



Shenandoah National Park Fish Monitoring Protocol

Version 5.0

Natural Resource Report NPS/SHEN/NRR—2018/1646



ON THE COVER

Shenandoah National Park Fish Crew sampling on the Rapidan River, 2016.

Photo courtesy of NPS/David Demarest

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As a legacy National Park Service monitoring protocol, this report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. A legacy protocol, as defined here, is a monitoring protocol that predates the National Park Service Inventory and Monitoring Program (est. 1998).

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Protocol Revision History

All protocols, regardless of how sound they are originally, require modification as new and different information becomes available. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...).

Protocol Revision History Log.

Version #	Date	Revised By	Changes	Justification
1.0	1982	Original protocol	NA	NA
2.0	1995	Atkinson	Many sampling locations changed, more multiple-pass electrofishing sites added	See protocol history
3.0	2004/05	Olson, Atkinson	Annual sampling changed to every other year, 5 yr. rotation changed to 8 yr.	Temporal changes due to budgets
4.0	2008	Atkinson, Demarest	Multiple pass electrofishing at all sites	Increase in e-fish passes required relatively small increase in effort
5.0	2018	Wofford, Demarest	Protocol updated to meet IMD standards	IMD requirement

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Executive Summary

This document culminates an attempt to update a legacy National Park Service monitoring protocol to current monitoring protocol standards (see Oakley 2003). A legacy protocol, as defined here, is a protocol with a history predating the National Park Service Natural Resource Inventory and Monitoring Program (est. 1998). Legacy protocols may have objectives, sampling designs, and other procedures that may be dated and may not follow current I&M guidance. Updating this protocol generally entailed providing more thorough written documentation on protocol procedures, goals, and objectives. No consideration was given to altering historic methods, procedures, or sampling designs. The primary purpose of this document is to clearly articulate how the protocol has been implemented over the past thirty-plus years. Much of this document was based upon a draft protocol by Atkinson (2002) that was updated with additional detail by J. Wofford and E.D. Demarest. E.D. Demarest has participated with implementation of this protocol since 1991.

During the late-1970's and early-1980's Shenandoah National Park (SHEN) identified brook trout (*Salvelinus fontinalis*) as an important component of ecosystem monitoring for park management. A more recent assessment confirmed this determination when the National Park Service's Mid-Atlantic Inventory and Monitoring Network (MIDN), identified brook trout and fish communities as an important ecosystem "vital sign" in SHEN (Comiskey and Callahan 2008).

Given the importance of brook trout management, fish monitoring was initiated in Shenandoah National Park in 1982. The early years of the program focused on gaining an improved understanding of brook trout population dynamics so that angling could be better managed (Haskell 1987). In 1991, fish monitoring was accepted into SHEN's Inventory and Monitoring (I&M) Prototype Park sampling program. In 1995, a review by National Park Service and state fisheries managers resulted in modifications to the monitoring program. These modifications led to a reduced number of sampling sites that would be sampled annually, an added focus on collocating sampling sites with Virginia Department of Game and Inland Fisheries (VDGIF) fish monitoring locations, and changes in monitoring techniques with an emphasis on shifting from one-pass to multiple-pass electrofishing.

The 1995 program identified a suite of "primary" sites that would be monitored annually, and additional "secondary" sites that would be monitored on a five-year rotation, or as financial resources allowed. Primary sites would be monitored using multiple-pass electrofishing and secondary sites would be monitored via single-pass electrofishing. In the 1980's, early monitoring and research results noted the strong effect of underlying bedrock geology on water quality and fish diversity and, in the 1995 site selection process, sites were loosely stratified across the three major bedrock geologic types found in Shenandoah. Most streams that are sampled have one site near the park boundary, with larger watersheds having one to four additional sites upstream. Sites are generally 100m long and most are sampled without the use of block nets. All captured fish are counted, and gamefish (namely salmonids and centrarchids) are individually measured and weighed. A gross weight of non-game fish by species and a maximum and minimum length of non-game fish by species is also collected. A variety of physical habitat characteristics are collected at each site,

including stream length, wetted width, substrate, gradient, etc. Water quality and quantity information is also collected during each sampling visit. As time has allowed, inventory of fish communities on new streams at the park boundary has occurred using sampling methods similar to the monitoring protocol, and to date, virtually every perennial stream in Shenandoah has been sampled for fish. These sites have been added to the original 1995 secondary site list.

Excluding the occasional addition of new secondary sites, from 1995 to 2004, protocols remained relatively unchanged. In 2004, budgetary constraints resulted in a very significant change to the monitoring rotation—primary sites would now be sampled every two years instead of annually. In addition, secondary sites would be sampled every eight years, instead of every five years as the 1995 protocol dictated. Lastly, in 2008 the protocol was modified to include multiple pass electrofishing at all sites. This change occurred because converting from one-pass to multi-pass electrofishing required a relatively small increase in total effort and the benefits (e.g. improved estimates of fish abundance, increased probability of rare species detection, etc.) were deemed worthwhile.

Background and Objectives

This document culminates an attempt to update a legacy National Park Service monitoring protocol to current monitoring protocol standards (see Oakley 2003). A legacy protocol, as defined here, is a protocol with a history predating the National Park Service Natural Resource Inventory and Monitoring Program (est. 1998). Legacy protocols may have objectives, sampling designs, and other procedures that may be dated and may not follow current I&M guidance. Updating this specific protocol generally entailed providing more thorough written documentation on protocol procedures, goals, and objectives. No consideration was given to altering historic methods, procedures, or sampling designs. The primary purpose of this document is to clearly articulate how the protocol has been implemented over the past thirty years. Much of this document was based upon a draft protocol by Atkinson (2002) that was updated with additional detail by J. Wofford and E.D. Demarest. E.D. Demarest has participated with implementation of this protocol since 1991.

Park purpose and mission

Shenandoah National Park (SHEN) was authorized by Congress in 1926 and was established in 1935, with a formal dedication by Franklin D. Roosevelt in 1936. Shenandoah National Park “preserves and protects nationally significant natural and cultural resources, scenic beauty, and congressionally designated wilderness within Virginia’s northern Blue Ridge Mountains, and provides a broad range of opportunities for public enjoyment, recreation, inspiration, and stewardship” (NPS 2015). The park is significant for its unique natural and cultural resources, including mountain peaks and high-elevation ecosystems, cascading streams, historic lodges, Skyline drive, a presidential retreat (Rapidan Camp), and an abundance of native and globally rare animal and plant populations.

Environmental setting

Shenandoah National Park encompasses 199,016 acres (805 square kilometers) of forested terrain on the crest of the Blue Ridge Mountains in northern Virginia. The Park has a long linear shape with a highly uneven boundary and variable width. The Park is divided east to west by the ridgetop, which Skyline Drive and the Appalachian Trail follow, and into three districts north to south by U.S. Highways 33 and 211. Shenandoah is entirely contained within the Blue Ridge physiographic region and can be characterized by steep slopes, narrow ridges, and high relief (Bailey 1999). Elevations within the park range from 192 to 1231 meters (530–4050 feet), with about 60 peaks above 914 meters (3000 feet) (Conners 1988). Low elevations in the park generally experience mild winters and hot, humid summers—average monthly temperatures range from 41.9°F (5.5°C) in January to 85.5°F (29.7°C) in July at low elevations. At higher elevations, winters are moderate and summers are relatively cool—average monthly temperatures range from 24.8°F (-4.0°C) in January to 65.5°F (18.6°C) in July on higher ridge tops (Vana Miller and Weeks 2004). Hydrographs are generally characterized with peak stream flows in the spring and low flows occurring in late summer or fall (Lynch 1987). SHEN contains three major bedrock units of different age and composition which can be loosely characterized as granitic, basaltic, and siliciclastic (Gathright 1976). Each of the three main bedrock formations associated with these rock types have distinct chemical and physical properties that directly influence the surrounding landscape, including terrestrial and aquatic

communities (Bulger et al. 1995, Butler 2006, Southworth et al. 2009, Young et al. 2009, Jastram et al. 2013).

