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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Gauley River National Recreation Area

Natural Resource Report NPS/GARI/NRR—2019/1859



ON THE COVER
The Gauley River as it passes through Gauley River National Recreation Area (SMUMN GSS Photo by Andy Nadeau)

Natural Resource Condition Assessment

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Natural Resource Report NPS/GARI/NRR—2019/1859

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Gauley River National Recreation Area (GARI) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at GARI. The final project framework contains 10 resource components, each featuring discussions of measures, stressors, and reference conditions. One of those resource components, surficial geologic features, was included as a non-scored component and was summarized only without assessing condition.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: good condition, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by GARI resource managers, NPS Eastern Rivers and Mountains Network (ERMN) staff, NPS Northeast Regional Office Staff, and/or outside experts.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for three of the nine scored components due to these data gaps.

For featured components with available data and fewer data gaps, assigned conditions varied. Two components were considered to be in good condition: upland forest communities and birds. Of those two components, however, only the birds component had enough data to assess a current trend with high confidence. Three components (riparian vegetation communities, water quality, dark night skies) were of moderate concern; riparian vegetation communities and dark night skies lacked sufficient data to assign a current trend, while water quality had enough recent data to confidently assign a stable trend. Only the air quality component was determined to be of significant concern. The current trend of air quality in GARI was determined to be improving (a designation assigned with moderate confidence). Condition could not be determined for three components: mammals, herpetofauna, and aquatic wildlife communities.

Several park-wide threats and stressors influence the condition of priority resources in GARI. Those of primary concern include climate change, exotic species, recreational use of the park, and water quality degradation. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem.

Acknowledgments

We acknowledge Gauley River National Recreation Area and Eastern Rivers and Mountains Network staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, John Perez, Claire Rozdilski, Lenza Paul, Layne Stricker, Lisa Wilson, Kathy Oney, Caleb Tzilkowski, Andy Weber, Stephanie Perles, and Matt Marshall. Their logistical insight and critical review of interim documents was essential to this project's completion. Additional insight and reviews were provided by Sheila Colwell, Holly Salazar, Pete Sharpe, Steve Kite, and Marian Norris. Christine Arnott, NPS Northeast Region Biologist and NRCA Coordinator, and Jeff Albright, National NRCA Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

ALR – Anthropogenic Light Ratio

AQI – Air Quality Index

ARD – Air Resources Division

BCI – Bird Community Index

Bd – Bactrachochytrium dendrobatidis

BLM – Bureau of Land Management

BLUE – Bluestone National Scenic River

BMI – Benthic Macroinvertebrates

Bsal – Batrachochytrium salamandrivorans

CAA – Clean Air Act

CCD – Charge-coupled Device

CL – Condition Level

DAMS – Water Impoundments Database

DBH – Diameter at Breast Height

DEWA – Delaware Water Gap National Recreation Area

DO – Dissolved Oxygen

DRINKS – Drinking Water Supplies Database

dv – Deciview

EAB – Emerald Ash Borer

EO – Element Occurrence

EPA – Environmental Protection Agency

EPT - Ephemeroptera, Plecoptera, and Trichoptera

ERMN – Eastern Rivers and Mountains Network

FTU – Formazin Turbidity Units

GAGES – Water Gages Database

GARI – Gauley River National Recreation Area

GIS – Geographic Information System

GPRA – Government Performance and Results Act

HBI – Hilsenhoff Biotic Index

HWA – Hemlock Wooly Adelgid

I&M – Inventory and Monitoring

IFD – Industrial Facilities Discharge Database

IMPROVE – Interagency Monitoring of Protected Visual Environments

IPCC – Intergovernmental Panel on Climate Change

IRMA – Integrated Resource Management Application

MADI – Mean Annual Diameter Increment

MDN – Mercury Deposition Network

MIBI – Multimetric Index of Biotic Integrity

MTI – Macroinvertebrate Tolerance Index

MTR – Mountain Top Removal

NAAQS – National Ambient Air Quality Standards

NADP-NTN – National Atmospheric Deposition Program – National Trends Network

NAWQA – National Water Quality Assesment

NERI – New River Gorge National River

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NSNSD – Natural Sounds and Night Sky Division

NTU – Nephelometric Turbidity Units

NVC – National Vegetation Classification

ORV – Off-road Vehicle

PAH – Polycyclic Aromatic Hydrocarbon

PCS – Point Count Survey

PM – Particulate Matter

ppb – Parts per Billion

ppm-hrs – Parts per Million Hours

RF3 – River Reach File Database

RSS – Resource Stewardship Strategy

RTH – Richest Targeted Habitat

SHEN – Shenandoah National Park

SL – Significance Level

SpC – Specific Conductance

SQM – Sky Quality Meter

STORET – Storage and Retrieval Water Quality Database Management System

TDS – Total Dissolved Solids

USACE – U.S. Army Corps of Engineers

USFWS – U.S. Fish and Wildlife Service

USGS – U.S. Geological Survey

VOC – Volatile Organic Compound

WCS – Weighted Condition Score

WNS – White Nose Syndrome

WVDEP – West Virginia Department of Environmental Protection

WVDNR – West Virginia Division of Natural Resources

WVNHP – West Virginia Natural Heritage Program

WVWDP – West Virginia Wildlife Diversity Program

ZLM – Zenith Limiting Magnitude

1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management

targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "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, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Gauley River National Recreation Area (GARI) was established in October 1988 as part of the West Virginia National Interest River Conservation Act "…in order to protect and preserve the scenic, recreational, geological, and fish and wildlife resources of the Gauley River and its tributary, the Meadow River" (Public Law 100-534). The legislation also highlighted that "The segment of the Gauley River below Summersville Dam has gained national recognition as a premier whitewater recreation resource" (P.L. 100-534). The federal policy governing the establishment and administration of National Recreation Areas states that

> *…outdoor recreation shall be recognized as the dominant or primary resource management purpose. If additional natural resource utilization is carried on, such additional use shall be compatible with fulfilling the recreation mission, and none will be carried on that is significantly detrimental to it* (RAC 1963).

2.1.2. Geographic Setting

The GARI boundary includes nearly 4,700 ha (just over 11,600 ac) in central West Virginia (Figure 1), although less than half of this area is owned by the NPS (NPS 2015c). GARI contains a 40-km (25-mi) stretch of the Gauley River, starting just downstream of the Summersville Dam, and a 10-km (6-mi) stretch of its tributary, the Meadow River (Marshall and Piekielek 2007b). The park lies in the Allegheny Mountains, in an area where streams have cut narrow canyons into the rocky slopes (Marshall and Piekielek 2007b).

The region around GARI has a humid, continental climate that can be influenced by local physiographic features (e.g., mountains, valleys) (Knight et al. 2015). The summers are warm, with average maximum temperatures in the 25-26°C range (77-79°F) (Table 1), and humid southwest winds coming over the mountains often trigger afternoon thunderstorms. Winter low temperatures average around -6°C (21°F), but can drop much lower during cold snaps (Davey et al. 2006). Precipitation is distributed throughout the year, with slightly higher amounts falling in the late spring through summer (Table 1).

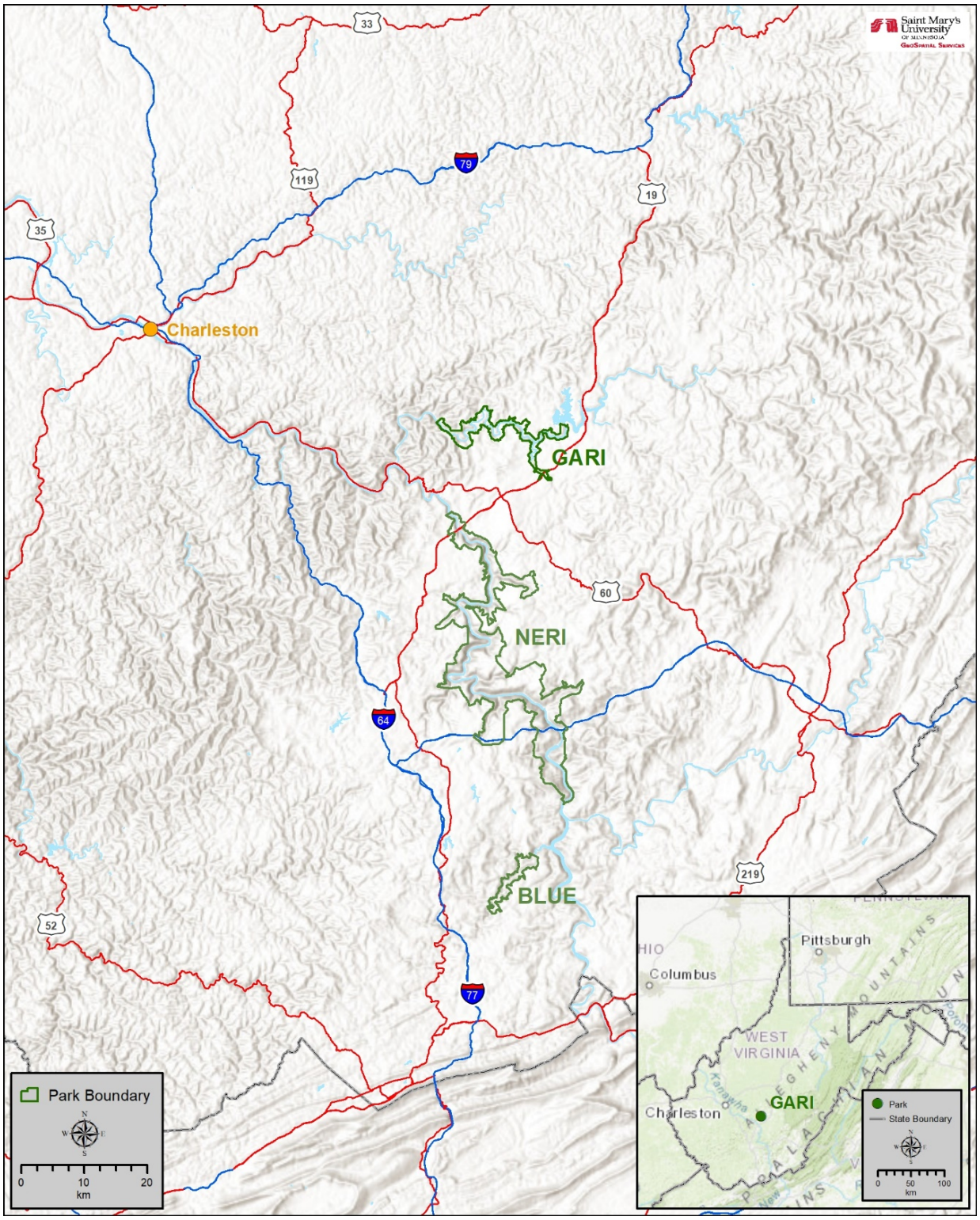


Figure 1. The location of Gauley River National Recreation Area within West Virginia.

Table 1. 30-year climate normals (1981-2010) for the Summersville Lake, West Virginia weather station just east of Gauley River National Recreation Area (NCDC 2015).

	Average Temperature (°C)		Average Precipitation (cm)
Month	**Max**	**Min**	**Total**
January	3.8	-6.4	8.4
February	5.7	-5.3	7.9
March	10.6	-1.7	9.7
April	17.1	3.1	10.1
May	21.2	8.5	12.8
June	25.0	13.3	11.5
July	26.8	15.6	15.0
August	26.3	14.9	11.3
September	22.9	11.1	8.7
October	17.5	5.1	8.1
November	12.0	0.3	8.7
December	5.7	-4.2	9.2
Annual	16.2	4.6	121.5

2.1.3. Visitation Statistics

On average, GARI received nearly 126,000 visitors per year between 2002 and 2016 (NPS 2017b). The highest visitation occurred in 2002 (188,000 visitors), and the lowest visitation during this period was in 2015 (105,000 visitors). The Gauley River as it runs through the park is considered to be one of the best whitewater rivers in the country (NPS 2016g), and consequently, the most popular recreational activity for visitors is whitewater rafting (Figure 2). Between 1994 and 2001, around 61,500 people participated in commercial whitewater rafting trips down the Gauley River within the park boundaries (Purvis 2002).



Figure 2. Rafting on the Gauley River (NPS photo by Shari Quinn).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

The Central Appalachians Level III Ecoregion encompasses the entirety of GARI and is defined as follows:

> *…primarily a high, dissected, rugged plateau composed of sandstone, shale, conglomerate, and coal. The rugged terrain, cool climate, and infertile soils limit agriculture, resulting in a mostly forested land cover. The high hills and low mountains are covered by a mixed mesophytic forest with areas of Appalachian oak and northern hardwood forest. Bituminous coal mines are common, and have caused siltation and acidification of streams* (EPA 2013).

The Environmental Protection Agency (EPA) divides Level III Ecoregions into smaller Level IV Ecoregions. The boundary of GARI spans two Level IV Ecoregions: the Forested Hills and Mountains and Dissected Appalachian Plateau (Figure 3).

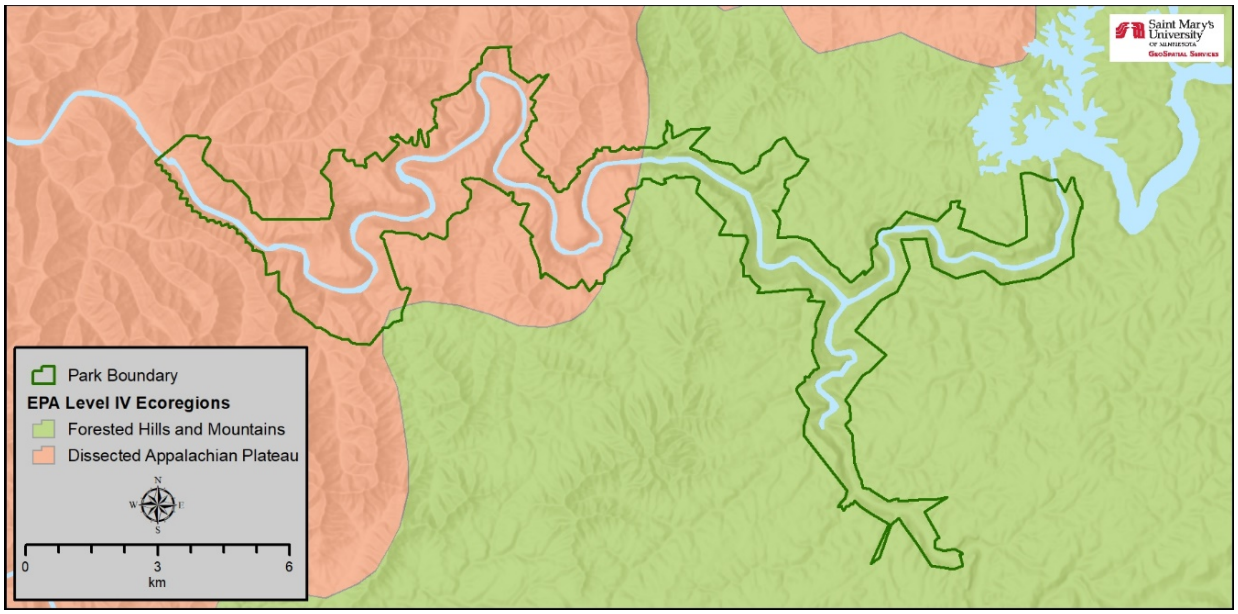


Figure 3. Environmental Protection Agency Level IV Ecoregions within Gauley River National Recreation Area.

All of GARI can be found inside the HUC 8 Gauley River subbasin, but the park is divided among two HUC 10 watersheds: the Outlet Gauley River and the Meadow River (Figure 4). Together, these two watersheds cover 182,400 ha (450,721 ac). In addition to the Meadow River, other notable tributaries of the portion of the Gauley River within GARI include Peters Creek, Horseshoe Creek, Laurel Creek, and Meadow Creek.

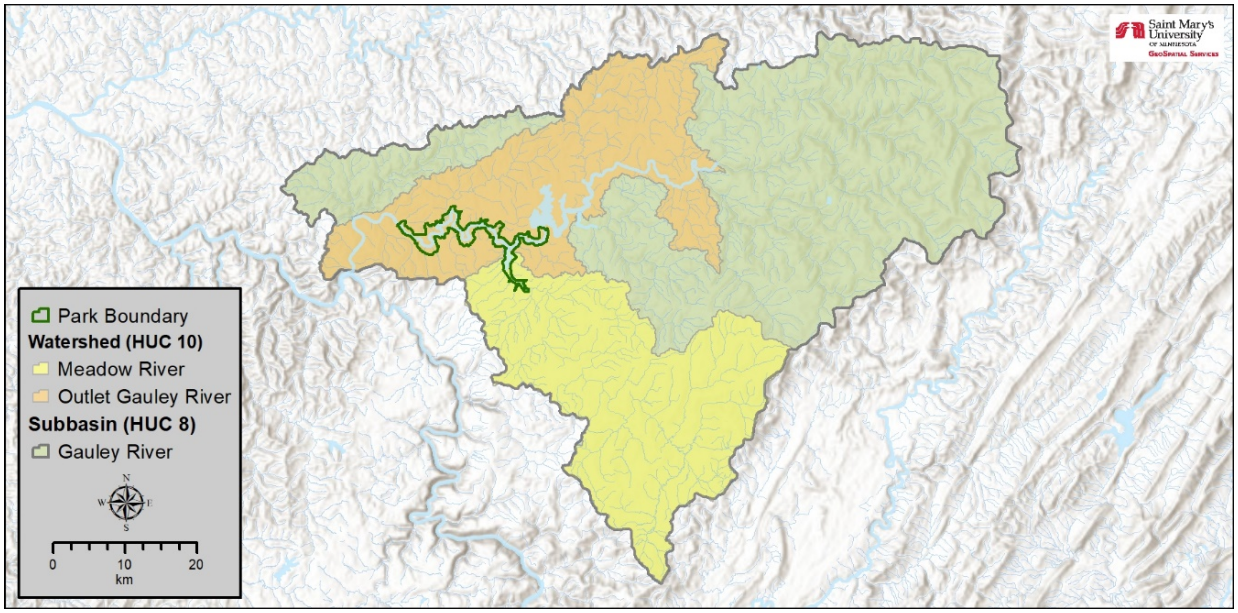


Figure 4. Two watersheds cover the boundary of Gauley River National Recreation Area.

