	Planktivore	Detritivore	Invertivore	Carnivore
Largescale stoneroller	*Campostoma oligolepis*	3, 5, 6, 9	M	X	–	–	–	–	X	–	–	–	–
Least brook lamprey adult	*Lampetra aepyptera*	2, 5, 8, 9	M-I	–	X	X	–	–	–	–	–	–	–
Least brook lamprey ammocoete	*Lampetra aepyptera*	5	Unk	–	–	–	X	–	X	–	–	–	–
Logperch	*Percina caprodes*	2, 3, 5, 8	M	–	X	X	–	–	–	–	–	–	–
Longear sunfish	*Lepomis megalotis*	2, 5, 6	I-M	X	–	X	–	X	–	–	–	X	–
Longnose gar	*Lepisosteus osseus*	1, 3, 5	M	–	–	–	–	X	–	–	–	–	X
Mississippi silvery minnow	*Hybognathus nuchalis*	3, 4, 5	M-I	–	–	X	–	–	–	–	X	–	–
Mooneye	*Hiodon tergisus*	3, 5, 7	I	–	–	–	–	–	–	–	–	X	–
Mountain madtom	*Noturus eleutherus*	2, 4, 5, 9	I	X	X	–	–	–	–	–	–	X	–
Mud darter	*Etheostoma asprigene*	4, 5, 7	M	–	X	X	–	–	–	–	–	X	–
Northern hog sucker	*Hypentelium nigricans*	1, 3, 4, 5	I-M	X	X	–	–	–	X	–	–	X	–
Northern studfish	*Fundulus catenatus*	2, 4, 5, 7	I	–	–	X	–	–	–	–	–	X	–
Orangespotted sunfish	*Lepomis humilis*	3, 4, 5	M	–	–	–	–	X	–	–	–	X	–
Orangethroat darter	*Etheostoma spectabile*	4, 5, 9	M	–	X	–	–	–	–	–	–	X	–
Ozark bass	*Ambloplites constellatus*	2, 5, 10	Unk	X	–	–	–	–	–	–	–	X	X
Ozark chub (traits from Streamline chub)	*Erimystax harryi*	2, 4, 5	I	X	X	–	–	–	–	–	–	–	–
Ozark madtom	*Noturus albater*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–
Ozark minnow	*Notropis nubilus*	3, 5, 8	I	X	X	–	–	–	X	–	–	–	–
Ozark shiner	*Notropis ozarcanus*	5, 9	Unk	X	–	X	–	–	–	–	–	X	–
Paddlefish	*Polyodon spathula*	2, 5, 6	I	–	–	–	–	–	–	X	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Substrate preference					Trophic status				
Common name	**Scientific name**	**Refs.**[a]	**Tolerance**[b]	**Cobble/ rubble/ (rocky)**	**Gravel**	**Sand**	**Mud (silt, clay detritus)**	**Vegetation**	**Herbivore**	**Planktivore**	**Detritivore**	**Invertivore**	**Carnivore**
Paddlefish	*Polyodon spathula*	2, 5, 6	I	–	–	–	–	–	–	X	–	X	–
Pealip redhorse (traits from Shorthead redhorse)	*Moxostoma pisolabrum*	2, 3, 4, 5	M	–	X	–	–	–	–	–	–	X	–
Pirate perch	*Aphredoderus sayanus*	2, 3, 4, 5	M	–	–	–	X	X	–	–	–	X	X
Pugnose minnow	*Opsopoeodus emiliae*	1, 4, 5, 9	I	–	–	–	–	X	–	X	X	–	–
Quillback	*Carpiodes cyprinus*	2, 3, 5	M-T	–	X	X	–	–	–	–	X	X	–
Rainbow darter	*Etheostoma caeruleum*	1, 2, 3, 4, 5	M-I	X	X	–	–	–	–	–	–	X	–
Rainbow trout	*Oncorhynchus mykiss*	1, 3, 5	M-I	–	X	–	–	–	–	–	–	X	X
Redear sunfish	*Lepomis microlophus*	2, 5, 6	M	–	–	X	X	–	–	–	–	X	–
Redfin pickerel	*Esox americanus*	1, 3, 5	M	–	–	–	–	X	–	–	–	X	X
Redfin shiner	*Lythrurus umbratilis*	3, 4, 5	M-T	–	–	–	X	–	–	–	–	–	–
Redspotted sunfish	*Lepomis miniatus*	4, 5, 6	Unk	–	–	X	X	–	–	–	–	X	–
Ribbon shiner	*Lythrurus fumeus*	not listed	M	–	–	–	–	–	–	–	–	–	–
River carpsucker	*Carpiodes carpio*	3, 5, 6	M	–	–	X	X	–	X	X	–	–	–
River redhorse	*Moxostoma carinatum*	2, 3, 4, 5	I	X	X	–	–	–	–	–	–	X	–
Sauger	*Sander canadensis*	2, 3, 5	M	–	X	X	X	–	–	–	–	X	X
Shadow bass	*Ambloplites ariommus*	2, 5, 10	Unk	–	X	X	X	–	–	–	–	X	X
Shortnose gar	*Lepisosteus platostomus*	3, 4, 5	M	–	–	–	–	–	–	–	–	–	X
Shovelnose sturgeon	*Scaphirhyncus platorynchus*	3, 4, 5	M	–	X	X	–	–	–	–	–	X	–
Silver redhorse	*Moxostoma anisurum*	2, 3, 4, 5	M	–	–	–	–	–	–	–	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