The relationship between bedrock lithology and stream water quality, particularly as it pertains to acid-base status and associated acid-neutralizing capacity (ANC), is well documented in the park (Lynch and Dise 1985, Webb 1988, Cosby et al. 1991). In addition, numerous studies have noted the correlation between ANC and aquatic biological parameters (Smith and Voshell 1994, Moeykens and Voshell 2002, Bulger et al. 1999, Cosby et al. 2006, Jastram et al. 2013). These studies documented general declines in measures of aquatic ecosystem health (macroinvertebrate and fish taxa diversity, brook trout condition and weight, etc.) as ANC declined. Streams with the lowest ANC values have alkalinity ranges from 0 - 25 ueq/L (microequivilents per liter), are associated with siliciclastic formations in the watershed, are all located along the southern half of the western slope of the park, and have the fewest number of fish species. Moderate ANC streams have alkalinity ranges from 50 - 100 ueq/L, are influenced by granitic formations, are more evenly distributed parkwide, and tend to have more fish diversity. Streams with higher ANC have alkalinity ranges from 150 - 200 ueq/L, are influenced by basaltic bedrock, are also fairly well distributed throughout the park, and also have relatively high fish diversity.

Shenandoah's Mid-Atlantic location straddles conditions of both the Northern and Southern Appalachian Mountains, and the park supports over 1,300 species of vascular plants. Ninety-five percent of SHEN is forested with Eastern deciduous woodland. In 2005, a vegetation map was completed that divides the park into 34 vegetation communities (Young et al. 2009). These include 22 upland forests and woodland community types, one alluvial/riparian forest, six non-alluvial wetlands, and five rock outcrop communities.

The park contains portions of the headwaters of three large river basins within Virginia: the James, the Shenandoah, and the Rappahannock watersheds. Streams within SHEN are generally 1st to 3rd order, with about 90 watersheds that contain perennial stream flow. Though inherently variable, streams tend to be of relatively high gradient, with step-pool or cascade morphology (Montgomery and Buffington 1997). Most streams are well shaded by vegetation and maintain cold or cool water temperatures during summer months. Springs and seeps provide the primary source of water for the streams that are further augmented by rain. Water quality within Shenandoah's streams is relatively good, though acid deposition and associated stream acidification are well documented (see Vana Miller and Weeks 2004 for review, Jastram et al. 2013). Additional baseline information on the environmental setting of Shenandoah National Park can be found in Costanzo (2016).

Protocol history

The fish monitoring program at Shenandoah began in 1982, and in the earlier years of the program, the focus was on evaluating brook trout population dynamics in order to better manage the brook trout fishery (Haskell 1987). During these early years, single-pass electrofishing techniques were used to obtain relative trout abundance and size classes of brook trout and a taxa list of other species present at 132 monitoring sites located along 46 park streams. The monitoring effort was structured such that the west side of the park was sampled one year and the east slope was sampled the following year. There were approximately an equal number of sites on each slope of the park. This

monitoring approach was adopted with the primary purpose to collect relative abundance data for trout in all reasonably accessible park streams known to contain brook trout. A secondary objective included distribution data for other fish species. Nevertheless, based on a review of early data, it is clear that very little effort or expertise went into non-game species identification. Non-game fish weren't always identified or counted and may have been frequently identified incorrectly. As such, fish richness data prior to 1996 should be viewed with strong caution.

The principal assumption of this early protocol was that a broadly applied qualitative approach would adequately address park management needs. Early identified shortfalls of the program included poor coordination with Virginia Department of Game and Inland Fisheries (VDGIF) on streams of mutual monitoring interest, and the use of dissimilar electrofishing techniques from those used by VDGIF and other agencies. The potential for a widespread multiple-pass monitoring component was not realized during the initial development of the park's fish monitoring program.

In August, 1995, National Park Service biologists and natural resource managers from the Washington Office, Shenandoah National Park, Great Smoky Mountains National Park, and biologists from the VDGIF met to review and revise the park's fish monitoring program. The primary purpose of this meeting was to establish the future goals and objectives for monitoring and managing fish populations in the park. Managers hoped to design a monitoring program that utilized standardized techniques to sample fish populations in a suite of large, medium, and small streams, which were stratified according to the park's three predominate geologic types. Geologic types were selected based on the clear relationships with acid neutralizing capacity (ANC) and ongoing concerns about acid deposition and the impacts on aquatic resources. Secondary goals included selecting a suite of joint sites with the VDGIF on streams of mutual interest and the use of combined crews and equipment to produce data that met the specifications of both agencies.

Ultimately, the revised 1995 monitoring program resulted in a sampling reduction of both sites and streams from the original program. During the 1995 review, the number of streams and sites to be monitored were selected from the original 1982 list. Initially, stream and transect selection for inclusion in the 1995 "primary" component focused on the three park Shenandoah Watershed Assessment Study (SWAS) research streams, which span the three dominant geologic types. These streams are Paine Run (siliciclastic bedrock), Piney River (basaltic bedrock) and Staunton River (granitic bedrock). These streams had a legacy of research and monitoring on water quality, and it was assumed that these streams would continue to provide supplemental water quality information (via the SWAS program) that would support future assessments of fish populations. Additional streams having the same bedrock and water chemistry characteristics as the three primary streams were selected in an attempt to identify gross fish population trends across the three principal bedrock strata. Other stream and site selection considerations included colocation with other monitoring efforts such as VDGIF fish monitoring sites, SWAS/University of Virginia (UVA) water chemistry monitoring sites, Park Research Natural Areas, and the park's aquatic macroinvertebrate monitoring sites. Where possible, sites were collocated in an attempt to provide linkages with other monitoring efforts and results. In large watersheds where annual quantitative (i.e. multiple-pass electrofishing) sampling would occur, additional qualitative (i.e. single-pass electrofishing) sites were added to the

annual sampling schedule with a focus on large tributaries or the headwaters of the mainstem. The resulting range of streams selected included a mix of small and large streams across a variety of geologic types and spanning all of the three park administrative districts. As such, these sampling sites were deemed representative of wide ranging lotic habitats present in Shenandoah National Park. The 1995 program ultimately included 40 streams and 74 sites split between “quantitative” or multiple-pass electrofishing and “qualitative” or single-pass electrofishing components. The quantitative component included 36 primary sites sampled annually along 15 streams stratified across the Park’s three dominant geologic types. An additional 5 tributary sites that were nearby to these primary sites were also sampled annually, though only qualitatively (i.e. single-pass electrofishing). Lastly, 25 additional streams and 33 additional sites were selected from the 1982 list that would represent the qualitative secondary component which would be sampled via single-pass electrofishing on a five-year rotation.

From 1995 to 2004, the monitoring program remained relatively unchanged. In 2004, budgetary constraints resulted in significant changes to the program. A new monitoring rotation was initiated where primary sites would now be sampled every two years, instead of annually as had occurred during the prior decade. Also, Lower Lewis Run was added to the list of primary sites in 2006 after serious trout population declines and ultimately, a population extirpation. In addition, in 2008, the park began using multiple-pass electrofishing at all sites. This occurred because multi-pass data were deemed valuable enough to offset the relatively minor increase in effort and sampling time associated with multi-pass sampling. Secondary sites that were on a five-year rotation were now sampled at a minimum of once at least every eight years. Lastly, over time, additional inventories of perennial streams were added to the secondary site list, ultimately resulting in a total of 80 streams (including 97 secondary sites). All sites are mapped with geology in Figures 1, 2, and 3 and are listed in Appendix A.