2.2.2. Resource Descriptions

The central feature of GARI is the Gauley River system and its surrounding gorge. The varying topography throughout the gorge supports a tremendous diversity of vegetation and wildlife. Much of the park is covered by upland deciduous forests and mixed evergreen-deciduous forests with small areas of cliff and riparian vegetation communities (Vanderhorst et al. 2010). Common upland tree species include eastern hemlock (*Tsuga canadensis*), maples (*Acer* spp.), and oaks (*Quercus* spp.). Although small, the riparian habitats in the park support many rare plant species, including the federally threatened Virginia spiraea (*Spiraea virginiana*) and the globally-rare Monongahela Barbara's buttons (*Marshallia grandiflora*) (Vanderhorst et al. 2010). Over 800 plant species have been documented within GARI boundaries (NPS 2016d).

Soils, particularly nutrient availability, often have a strong influence on vegetation composition, structure, and dynamics (Perles et al. 2012). The soils at GARI are generally well-drained with a shallow organic horizon (0-5 cm [0-2 in]) (NRCS 2013). The organic horizon is important for water retention, nutrient provision, and insulating deeper soils from extreme temperatures (Binkley and Fisher 2012). Ridgetop soils are generally more acidic than valley soils and may be vulnerable to negative impacts from acidic deposition (e.g., acidic precipitation) (Perles et al. 2014a). Within GARI and other West Virginia parks, tree mortality and growth are impacted by soil mineral and nutrient ratios (calcium:aluminum, carbon:nitrogen) (Perles et al. 2016).

Most mammals found at GARI are typical of eastern forests, including white-tailed deer (*Odocoileus virginianus*), red and gray foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), eastern chipmunks (*Tamias striatus*), and squirrels (*Sciurus* spp.) (NPS 2016d). Nine species of bats (Order Chiroptera) also occur in the park, some of which are management priorities due to increasing conservation concern in recent years.



A young white-tailed deer (*Odocoileus virginianus*) (left) and a red fox (*Vulpes vulpes*) (right) (NPS photos).

Nearly 150 bird species have been documented at GARI, from waterbirds to songbirds and raptors, including over 20 West Virginia species of conservation concern (NPS 2016d). The park's largely unbroken interior forests provide habitat for a variety of breeding songbirds, such as vireos (*Vireo* spp.) and warblers (Family Parulidae), as well as migratory species and those that depend on continuous stands of forests. Additionally, the narrow riparian corridors support waterfowl (e.g., ducks and geese) and wading birds (e.g., herons and egrets) (NPS 2016d).

The park's diverse habitats also support 19 reptile species, 27 amphibian species, over 30 fish species, and numerous invertebrate species, including several species of conservation concern. Highlighting the uniqueness of GARI's many habitats is the fact that three of these salamander species and two fish species are considered endemic (i.e., native to a limited geographic area) to the region.



Clockwise from top left: Great blue heron (*Ardea herodias*, NPS photo by Gary Hartley), swallowtail butterfly (*Papilio* sp., NPS photo by Louise McLaughlin), wood frog (*Lithobates sylvaticus*, NPS photo by Leah Perkowski-Sisk), and five-lined skink (*Eumeces fasciatus*, NPS photo).

2.2.3. Resource Issues Overview

Hydrology – Dam Impacts

The impoundment of the Gauley River by the Summersville Dam in 1965 created the large reservoir known now as Summersville Lake. The reservoir waters become thermally stratified in the summer, with warmer waters towards the surface and colder waters towards the bottom (USGS 2016c). Water released through the dam into the Gauley River comes from closer to the bottom of Summersville Lake, meaning it is relatively colder than water on uncontrolled portions of the river. These cooler temperatures can impact water quality parameters and aquatic organisms just downstream of the dam (Caissie 2006). For example, cold water releases have been shown to influence the distribution and growth rates of aquatic organisms (Robinson and Childs 2001, Caissie 2006). Water temperatures also influence the timing of seasonal cycles, including fish reproduction and movements (Albanese et al. 2004, Caissie 2006).

The Summersville Dam also disrupts the natural flow regime of the Gauley River, generally reducing the variability and extremes in flow typical of Appalachian streams and rivers (Hebner 1991, Purvis 2002). The natural high flows that are common during spring runoff are captured and moderated by the dam, reducing the frequency and magnitude of scour events that are usually associated with high spring flows. Then, during the summer when stream flows are often naturally low, a relatively consistent flow level is maintained with steady water releases from the dam. In early fall (September-beginning of October), when Appalachian streams are often at their lowest levels, abnormally high flows occur in the GARI stretch of the Gauley River as Summersville Lake levels are lowered to make room for winter and spring runoff and to support a fall commercial rafting season (Hebner 1991, Purvis 2002). This moderation of stream flow, particularly the reduction in peak flows and flooding, can impact downstream riparian areas, including rare native plant communities (Norris 1992, Purvis 2002). Figure 5 shows a graph of daily discharge on the Gauley River at a monitoring station approximately 7 km (~4 mi) downstream of GARI from 1930-2010. The variability and extremes in flow regime were clearly reduced with the completion of Summersville Dam in 1965.

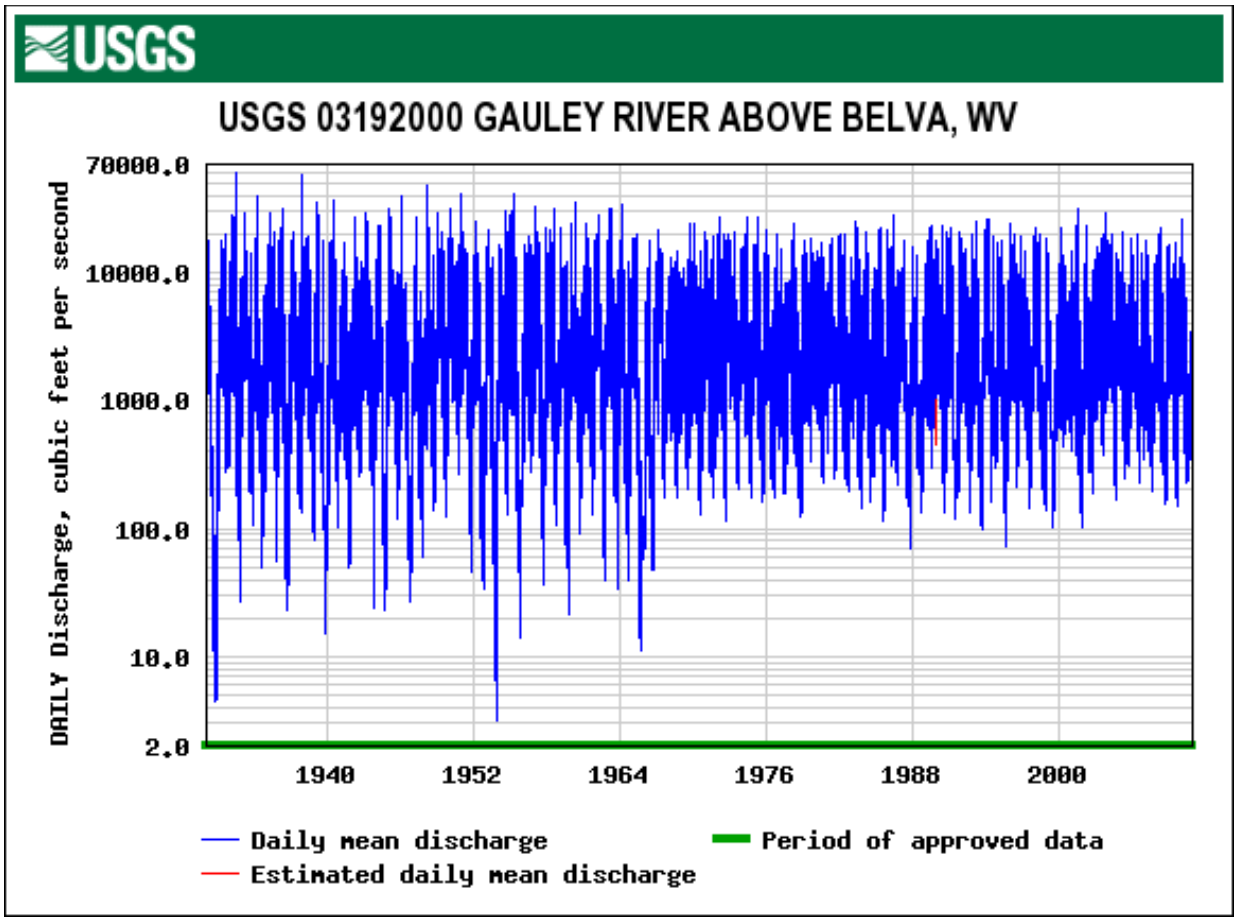


Figure 5. Mean daily discharge (cfs) on the Gauley River above Belva (approximately 7 km [~4 mi] downstream of Gauley River National Recreation Area), 1930-2010 (USGS 2016a). The change in flow regime following Summersville Dam construction in 1965 is notable near the middle of the graph.

Exotic Plants and Pests

Exotic invasive species pose one of the greatest threats to biodiversity and ecosystem integrity worldwide, with the potential to impact ecological community composition, structure, and function (Mooney et al. 2005, Perles et al. 2014b). These species can compete with native plants and animals and disrupt ecosystem processes such as nutrient cycling and disturbance regimes (e.g., fire, flooding). Invasive exotic species have been identified as a serious threat to GARI's resources, particularly its vegetation communities (Perles et al. 2010). Just over 80 exotic plant species have been documented at GARI, the majority of which are considered invasive in West Virginia (Appendix A) (WVNHP 2009, NPS 2016d). The most common invasive plants include multiflora rose (*Rosa multiflora*), and tree of heaven (*Ailanthus altissima*) (Perles et al. 2010).

Several exotic pests (insects or diseases) are also impacting GARI's vegetation. Perhaps the most serious is hemlock wooly adelgid (HWA; *Adelges tsugae*), an aphid-like insect native to Japan (Strickler 2014). The HWA, which feeds at the base of hemlock (*Tsuga* spp.) needles, was first observed at GARI in 2007. Although a successful chemical treatment for HWA has been identified and subsequently applied at GARI, the decline in hemlock triggered by this pest could cause the most

significant change in forest composition since the logging of the 1900s (Vanderhorst et al. 2010). Additional exotic insects threatening the park include emerald ash borer (EAB; *Agrilus planipennis*) and gypsy moth (*Lymantria dispar*) (Perles et al. 2016).

Mineral Extraction

West Virginia has long been known as a coal-bearing region, and the mining industry played a key role in the state's history (Purvis 2002, NPS 2011). A 13-county area in southern West Virginia is now designated as the National Coal Heritage Area (NCHA 2016). GARI lies on the northeastern boundary of this heritage area. Coal mining has occurred in the watersheds draining into GARI and has impacted many park resources, particularly water quality (Purvis 2002). Streams draining mined areas typically have higher concentrations of dissolved minerals (e.g., calcium, magnesium, sulfate, bicarbonate) and higher specific conductance (Purvis 2002). Wastes from coal mining may also carry polycyclic aromatic hydrocarbons (PAHs), organic compounds that can be toxic to wildlife and humans, and trace metals (e.g., manganese, aluminum, iron) (Purvis 2002, Sheeder et al. 2004). Due to the low sulfur content of West Virginia's coal deposits, acidification (i.e., lowering of pH) of surface waters has not been as significant of an issue compared to other mining regions (Purvis 2002, NPS 2011). There are still active coal mines in the watersheds that flow into GARI, primarily in the Peters Creek watershed north of the park, including large mountaintop removal sites (WVDEP 2017).

The region around GARI has also experienced natural gas exploration and extraction. According to the West Virginia Department of Environmental Protection (WVDEP), there are currently four active gas wells within GARI boundaries, and an additional 25 active wells within 1 km (0.6 mi) of park boundaries (WVDEP 2016b). During drilling and extraction, there is a risk that drilling fluids, gas, or waste fluids may spill or leak, potentially contaminating nearby waters (Purvis 2002, NPS 2009). The Marcellus Shale is a gas-bearing rock formation that underlies New York, Pennsylvania, West Virginia, and eastern Ohio (NPS 2009). GARI lies within the south central portion of this formation. Developments in drilling technology over the past two decades (e.g., hydraulic fracturing or "fracking" and horizontal drilling) have made development of the Marcellus Shale more viable than previously thought, triggering increased exploration and development during the past 10-15 years. The developments required to extract the shale gas found in the Marcellus poses risks for air and water quality, vegetation and wildlife, and park visitor experience (NPS 2009); water use and contamination issues are among the highest concerns. The hydraulic fracturing process requires significantly more water than traditional (vertical) drilling. While a traditional well typically requires less than 1 million gallons, a "fracking" well can use 3 to 5 million gallons (NPS 2009). This water is often taken from nearby ground or surface waters, which reduces the amount of water available for other purposes (e.g., streamflow, supplying plants and wildlife, recreation). Chemicals are added to the water during the drilling process and could contaminate local ground and surface waters if spills or leaks occur during the drilling and disposal of used fluids (NPS 2009).

The machinery required for drilling and vehicles needed for construction and transportation would generate emissions that may degrade the area's air quality (NPS 2009). Pollutants from these operations include nitrogen oxides and volatile organic compounds (VOCs), which can combine to form ozone, as well as particulate matter (PM) (NPS 2009). The construction of drilling and

transportation infrastructure would also disturb soils and vegetation, while the noise from construction and drilling operations would disturb wildlife and human visitors alike (NPS 2009).

Development/Land Use Change

Development or other changes in surrounding land use can have a significant impact on the environmental quality, wildlife community, and visitor experience in protected areas. While much of the land within the GARI watershed is forested, a small percentage is in agricultural use and logging occasionally occurs near the park (Purvis 2002, USGS 2011b). Agriculture and logging can contribute pollutants (e.g., chemicals, nutrients) and excess sediment to streams. Clearing and construction for residential and recreational developments can also impact water quality, cause habitat fragmentation, and increase threats to wildlife populations (Rentch 2006). Many communities and households in the region around the park lack adequate septic or sewage systems for the proper treatment of human and other domestic wastes, which has contributed to high fecal coliform bacteria levels in park waters (Purvis 2002, 2009). Developments often involve an increase in impervious surface area (e.g., roads, parking lots) and a reduction in precipitation infiltration. This can contribute to increased storm runoff (amount and velocity) and a higher potential for flash flooding (Purvis 2002). High stormflows can also cause streambank erosion and increased sedimentation, which can alter stream hydrology (Marshall et al. 2006).

Climate Change

Climate is a key driving factor in the ecological and physical processes influencing park ecosystems throughout the Eastern Rivers and Mountains Network (ERMN) (Davey et al. 2006). As a result of global climate change, temperatures are projected to increase across the eastern United States over the next century (Horton et al. 2014). Warmer air temperatures will increase evaporation rates and plant transpiration (i.e., plant water use), meaning that even if annual precipitation remains constant or slightly increases, overall conditions could still become drier in the future (Dale et al. 2001, Carter et al. 2014). Drier conditions pose obvious threats to riparian vegetation communities, aquatic wildlife, herpetofauna (amphibians and reptiles), and river recreation, but will likely impact upland vegetation and other wildlife as well (NABCI 2010, Fisichelli et al. 2014). The potential impacts of climate change on various park resources will be discussed specifically in Chapter 4 of this report.

2.3. Resource Stewardship

2.3.1. Status of Supporting Science

The ERMN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2007, the ERMN completed and released a Vital Signs Monitoring Plan (Marshall and Piekielek 2007a); Table 2 shows the ERMN Vital Signs selected for monitoring in GARI.

Table 2. Eastern Rivers and Mountains Network Vital Signs selected for monitoring in Gauley River National Recreation Area (Marshall and Piekielek 2007a).

Category	ERMN Vital Sign	Category 1[A]	Category 2[B]	Category 3[C]
Air and Climate	Ozone	–	X	–
	Wet and Dry Deposition	–	X	–
	Weather and Climate	X	X	–
Geology and Soils	Stream/River Channel Characteristics	–	–	X
	Soil Erosion and Compaction	–	–	X
	Soil Function and Dynamics	X	–	–
Water	Surface Water Dynamics	X	X	–
	Wetland Water Dynamics	–	–	X
	Groundwater Dynamics	–	–	X
	Water Chemistry	X	X	–
	Aquatic Macroinvertebrates	X	X	–
	Aquatic Periphyton	–	–	X
Biological Integrity	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	X	–	–
	Invasive/Exotic Plants, Animals and Diseases - Early Detection	X	–	–
	Shrubland Forest and Woodland Communities	X	–	–
	Riparian Communities	X	–	–
	Birds – Riparian Communities	–	–	X
	Mammals - Riparian Communities	–	–	X
	Birds – Breeding Communities	X	–	–
	Terrestrial Invertebrates	–	–	X
	Freshwater Communities - Mussels	–	–	X
	Freshwater Communities - Crayfish	–	–	X
	Freshwater Communities - Macrophytes	–	–	X
	Fish Communities - Streams	–	–	X
	Fish Communities - Rivers	–	–	X
	Amphibians and Reptiles – Vernal Pond Community	–	–	X

[A] Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

[B] Category 2 represents Vital Signs that are monitored by GARI, another NPS program, or by another federal or state agency using other funding.

[C] Category 3 represents high priority Vital Signs for which monitoring will likely be done in the future.

Table 2 (continued). Eastern Rivers and Mountains Network Vital Signs selected for monitoring in Gauley River National Recreation Area (Marshall and Piekielek 2007a).

Category	ERMN Vital Sign	Category 1[A]	Category 2[B]	Category 3[C]
Biological Integrity (continued)	Amphibians and Reptiles – Streamside Salamander Community	–	–	X
	T&E Species and Communities – State and Federal	X	–	–
Human Use	Bioaccumulation	–	–	X
	Visitor Use	–	–	X
Landscapes (Ecosystem Patterns and Processes)	Land Cover and Use	X	–	–
	Landscape Pattern	X	–	–
	Primary Production	–	–	X
	Nutrient Dynamics	–	–	X

[A] Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

[B] Category 2 represents Vital Signs that are monitored by GARI, another NPS program, or by another federal or state agency using other funding.

[C] Category 3 represents high priority Vital Signs for which monitoring will likely be done in the future.