				Substrate preference					Trophic status				
Common name	Scientific name	Refs.[a]	Tolerance[b]	Cobble/rubble/(rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vegetation	Herbivore	Planktivore	Detritivore	Invertivore	Carnivore
Skipjack herring	*Alosa chrysochloris*	3, 5, 6	M	–	X	X	–	–	–	X	–	–	–
Slender madtom	*Noturus exilis*	3, 4, 5, 7	I	–	X	–	–	–	–	–	X	X	–
Smallmouth bass	*Micropterus dolomieu*	1, 2, 3, 5	M-I	–	X	–	–	–	–	–	–	X	X
Smallmouth buffalo	*Ictiobus bubalus*	3, 4, 5	M-I	–	–	–	–	–	X	–	–	X	–
Southern brook lamprey adult	*Ichthyomyzon gagei*	2, 5, 8, 9	I	X	X	X	–	–	–	–	–	–	–
Southern brook lamprey ammocoete	*Ichthyomyzon gagei*	5	Unk	–	–	–	X	–	X	–	–	–	–
Southern cavefish	*Typhlichthys subterraneus*	not listed	Unk	–	–	–	–	–	–	–	–	–	–
Southern redbelly dace	*Chrosomus erythrogaster*	3, 4, 5	M-I	–	X	–	–	–	–	X	–	–	–
Speckled darter	*Etheostoma stigmaeum*	2, 4, 5	Unk	–	X	X	–	–	–	–	–	–	–
Spotted bass	*Micropterus punctulatus*	2, 4, 5	M	–	X	–	–	–	–	–	–	X	X
Spotted gar	*Lepisosteus oculatus*	4, 5, 7	M	–	–	–	–	–	–	–	–	–	X
Spotted sucker	*Minytrema melanops*	3, 4, 5	M-I	–	–	X	X	–	–	–	–	X	–
Stargarzing darter	*Percina uranidea*	2, 4, 5	I	–	X	–	–	–	–	–	–	X	–
Steelcolor shiner	*Cyprinella whipplei*	2, 4, 5	M-I	X	–	X	–	–	–	–	–	X	–
Stippled darter	*Etheostoma punctulatum*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–
Striped shiner	*Luxilus chrysocephalus*	2, 3, 4, 5	M-T	–	X	X	–	–	–	–	–	X	–
Suckermouth minnow	*Phenacobius mirabilis*	2, 3, 4, 5	M	X	X	X	–	–	–	–	–	X	–
Tadpole madtom	*Noturus gyrinus*	2, 3, 5, 7	M-I	X	–	–	X	–	–	X	–	X	–
Telescope shiner	*Notropis telescopus*	2, 4, 5	Unk	X	–	–	–	–	–	–	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Table A-5b (continued). Substrate and trophic preferences and tolerance classifications of fish species known to occur in Buffalo National River and Ozark National Scenic Riverways. Modified from Goldstein and Meador (2004). Fish names follow Page et al. (2013).