Additional information on the history of the monitoring protocol can be found in Atkinson (2002).

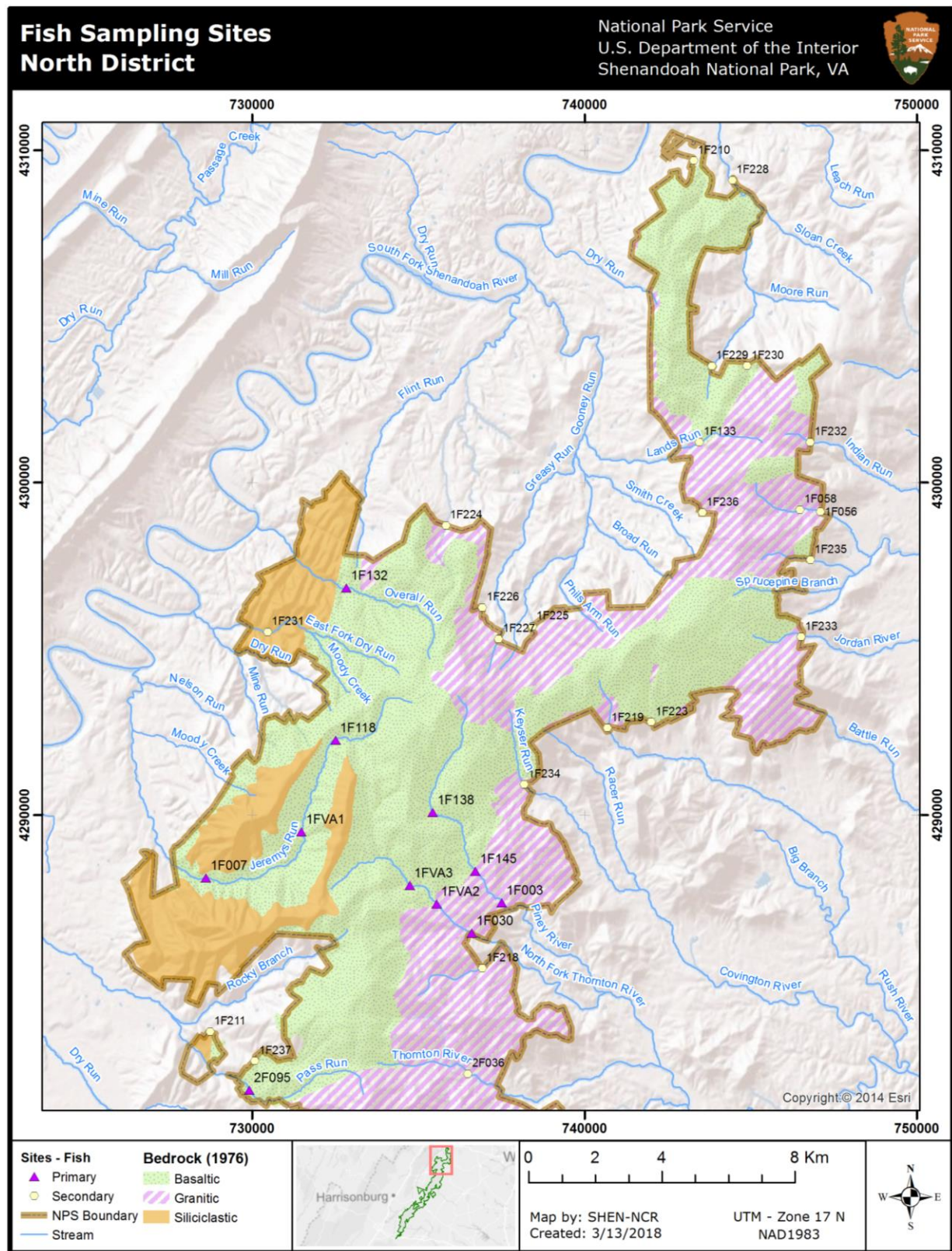
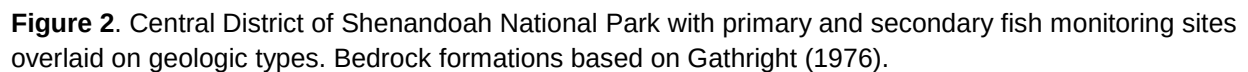


Figure 1. North District of Shenandoah National Park with primary and secondary fish monitoring sites overlaid on geologic types. Bedrock formations based on Gathright (1976).



Fish Sampling Sites South District

National Park Service
U.S. Department of the Interior
Shenandoah National Park, VA

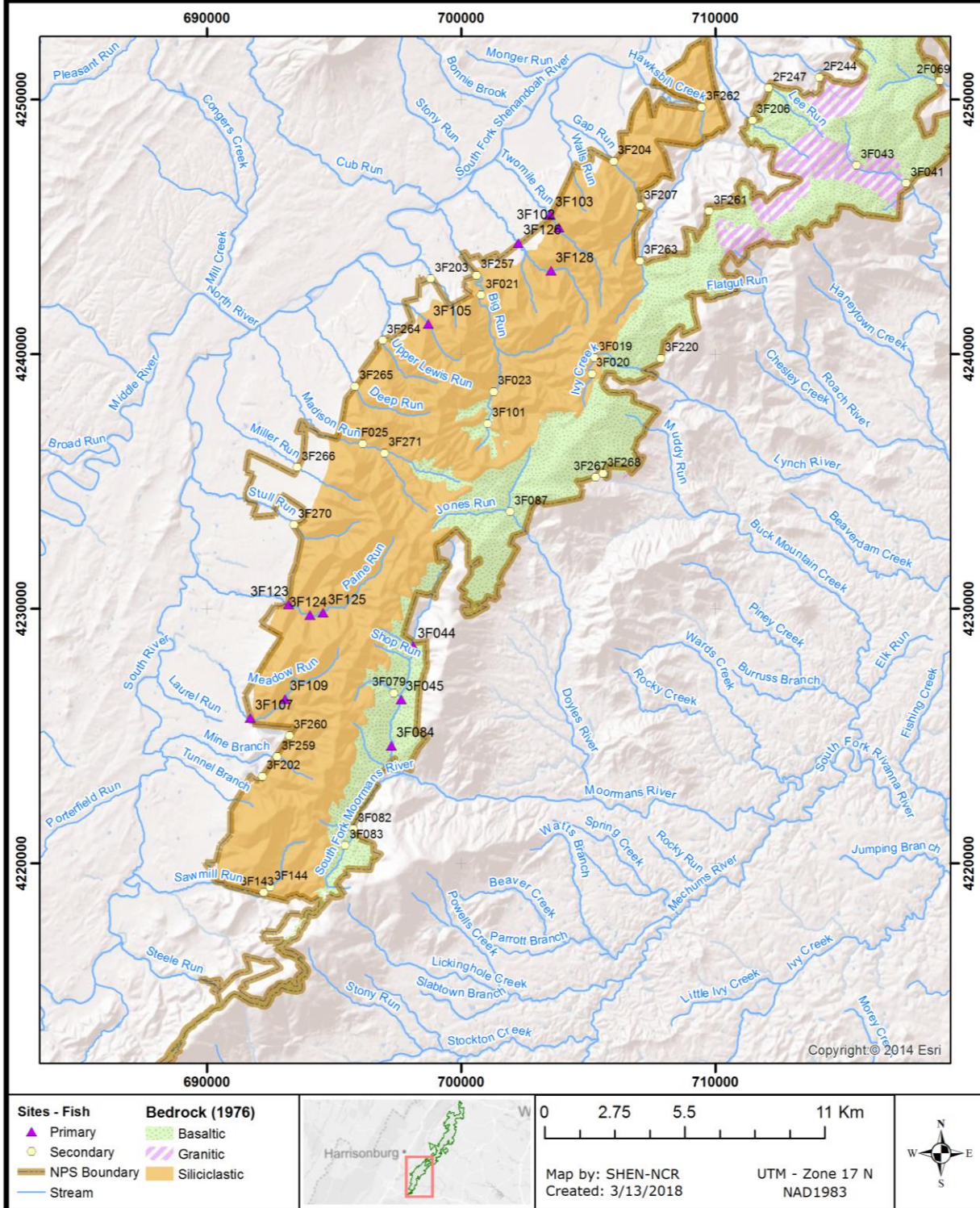


Figure 3. South District of Shenandoah National Park with primary and secondary fish monitoring sites overlaid on geologic types. Bedrock formations based on Gathright (1976).