3. Study Scoping and Design

This NRCA is a collaborative project between the NPS and SMUMN GSS. Project stakeholders include the GARI resource management team, and ERMN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1. Preliminary Scoping

A preliminary scoping meeting was held from 24-27 October 2016. At this meeting, SMUMN GSS and NPS, ERMN, and park staff confirmed that the purpose of the GARI NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to GARI managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by GARI resource management;

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid GARI resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding
- resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including GARI resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project;

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point;

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process;

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually;

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the GARI NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in GARI. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established

ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were adapted from the ERMN Vital Signs monitoring plan (Marshall and Piekielek 2007). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized at the end of January 2017 following a scoping workshop 24-27 October 2016, and acceptance from NPS resource staff. The framework contains a total of 10 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

3.2.2. General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time GARI staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from GARI and the ERMN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A "Significance Level" represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component's condition; each Significance Level is defined in Table 4. This categorization allows measures that are more important for determining condition of a component (higher significance level) to be more heavily weighted in calculating an overall condition. If a measure is given a Significance Level of 1, it is thought to be of low importance when determining the overall condition of the component. For this reason, measures with a Significance Level of 1 are not discussed in detail in the Current Condition and Trends section of a component's chapter. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 3. Gauley River National Recreation Area natural resource condition assessment framework.

Component	Measures (Significance Level)	Stressors	Reference Condition
Upland Forest Communities	Community extent (3), plant species richness (3), rare plant element occurrences (number and ranks) (3), proportion of total cover of exotic and invasive plants (3), tree mortality (3), recruitment (3), tree mean annual diameter increment (3)	Pests and pathogens, exotic species, extreme weather events, climate change, deer browse, feral swine, gas extraction, forest fragmentation, recreational use, illegal moss harvest	Unknown; Best professional judgement and comparisons to similar forests in other ERMN parks will be used to assess condition
Riparian Vegetation Communities	Total acreage (3), acreage by wetland type (3), plant species diversity by type (3), water quality (3), soil quality (2)	Invasive exotic species, pests and pathogens, flow regulation by Summersville Dam, climate change, recreational use, water quality	Same as above
Birds	Species richness (3), species abundance (2), species distribution (2), Bird Community Index (BCI) (3)	Land development on private inholdings, gas development, climate change, water quality, recreational use, invasive species	Undefined
Herpetofauna (Reptiles and Amphibians)	Species richness (3), species abundance (3), species distribution (3)	Water quality, recreational use, bait collection, diseases, climate change, invasive vegetation, illegal moss harvest, habitat fragmentation, pesticides, non-native bait releases	Undefined
Mammals	Species richness (3), bat species richness (3), Allegheny woodrat presence/absence (3), annual harvest numbers (3)	Habitat fragmentation, land development on private inholdings, gas development, hunting pressure, recreational use, invasive vegetation, adjacent land use, white nose syndrome	Undefined
Aquatic Wildlife Community	Fish species richness (3), percent native species (3), fish species relative abundance (3), macroinvertebrate species richness (3), benthic macroinvertebrate IBI (3)	Non-native species (e.g., fish stocking, bait bucket releases), coal activity, water temperatures (related to dam operations) and release schedule, invasive aquatic plants, boat traffic, extreme hydrologic/ weather events, inadequately treated sewage, pesticides, adjacent land use/ development	Welsh et al. (2004) for fish measures, ranges used by ERMN for macroinvertebrate IBI

Table 3 (continued). Gauley River National Recreation Area natural resource condition assessment framework.

Component	Measures (Significance Level)	Stressors	Reference Condition
Water Quality	Temperature (2), pH (3), conductivity (3), dissolved oxygen (3), turbidity (3), fecal coliform bacteria (3)	Upstream land use (agriculture, logging), coal mining, oil and gas development, flow regulation (dam operation), residential & other development, inadequately treated sewage, pesticides, road de-icers, bilge waste from boats	West Virginia state standards
Air Quality	Ozone (3), atmospheric deposition of sulfur/nitrogen (3), atmospheric deposition of mercury (3), visibility (3)	Power plant emissions, vehicle emissions, dust from mountaintop mining, prescribed burning	NPS ARD standards and ranges
Dark Night Skies	NPS NST Suite of 6 measures	Light from state parks, Summersville Lake/Dam area, and other camping; nearby city light pollution, train and auto traffic, infrastructure (cell towers, power lines), coal mining activity	Absence of anthropogenic light
Surficial Geologic Features[A]	Features of interest: Cliffs, boulders, algific areas, mass movements	oil and gas exploration and development, recreation (particularly rock climbing), climate change, and extreme weather events	N/A

[A] included as a non-scored component and summarized only without assessing condition

Table 4. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 5). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 5. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of NO concern. No net loss, degradation, negative change, or alteration.
1	Of LOW concern. Signs of limited and isolated degradation of the component.
2	Of MODERATE concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of SIGNIFICANT concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: resource is in good condition (WCS = 0.0 – 0.33); condition warrants moderate concern (WCS = 0.34 - 0.66); and condition warrants significant concern (WCS = 0.67 to 1.00). Tables 6 and 7 display and describes the symbology used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern, and green circles are in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there was currently insufficient data to make a statement about the condition of a component. The border of the circles represents the confidence in the assessment of current condition; bold borders indicate high confidence, normal borders indicate

medium confidence, and a dashed-border indicates low confidence. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. An arrow that points to the left and right indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. An empty circle with no arrow is reserved for situations in which the trend of the component's condition is currently unknown.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts, and GARI and ERMN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Table 6. Description of symbology used for individual component assessments.

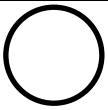
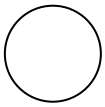
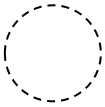
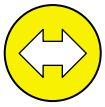
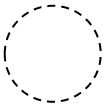
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 7. Examples of how the symbols should be interpreted for individual component assessments.

Symbol Example	Verbal Description
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by GARI resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that

analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component. Sources are listed alphabetically by last name.

4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 10 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 3):

4.1 Upland Forest Community

4.2 Riparian Vegetation Communities

4.3 Birds

4.4 Mammals

4.5 Herpetofauna

4.6 Aquatic Wildlife Community

4.7 Water Quality

4.8 Air Quality

4.9 Dark Night Skies

4.10 Surficial Geologic Features (non-traditional, unscored component)

4.2. Upland Forest Communities

4.2.1. Description

GARI lies in the mixed mesophytic region of the eastern deciduous forest (Braun 1950, Vanderhorst et al. 2010). The vast majority of the park (86%) is covered in upland forest and woodland dominated by eastern hemlock, maples, oaks, tuliptree (*Liriodendron tulipifera*), and other hardwoods (Vanderhorst et al. 2010). The eastern two-thirds of the park are dominated by mixed evergreen-deciduous forest while the western third is dominated by deciduous forest. These forests provide food and habitat for a variety of wildlife and perform many valuable ecosystem services (e.g., carbon storage, air purification, erosion control) (Miller et al. 2016). The ERMN identified vegetation as a high priority for long-term monitoring as part of the Vital Signs program (Marshall and Piekielek 2007a, Perles et al. 2010). The condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Perles et al. 2010).

Vegetation classification and mapping efforts at GARI identified 12 unique upland forest community types occurring within park boundaries (Vanderhorst et al. 2010). These types (or "associations") and the prominent or characteristic tree species in GARI stands are presented in Table 8.

Table 8. Upland forest vegetation associations documented within Gauley River National Recreation Area and the most prominent tree and shrub species in each (Vanderhorst et al. 2010).

Vegetation Community	Prominent Tree/Shrub Species
Cliff Top Virginia Pine Forest	Virginia pine (*Pinus virginiana*)
Eastern Hemlock - Chestnut Oak / Catawba Rosebay Forest	chestnut oak (*Quercus montana*), eastern hemlock, black oak (*Q. velutina*), scarlet oak (*Q. coccinea* var. *coccinea*), Catawba rosebay (*Rhododendron catawbiense*)
Eastern Hemlock - Oak - Sweet Birch / Great Laurel Forest	eastern hemlock, red maple (*Acer rubrum*), northern red oak (*Q. rubra*), sweet birch (*Betula lenta*), chestnut oak, great laurel (*Rhododendron maximum*)
Eastern Hemlock Plateau Forest	eastern hemlock, tuliptree, red maple, northern red oak, black oak, American beech (*Fagus grandifolia*)
Oak / Ericad Forest	black oak, chestnut oak, scarlet oak, white oak (*Q. alba*), mountain laurel (*Kalmia latifolia*)
Oak / Great Laurel Forest	chestnut oak, black oak, northern red oak, white oak, sweet birch, red maple, great laurel
Oak - Hickory Forest	mockernut hickory (*Carya alba*), black oak, chestnut oak, tuliptree, white oak, northern red oak, scarlet oak
Oak - Hickory - Sugar Maple Forest	northern red oak, chestnut oak, sugar maple (*Acer saccharum* var. *saccharum*), white oak, black oak, pignut hickory (*Carya glabra*), mockernut hickory
Successional (Virginia, Pitch) Pine Forest	Virginia pine, eastern hemlock
Successional Tuliptree Forest	tuliptree, sweet birch, red maple, northern red oak, sourwood (*Oxydendrum arboreum*)

Table 8 (continued). Upland forest vegetation associations documented within Gauley River National Recreation Area and the most prominent tree and shrub species in each (Vanderhorst et al. 2010).

Vegetation Community	Prominent Tree/Shrub Species
Successional Tuliptree Forest	tuliptree, sweet birch, red maple, northern red oak, sourwood (*Oxydendrum arboreum*)
Sugar Maple - Yellow Buckeye - American Basswood Forest	sugar maple, northern red oak, tuliptree, red maple, American basswood (*Tilia americana*), white ash (*Fraxinus americana*), yellow buckeye (*Aesculus flava*)
Yellow Birch Cold Cove Forest	yellow birch (*B. alleghaniensis* var. *alleghaniensis*), tuliptree, red maple, sweet birch, eastern hemlock, mountain magnolia (*Magnolia fraseri*)

4.2.2. Measures

- Community extent
- Plant species richness
- Rare plant element occurrences
- Proportion of total cover of exotic plants and invasive plants
- Tree mortality
- Recruitment
- Tree mean annual diameter increment

4.2.3. Reference Condition/Values

Due to the relatively recent establishment of the park, there is little historical information available on vegetation communities within GARI. This makes identifying reference conditions challenging. For the purposes of this assessment, current condition will be assessed based on comparisons to similar forests in other ERMN parks (particularly within West Virginia) and on best professional judgement. The information presented here could serve as a baseline for future assessments.

4.2.4. Data and Methods

In 1991, GARI was surveyed on foot for rare plant and animal species (Norris 1992). Both banks of the Gauley and Meadow Rivers were covered, totaling nearly 95 km (59 mi), as were several roads and trails. When rare species were found, the location was noted, along with information on habitat, population size and condition, reproduction, and evidence of disturbance or threats (Norris 1992). A similar re-inventory was conducted by the West Virginia Natural Heritage Program (WVNHP) from July through mid-October of 2003 (WVNHP 2004).

Grafton (1993) sampled vegetation transects in "moist" and "dry" vegetation communities along the Gauley, Meadow, and Bluestone Rivers throughout the 1992 growing season. The objective was to identify the most common plant species and community types along these rivers and document variation between moist and dry habitats and different slope aspects. Data recorded along transects

included forest cover type, overstory age, dominant shrub species, and dominant herbaceous species (Grafton 1993).

A vegetation reconnaissance study of vegetation in the Bluestone, Gauley, and New River gorges was completed by Fortney et al. (1995) during the summer and fall of 1994. For the Gauley River gorge, a sampling transect was established in the northeastern part of Carnifex Ferry Battlefield State Park. This transect included three 20x50 m (65.6x164.0 ft) quadrats, representing upper, middle, and lower slope positions (Fortney et al. 1995). In addition, two quadrats were sampled at Koontz Bend, near the confluence with Peters Creek. Vegetation composition and structure were studied by measuring diameter at breast height (DBH) of all trees and counting the number of saplings in the full quadrat. The number of seedlings and shrubs were recorded in smaller, nested 5x5 m (16.4x16.4 ft) plots within the quadrats. Percent cover of herbaceous species, woody debris, and exposed rock were estimated in nested 1x1 m [3.3x3.3 ft] plots. Herbaceous species observed in the larger quadrat but not within these smaller plots were also noted (Fortney et al. 1995).

The WVNHP completed a vegetation classification and mapping project for GARI based on field sampling and aerial imagery interpretation (Vanderhorst et al. 2010). Researchers sampled 187 vegetation plots in and near the park from 2006-2009, and incorporated previous analyses from 33 plots sampled in the mid-1990s. The 187 plots sampled from 2006-2009 were typically 20×20 m^2 (65×65 ft^2), but shape and size were occasionally changed to accommodate linear communities or small patches. Data collected addressed species composition and community structure (e.g., percent cover by strata, DBH of woody species). Plant communities were classified into vegetation associations using the U.S. National Vegetation Classification (NVC). Vegetation mapping was based on March 2003 aerial imagery of the park (Vanderhorst et al. 2010). Concurrent to this effort, the WVNHP also completed a floristic inventory for the park, which included efforts to document rare plant occurrences (Streets and Vanderhorst 2010).

In 2007, the ERMN initiated vegetation and soil monitoring in eight of its nine parks, including GARI (Perles et al. 2010). Approximately one-quarter of each park's plots are sampled per year, so that individual plots are visited on a 4-year rotation. Forty monitoring plots are located at GARI, 15 in mesic (moderate moisture levels) vegetation communities and 25 in xeric (dry) communities (Perles et al. 2016). Each plot is circular, with a 15-m (49.2-ft) radius, but contains smaller embedded plots for sampling various parameters. Sampling methods are described in detail in the ERMN monitoring protocol document (Perles et al. 2014c). Data collected allows managers to evaluate forest stand structure, tree regeneration, tree health and growth, understory diversity, invasive species, and soils (Perles et al. 2010). Assessments based on monitoring data collected to date are presented in Perles et al. (2010, 2014b, 2016). These reports provide information for the tree mortality, recruitment, and mean annual diameter increment measures of this NRCA.

The ERMN assesses tree mortality by calculating the annual mortality rate (% trees/year) between sampling periods. This is done by dividing the current number of dead trees by the total number of trees during the previous sampling period, and then dividing this by the number of years between sampling periods (Perles et al. 2016). Similarly, recruitment is based on the annual recruitment rate (% trees/year), which is based on the percentage of trees that crossed the minimum threshold for trees

(DBH = 10 cm) between sampling periods. This is calculated by dividing the number of "new" trees by the total number of trees during the previous sampling period, and dividing this by the number of years between sampling periods (Perles et al. 2016).

Tree mean annual diameter increment (MADI) is one way to measure and assess tree growth (Perles et al. 2016). MADI is calculated by first summing the diameter increment (DBH increase in cm between sampling periods) for all trees within a plot or of a particular species. This sum is first divided by the number of years between sampling periods, and then divided by the total number of trees included in the calculation (Perles et al. 2016).

4.2.5. Current Condition and Trend

Community Extent

According to the vegetation map generated by Vanderhorst et al. (2010), upland forest communities cover 3,929 ha (9,709 ac) within the GARI boundary (Table 9). Over half of this area (1,967 ha [4,861 ac]) consists of Eastern Hemlock - Oak - Sweet Birch / Great Laurel Forest (Figure 7). Only two other communities cover more than 400 ha (988 ac): Sugar Maple - Yellow Buckeye - American Basswood Forest and Oak - Hickory Forest. The smallest communities are Eastern Hemlock - Chestnut Oak / Catawba Rosebay Forest at 3.8 ha (9.5 ac) and Yellow Birch Cold Cove Forest with 4.5 ha (11.2 ac) (Vanderhorst et al. 2010).

Table 9. Upland forest extent at Gauley River National Recreation Area by vegetation community type (reproduced from Vanderhorst et al. 2010).

Vegetation Community	Area in ha (ac)
Cliff Top Virginia Pine Forest	16.1 (238.9)
Eastern Hemlock - Chestnut Oak / Catawba Rosebay Forest	3.8 (9.5)
Eastern Hemlock - Oak - Sweet Birch / Great Laurel Forest	1,967.3 (4,861.4)
Eastern Hemlock Plateau Forest	243.3 (601.1)
Oak / Ericad Forest	55.9(138.1)
Oak / Great Laurel Forest	197.9 (488.9)
Oak - Hickory Forest	425.3 (1,050.9)
Oak - Hickory - Sugar Maple Forest	353.2 (872.7)
Successional (Virginia, Pitch) Pine Forest	91.6 (226.3)
Successional Tuliptree Forest	135.6 (335.1)
Sugar Maple - Yellow Buckeye - American Basswood Forest	434.8 (1,074.3)
Yellow Birch Cold Cove Forest	4.5 (11.2)
Total upland forest	3,929.2 (9,709.4)

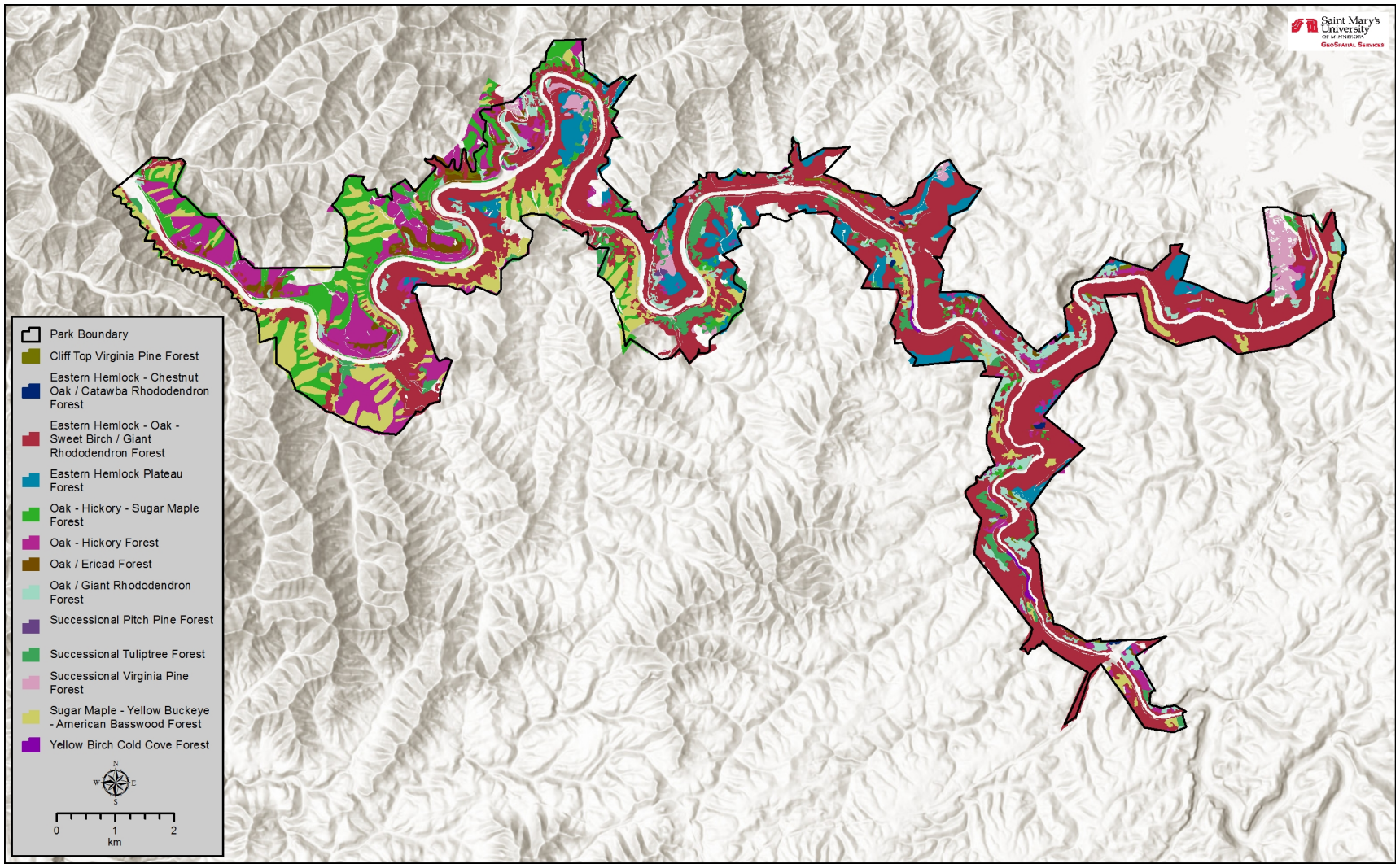


Figure 7. Upland forest extent within Gauley River National Recreation Area by vegetation community type (Vanderhorst et al. 2010).