Common name	Scientific name	Refs.[a]	Tolerance[b]	Substrate preference					Trophic status				
				Cobble/ rubble/ (rocky)	Gravel	Sand	Mud (silt, clay detritus)	Vegetation	Herbivore	Planktivore	Detritivore	Invertivore	Carnivore
Threadfin shad	*Dorosoma petenanse*	2, 4, 5, 6	M	–	–	–	–	–	–	X	–	–	–
Walleye	*Sander vitreus*	2, 3, 5	M	–	–	–	–	–	–	–	–	X	X
Warmouth	*Lepomis gulosus*	2, 4, 5	M	–	–	–	X	X	–	–	–	X	X
Wedgespot shiner	*Notropis greenei*	5, 8	Unk	X	X	X	–	–	–	–	–	–	–
Weed shiner	*Notropis texanus*	3, 4, 5	I	–	–	X	–	X	–	–	X	–	–
Western creek chubsucker (traits from Eastern creek chubsucker)	*Erimyzon claviformis*	2, 3, 4, 5	M-T-I	–	X	X	–	X	–	–	–	X	–
Western mosquitofish	*Gambusia affinis*	4, 5, 7	M-T	–	–	–	–	–	–	–	–	X	–
White bass	*Morone chrysops*	2, 3, 5	M-T	–	–	–	–	–	–	–	–	X	X
White crappie	*Pomoxis annularis*	2, 3, 5	M-T	–	–	X	X	–	–	–	–	X	X
White sucker	*Catostomus commersonii*	2, 3, 4, 5	T	X	X	–	–	–	X	–	X	–	–
Whitetail shiner	*Cyprinella galuctura*	2, 4, 5	Unk	X	–	–	–	–	–	–	–	X	–
Yellow bullhead	*Ameiurus natalis*	1, 2, 3, 5	T-M	–	–	X	X	X	–	–	–	X	X
Yellow perch	*Perca flavescens*	1, 2, 3, 5	M	–	–	–	–	X	–	–	–	X	X
Yoke darter	*Etheostoma juliae*	5, 8, 9	Unk	X	–	–	–	–	–	–	–	X	–

[a] References are literature used to designate preferences for each species: 1 = Scott and Crossman 1973; 2 = Jenkins and Burkhead 1994; 3 = Becker 1983; 4 = Etnier and Starnes 1993; 5 = Page and Burr 1991; 6 = Mettee et al. 1996; 7 = Ross 2001; 8 = Pflieger 1997; 9 = Robison and Buchanan 1988; 10 = Rohde et al. 1994

[b] Tolerance values from Barbour et al. (1999); Unk = unknown; I = intolerant, M = moderate tolerance; T = tolerant; first tolerance value is greatest consensus.

Appendix 6. Index of Biotic Integrity Metrics for Midwestern Streams

Table A-6. Metrics used in an index of biotic integrity for midwestern streams (Karr 1981).

Metric classification	Metric description
Richness	Total number of fish species Number and identity of darter species[a] Number and identity of sunfish species Number and identity of sucker species[a]
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[a] 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

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

Appendix 7. Index of Biotic Integrity Metrics for Use on the Current River in Southeastern Missouri

Table A-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[a] Number and identity of darter, sculpin, and round bodied sucker species[a]
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[a] Proportion of individuals as piscivores
Spawning preference	Proportion of individuals as lithophilic spawners[a]

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

Appendix 8. Index of Biotic Integrity Metrics Used in Missouri Streams by the Missouri Department of Conservation

Table A-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 communication, 2004.

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

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

Appendix 9. Index of Biotic Integrity Metrics for Wadeable Streams in the Ozark Highlands

Table A-9. Metrics selected for an index of biotic integrity for wadeable streams in the Ozark Highlands. From Dauwalter et al. (2003).

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

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

[b] This metric could also be classified under "Taxa Richness." However, in the Ozarks, these groups generally represent tolerant species.

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

Appendix 10. List of Standard Operating Procedures

List of Standard Operating Procedures (SOPs) for the Methods for Monitoring Fish Communities of Buffalo National River and Ozark Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri, Version 2.0 protocol:

Standard Operating Procedure 1: Preparation, Version 1.1

Standard Operating Procedure 2: Training, Version 1.1

Standard Operating Procedure 3: Reach Selection, Version 1.1

Standard Operating Procedure 4: Documenting CORE 5 Water Quality, Version 1.1

Standard Operating Procedure 5: Fish Community Sampling, Version 1.1

Standard Operating Procedure 6: Habitat Collection, Version 1.1

Standard Operating Procedure 7: Measuring Stream Discharge, Version 1.1

Standard Operating Procedure 8: Equipment Maintenance and Storage, Version 1.1

Standard Operating Procedure 9: Data Management, Version 2.0

Standard Operating Procedure 10: Data Analysis, Version 2.0

Standard Operating Procedure 11: Reporting, Version 1.1

Standard Operating Procedure 12: Revision of Standard Operation Procedures, Version 1.1

NPS 173/145004, 614/145004, May 2018

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525