Rationale for monitoring fish populations

Aquatic biota are recognized as an important resource in Shenandoah National Park, and brook trout may have played a major role in developing initial interests for the establishment of the park (Haskell 1987). The relatively pristine and high-elevation headwater streams in Shenandoah currently support coldwater aquatic communities that are increasingly rare in Virginia and the Southeast (EBTJV 2006). Within coldwater ecosystems, fish populations can serve as measures of aquatic ecosystem health and are frequently used to assess environmental disturbance (Simon 1999).

Some threats to aquatic resources in the Park are well documented—acid deposition has long been recognized a threat to the ecological function of lotic habitats in Shenandoah (Vana Miller and Weeks 2004). In addition, recreational activities in the Park frequently target angling (including harvest) for brook trout, and SHEN supports a regionally important fishery for trout anglers. As the state fish of Virginia, public interest in brook trout is presumed to be high, particularly with anglers. The relative rarity of coldwater native fish resources in Virginia, along with the identification of known and persistent threats, and a high level of public interest suggests that monitoring of fish populations should be important for tracking vital signs in SHEN. An independent review by scientists and park managers indicated that, out of 43 potential vital signs that were assessed during vital sign development for SHEN, brook trout and fish communities ranked as the 3rd and 5th most significant, respectively, based on combined ecological, management, and policy criteria (Comiskey and Callahan 2008).

Monitoring goals and objectives

Fish population monitoring in Shenandoah National Park is nested within the larger context of the National Park Service vital signs monitoring program. Vital signs are “a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources” (Comiskey and Callahan 2008). Goals associated with the national NPS vital signs program are:

1. Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress towards performance goals.

Protocol objectives should provide specific measurable criteria for vital signs and should articulate the focus of a monitoring plan. Objectives for fish monitoring in SHEN were explicitly stated in the

2002 protocol (Atkinson 2002), but not earlier, when many of the data collection procedures were established. The 2002 objectives were modified as written below based upon an assessment of specific data collection procedures (i.e. what information is collected) and in order to ensure the stated objectives were more discrete and measurable.

Four monitoring objectives are identified for fish populations in Shenandoah National Park:

1. Determine long-term trends in fish species abundance, biomass, and community composition within sample sites over time.
2. Determine long-term trends in biological condition (i.e. length and weight) and reproduction of game fish within sample sites over time.
3. Determine relationships between physical and biological parameters (i.e. benthic macroinvertebrates) and fish community and population dynamics (species abundance, community composition, biomass, condition, reproduction, etc.) within sample sites over time.
4. Establish thresholds of fish community or population metrics that inform management actions or initiate additional research activities.

Sampling Design

The initial sample design was established in 1982 and focused on collecting information on larger trout populations within Shenandoah National Park. Sampling locations were generally established beginning at the park boundary, and site locations relied heavily upon professional opinion and, at least in part, on the “representativeness” of the sample reach. Nevertheless, it is also clear that some sites were selected that may not be representative but do allow for more effective sampling of fish or that support ideal fish habitat (see “Spatial Design” below). In general, smaller streams contained one sample site and larger streams contained multiple sample sites. Specific objectives were not defined in the initial program. Nevertheless, the current protocol inherited much from that initial sampling design. Even though the 1995 review resulted in a program revision and adjustment based largely on bedrock and associated water chemistry parameters, as with the initial design, no randomization was used in determining appropriate reaches to sample, and some sample sites have been moved in an attempt to be “more representative” of surrounding habitats. Due to the large number of sites involved in the current design, nearly every perennial stream in the park is now sampled at least once every eight years.

Spatial design

The initial fish population monitoring effort began with a design based on an attempt to sample all of the SHEN streams that were known to contain relatively large trout populations. Forty-six populations (i.e. streams containing brook trout) were identified, and at least one sample site per stream was selected. Though not clearly documented, it is assumed that these sites were selected because of accessibility, “representativeness”, and suitability for fish sampling or supporting ideal fish habitat (e.g. in a stream that is dry or extremely low flow in later summer months the sample site is often located in the one reach with more substantial water and pool habitat due to bedrock influences). Within a particular watershed, at least one site would begin at the park boundary, with additional sites occurring upstream as needed (i.e. in larger watersheds). The exact number of sites in a watershed was determined based upon professional judgement and likely included the consideration of stream and watershed size and perceived fishing pressure with more sites allocated to heavily fished streams. Sites are generally 100m long, with actual site lengths established to capture multiple fish habitat types, and to allow for the start and end point of the reach to occur at geomorphic breaks that limit fish movement during sampling (with rare exceptions, no block nets are utilized during sampling). These methods resulted in 132 sites being sampled on 46 streams.

In the 1995 review, the original list of sample sites were reviewed and adjusted as follows. First, streams to be monitored were identified. Managers looked for streams supporting brook trout that spanned a range of bedrock types (a stream is considered fully contained in a bedrock type if >50% of the watershed is in one of the three principle bedrock categories), that had collocated monitoring sites for other programs, that contained brook trout and non-native trout, and that were exposed to a variety of different fishing pressures. These were selected from the 1982 list for inclusion as primary streams in current protocols. The sum of the selection process resulted in a suite of 15 primary streams. Of the remaining streams from the 1982 protocol, 25 streams were selected for the secondary component.

Continuing with the 1995 review, once streams to be monitored were identified, monitoring sites located on these streams were selected from the list of original sites. Site selection or retention for the revised monitoring program followed several criteria and did include some assessment of monitoring data from the pilot years of the program. Retained sites had single channels, were often located at the boundary, were collocated with other monitoring sites, and had adequate perennial water flows. Sites that were readily eliminated included those that were closely spaced along a particular section of stream, sites with badly braided or split channels and in a few cases, sites that were devoid of brook trout.

Lower Lewis Run was added to the list of primary sites in 2006 after serious trout population declines and ultimately, a population extirpation. Lastly, as time has allowed, additional boundary locations on previously unsampled streams have been inventoried for fish using methodologies outlined in this protocol. These unsampled streams were inventoried for fish if they had water at the end of June; otherwise, they were assumed to be non-fish bearing streams. Following inventory, these sites were added to the secondary list of monitoring sites.

The process above has now resulted in a suite of 41 primary sites and 97 secondary sites which are loosely stratified by bedrock geology, represent a range of stream sizes, are under a variety of fishing pressures, and are widely distributed across the park.

Temporal design

Since 2004, primary sites are sampled once every two years while secondary sites are sampled once every eight years. To reduce temporal variability, individual streams and sites are sampled during a reasonably similar calendar period between May and August. A sampling differential of two to three weeks is acceptable across years but, to limit the influence of seasonal effects, streams that are typically sampled in June are not sampled in August or vice-versa. Specific sampling days may also be influenced by environmental conditions (i.e. high-flow, high water turbidity, weather, etc.).