Plant Species Richness

Vanderhorst et al. (2010) documented 403 plant taxa (including subspecies and varieties) within GARI's upland forest vegetation communities (Appendix B). Only 19 of these species (4.7%) are considered exotic. The greatest total number of plant species was documented in the Oak - Hickory Forest, with 238 species (Table 10). However, this may be related to the high number of plots sampled within this community. The highest mean number of species per plot (total species per community divided by total number of plots) was 21.1 in the Successional Tuliptree Forest. The lowest mean number of species per plot was 4.8 for the Eastern Hemlock-Oak-Sweet Birch/Great Laurel Forest, likely due to the competition for light in dense understory thickets (Stephanie Perles, ERMN Plant Ecologist, written communication, May 2017).

Table 10. Plant species richness by upland forest community type at Gauley River National Recreation Area, as documented by Vanderhorst et al. (2010).

Vegetation Community	# of Plots	# of Species	Mean Species/Plot
Cliff Top Virginia Pine Forest	6	67	11.2
Eastern Hemlock - Chestnut Oak/Catawba Rosebay Forest	5	53	10.6
Eastern Hemlock - Oak - Sweet Birch/Great Laurel Forest	24	114	4.8
Eastern Hemlock Plateau Forest	8	96	12.0
Oak/Ericad Forest	10	133	13.3
Oak/Great Laurel Forest	7	93	13.3
Oak - Hickory Forest	23	238	10.3
Oak - Hickory - Sugar Maple Forest	12	177	14.8
Successional (Virginia, Pitch) Pine Forest	4	76	19.0
Successional Tuliptree Forest	8	169	21.1
Sugar Maple - Yellow Buckeye - American Basswood Forest	17	148	8.7
Yellow Birch Cold Cove Forest	3	54	18.0

Since ERMN vegetation monitoring began in 2007, 380 plant species have been documented in upland forest plots (ERMN 2017) (Appendix B). This included 24 exotic species (6.3%), 13 of which had not been previously documented in GARI's upland forests. Cumulatively, a total of 521 plant species have been found in GARI's upland forests by various surveys over time (Appendix B). Thirty-four of these species (6.5%) are exotic. GARI supports a high diversity of nonvascular plants (e.g., mosses, liverworts), as 46 of the plant species identified are nonvascular (Vanderhorst et al. 2010). In addition to plants, a wide variety of lichens (20 species) have been found in GARI's upland forests (Appendix C) (Vanderhorst et al. 2010).

Rare Plant Element Occurrences

Element occurrences (EOs) are one way of surveying, mapping, and assessing populations of high-priority species (NatureServe 2016). NatureServe (2016) developed the EO data standard, which

provides standardized vocabulary, definitions, and guidelines for the collection and management of EO data. EO data provides information on where specific species exist on the ground, and their populations are ranked based on their overall viability or probability of persistence (NatureServe 2016). This information is stored in a georeferenced database called Biotics, which is maintained by NatureServe and various state Natural Heritage Programs (Streets and Vanderhorst 2010).

According to Streets and Vanderhorst (2010), 17 rare plant species have been confirmed in GARI's upland forests (Table 11). Several of these species were first documented in the park during the Streets and Vanderhorst (2010) 2006-2009 inventory. Norris (1992) only observed two of these species (largeseed forget-me-not [*Myosotis macrosperma*] and Curtiss' milkwort [*Polygala curtissii*]), and just one occurrence of each species was noted. Later searches for these two species by WVNHP (2004) did not relocate any occurrences, although this may have been because it was past their flowering time, which makes the plants more difficult to spot and identify. During regular forest monitoring by ERMN since 2007, two of these rare species have been observed in sampling plots (Table 11) (ERMN 2017).

Table 11. Documented rare plant occurrences at Gauley River National Recreation Area upland forest communities. Norris (1992) and WVNHP (2004) reported the number of personal observations during a thorough park survey. Streets and Vanderhorst (2010) information is based on element occurencess records in the WVNHP Biotics database in 2010. The Eastern Rivers and Mountains Network (2017) column represents species observed during routine forest monitoring (i.e., opportunistic observations, not a targeted search) since 2007.

Scientific Name	Common Name	State Rank[A]	Norris (1992)	WVNHP (2004)	Streets and Vanderhorst (2010)	ERMN (2017)
Adlumia fungosa	Allegheny vine	S2?	–	–	X	X
Aristida purpurascens var. *purpurascens*	arrowfeather threeawn	S1	–	–	X	–
Carex aestivalis	summer sedge	S2	–	–	X	–
Carex cumberlandensis	Cumberland sedge	S2	–	–	X	–
Carex molesta	troublesome sedge	S3	–	–	X	–
Cymophyllus fraserianus	Fraser's cymophyllus	S3	–	–	X	X
Danthonia sericea	downy danthonia	S1	–	–	X	–
Dichanthelium acuminatum ssp. *columbianum*	hemlock rosette grass	S1	–	–	X	–
Digitaria filiformis	slender crabgrass	S1	–	–	X	–
Eupatorium godfreyanum	Godfrey's thoroughwort	S2S3	–	–	X	–
Helianthus occidentalis ssp. *occidentalis*	fewleaf sunflower	S2	–	–	X	–

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, ? = rank uncertain.

Table 11 (continued). Documented rare plant occurrences at Gauley River National Recreation Area upland forest communities. Norris (1992) and WVNHP (2004) reported the number of personal observations during a thorough park survey. Streets and Vanderhorst (2010) information is based on element occurencess records in the WVNHP Biotics database in 2010. The Eastern Rivers and Mountains Network (2017) column represents species observed during routine forest monitoring (i.e., opportunistic observations, not a targeted search) since 2007.

Scientific Name	Common Name	State Rank[A]	Norris (1992)	WVNHP (2004)	Streets and Vanderhorst (2010)	ERMN (2017)
Lechea tenuifolia	narrowleaf pinweed	S1	–	–	X	–
Lygodium palmatum	American climbing fern	S3	–	–	X	–
Monarda fistulosa var. *brevis*	wild bergamot	S1	–	–	X	–
Myosotis macrosperma	largeseed forget-me-not	S2	1	Not found[B]	X	–
Polygala curtissii	Curtiss' milkwort	S2	1	Not found[B]	X	–
Rudbeckia fulgida var. *fulgida*	orange coneflower	S2	–	–	X	–

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, ? = rank uncertain.

[B] Surveys may have been unsuccessful because it was past flowering time, making these species more difficult to spot and identify.

Proportion of Total Cover of Exotic Plants and Invasive Plants

Not all exotic plant species are considered invasive. Exotic species considered invasive by the state of West Virginia, and therefore a greater threat to native plants, are listed in Appendix A. Both categories (exotic and invasive) will be addressed within this measure.

The Vanderhorst et al. (2010) report includes mean percent cover estimates by plant species for each vegetation community identified within the park. Within the 13 upland forest community types, mean exotic plant species cover ranged from 0% (in seven different communities) to 30.5% in Successional Tuliptree Forest. (Vanderhorst et al. 2010). Mean invasive species cover by forest community type was nearly identical to exotic cover, varying by <0.1% in just two of the 13 upland communities. Exotic and invasive species percent covers for all upland forest communities are shown in Table 12.

Table 12. Mean exotic and invasive plant species cover by upland forest community type within Gauley River National Recreation Area (Vanderhorst et al. 2010).

Vegetation Community (# of plots)	# of Exotic Species	Mean % Exotic Cover	Mean % Invasive Cover
Successional Tuliptree Forest (8)	4	30.5	30.5
Sugar Maple - Yellow Buckeye - American Basswood Forest (17)	8	4.0	4.0
Oak - Hickory Forest (23)	6	3.0	3.0
Oak/Great Laurel Forest (7)	2	1.0	1.0
Oak - Hickory - Sugar Maple Forest (12)	3	0.5	0.5
Successional Virginia Pine Forest (3)	6	<0.1	<0.1
Cliff Top Virginia Pine Forest (6)	0	0	0
Eastern Hemlock - Chestnut Oak/Catawba Rosebay Forest (5)	0	0	0
Eastern Hemlock - Oak - Sweet Birch/Great Laurel Forest (24)	0	0	0
Eastern Hemlock Plateau Forest (8)	0	0	0
Oak/Ericad Forest (10)	0	0	0
Successional Pitch Pine Forest (1)	0	0	0
Yellow Birch Cold Cove Forest (3)	0	0	0

Compared to other parks within ERMN from 2009-2012, GARI showed a similar proportion of *exotic* species cover as the nearby New River Gorge National River (NERI), but a much lower proportion of exotic cover than all other parks (Figure 8) (Perles et al. 2014b). In terms of *invasive* plant species from 2013-2016, GARI showed one of the lowest proportions of mean cover (3.2%) park-wide, second only to NERI (2.3%) (Figure 9) (ERMN 2017).

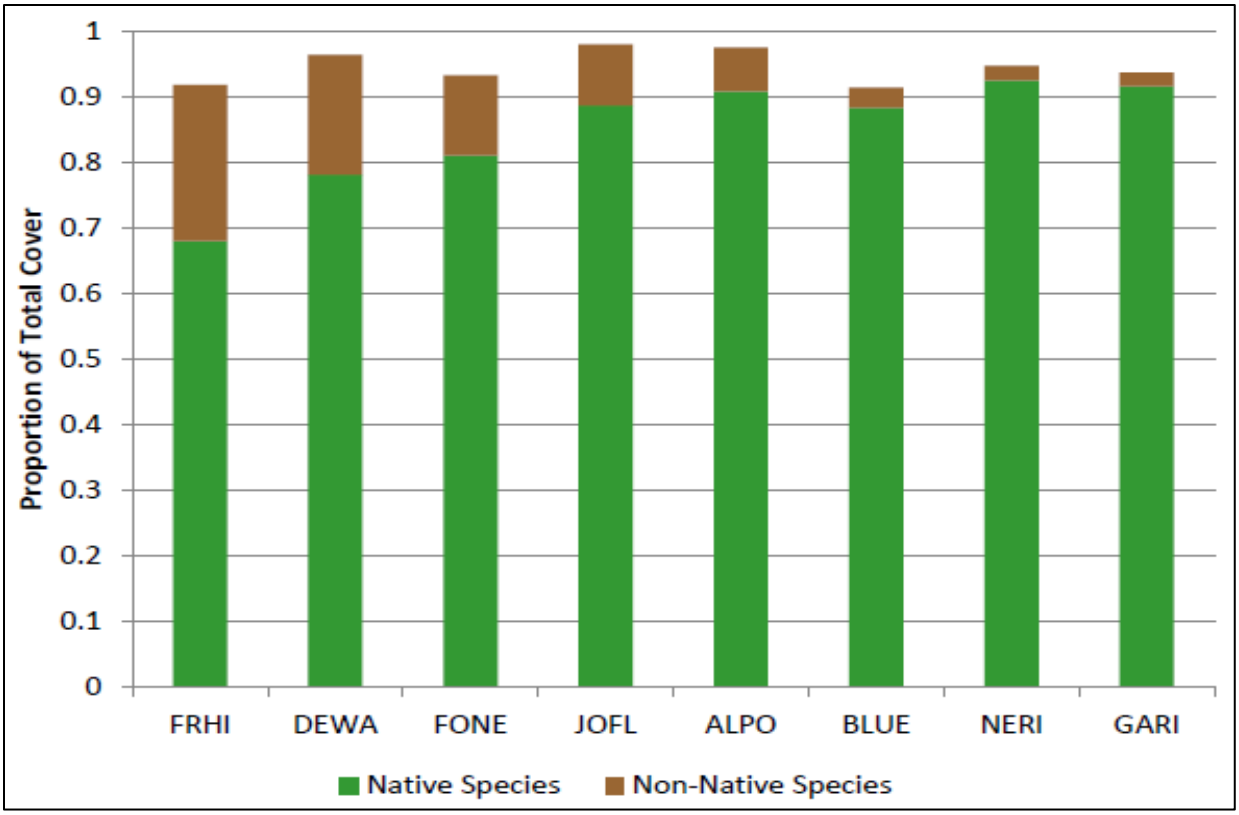


Figure 8. Proportion of total quadrat cover occupied by native and nonnative plant species in Eastern Rivers and Mountains Network parks (2009-2012). The three West Virginia parks (Gauley River National Recreation Area, New River Gorge National River, and Bluestone National Scenic River) are on the far right of the graph. Proportions do not add to one because some plants cannot be identified to species and therefore nativity cannot be assigned to those taxa (Perles et al. 2014b).

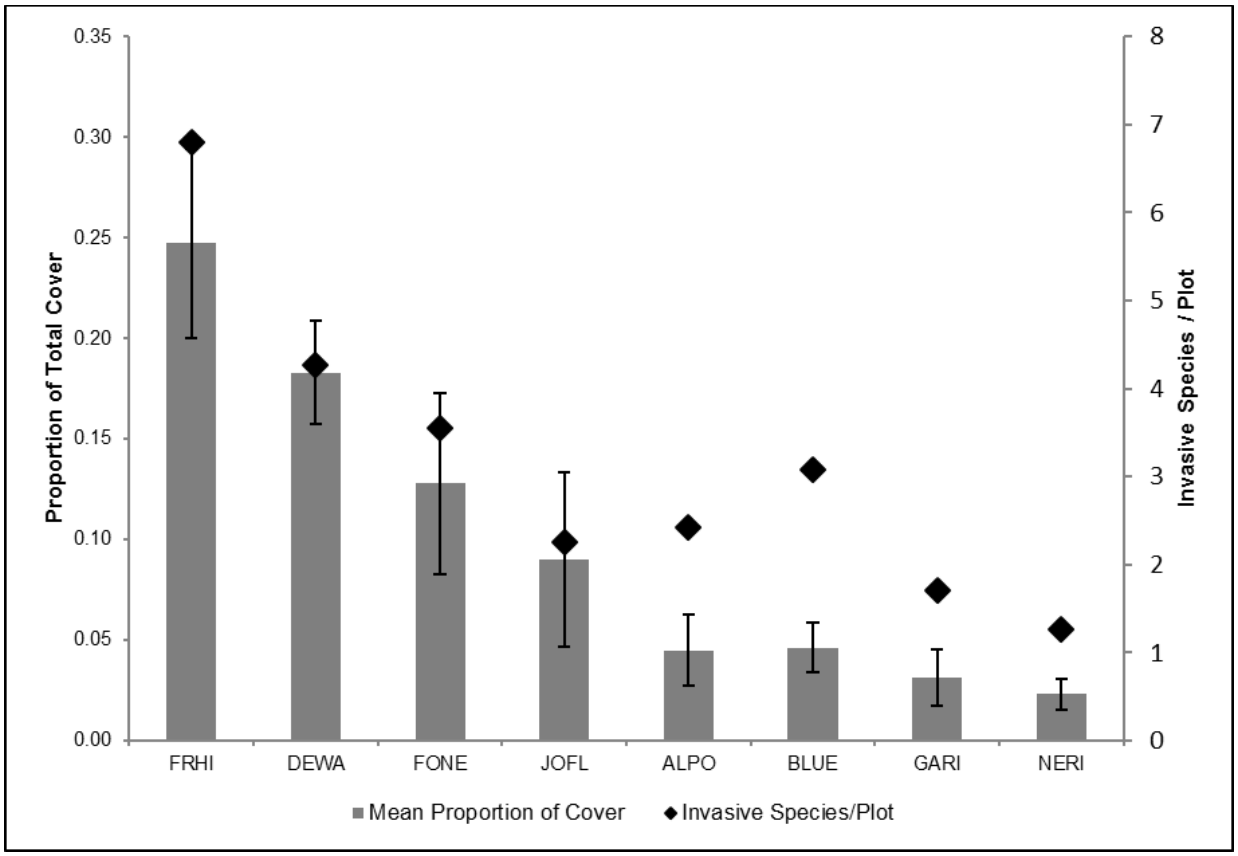


Figure 9. Average (± standard error) proportion of the total cover held by invasive exotic plant species as measured in monitoring quadrats in Eastern Rivers and Mountains Network parks (based on 2013-2016 data) (ERMN 2017). The black diamonds show the average number of invasive species/plot for each park (based on 2012-2015 data).

Tree Mortality

During the 2011-2014 ERMN monitoring cycle, the annual tree mortality rate in GARI's forest was 1.8%/year (Perles et al. 2016). In comparison, NERI showed a tree mortality rate of 1.5%/year (Figure 10). The highest tree mortality rates at the park were experienced by American basswood (*Tilia americana*) (~2.2%) in mesic habitats and sweet birch (*Betula lenta*) (~2.1%) in xeric habitats (Figure 11, Figure 12) (Perles et al. 2016). According to Perles et al. (2016), much of the observed mortality is in sub-canopy or "overtopped" trees that are shaded and out-competed by larger trees. The most recent calculated mortality rate for GARI is just slightly above reported rates for other eastern forests, which ranged from 0.3-1.6%/year (Lorimer 1980, Runkle 1998, 2000, Busing 2005, Perles et al. 2016). Some of the increased mortality may have been due to high winds that struck the park during severe storms in the summer of 2012 (Perles et al. 2016).