Inference

Streams and sites in SHEN were selected at least partly upon their “representative” status and were deemed to capture the variability of park environmental conditions. Professional opinion and analyses to date indicate that these sites are likely ecologically representative of aquatic systems in SHEN within defined geologic groups, as geology and associated acid neutralizing capacity is a well-documented major driver of aquatic biological communities in SHEN (Bulger et al. 1999, Jastram et al. 2013, Vana Miller and Weeks 2004, Shenandoah National Park unpublished data). Certain site-scale data are likely reasonably representative of larger scales (e.g. fish taxa richness). Nevertheless because no randomization procedures were used in site selection, sites are not statistically representative of a larger population of sites (i.e. larger spatial scale) and extrapolation of the data should be done with strong caution.

Because of the large number and wide spatial distribution of sample sites (particularly secondary sites), over a full sampling rotation (i.e. 8 years) the protocol represents a near census of fish-bearing streams in SHEN (at least one sampled reach per fish-bearing stream), including locations where fish diversity is generally maximized (i.e. downstream reaches where those streams intersect the park

boundary). Lastly, a review of data collected prior to 1996 indicates that non-game fish identification and the full capture of all fish species present was not a focus of the program. As such, use of the fish richness data prior to 1996 is discouraged.

Standard Operating Procedures

A series of standard operating procedures (SOPs) have been developed to ensure that the protocol is implemented in a consistent manner and high-quality data is captured. Unlike the protocol, these SOPs are intended to change more frequently over time as specific methods are refined and equipment is replaced. Therefore, the SOPs are published separately from the protocol to facilitate timely updates to procedures. The most updated versions of the SOPs will be maintained by SHEN. Updated SOPs will be published and made available on the [NPS Integrated Resource Management Application Data Store](#). Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Small changes or additions to existing methods will be reviewed by Shenandoah National Park or Mid-Atlantic Network staff. However, if a complete change in methods is sought, an outside review is required.

Field Methods and Descriptions

Detailed methods and procedures for field methods are outlined in the Standard Operating Procedures (SOPs) for the protocol (Table 1).

Table 1. List of Standard Operating Procedures associated with the field and laboratory methods for monitoring fish in SHEN.

SOP Title	SOP #
Pre and post-season tasks	1
Training and safety	2
Sampling conditions and times	3
Locating sites in the field	4
Using the global positioning system	5
Hydrolab calibration and cleaning	6
Water chemistry sampling	7
Site photography	8
Fish sampling	9
Voucher specimens preparation	10
Habitat sampling	11
Using a clinometer	12
Measuring discharge	13
Equipment cleaning and biosecurity	14
Data forms	18

Pre and postseason tasks (SOP 1)

Preparations for the field season includes hiring seasonal technicians or interns, ensuring SHEN compliance documents are valid and up-to-date, and completing assessments or purchase of required equipment (SOP 1). The hiring process is generally initiated in October of the prior year. Barring major changes in protocol methods, compliance is renewed in conjunction with the macroinvertebrate monitoring program on a five-year basis. If compliance documents are expiring, the renewal process should begin in January of the monitoring year. Visual and mechanical assessments of field gear should begin in February of the monitoring year and are outlined in SOP 1.

Personnel training in field procedures (SOP 2)

By late May, the full complement of biological technicians and volunteers will have arrived in the park for the summer field season. Prior to the start of the annual monitoring schedule, the full crew will undergo two to three days of training in the principles, use, and safety of electrofishing gear, fish

identification, taking fish measurements and recording data, the collection of habitat data, CPR and first aid, and job hazard analysis discussions. All individuals are further instructed in the use of equipment during initial sampling visits.

Personnel safety (SOP 2)

Electrofishing in mountain stream habitats ranks among the most hazardous work activities performed by biological technicians and volunteers at Shenandoah National Park. That being said, with adequate preparation, training, the use of personal protective gear, and by being ever mindful of potential hazards during the course of the workday, all of the risks associated with electrofishing can be mitigated.

Prior to the beginning of the fisheries monitoring field schedule, most if not all of the crew will attend a one day first aid/CPR training session. Numerous job hazard analyses (JHA) specific to SHEN are also reviewed by the crew. These JHAs include, but are not limited to, “working in tick infested areas”, “light vehicle use”, “backcountry travel”, “electrofishing operations”, “aquatic macroinvertebrate collection”, “lifting and carrying”, and “hantavirus”. Certain JHAs may require additional safety training. JHAs are maintained by the SHEN safety manager.

Sampling conditions and times (SOP 3)

The field component of the fish monitoring program typically begins in early to mid-June and ends by mid-August. Starting and ending dates are largely determined by the frequency of rain events, the amount of total rainfall, and the associated water levels in the streams. Optimal conditions include low to average water flows of clear condition.

Individual streams should be sampled within the same general period of time each year to facilitate comparisons of density and biomass between years. A sampling differential of two to three weeks is acceptable from one year to the next but streams that are typically sampled in June should not be sampled in August and vice-versa.

Locating sites in the field (SOP 4 and 5)

Specific site directions are maintained for each stream and each monitoring site in the park and are organized with respect to eastern versus western slope locations. Site directions include written descriptions of specified road and trail routes and a U.S. Geological Survey (USGS) topographic map of the stream with clearly marked site locations. Sites are generally 100m long, with actual site lengths established to capture multiple fish habitat types, and to allow for the start and end point of the reach to occur at geomorphic breaks that limit fish movement during sampling. The start and endpoints of all monitoring sites are referenced by physically tagged live trees located on the adjacent stream bank. A list of sites can be found in Appendix A. UTM coordinates for each site are also available to aid in navigation if needed. A GPS unit can also be utilized to locate field sites (SOP 5).

Field measurements

Sampling sites are generally 100 m long sections of stream, and fish are collected within the entire 100 m. Water chemistry, discharge, and photos are also collected during a site visit. Habitat measurements are collected at 10 m transects within the reach or within segments between transects

(Figure 4), depending on the habitat metric. Details on data collection are documented below and in relevant SOPs. All data forms can be found in SOP 18.

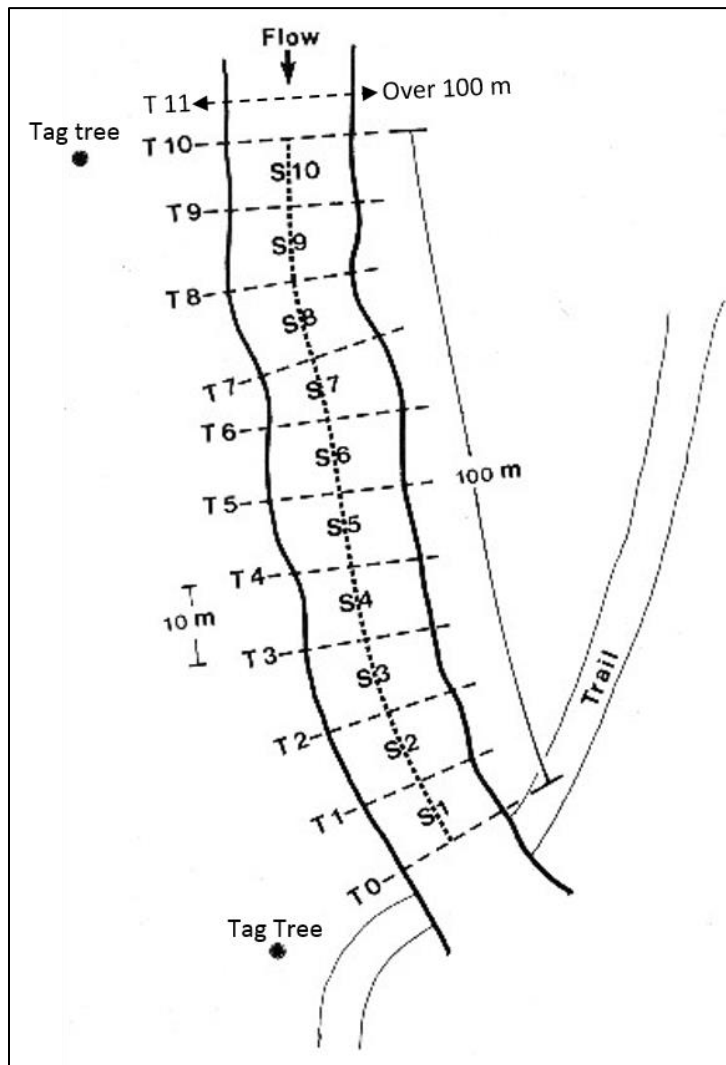


Figure 4. Diagram of a stream reach showing sample transects and segments. Width, depth, riparian vegetation, and substratum are measured at each transect. Pool-riffle ratio, and % slope (gradient) are measured throughout each segment.

Water chemistry sampling (SOP 6 and 7)

Water chemistry sampling occurs prior to any in-stream disturbance associated with fish monitoring and is thus the first data collected during a site visit. The “Core 4” water quality parameters are collected at each site (NPS 2002) and spot values of water temperature, pH, conductivity, and dissolved oxygen are collected during each sampling event. Total dissolved solids is also collected. At least once weekly, water quality equipment is calibrated to relevant standards.

Site photography (SOP 8)

Digital photos are inexpensive and relatively easy to capture. Typically, a single photograph is taken at the lower end of the site to help document the conditions present at the time of sampling. Wide-angle digital photos taken of the sites should feature the bottom of the transect looking upstream capturing the water level, stream side vegetation and some reference for the location of the start of the sample reach. The two best times to take this photograph are either as water chemistry data are being collected, or just before habitat measurements are initiated. The photograph is taken to capture the first transect (i.e. T0) in the lower portion of the picture frame.

Fish sampling (SOP 9 and 10)

Since 2008, three-pass backpack electrofishing is used for all surveys with the objective of three thorough and efficient passes sampling all habitats and of equal effort through the site. Naturally occurring geomorphic habitat breaks that minimize fish movement occur at the lower and upper ends of most sample reaches and these locations may be modified or supplemented via cobble dam construction prior to sampling. Therefore, during most electrofishing surveys, block nets are not used (excluding select Rapidan and N.F. Moorman's sites). Modified reach breaks are restored to their prior condition following sampling.

Initial settings used on electrofishers are determined by conductivity information collected during water quality sampling. The number of electrofishers required to adequately sample each reach has been established during prior sampling events (see site list in Appendix A) and follows recommendations set forth by the SDAFS Trout Committee (SDAFS 1992). The number of electrofishers is largely based on stream wetted-width and the difficulty of sampling specific habitat characteristics. In general, two netters accompany each electrofisher during sampling. During an electrofishing pass, operators proceed upstream sampling all wetted habitats thoroughly and efficiently. Electrofishing procedures largely follow those outlined in the National Water Quality Assessment Program (Moulton et al. 2002).

Following each electrofishing pass, captured fish are sorted to species and counted. Fish are identified using professional judgement, taxonomic keys, or other appropriate information. Gamefish (namely salmonids and centrarchids) are individually measured and weighed. Gamefish may be anesthetized prior to processing to reduce stress in handling. For nongame fish, the smallest and largest individual per species is measured. A total weight of all non-game fish by species is also collected. Mortalities are also counted for each species. All captured fish are placed in holding cages located outside of the sampling area while additional electrofishing passes are completed. At the conclusion of all the sampling, all live fish are released back into the stream in the approximate proportions and habitats from which they were captured. Any dead fish are separated out during processing and disposed of well away from the stream.

If a fish cannot be ID'd in the field, a voucher specimen should be collected. See SOP 10 for proper voucher specimen processing.

Habitat sampling (SOP 11 and 12)

Habitat sampling includes a combination of actual measurements (stream width, site length, depth, and gradient) and visual estimates (stream substrates, pool/riffle ratios, riparian cover, and riparian type). These variables are used in calculations and interpretation of fish density and biomass, and to provide a physical assessment of environmental attributes that may influence fish populations.

Habitat measurements are collected at 10 meter transects through the sample reach. Transects include only wetted portions of the stream channel. Wetted stream widths are recorded at each transect up to and including the end point at the upstream end of the monitoring site. Water depths are measured and stream substrates are estimated at the $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ points across a transect. At each point ($\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$), the water depth is also recorded.

From the center of each transect, an observer also records the riparian cover category that exists directly above the transect. This is a visual estimate of the percent of riparian canopy cover over the wetted channel. The riparian composition (trees, shrubs, etc.) is also recorded. Using a clinometer, observers record stream gradient between transects (SOP 12). Between each transect an observer also conducts a visual estimate of the relative amount of pool habitat (water with near zero velocity, as visually estimated) and riffle habitat (water with > zero velocity) present.

Discharge sampling (SOP 13)

Discharge is measured during each site visit. Specific discharge measuring locations at each site have not formally identified but are selected on an annual basis. Ideally, discharge is measured in a location with bedrock or smaller grained substrates (i.e. gravel/cobble), and in an area with a uniform channel width and depth. Park staff utilize the 6/10ths flow measuring technique recommended by the USGS (Buchanan and Somers 1969) and the U.S. Forest Service (Platts et al. 1983). When feasible, measurements are taken from at least ten evenly spaced intervals at the selected cross section, perpendicular to stream flow.

Cleaning equipment (SOP 14)

In order to limit the introduction and spread of invasive or exotic aquatic organisms in Shenandoah, all equipment that is exposed to water is always cleaned prior to moving equipment between watersheds (i.e. Shenandoah, Rappahannock, James). Currently, with few exceptions, equipment is cleaned any time the crew moves between sampled streams (~5-6th field sub-watersheds). Specific cleaning procedures are outlined in SOP 14.

Data Management, Analysis, and Reporting

Detailed methods and procedures for data management are outlined in Standard Operating Procedures (SOPs) for the protocol (Table 2).

Table 2. List of Standard Operating Procedures associated with data management, analysis, and reporting for monitoring fish in SHEN.

SOP Title	SOP #
Data recording, entry, management, and archiving	15
Data analysis	16
Reporting	17
Data forms	18

Data recording and entry (SOP 15)

When in the field, it is critically important that the data recorder have good penmanship as the written records need to be clearly legible on paper data forms. Prior to leaving the site, all completed forms are reviewed to ensure legibility and that there are no missing data. Upon arrival back at the office at the end of the day, data forms are filed appropriately.

Specific instructions for using the park's Aquatic Database System to perform data entry, edits, and validations can be found in SOP 15. Briefly, SHEN's fish data entry program consists of three main components: the data entry application, the temporary storage databases, and the master database. Data is entered into the first temporary database using the data entry application. As a means of error checking, the data is entered a second time and by a different person into a second temporary database. The two temporary databases are compared by an application in the database and any discrepancies can then be reviewed and corrections made as needed. At the end of the field season the data in the temporary databases are reviewed by program staff and then added to the master database.

Data management and archival procedures (SOP 15)

Electronic data files including the databases, scanned data forms, and photo monitoring images are stored in a directory structure on a file server with appropriate access levels granted to users. A variety of data back-up procedures have been established in order to protect monitoring data and associated information.

Data compiled by Shenandoah National Park must be accompanied by Federal Geographic Data Committee (FGDC) compliant metadata. This includes both spatial and non-spatial datasets.

Data analysis and reporting (SOP 16 and 17)

Monitoring programs should produce data, analyses, and products that can be utilized to develop management actions that support park objectives. Analyses of fish populations at SHEN can be

structured at multiple spatial scales (see Inference, page 12). These may including the sample site, stream (when more than one sample site occurs in a particular watershed), and geologic type or corresponding ANC group (<20µeq/L, 20-100µeq/L, >100µeq/L). Primary approaches to analyzing SHEN fish data relies on metric estimation (see SOP 16 for specific metrics). Metrics for analysis of fish populations include those that assess community richness, balance, and production. Because all game fish are individually measured, reproduction can be assessed by establishing fish age-classes via a length-frequency analysis.