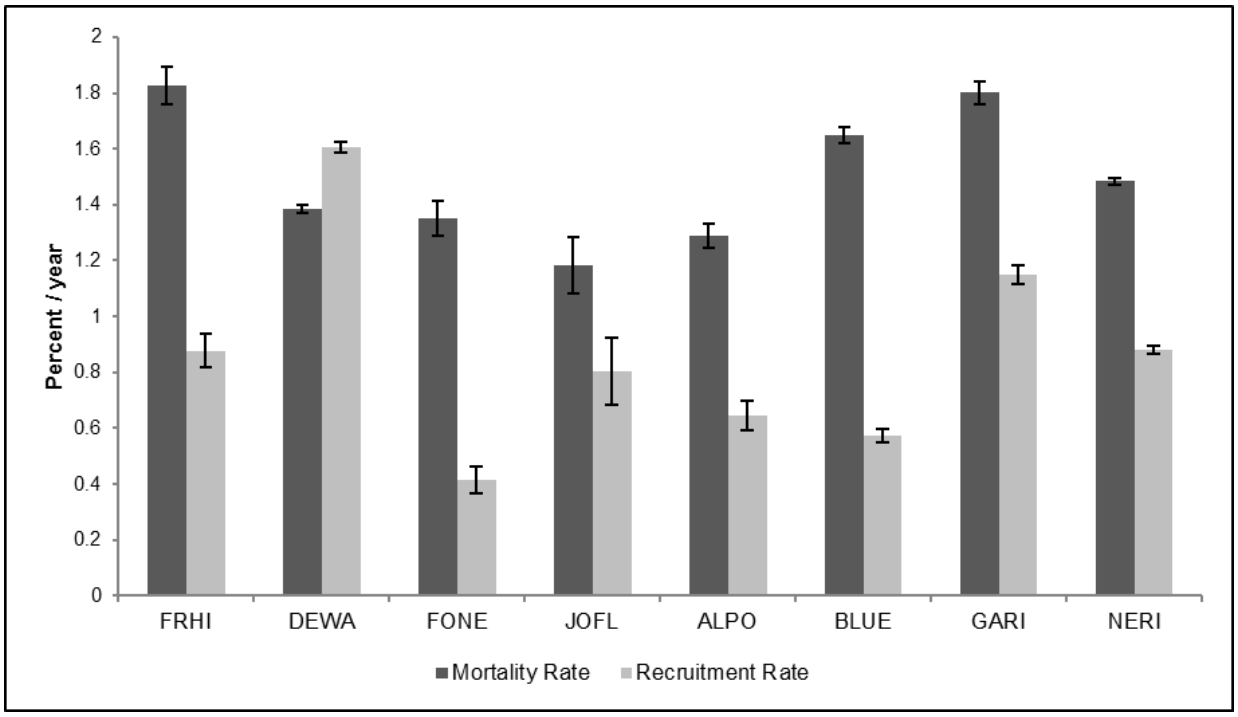


Figure 10. Mortality and recruitment rates (percent/year) for trees in Eastern Rivers and Mountains Network parks, 2007-2014 (note that these results are not limited to upland forest communities and also incorporate riparian community plots for some parks, although not for Gauley River National Recreation Area). Error bars represent one standard error above and below the mean (Perles et al. 2016).

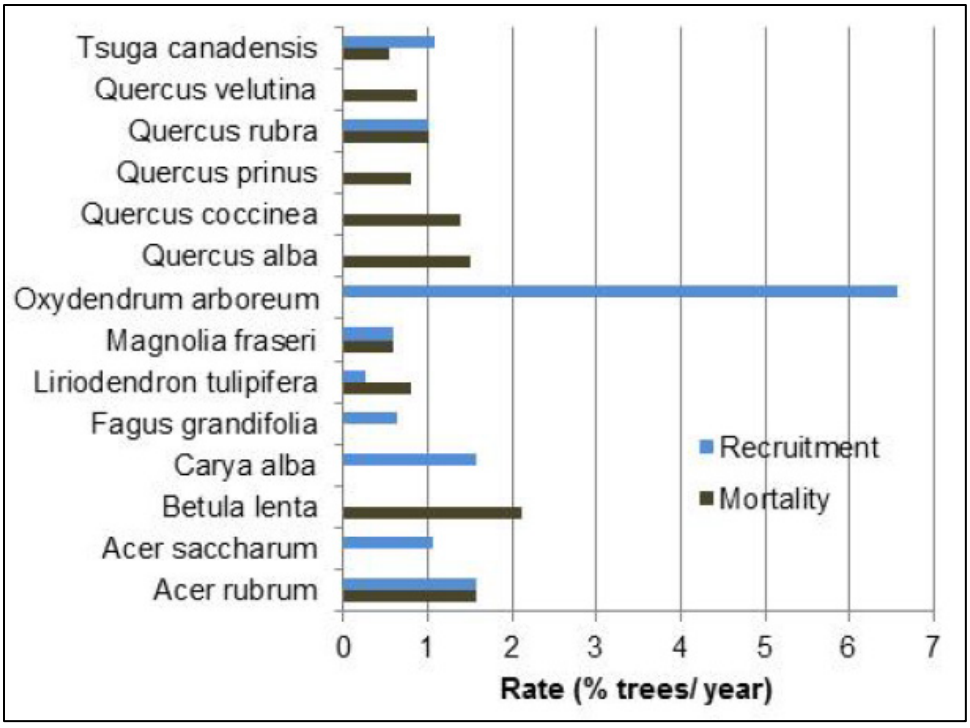


Figure 11. Mortality and recruitment rates for common tree species in xeric forest habitats in Gauley River National Recreation Area (Perles et al. 2016).

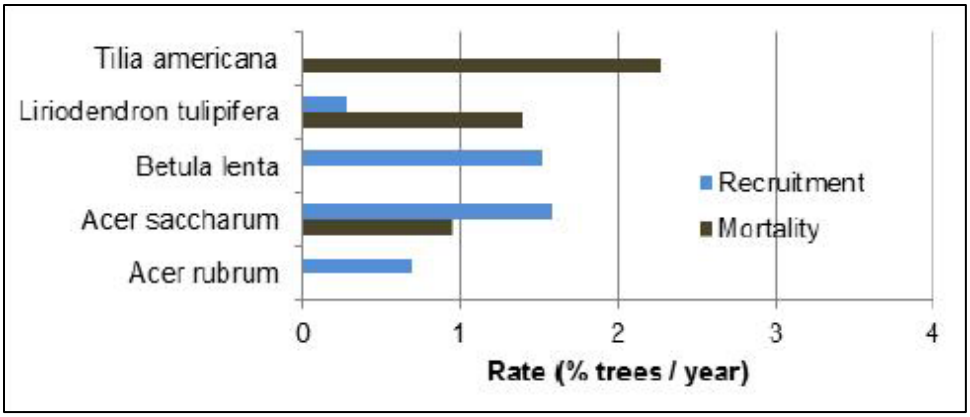


Figure 12. Mortality and recruitment rates for common tree species in mesic forest habitats in Gauley River National Recreation Area (Perles et al. 2016).

Recruitment

Annual tree recruitment rates at GARI during the 2011-2014 ERMN monitoring cycle were just below 1.2%/year (Perles et al. 2016). In comparison, recruitment at the nearby NERI was around 0.9% per year (Figure 10). The highest recruitment rate at GARI was shown by sourwood (*Oxydendrum arboreum*), at nearly 6.5%/year in xeric habitats (Figure 11). Other species with above average recruitment rates included mockernut hickory (*Carya tomentosa*) in xeric habitats and sweet birch and sugar maple (*Acer saccharum*) in mesic habitats (Figure 12). Recruitment was notably lacking in all oak species except for red oak (Perles et al. 2016).

Tree Mean Annual Diameter Increment

The ERMN (2017) has calculated MADI by comparing tree DBH measurements collected during the 2007-2010 sampling period to measurements from the 2011-2014 sampling period. Over this time, GARI experienced the highest MADI of the three West Virginia parks, at 0.24 cm/year (Figure 13). This falls just below the expected MADI range for Appalachian forests of 0.25-0.40 cm/year (Runkle 1998, 2000, Perles et al. 2016).

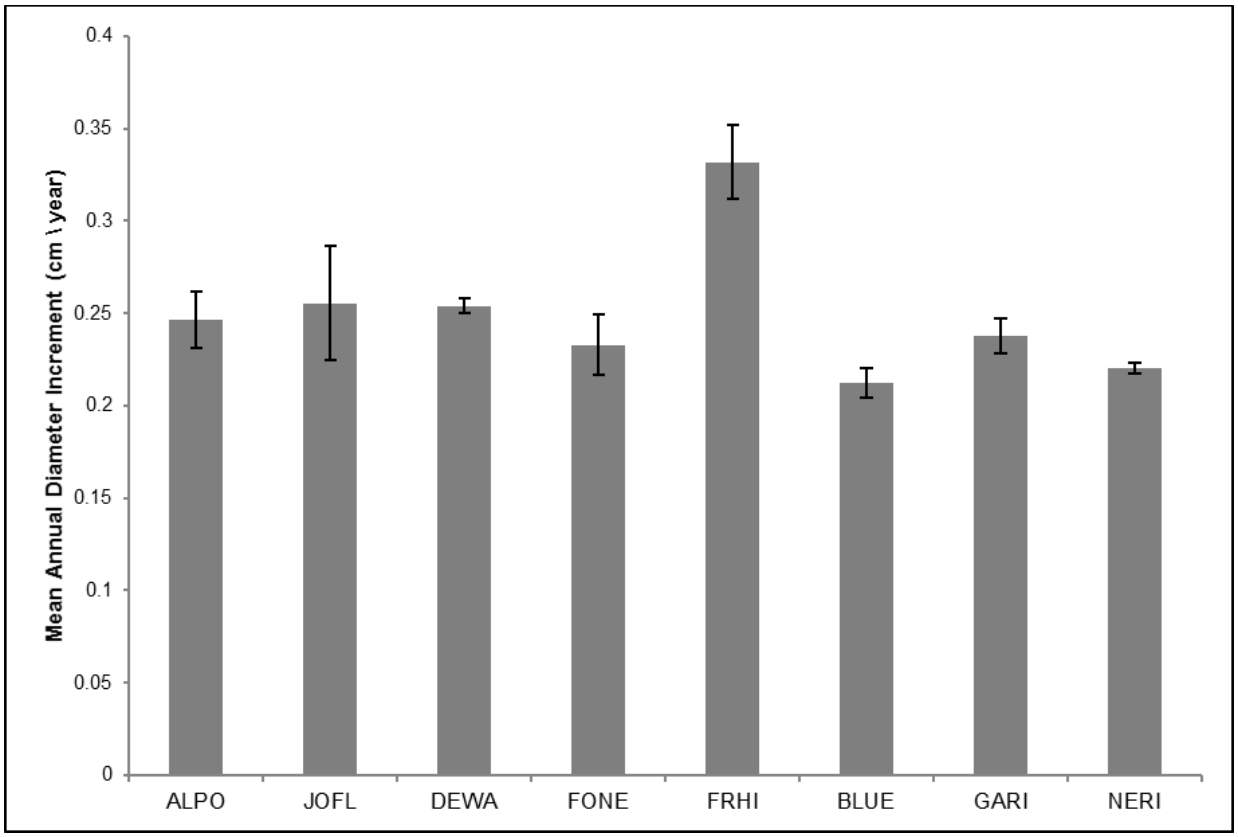


Figure 13. Mean annual diameter increments (± standard error) by Eastern Rivers and Mountains Network park, based on growth between the 2007-2010 and 2011-2014 sampling periods (ERMN 2017). The three West Virginia parks (Gauley River National Recreation Area, New River Gorge National River, and Bluestone National Scenic River) are on the far right of the graph.

Threats and Stressor Factors

Threats to GARI's upland forests include exotic invasive species (plants and pests/pathogens), deer browsing, forest fragmentation, moss poaching, recreational use, natural gas extraction, extreme weather events, and climate change. As mentioned in Chapter 2, exotic invasive species pose a serious threat to vegetation communities worldwide, due to their ability to compete with native species and disrupt ecosystem processes, such as nutrient cycling and disturbance regimes (Mooney et al. 2005, Perles et al. 2014b). For example, the invasive Japanese stiltgrass (*Microstegium vimineum*) can form a dense, monospecific understory in temperate forests, severely inhibiting tree regeneration (Rentch 2006). Although invasive cover averages 3.2% across GARI's upland forest (ERMN 2017), invasive cover has exceeded 30% in one of the park's successional forest types (Vanderhorst et al. 2010).

Native and exotic insect, fungal, and bacterial pests pose serious threats to forests across the eastern U.S., including the upland forests of GARI. These pests are capable of altering plant community structure and composition, as well as reducing overall species diversity (Keefer 2009). Potential exotic insect threats to the parks upland forests include HWA, EAB, and gypsy moth (Perles et al. 2016).

Gypsy moth infestation does not cause direct mortality but increases a tree's vulnerability to other stressors (e.g., disease, drought, other pests) (Hoover 2001). Oaks are the primary host for this moth, but it will also feed on maple, beech, cherry, and other hardwoods (Weese 1992, Hoover 2001). In 2015, gypsy moths defoliated approximately 100,000 acres of forest in West Virginia, primarily in the eastern portion of the state (USFS and WVDA 2016). Gypsy moths have been present in low abundance at GARI as far back as the 1990s (Weese 1992), but cause little defoliation and have not contributed to any known tree mortality (John Perez, NERI/GARI/BLUE Biologist, email communication, 20 April 2017).

Emerald ash borer infests only ash tree species and is always fatal, although it may take 1-3 years for trees to die (APHIS 2009). An early sign of EAB infestation is dead upper branches; in later stages, bark sloughs off to reveal S-shaped tunnels formed by feeding EAB larvae. EAB was first detected in Fayette County, WV, in 2007, and in Nicholas County in 2010 (USFS and WVDA 2016). Infestations are not treated because no cost-effective treatments for large numbers of trees are currently available (Manning 2016). In 2015, just over 37,200 ha (92,000 ac) of West Virginia forests were impacted by EAB mortality (USFS and WVDA 2016). EAB is considered pervasive at GARI and has resulted in heavy mortality of white and green ash trees (*Fraxinus americana* and *F. pennsylvanica*) (Perez, email communication, 20 April 2017).

The HWA, an aphid-like insect, was first observed in the eastern U.S. in Virginia during the early 1950s (Wood et al. 2009). The HWA feeds at the base of hemlock needles, depleting xylem cells of nutrients and desiccating the needles (McClure et al. 2001). The resulting needle loss prevents trees from generating new apical buds, where new growth occurs. Limb dieback can occur within 2 years, with tree mortality occurring in as little as 4 years from the initial infestation (McClure et al. 2001). HWA can be spread by wind, wildlife, or human activity.

HWA was first detected at GARI in 2007 (Strickler 2014). Monitoring of hemlocks in Bluestone National Scenic River (BLUE), GARI, and NERI show declining crown vigor and increasing tree mortality since initial HWA infestations, with highest impacts in xeric forests (Strickler 2014). Since 2010, park management has been chemically treating certain hemlock areas within GARI by applying insecticides to individual trees. Observations of HWA infestations at treated sites and measures of tree vigor show that insecticide treatment appears to be effective in stabilizing or even increasing the health of hemlock trees within infested areas (Strickler 2016). However, chemical treatment is a resource-intensive process (i.e., staff time and chemical cost) and is considered a temporary solution (Strickler 2014). NPS staff are studying the potential of biocontrol with beetles that prey on HWA; insects were first released at GARI in 2005 and at NERI in 2006 (Figure 14) (Strickler 2014). The effectiveness of these predatory beetles is still being evaluated.



Figure 14. A *Laricobius nigrinus* beetle feeding on hemlock wooly adelgid (left, USFS photo) and *L. nigrinus* being released onto a hemlock at Gauley River National Recreation Area in 2014 (right, NPS photo).

Excessive browsing by white-tailed deer can inhibit forest regeneration and negatively affect some rare plant populations (Rentch 2006, Marshall and Piekielek 2007a, Perles et al. 2014b). According to Rentch (2006), selective deer browsing can alter forests by contributing to tree regeneration failures, changes in species composition, and changes in forest structure (e.g., woody species density and height, herbaceous species abundance and height. These changes can result in "habitat simplification", where the forest understory is dominated by a small number of species unpalatable to deer (Rentch 2006). Deer browsing may be contributing to poor oak regeneration in eastern hardwood forests (Lorimer 1993).

Forest fragmentation has been occurring in the region around GARI since logging began in the late 1800s, aided by the construction of railroads and large band mills around 1885 (Streets and Vanderhorst 2010). Some of the tracts currently owned by the NPS were logged shortly before their acquisition, and some private holdings within the park boundary have been logged more recently (Streets and Vanderhorst 2010). Norris (1992) noted that cutting was occurring on Koontz Bend in 1991. Since just over half of the land within the GARI boundary is still in private ownership (NPS 2015c), logging, gas extraction development, and other forms of fragmentation may still occur within the park. Fragmentation creates barriers to species dispersal, which can influence interspecific interactions, genetic and species diversity, and species density and abundance (Rentch 2006). Recreational trails, transportation corridors (roads and railways), and gas extraction structures also fragment the landscape, exposing the forest edges to additional threats such as exotic species invasion and exposure to harsh weather conditions (Rentch 2006, Perles et al. 2014b).

Recreational activities in the area that threaten park vegetation include off-road vehicle (ORV) use and rock climbing. Due to the growing popularity of nearby NERI in recent decades (Mahan 2016), central West Virginia has become a destination for rock climbers. Several rock climbing sites occur within GARI. Studies of rock climbing in a variety of locations have found impacts to the surrounding environment, including damage to mature trees (from climbing equipment), decreases in

shrub and herbaceous cover, and increased soil erosion and compaction (Sutter et al. 1994, McMillan and Larson 2002, Wood 2006).

Damage from extensive ORV use has been observed within GARI's forests (Perez, personal communication, October 2016). ORVs are known to cause soil compaction on trails, significantly more so than hiking or horseback riding (Sack and da Luz 2003). This compaction reduces water infiltration and increases surface runoff on the trails. ORV trails also show significant sediment flux (i.e., shifting of soils), as the tires disturb and kick up sediment that settles on the land adjacent to the trail (Sack and da Luz 2003). Such disturbances negatively impact surrounding vegetation and can contribute to dramatic soil erosion. These disturbed areas and the ORV traffic provide opportunities for the dispersal and establishment of invasive plant species (Perles et al. 2014b).

The abundant growth of moss in the cool, humid Appalachian Mountains has contributed to the widespread collection of moss for commercial purposes (i.e., "mossing") (Peck et al. 2011). The moss is used by the horticultural industry to cover soils in potted plants and terrariums, and to line hanging baskets. Moss is also sold commercially for green roofs, moss gardens, and for arts and crafts (Peck et al. 2011). According to permit records, over 22,000 kg (around 50,000 lbs, fresh weight) were removed from federal public lands per year between 1997 and 2001. Moss from the U.S. is exported to at least 40 countries worldwide and is estimated to contribute at least $2.3 million to the Appalachian economy annually (Peck et al. 2011). Mossing is not permitted on NPS property within GARI, but moss poaching likely occurs (Layne Strickler, NPS Biological Science Technician, personal communication, October 2016). Some of the most commonly sought-after mosses that are present at GARI include the sheet mosses (Figure 15) *Thuidium delicatulum* and *Hypnum imponens*, and the mood mosses (round clumps/cushions) *Dicranum scoparium* and *Leucobryum glaucum* (Studlar and Peck 2007, Peck et al. 2011). Little is known about the impacts of moss removal on the forest ecosystem, but it certainly impacts the other nonvascular (e.g., liverworts) and flowering plants that typically intermingle with mosses, as well as associated lichens, fungi, cyanobacteria, and invertebrates (Peck et al. 2011). Mosses also provide salamander habitat, and one salamander species was found inside a bag of moss collected in West Virginia (Studlar and Peck 2007).



Figure 15. Sheet moss growing in a Gauley River National Recreation Area forest (SMUMN GSS photo by Hannah Hutchins).

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). Climate affects the spread of invasive plant species as well, which also threaten GARI's upland forests (Fisichelli et al. 2014). As a result of global climate change, temperatures are projected to increase across the eastern U.S. over the next century (Horton et al. 2014). Warming temperatures will likely allow invasive plants and forest pests to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014). In an effort to estimate the magnitude of potential change that forests on eastern NPS lands may experience, Fisichelli et al. (2014) assessed the percentage of tree species expected to show large decreases or large increases in habitat suitability under climate change scenarios. Across 121 NPS properties in the eastern U.S., estimated potential forest change ranged from 22-77%. The estimated forest change for GARI (i.e., percent of tree species expected to experience large increases or decreases in habitat suitability) was 61% (Fisichelli et al. 2014). Habitat suitability projections for several of GARI's key upland tree species are shown in Table 13.

Table 13. Potential change in habitat suitability by 2100 for select Gauley River National Recreation Area upland tree species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific Name	Common Name	Least Change Scenario	Major Change Scenario
Acer rubrum	red maple	no change	large decrease
Acer saccharum	sugar maple	no change	large decrease
Betula alleghaniensis var. *alleghaniensis*	yellow birch	small decrease	large decrease
Betula lenta	sweet birch	small decrease	large decrease
Carya cordiformis	bitternut hickory	large increase	large increase
Carya ovata	shagbark hickory	large increase	large increase
Fagus grandifolia	American beech	small decrease	large decrease
Juniperus virginiana	eastern redcedar	large increase	large increase
Liriodendron tulipifera	tuliptree	no change	large decrease
Quercus coccinea	scarlet oak	no change	large decrease
Quercus muehlenbergii	chinkapin oak	large increase	large increase
Tilia americana	American basswood	small decrease	large decrease
Carya texana	black hickory	new habitat	new habitat
Celtis laevigata	sugarberry	–	new habitat
Maclura pomifera	osage-orange	–	new habitat
Pinus elliotti	slash pine	–	new habitat
Pinus taeda	loblolly pine	new habitat	new habitat
Quercus marilandica	blackjack oak	new habitat	new habitat
Ulmus alata	winged elm	new habitat	new habitat

Climate change may also alter the frequency and intensity of extreme weather events that already threaten GARI's forests, such as tornadoes/wind storms, ice storms, and droughts (Dale et al. 2001, Rentch 2006). During the summer of 2012, a severe storm with high winds (called a derecho) passed over GARI, causing extensive damage to its forests (NWS 2012, Perles et al. 2016). A blizzard triggered by Superstorm Sandy also hit the park in October 2012 (Strickler 2014). So many trees fell during these storms that a slight decrease in live tree basal area was detected the following year. The canopy gaps opened by such storms provide opportunities for fast-growing invasive plant species, such as tree-of-heaven (Figure 16), which often out-compete native species that typically would regenerate in these openings (Perles et al. 2016). While the connections are not yet clear, evidence suggests that the storm conditions contributing to tornado formation have increased with warming temperatures and will continue to do so under projected future climate changes (Dale et al. 2001).

The warmer temperatures associated with climate change are also likely to increase the survival, reproduction, and dispersal/distribution of some forest pests and pathogens (Dale et al. 2001). An increase in drought frequency and/or intensity as a result of climate change would likely make forests more vulnerable to these pests and pathogens (Dale et al. 2001).



Figure 16. Tree-of-heaven (foreground) invading a forest canopy gap at Gauley River National Recreation Area (NPS photo by Doug Manning).

Data Needs/Gaps

Prior to the 1990s, very little scientific information was gathered regarding the vegetation within current GARI boundaries. Several surveys during the 1990s and the ERMN vegetation monitoring program have begun to address these data gaps and should continue. Further research is needed into the current poor oak regeneration and factors that are contributing to it (Perles et al. 2010). This could include adaptive management experiments to monitor the impacts of fire, browsing (using exclosures), and canopy thinning on regeneration (Perles et al. 2014b). Additional information on the diversity of GARI's non-vascular flora and its importance to the forest ecosystem would be of interest. Lastly, little is known about the area's soil biota (e.g., invertebrates, fungi, bacteria) and the critical role they play in ecological processes that influence forest health (e.g., decomposition, nutrient cycling, mineralization) (Rentch 2006).

Overall Condition

Community Extent

The NRCA project team assigned this measure a *Significance Level* of 3. The vast majority of the park (86%) is covered in upland forest and woodland, primarily a mix of eastern hemlock and oak species (Vanderhorst et al. 2010). While forest loss does not appear to be a major issue, much of the land within park boundaries is privately owned and could be vulnerable to logging. As a result, community extent is of slight concern and is assigned a *Condition Level* of 1.

Plant Species Richness

This measure was also assigned a *Significance Level* of 3. GARI's upland forests are very diverse, with a total of 521 plant species documented by various surveys over time. Nonvascular plant diversity is particularly high. However, there is some concern that the number of invasive, exotic plant species may be slowly increasing. Thirty-four exotic species (6.5%) have now been confirmed in the park's upland forests. A *Condition Level* of 1, indicating low concern, is assigned for this measure.

Rare Plant Element Occurrences

The rare plant measure was assigned a *Significance Level* of 3. Seventeen rare plant species have been documented in GARI's upland forest communities (Table 9), but information on the number of occurrences (EOs) within park boundaries is limited. No recent information on the condition (i.e., viability) of rare species EOs could be found. As a result, a *Condition Level* has not been assigned for this measure.

Proportion of Total Cover of Exotic Plants and Invasive Plants

A *Significance Level* of 3 was assigned to this measure. GARI shows a much lower proportion of exotic and invasive cover than nearly all other ERMN parks (Figure 8, Figure 9). Therefore, this measure is assigned a *Condition Level* of 1, indicating low concern.

Tree Mortality

The project team assigned this measure a *Significance Level* of 3. From 2011-2014, the mean annual tree mortality rate in GARI upland forest monitoring plots was 1.8% (Perles et al. 2016). This is slightly higher than reported rates for other eastern forests, which ranged from 0.3-1.6%/year (Perles et al. 2016). Some of the mortality was likely due to high winds that struck the park during severe storms in the summer of 2012. Given that information regarding tree mortality is limited to this one time period, a *Condition Level* was not assigned for this measure at this time.

Recruitment

The recruitment measure was also assigned a *Significance Level* of 3. The 2011-2014 mean annual tree recruitment rate for GARI upland forest monitoring plots was 1.2%/year (Perles et al. 2016). Several key tree species showed no recruitment at all, including scarlet, white, black, and chestnut oak (Perles et al. 2016). As with tree mortality, a *Condition Level* was not assigned for this measure due to limited information.

Tree Mean Annual Diameter Increment

A *Significance Level* of 3 was assigned to this measure. The MADI calculated for GARI based on ERMN monitoring (0.24 cm/year) was the highest of all three West Virginia parks but slightly below the range expected for Appalachian forests (0.25-0.40 cm/year) (Perles et al. 2016). Currently, this measure is of low concern (*Condition Level* = 1).

Weighted Condition Score

The *Weighted Condition Score* for GARI's upland forest communities is 0.33, which is at the top of the good condition range (Table 14). Any declines in measure conditions could push this resource into the moderate concern range. Given that data and information for the selected measures is somewhat limited, a trend has not been assigned and a moderate confidence border is applied.

Table 14. Current condition of Gauley River National Recreation Area's Upland Forest Communities.

Measures	Significance Level	Condition Level	WCS = 0.33
Community Extent	3	1	
Plant Species Richness	3	1	
Rare Plant EOs	3	n/a	
Exotic & Invasive Cover	3	1	
Tree Mortality	3	n/a	
Recruitment	3	n/a	
Mean Annual Diameter Increment	3	1	

4.2.6. Sources of Expertise

- John Perez, NERI/GARI/BLUE Biologist
- Stephanie Perles, ERMN Plant Ecologist
- Layne Strickler, NERI/GARI/BLUE Biological Science Technician

4.3. Riparian Vegetation Communities

4.3.1. Description

Riparian and wetland vegetation communities cover just 2% of GARI, but contribute significant biological diversity to the park (Vanderhorst et al. 2010). These riparian areas are primarily wooded, with species such as eastern hemlock and American sycamore (*Platanus occidentalis*), but also include herbaceous plant communities, like the riverscour shrub prairies. The park's riverscour communities support high plant diversity and a number of rare species, including the federally-threatened Virginia spiraea and the globally-rare Monongahela Barbara's buttons (Vanderhorst et al. 2010). As mentioned in the previous component, the ERMN identified vegetation as a high priority resource for long-term monitoring as part of the Vital Signs program, since the condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Marshall and Piekielek 2007a, Perles et al. 2010).



An American Sycamore - River Birch Riverscour Woodland in the Gauley River National Recreation Area riparian area (Vanderhorst et al. 2010).

Vegetation classification and mapping efforts at GARI identified nine unique riparian vegetation community types occurring within park boundaries (Vanderhorst et al. 2010). These types (or "associations") and the prominent or characteristic tree species in GARI stands are presented in Table 15.

Table 15. Riparian and wetland vegetation associations documented within Gauley River National Recreation Area and the most prominent plant species in each (Vanderhorst et al. 2010).

Vegetation Community	Prominent Plant Species
American Sycamore - River Birch Riverscour Woodland	river birch (*Betula nigra*), American sycamore, red maple, blackgum (*Nyssa sylvatica*), common persimmon (*Diospyros virginiana*)
American Sycamore - Tuliptree - Sweetgum Floodplain Forest	American sycamore, tuliptree, sweetgum (*Liquidambar styraciflua*), river birch, American hornbeam (*Carpinus caroliniana* ssp. *virginiana*)
American Water-willow Cobble Bar	American water-willow (*Justicia americana*),
Bur-reed Marsh	bur-reed (*Sparganium* sp.), needle spikerush (*Eleocharis acicularis*), rice cutgrass (*Leersia oryzoides*), broadleaf arrowhead (*Sagittaria latifolia*)
Eastern Hemlock Floodplain Forest	eastern hemlock, red maple, tuliptree, sweet birch, northern red oak, river birch, sourwood, great laurel
Forest Seep	tuliptree, red maple, sweet birch, white oak, slippery elm (*Ulmus rubra*), white ash, American sycamore
Oak - Hickory Floodplain Forest	black oak, tuliptree, white oak, mockernut hickory, sassafras (*Sassafras albidum*), umbrella-tree (*Magnolia tripetala*)
Riverscour Shrub Prairie	river birch, big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), Rand's goldenrod (*Solidago simplex* var. *racemosa*)
(Virginia, Pitch) Pine Floodplain Forest	Virginia pine, pitch pine (*Pinus rigida*), red maple, blackgum, tuliptree, chestnut oak, white oak, American sycamore

4.3.2. Measures

- Riparian vegetation community extent
- River shrub prairie extent
- Plant species richness
- Rare plant element occurrences
- Proportion of total cover of exotic plants and invasive plants
- Cover of woody plants in river shrub prairies

4.3.3. Reference Condition/Values

As with upland forests, identifying reference conditions for riparian communities are challenging, as little historical information is available on vegetation within current GARI boundaries. For the purposes of this assessment, current condition will be assessed based on comparisons to similar forests in other ERMN parks (particularly within West Virginia) and on best professional judgement. The information presented here could serve as a baseline for future assessments.

4.3.4. Data and Methods

The majority of sources utilized for the upland forest communities component will also be used for this component. These include Norris (1992), Grafton (1993), Fortney et al. (1995), WVNHP (2004) Vanderhorst et al. (2010), Streets and Vanderhorst (2010), and Perles et al. (2010, 2014b, 2016). Descriptions of these sources can be found in Chapter 4.1.4.

Walton and Anderson (1997) sampled Gauley River riparian areas in an effort to describe and roughly map the vegetation communities that support rare plant species. Sampling was conducted from July-October 1995, with 37 plots that ranged in size from 40-100 m^2 (430-1,076 ft^2). Percent cover was estimated by strata for every vascular plant species within each plot (Walton and Anderson 1997).

In 2006, the West Virginia Division of Natural Resources (WVDNR) was contracted to map and evaluate the riparian zone of the Gauley and Meadow Rivers within GARI (Bennett and McDonald 2006). The study area included 41.0 km (25.5 mi) along the Gauley and 8.9 km (5.5 mi) along the Meadow River. To assess riparian condition, the WVDNR utilized color infrared orthorectified aerial photography and protocols designed by the U.S. Bureau of Land Management (BLM) (Bennett and McDonald 2006).

The ERMN recently began monitoring vegetation in GARI's riverscour or river shrub prairies. Permanent plots have been established, where plant species composition and abundance are recorded (NPS 2016e). Transects are also in place for documenting woody vs. herbaceous species cover. Ten sites were surveyed in 2016 and five additional sites will be monitored in 2017 (Perles 2016). Sites will be revisited every 7 years to detect any changes that may be occurring in these communities (NPS 2016e).

4.3.5. Current Condition and Trend

Riparian Vegetation Community Extent

The vegetation map created by Vanderhorst et al. (2010) shows nearly 102 ha (251 ac) of riparian and wetland vegetation within GARI (Figure 17, Figure 18). The greatest extent (63.7 ha or 157.3 ac) was covered by the "Riparian Zone" category, a complex map class that includes three vegetation associations: American Water-willow Cobble Bar, Riverscour Shrub Prairie, and interspersed patches of American Sycamore-River Birch Riverscour Woodland (Table 16). Only one other community, Eastern Hemlock Floodplain Forest, covered more than 20 ha (49 ac). The smallest extent was <0.1 ha (0.1 ac) for the Bur-reed Marsh association (Vanderhorst et al. 2010).

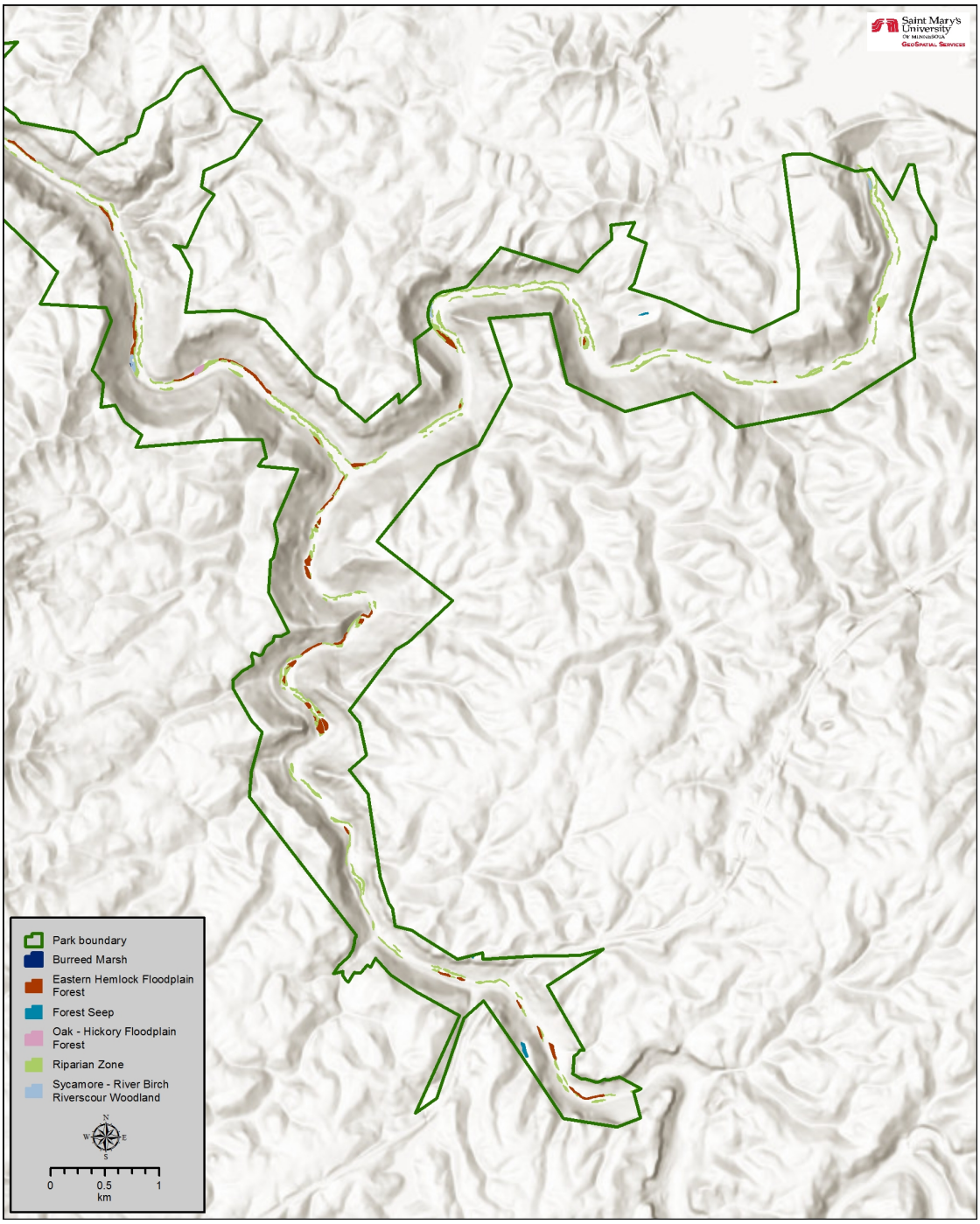


Figure 17. Riparian and wetland vegetation extent by community type within the eastern portion of Gauley River National Recreation Area (Vanderhorst et al. 2010).