Annual data summaries

Annual data summaries can take the form of a report or resource brief (or both). An example of a short report can be found in Wofford and Demarest (2012).

Data summaries have a primary audience of park program managers, superintendents, and other park staff. As such, summaries should target metrics and appropriate data displays that are easily understood and communicated. Using a subset of metrics, control charts can be employed to visualize trends and changes in fish communities. Control charts allow for the visual display of trends and thresholds for management action or further data analyses. Initially, the first ten years of data will serve as a baseline (see Morrison 2008) and initial thresholds will be defined as plus or minus two standard deviations around the ten-year mean (i.e. baseline) of the statistic (see Figure 1, SOP 17 for example). During any year where thresholds are crossed, more targeted data analyses will be conducted to assess the driver behind the threshold transgression and to help determine the potential need for management action. Baselines and thresholds may be altered in the future to potentially better reflect meaningful management or biological thresholds that might not be represented by the initial ten-year mean $\pm$ 2 standard deviations of the mean.

Comprehensive analyses and reports

Comprehensive trend reports and associated analyses should occur on an approximate ten-year timeframe. These analyses focus on trend detection and characterizing associations between habitat variables and fish population characteristics (see Jastram et al. 2013 for an example). Rather than requiring a detailed list of specific data analyses, the data analysis process should be flexible enough to allow the use of newly developed statistical and analytical techniques and tailoring of analyses for a variety of audiences with a variety of questions about the aquatic resources at SHEN. Analyses may occur at a variety of temporal and spatial scales.

Reporting format

Efficient reporting of monitoring results is critical in assisting park resource managers in management decisions. When writing reports, the most recent report template for regional natural resource technical reports is followed (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). Natural resource reports are the designated medium for disseminating comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The natural resource data reports series is used to disseminate basic data sets and data summaries. Ideally, for each report, a one or two page resource brief will also be produced that summarizes reported information.

Field data forms (SOP 18)

All of the SHEN fish monitoring field data forms can be found in SOP 18.

Operational Requirements

Number of personnel required for field component

Most of the Shenandoah streams and sites can be optimally sampled with an electrofishing crew of 10 people. Since the majority of SHEN's streams are most efficiently sampled with two electrofishing units, a crew size of 10 allows for an electrofishing crew of six to eight and a fish processing crew of two to four. The electrofishing crew consists of two shocker operators, three or four netters and one or two bucket carriers. The shore crew consists of one to three individuals responsible for sorting, measuring and weighing fish and for maintaining fresh water in the buckets. When sampling larger streams and sites, where three or four electrofishers are needed and thousands of fish may be captured, ideal crew sizes may approach 18 or more.

Roles and responsibilities

The park fish and wildlife biologist (GS-11) coordinates all aspects of the program. Implementation of the protocol is led by a GS-07 crew leader and eight technicians/interns. The park data manager (GS-11) provides leadership support and guidance on data entry, analysis, management, and archiving.

Fish and wildlife biologist

The park fish and wildlife biologist operates as the project manager to oversee all aspects of the monitoring program, including:

- Permits, scheduling, hiring, purchasing, contracting, and budget
- Maintaining and updating monitoring protocol
- Conducting or assisting in training and participating in field work as possible
- Recruiting and supervising the field crew, providing logistical, administrative, and technical support
- Analyzing data and preparing reports
- Ensuring QA/QC standards are met
- Coordinating with the park data manager
- Communicating results to the park I&M coordinator, other interested staff, cooperators, and the public

Lead biological technician

The lead biological technician is responsible for assisting the fish and wildlife biologist with program management obligations as well as taking the lead in the day-to-day operations of the field crew.

Tasks include:

- Coordinating and leading daily field activities and ensuring equipment is in working order

- Coordinating directly with biologist and communication center when conducting field work
- Conducting weekly safety briefings and offering safety reminders appropriate to current activities
- Ensuring that all field crew members are following proper data collection procedures
- Coordinating data entry into database, verification, corrections, and archiving of data from paper data forms
- Assisting the biologist with program obligations such as hiring , purchasing, contracting, budget, updating the protocol, analyzing data, and preparing reports
- Ensuring vehicles are properly maintained and cleaned
- Ensuring QA/QC standards are met

Monitoring crew technicians and interns

The crew technicians are responsible for data collection. Tasks include:

- Collecting field data accurately as described in the SOPs
- Entering data accurately into the project database either in the field or from paper data forms
- Ensuring all necessary equipment is available, well cared for, clean, and functional prior to each trip
- Performing work safely and efficiently

Data manager

The data manager in the Natural and Cultural Resources Division provides oversight for all data related aspects of the project including:

- Providing database training to the crew
- Maintaining the fish population monitoring database
- Preparing maps of sample point locations
- Ensuring data management practices are met, including data backup, transfer, and archiving
- Ensuring QA/QC standards are met
- Running routine predetermined scripts/formulas for analysis and report writing

Annual workload and field schedule

Field work and data entry, verification, and archiving is conducted primarily between mid-May and the end of October. Field planning, data analysis and report writing largely occur between October

and April. Hiring of temporary employees commences in the fall and continues throughout the spring. Budget and other administrative support activities occur year-round.

Facility and equipment needs

The field crew is based at Shenandoah National Park Headquarters and operates out of the Natural and Cultural Resource Division's lower office. All equipment needed to conduct the field work is listed in SOP 1, and is stored in the office or nearby storage buildings. The lead technician is responsible for ensuring that all equipment is in working order and coordinating with the biologist to replenish supplies as needed.

Operating costs and budget considerations

Annual operating costs are based on the costs incurred in FY2016, including personnel and supplies (Table 3). Additional costs are occasionally incurred to replace or repair equipment including electrofishers, water quality multimeters, GPS units, cameras, and vehicles.

Table 3. Estimated annual cost to implement Shenandoah National Park Fish Population Monitoring Protocol. The permanent staff cost estimate includes 80 hours of a GS-11 data manager's time, 720 hours of a GS-11 biologist's time, and 840 hours of a GS-07 crew leader's time. Temporary staff costs include 960 hours of GS-05 technician time, 960 hours of GS-04 technician time, and 1920 hours SCA intern's time (2016 dollars).

Category	Expense (2016 dollars)
Permanent staff	\$ 67,500.00
Seasonal Staff	\$ 35,800.00
Interns	\$ 24,000.00
Equipment	\$ 3,0000.00
Supplies	\$ 1,500.00
Total	\$ 131,800.00

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Appendix A: Fish monitoring sites.

Table A-1. Shenandoah National Park primary fish sample sites. Table includes the sample stream, site number, number of electrofishers needed, number of personnel needed, and watershed geologic composition by percentage.

Stream	Site #(s)	Electrofishers (#)	People (#)	Basaltic (%)	Granitic (%)	Siliciclastic (%)
Dry Run, North Fork	2F131	1	9-10	0	100	0
Hannah Run	2F050	1	10-12	0	100	0
Hogcamp Branch	2F055	1	9-10	85	15	0
Hughes River	2F038, 2F039, 2F040	3, 2, 2	10-12	7	93	0
Jeremy's Run	1F007, 1FVA1, 1F118	2, 2, 2	10-12	69	3	28
Lower Lewis Run*	3F105*	1	9-10	5	0	95
Meadow Run	3F107, 3F109	2, 2	10	0	0	100
Moorman's River, North Fork	3F084, 3F045, 3F044	2-3, 2, 2	12+	66	1	33
One Mile Run	3F126, 3F128	2, 2	10	1	0	99
Overall Run	1F132	2	9-10	68	17	15
Paine Run	3F123, 3F124, 3F125	3, 2, 2	10	0	0	100
Pass Run	2F095	2	9-10	44	56	1
Piney River	1F003, 1F145, 1F138	2, 2, 2	10-12	58	42	0
Rapidan River	2F093, 2F135, 2FVA4, 2FVA5	3-4, 3, 3, 2	10-20	6	94	0
Rose River	2F015, 2F016, 2F017	2, 2, 2	10-20	85	15	0
Staunton River	2F072, 2F074, 2F075, 2F076	2, 2, 2, 2	10-20	0	100	0
Thornton River, North Fork	1F030, 1FVA2, 1FVA3	2, 2, 2	10-20	67	33	0
Two Mile Run	3F102, 3F103	2, 2	9-10	0	0	100

*Sampling in Lewis Run occurs from the site start (boundary) upstream for 800m. This occurs to not only sample the site, but to also potentially document brook trout recolonization in Lewis Run.