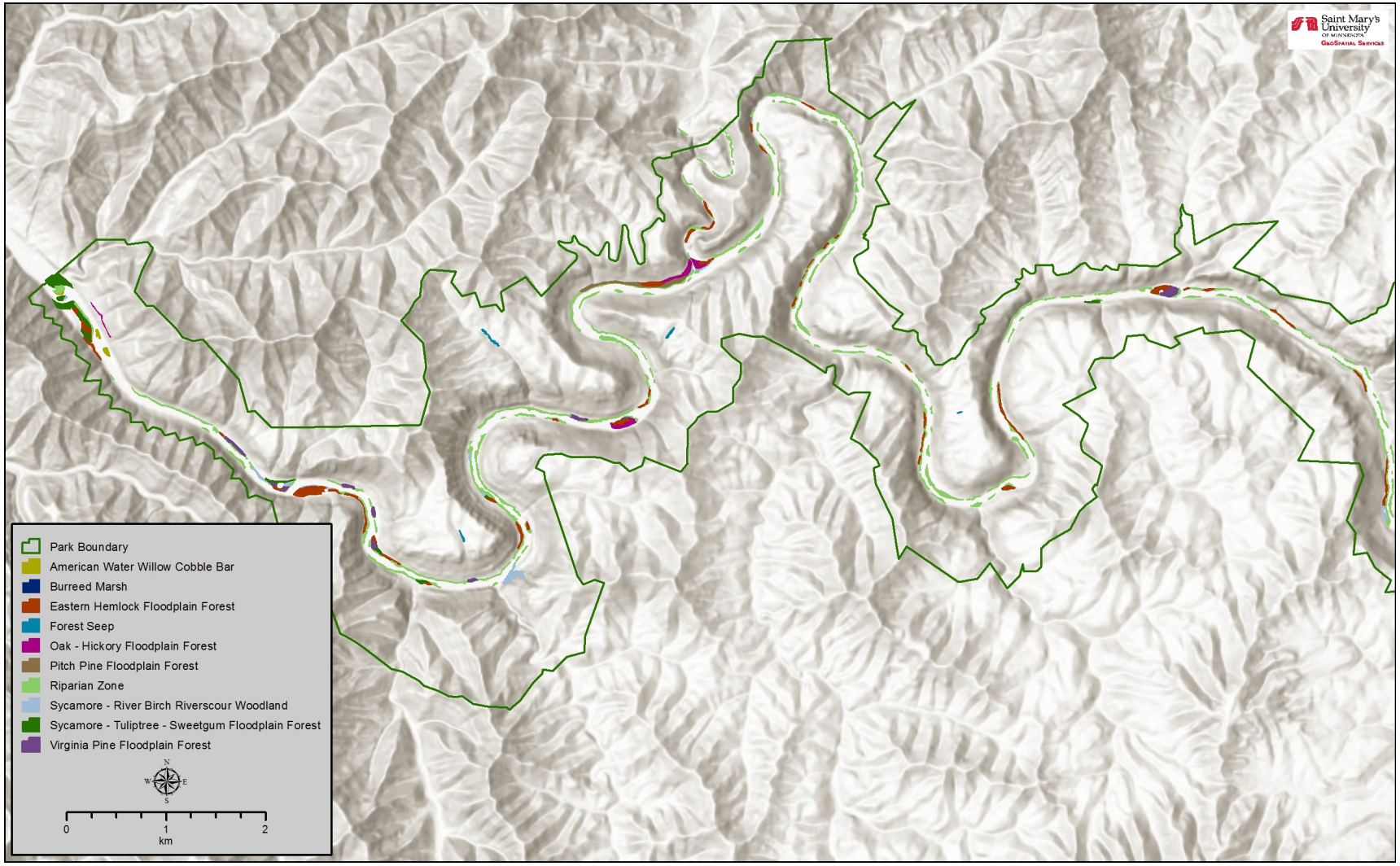


Figure 18. Riparian and wetland vegetation extent by community type within the western portion of Gauley River National Recreation Area (Vanderhorst et al. 2010).

Table 16. Riparian and wetland vegetation extent at Gauley River National Recreation Area by community type (Vanderhorst et al. 2010).

Vegetation Community	Area in ha (ac)
American Sycamore - River Birch Riverscour Woodland	2.2 (5.3)
American Sycamore - Tuliptree - Sweetgum Floodplain Forest	4.8 (11.9)
American Water-willow Cobble Bar	0.6 (1.4)
Bur-reed Marsh	<0.1 (0.1)
Eastern Hemlock Floodplain Forest	21.3 (52.5)
Forest Seep	1.2 (3.0)
Oak - Hickory Floodplain Forest	2.9 (7.2)
Riparian Zone	63.7 (157.3)
(Virginia, Pitch) Pine Floodplain Forest	5.1 (12.6)
Total riparian and wetland vegetation	101.7 (251.4)

River Shrub Prairie Extent

River shrub prairies are limited to areas where regular flooding maintains open areas by preventing tall, woody vegetation from shading out herbaceous vegetation (Vanderhorst et al. 2010). These areas are typically small (<1 ha [<2.5 ac]) and often isolated. Fifty different river shrub prairie areas have been identified along the Gauley and Meadow Rivers within GARI boundaries (Figure 19), ranging in size from 0.05-1.2 ha (0.1-3.0 ac) (NPS 2016b). These areas cover a total of just 16.1 ha (39.8 ac), or less than 0.5% of total park area.

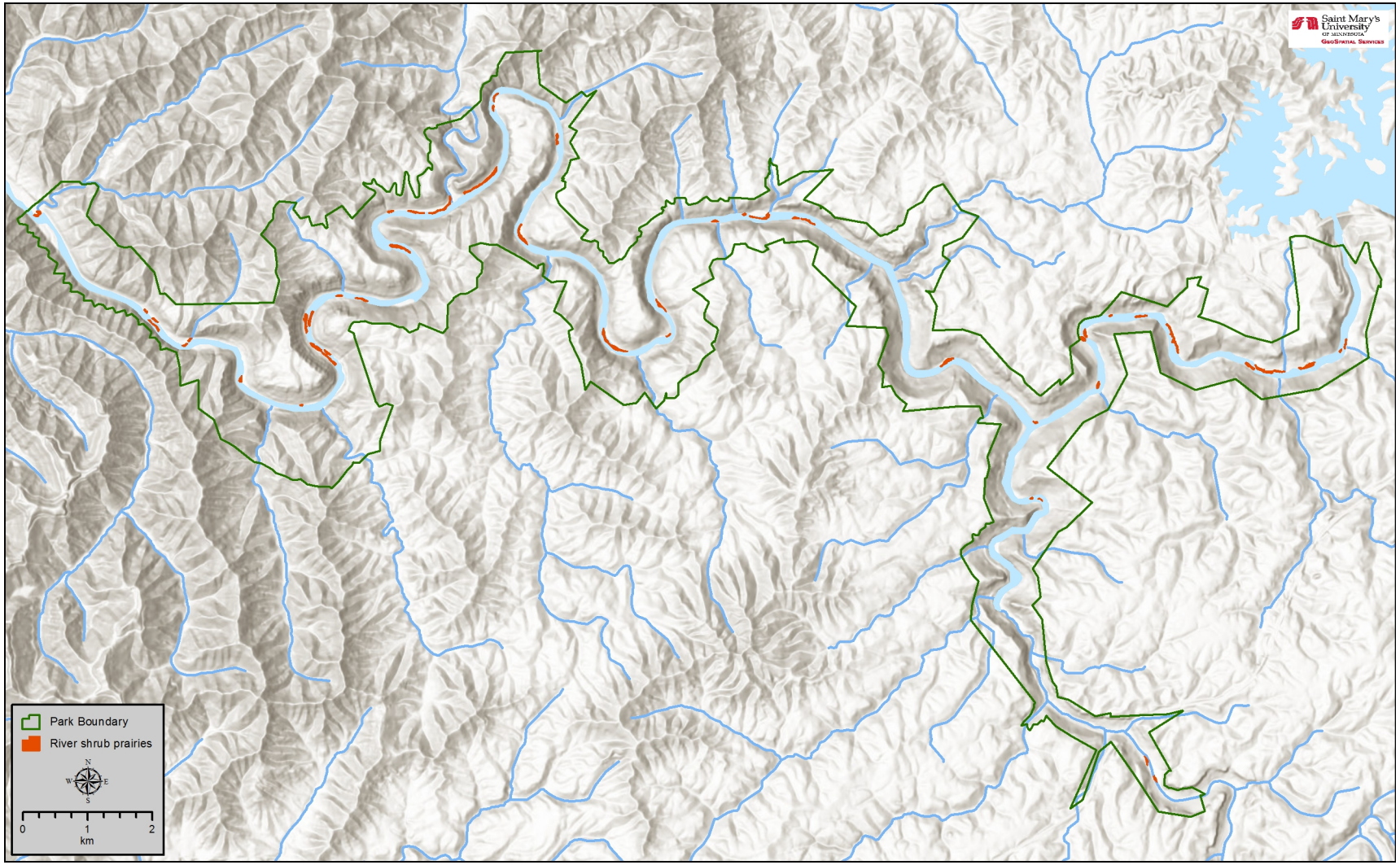
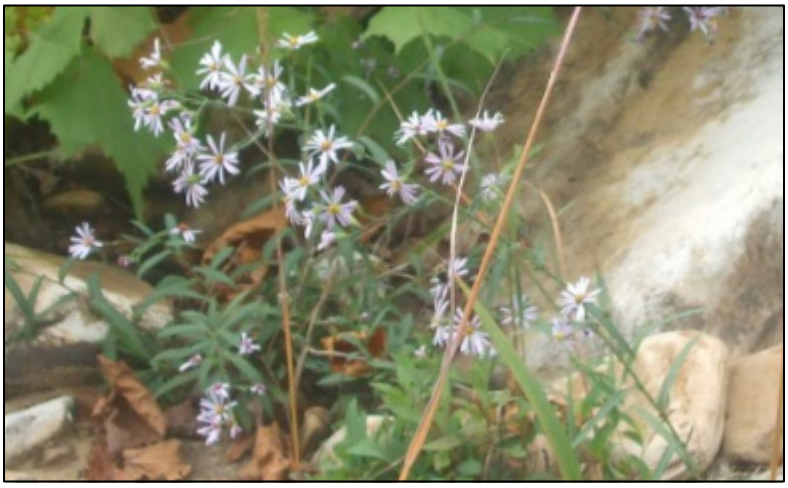


Figure 19. River shrub prairie extent within Gauley River National Recreation Area (NPS 2016b).



A river shrub prairie on the Meadow River within Gauley River National Recreation Area (SMUMN GSS photo).



Wildflowers (*Aster* sp.) growing in the river shrub prairie above (SMUMN GSS photo).

Plant Species Richness

Vanderhorst et al. (2010) documented 457 plant taxa (including subspecies and varieties) within GARI's riparian vegetation communities (Appendix D). Only 28 of these species (6%) are considered exotic. The greatest total number of plant species (271) was recorded in the American Sycamore - River Birch Riverscour Woodland (Table 17). The Riverscour Shrub Prairie also supported over 200 plant species, although this may be related to the high number of plots sampled within these communities. The highest mean number of species per plot (total species per community divided by total number of plots) was 29.3 in the (Virginia, Pitch) Pine Floodplain Forest, followed closely by the American Sycamore-Tuliptree-Sweetgum Floodplain Forest with 28.3 species. The lowest mean number of species per plot was in the American Water-willow Cobble Bar (6.0 species/plot), and the Riverscour Shrub Prairie (8.1 species/plot) (Table 17). The apparent low species richness in these communities may be due to the high frequency of flooding disturbance they experience.

Table 17. Plant species richness by riparian community type at Gauley River National Recreation Area, as documented by Vanderhorst et al. (2010).

Vegetation Community	# of Plots	# of Species	Mean Species/Plot
American Sycamore - River Birch Riverscour Woodland	23	271	11.8
American Sycamore - Tuliptree - Sweetgum Floodplain Forest	4	113	28.3
American Water-willow Cobble Bar	2	12	6.0
Bur-reed Marsh	1	39	39
Eastern Hemlock Floodplain Forest	11	183	16.6
Forest Seep	9	168	18.7
Oak - Hickory Floodplain Forest	1	44	44
Riverscour Shrub Prairie	27	218	8.1
(Virginia, Pitch) Pine Floodplain Forest	6	176	29.3

During 2016 ERMN river shrub prairie monitoring, 131 plant species were observed at 10 different sites within GARI (ERMN 2017). Fifteen of these species (11.5%) were exotic. Total richness per site ranged from 19 to 63. Cumulatively, 473 plant species have been found in GARI's riparian communities by various surveys over time (see Appendix D). This is nearly as many species as have been documented in upland forest communities, which cover over 200 times more area within the park. Thirty-four species (7.2%) are exotic, a slightly higher percentage than in upland forest communities (6.5%).

Rare Plant Element Occurrences

According to Streets and Vanderhorst (2010), 21 rare plant species have been confirmed in GARI's riparian vegetation communities (Table 18). Two of these species were first documented in the park during the Streets and Vanderhorst (2010) 2006-2009 inventory. Norris (1992) only documented six

of these species, with the number of occurrences ranging from four (globe beaksedge [*Rhynchospora recognita*] and mountain meadow-rue [*Thalictrum clavatum*]) to >100 (balsam groundsel [*Packera paupercula*]). Later searches by WVNHP (2004) located four of these species, with one species (Monongahela Barbara's buttons) showing an increased number of EOs. During 2016 river shrub prairie monitoring, ERMN researchers documented four rare species in their sampling plots (ERMN 2017).

Table 18. Documented rare plant occurrences at Gauley River National Recreation Area riparian vegetation communities. Norris (1992) and WVNHP (2004) reported the number of personal observations during a thorough park survey. Streets and Vanderhorst (2010) information is based on element occurence records in the WVNHP Biotics database in 2010. The Eastern Rivers and Mountains Network (2017) column represents species observed during 2016 river shrub prairie monitoring (i.e., opportunistic observations, not a targeted search).

Scientific Name	Common Name	State rank[A]	Norris (1992)	WVNHP (2004)	Streets and Vanderhorst (2010)	ERMN (2017)
Andropogon glomeratus var. *glomeratus*	bushy bluestem	S2	–	–	X	–
Baptisia australis var. *australis*	blue wild indigo	S3	–	–	X	–
Carex bromoides ssp. *bromoides*	brome-like sedge	S3	–	–	X	–
Carex seorsa	weak stellate sedge	S1	–	–	X	–
Desmodium pauciflorum	fewflower ticktrefoil	S1	–	–	X	–
Helianthemum propinquum	low frostweed	S1	–	–	X	–
Juglans cinerea	butternut	S3	–	–	X	–
Lechea tenuifolia	narrowleaf pinweed	S1	–	–	X	–
Liatris squarrulosa	Appalachian blazing star	S1	–	–	X	–
Marshallia grandiflora	Monongahela Barbara's buttons	S2	63	82	X	X
Packera paupercula	balsam groundsel	S2	>100	>100[C]	X	X
Prunus pumila var. *depressa*	eastern sandcherry	S1	14	14	X	–
Rhynchospora recognita	globe beaksedge	S2	4	–[B]	X	–

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, ? = rank uncertain.

[B] Surveys for these species were abandoned or curtailed for a variety of reasons, including high water, extensive sand and debris deposits (from earlier flooding), and the late season (past flowering)

[C] WVNHP (2004, p. 1) did not fully survey this species, as they considered it “so widespread” that it would take too much time “to map the hundreds of occurrences.”

Table 18 (continued). Documented rare plant occurrences at Gauley River National Recreation Area riparian vegetation communities. Norris (1992) and WVNHP (2004) reported the number of personal observations during a thorough park survey. Streets and Vanderhorst (2010) information is based on element occurence records in the WVNHP Biotics database in 2010. The Eastern Rivers and Mountains Network (2017) column represents species observed during 2016 river shrub prairie monitoring (i.e., opportunistic observations, not a targeted search).

Scientific Name	Common Name	State rank[A]	Norris (1992)	WVNHP (2004)	Streets and Vanderhorst (2010)	ERMN (2017)
Solidago simplex ssp. *randii* var. *racemosa*	Rand's goldenrod	S2	–	–	X	X
Spiraea virginiana	Virginia spiraea	S1	–	–	X	–
Spiranthes lucida	shining ladies'-tresses	S1S2	–	–	X	–
Spiranthes vernalis	spring ladies'-tresses	S3	–	–	X	–
Stachys cordata (*S. nuttallii*)	heartleaf hedgenettle	S3	–	–	X	–
Symphyotrichum laeve var. *concinnum*	smooth blue aster	S2	–	–	X	–
Thalictrum clavatum	mountain meadow-rue	S2	4	2	X	–
Viola appalachiensis	Appalachian violet	S3	8	–[B]	X	X

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, ? = rank uncertain.

[B] Surveys for these species were abandoned or curtailed for a variety of reasons, including high water, extensive sand and debris deposits (from earlier flooding), and the late season (past flowering)

A 1991 survey of the Meadow River that focused specifically on Virginia spiraea identified 20 occurrences within GARI boundaries (WVDNR 1998). Two of the occurrences were flowering and 10 were fruiting. Two occurrences showed evidence of browsing by deer and two others had been cut by beavers (*Castor canadensis*) (WVDNR 1998). Two of the 20 occurrences visited in 1991 were re-located in 1996 and 1997 and the health of the populations at that time were considered good (WVDNR 1998).

Proportion of Total Cover of Exotic Plants and Invasive Plants

Vanderhorst et al. (2010) includes mean percent cover estimates by plant species for each vegetation community identified within the park. Within the nine riparian community types, mean *exotic* plant species cover ranged from 0% in Oak - Hickory Floodplain Forest (only one plot sampled) to 10.8% in American Sycamore - River Birch Riverscour Woodland (Vanderhorst et al. 2010). The highest observed *invasive* species cover was only slightly lower, at 9.8%. Exotic and invasive species percent covers for all riparian communities are shown in Table 19.

Table 19. Mean exotic and invasive plant species cover by riparian vegetation community type within Gauley River National Recreation Area (Vanderhorst et al. 2010).