Table A-2. Shenandoah National Park secondary fish sample sites. Table includes the sample stream, site number, number of electrofishers needed, number of personnel needed, and watershed geologic composition by percentage.

Stream	Site #(s)	Electrofishers (#)	People (#)	Basaltic (%)	Granitic (%)	Siliciclastic (%)
Berry Hollow Run	2F063	1	4-5	0	100	0
Big Branch	3F079	1	4-5	66	1	33
Big Creek	2F238	2-3	9-10	81	2	18
Big Fill Hollow	2F239	1-2	9-10	3	97	0
Big Mine Branch	3F202	1	2-3	0	0	100
Big Run	3F257, 3F021, 3F023, 3F101	3, 3, 2, 1	12+	19	0	81
Bolton Branch	1F056, 1F058	2, 1	9-10	7	93	0
Broad Hollow Run	2F067	1	4-5	0	100	0
Brokenback Run	2F252	2	9-10	6	94	0
Brown Hollow Run	1F224	1	4-5	42	58	0
Bush Mountain Stream	2F222	1	4-5	4	96	0
Butterwood Branch	1F218	1	4-5	0	100	0
Cedar Run	2F062	2	9-10	100	0	0
Collet's Run	2F241*	1	2-3	0	100	0
Conway River	2F255	1-2	9-10	13	87	0
Cool Spring Hollow	3F259	1	4-5	0	0	100
Crow Hollow	2F240	1	4-5	0	0	100
Deep Run	3F265	1	4-5	0	0	100
Devil's Ditch	2F242	2	9-10	5	95	0
Dorsey Hanger Hollow	3F260*	1	2-3	0	0	100
Doyles River	3F087	2	9-10	92	0	8
Dry Run Falls	2F243	1	4-5	100	0	0
Dry Run, South Fork	2F140	1	4-5	21	79	0
Eaton Hollow	3F261	1	4-5	64	16	20
Elk Run	2F244	1	4-5	0	0	0
Entry Run	2F212	1	4-5	61	39	0
Front Royal	1F210	1	4-5	0	0	0

*Though likely perennial, no fish were observed in these sites during monitoring efforts.

Table A-2n (continued). Shenandoah National Park secondary fish sample sites. Table includes the sample stream, site number, number of electrofishers needed, number of personnel needed, and watershed geologic composition by percentage.

Stream	Site #(s)	Electrofishers (#)	People (#)	Basaltic (%)	Granitic (%)	Siliciclastic (%)
Fultz Run	2F122	1	4-5	11	9	80
Gap Run	3F204, 3F207	1	4-5	6	0	94
Gooney Run	1F225	1	4-5	33	67	0
Gravel Springs	1F219	1	4-5	100	0	0
Greasy Run, East	1F227*	1	2-3	0	100	0
Greasy Run, West	1F226	1	4-5	0	100	0
Hangman Run	3F203	1	2-3	33	0	67
Happy Creek	1F228, 1F229	3, 1	10-12	95	5	0
Harris Cove	2F245	1	4-5	5	37	58
Hawksbill Creek	3F262, 3F263	3, 2	9-11	64	16	20
Hawksbill Creek, East	2F119	2	9-10	17	83	0
Hawksbill Creek, Little	2F110	1	4-5	48	52	0
Hazel River	2F071, 2F053, 2F090	3, 2, 2	10-12	0	100	0
Hazel River (Runyon)	2F139	1	4-5	0	100	0
Heiskell Hollow (East Fork Compton Creek)	1F231	1	4-5	70	1	29
Hickerson Hollow	1F230	1	4-5	29	71	0
Indian Run	1F232*	1	2-3	0	100	0
Ivy Creek	3F019, 3F020, 3F220	2, 2, 1	9-10	73	1	26
Jordan River	1F233	1	4-5	60	40	0
Kettle Canyon	2F208	1	4-5	3	97	0
Keyser Run	1F234	1	4-5	86	14	0
Kinsey Run	2F221	1	4-5	0	100	0
Land's Run	1F133	1	4-5	9	91	0
Lee Run	2F247	1	4-5	60	40	0
Lewis Spring Falls	2F250	1	4-5	83	17	0
Madison Run	3F025	2	9-10	14	0	86

*Though likely perennial, no fish were observed in these sites during monitoring efforts.

Table A-2n (continued). Shenandoah National Park secondary fish sample sites. Table includes the sample stream, site number, number of electrofishers needed, number of personnel needed, and watershed geologic composition by percentage.

Stream	Site #(s)	Electrofishers (#)	People (#)	Basaltic (%)	Granitic (%)	Siliciclastic (%)
Miller Run	3F266*	1	2-3	8	0	10
Moormans River, S.F.	3F082, 3F083	2	9-10	75	0	25
Naked Creek, East Branch	2F029	2	9-10	78	4	18
Naked Creek, South Branch	2F251	2	9-10	0	0	100
Naked Creek, W. Branch (Post 1996)	2F113	2	9-10	70	3	27
Pocosin Hollow Run	2F048	2	9-10	18	82	0
Popham Run	2F216	1	4-5	0	100	0
Ragged Run	2F060	1	4-5	0	100	0
Rocky Bar Hollow Tributaries	3F267*, 3F268*	1	2-3	100	0	0
Rocky Run	2F217	1	4-5	0	100	0
Rosson Hollow (Big Tributary)	2F213	2	9-10	0	100	0
Rosson Hollow (Medium Tributary)	2F214	1	4-5	0	100	0
Rush River - Waterfall Branch	1F235*	1	2-3	17	83	0
Rush River (Big Devils Stairs)	1F223*	1	2-3	99	1	0
Sawmill Run	3F143, 3F144	2	9-10	20	0	80
Shenks Hollow Run	1F211, 1F237	2, 1	9-10	100	0	0
Smith Creek	1F236	1	4-5	3	97	0
South River	2F069	2	9-10	100	0	0
Stony Run	2F205	1	4-5	16	2	82
Stull Run	3F270*	1	2-3	0	0	100
Swift Run	3F041, 3F043	2	9-10	70	30	0
Thornton River, South Fork	2F036	2	9-10	10	90	0

*Though likely perennial, no fish were observed in these sites during monitoring efforts.

Table A-2n (continued). Shenandoah National Park secondary fish sample sites. Table includes the sample stream, site number, number of electrofishers needed, number of personnel needed, and watershed geologic composition by percentage.

Stream	Site #(s)	Electrofishers (#)	People (#)	Basaltic (%)	Granitic (%)	Siliciclastic (%)
Unnamed Robinson River Tributary	2F215	1	4-5	0	100	0
Upper Lewis Run	3F264	1	4-5	0	0	100
West Swift Run	3F206	1	4	74	26	0
White Oak Canyon Run	2F009, 2F253	2	9-10	85	15	0
Whiteoak Run	3F271	1-2	9-10	14	0	86

*Though likely perennial, no fish were observed in these sites during monitoring efforts.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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