Vegetation Community	# of Exotic Species	Mean % Exotic Cover	Mean % Invasive Cover
American Sycamore - River Birch Riverscour Woodland (23)	18	10.8	9.8
(Virginia, Pitch) Pine Floodplain Forest (6)	11	8.3	8.3
American Sycamore - Tuliptree - Sweetgum Floodplain Forest (4)	8	7.6	7.6
Riverscour Shrub Prairie (27)	14	6.7	4.2
Forest seep (9)	4	6.1	6.1
Eastern Hemlock Floodplain Forest (11)	4	3.5	3.5
American Water-willow Cobble Bar (2)	1	<0.1	<0.1
Bur-reed Marsh (1)	1	<0.1	<0.1
Oak - Hickory Floodplain Forest (1)	0	0	0

ERMN researchers documented native vs. exotic species cover at the 10 GARI river shrub prairie sites visited in 2016. These results may not be directly comparable to Vanderhorst et al. (2010), since plots were non-randomly placed to capture characteristic vegetation associations in Vanderhorst et al. (2010) and plots were randomly placed within prairie sites for ERMN monitoring (Perles, written communication, August 2017). Exotic species comprised between 0% and 8.2% (with a mean of 2.6%) of the total plant cover at GARI river shrub prairie sites (ERMN 2017). The proportion of exotic cover at GARI sites was slightly greater (<1% on average) than at NERI river shrub prairie sites (Figure 20). However, this is based on one sampling season alone and it is unclear how much exotic species cover may vary between years, especially following flooding and/or scour disturbance.

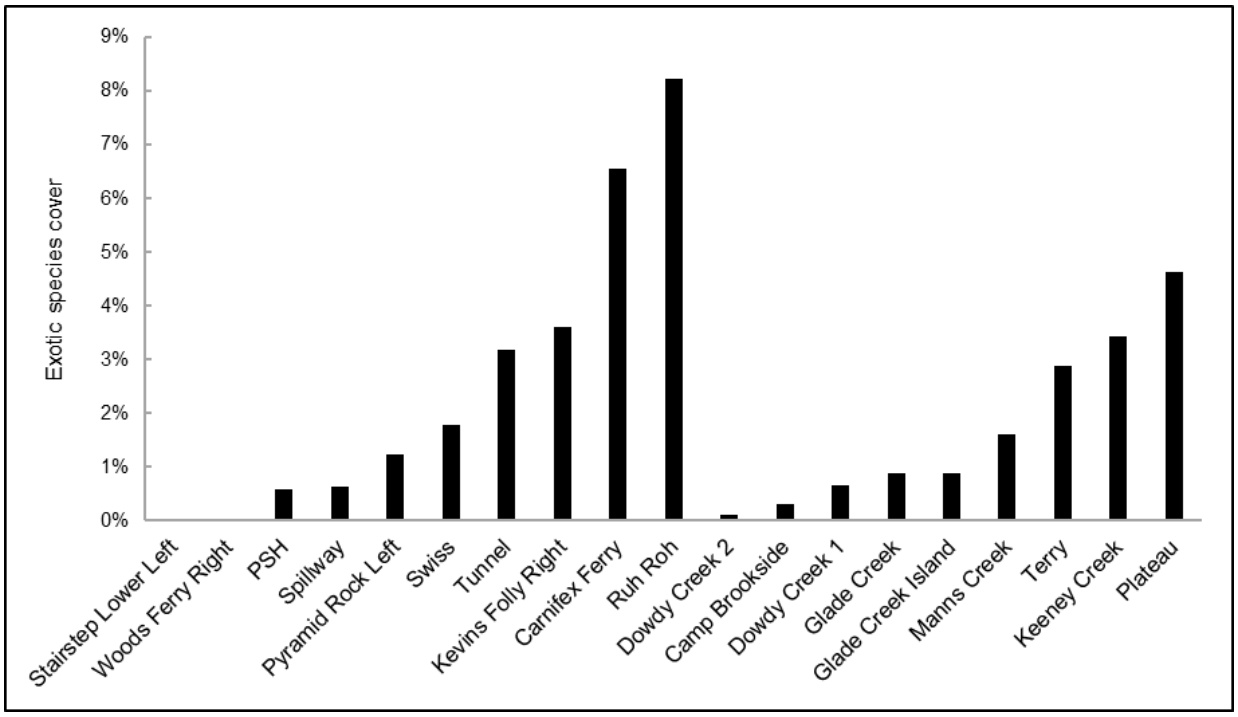


Figure 20. Average proportion of total cover by exotic plant species in river shrub prairie sites at Gauley River National Recreation Area (10 sites on left) and New River Gorge National River (nine sites on right) in 2016 (Perles 2016, ERMN 2017).

Cover of Woody Plants in River Shrub Prairies

Woody plant encroachment is a threat to river shrub prairies, as these plants are typically taller and can shade out herbaceous prairie species (Perles 2016). Between 2012 and 2016, the ERMN monitoring program measured woody plant cover at 10 GARI river prairie sites and at nine river prairie sites in NERI. Within GARI, woody cover at prairie sites ranged from 14.7-38.2%, with an overall average of 25.5% (Figure 21) (ERMN 2017). Even the highest woody cover percentage at GARI was lower than woody cover percentages for the majority of NERI river shrub prairies. However, researchers noted that woody cover may have been lower than normal at GARI in 2016 due to a significant storm/scouring event in June of that year (ERMN 2017).

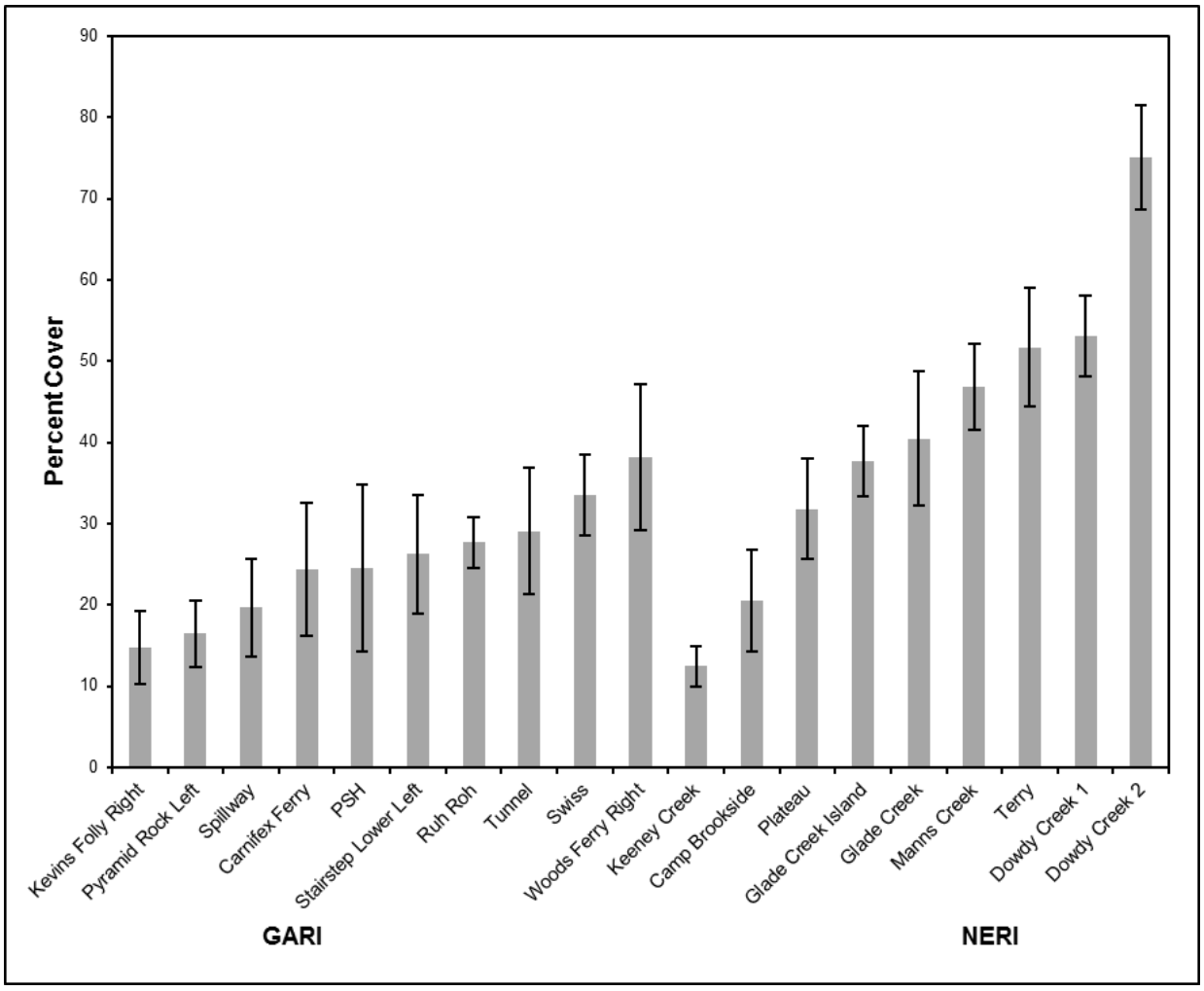


Figure 21. Percent cover of woody plant species (>1 m [3.3 ft] tall) in river shrub prairie sites at Gauley River National Recreation Area (10 sites on left) and New River Gorge National River (nine sites on right). Error bars represent one standard error (Perles 2016).

Threats and Stressor Factors

Threats to GARI's riparian vegetation communities include exotic invasive species (plants and pests/pathogens), flow regulation by the Summersville Dam, recreational use, poor water quality, land ownership, extreme weather events, and climate change. According to Richardson et al. (2007), the abundance and diversity of exotic plants has increased in riparian areas all around the world. As mentioned previously, exotic invasive species pose a serious threat to vegetation communities, due to their ability to compete with native species and disrupt ecosystem processes (Mooney et al. 2005, Perles et al. 2014b). At GARI, the invasives multiflora rose and autumn olive (*Elaeagnus umbellata* var. *parvifolia*) have been considered particular threats to the rare and unique species of the river shrub prairie communities for many years (Walton and Anderson 1997). Additional invasive species of concern include honeysuckles (*Lonicera* spp.), wine raspberry (*Rubus phoenicolasius*), sericea lespedeza (*Lespedeza cuneata*), and Japanese knotweed (*Polygonum cuspidatum*) (Strickler, NERI/GARI/BLUE Biological Science Technician, August 2017). The river itself and recreational

use areas within the floodplain may serve as pathways for the invasion and spread of these exotic species (Richardson et al. 2007, Perles et al. 2014b).

Many of the forest pests that threaten GARI's uplands also impact the riparian communities, particularly EAB and HWA. In addition, butternut trees (*Juglans cinerea*) in the floodplain are threatened by butternut canker (*Sirococcus clavigignenti- juglandacearum*), a fungal disease that is currently decimating butternut populations throughout their range and may have already extirpated the species in some southern states (Schlarbaum et al. 1998). The decline has been so severe that the U.S. Fish and Wildlife Service (USFWS) has listed butternut as a species of federal concern (Schlarbaum et al. 1998).

Flow regulation by the Summersville Dam has altered the natural hydrological and disturbance regimes that native riparian vegetation communities within GARI have adapted to historically (Norris 1992, Walton and Anderson 1997). Prior to dam construction, seasonal floodwaters would scour the riparian areas, particularly the river shrub prairies, preventing the establishment of dense and/or woody vegetation (Norris 1992, Walton and Anderson 1997). Water releases from the dam are currently controlled and moderated, resulting in a more stable flow regime throughout the year (Norris 1992). The lack of flooding allows additional vegetation establishment, which competes with and can "crowd out" native endemic and rare plant species (Walton and Anderson 1997, Richardson et al. 2007). According to Norris (1992), local residents have noted changes in vegetation, with previously sandy areas along the river becoming forested.

Recreational use, particularly ORVs and camping/access by whitewater rafters, has the potential to disturb riparian vegetation within GARI (Cole and Marion 1988, Vanderhorst et al. 2010). In a study on the nearby New River, Cole and Marion (1988) found that the disturbance caused by outfitter-led rafting parties was much greater than that caused by smaller fishing parties. Outfitter sites were larger overall than fishing party camp sites, with nearly four times the devegetated area and three times the disturbed shoreline length (Cole and Marion 1988). At GARI, the most suitable sites for camping during rafting excursions are coincidentally some of the park's rarest vegetation communities (e.g., river shrub prairies and riparian forests/woodlands) and habitat for numerous rare plant species (Norris 1992, Vanderhorst et al. 2010). Bennett and McDonald (2006) observed varying degrees of disturbance at several riverbank campsites and river access points within the park, primarily to the herbaceous vegetation layer, during their 2006 riparian zone evaluation. The impacts of ORVs in the riparian areas are similar to those discussed for upland forests, but can be even more damaging in the wetter soils of riparian areas.

As noted in the previous component, climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). As with the upland forests, warming temperatures will alter the habitat suitability of certain areas for some riparian tree species (Fisichelli et al. 2014). Habitat suitability projections for several key riparian tree species are shown in Table 20. Higher temperatures also increase evaporation and transpiration (by plants), causing less water to be available for plants and increasing moisture stress (Dale et al. 2001), particularly for species adapted to wet environments. Extreme weather events triggered by climate change, as discussed in the previous component, could also impact riparian forests.



Trash, campfire remains, and ORV tracks left by campers near a river scour prairie at Gauley River National Recreation Area (NPS photos by Jim Vanderhorst).

Table 20. Potential change in habitat suitability by 2100 for select Gauley River National Recreation Area riparian tree species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific Name	Common Name	Least Change Scenario	Major Change Scenario
Acer pensylvanicum	striped maple	small decrease	large decrease
Diospyros virginiana	common persimmon	large increase	large increase
Liquidambar styraciflua	sweetgum	large increase	large increase
Pinus rigida	pitch pine	large decrease	small decrease
Platanus occidentalis	sycamore	small increase	large increase
Ulmus americana	American elm	no change	large increase
Gleditsia aquatica	water locust	–	new habitat
Populus deltoides	eastern cottonwood	–	new habitat
Quercus nigra	water oak	–	new habitat
Quercus texana	Nuttall oak	–	new habitat

Data Needs/Gaps

The ERMN river shrub prairie monitoring program has begun to address historical data gaps for these unique communities at GARI, but forested riparian communities have not been monitored. Additional surveys to document the locations, numbers, and status of rare plants in the park's riparian areas would be helpful for better understanding the condition of these species.

Overall Condition

Riparian Vegetation Community Extent

The project team assigned this measure a *Significance Level* of 3. Riparian vegetation communities cover a relatively small area within GARI, making them somewhat vulnerable to both natural and anthropogenic changes. However, there is no current evidence that the community's extent is declining, and its limited accessibility offers some protection for the riparian area. As a result, this measure is assigned a *Condition Level* of 1, indicating low concern.

River Shrub Prairie Extent

This measure was also assigned a *Significance Level* of 3. Fifty different river shrub prairie areas have been identified along the Gauley and Meadow Rivers within GARI boundaries, totaling just 16.1 ha (39.8 ac) (NPS 2016b). No historic information on shrub prairie extent was available for comparison to identify any trends in this measure. However, the small and isolated nature of most river shrub prairies increases their vulnerability to habitat loss or elimination. Therefore, this measure is currently of moderate concern (*Condition Level* = 2).

Plant Species Richness

The plant species richness measure was assigned a *Significance Level* of 3. A total of 473 plant species have been documented in GARI's riparian communities (see Appendix D), nearly as many species as have been documented in upland forest communities, which cover over 200 times more area. A slightly higher percentage of these species (7.2%) are exotic than in upland forest communities (6.5%). At this time, plant species richness is of low concern (*Condition Level* = 1).

Rare Plant Element Occurrences

The project team assigned this measure a *Significance Level* of 3. Twenty-one rare plant species have been documented in GARI's riparian vegetation communities (Table 18), but information on the number of occurrences (EOs) within park boundaries is limited. No recent information on the condition (i.e., viability) of rare species EOs could be found. As a result, a *Condition Level* has not been assigned for this measure.

Proportion of Total Cover of Exotic Plants and Invasive Plants

A *Significance Level* of 3 was assigned to this measure. Vanderhorst et al. (2010) found that exotic plant cover in GARI's riparian vegetation communities varied from 0% to 10.8%. The highest invasive plant cover was 9.8%. At ERMN river shrub prairie monitoring sites within GARI, exotic cover ranged from 0% to 8.2%, with a mean of 2.6% (ERMN 2017). Because of the severity of the potential impacts to the riparian ecosystem from invasive plants, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

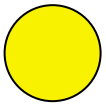
Cover of Woody Plants in River Shrub Prairies

This final measure was also assigned a *Significance Level* of 3. Although woody plant cover was generally lower in GARI river shrub prairies than at nearby NERI sites, cover at all GARI sites exceeded 10% (Figure 21) (Perles 2016). Coverage at seven of the 10 sites exceeded 20%, with a maximum of 38.2%. Because woody vegetation is such a severe threat to these rare endemic communities, this measure is assigned a *Condition Level* of 2.

Weighted Condition Score

The *Weighted Condition Score* for GARI's riparian vegetation communities is 0.53 (Table 21), which falls in the moderate concern range. As with the upland forests component, a trend has not been assigned and a moderate confidence border is applied due to limited data and information for the selected measures.

Table 21. Current condition of Gauley River National Recreation Area's Riparian Vegetation Communities.

Measures	Significance Level	Condition Level	WCS = 0.53
Riparian Community Extent	3	1	
River Shrub Prairie Extent	3	2	
Plant Species Richness	3	1	
Rare Plant EOs	3	n/a	
Exotic & Invasive Cover	3	2	
Woody Plant Cover (prairies)	3	2	

4.3.6. Sources of Expertise

- John Perez, NERI/GARI/BLUE Biologist
- Stephanie Perles, ERMN Plant Ecologist
- Layne Strickler, NERI/GARI/BLUE Biological Science Technician

4.5. Birds

4.5.1. Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). GARI is home to many unique ecosystems, ranging from rugged mountainous terrain, to lower elevation riparian habitats along the Gauley River and its tributaries. All of the habitats in the park support unique, specific bird communities. Like much of West Virginia, the forests of GARI are largely unbroken, and provide critical habitat for forest interior dependent species (Weakland and Wood 2002). These types of forests are becoming increasingly rare, as forest fragmentation and loss accelerates due to human development. Logging and mining in West Virginia remain a major source of forest fragmentation and loss; forest areas surrounding active or reclaimed mines often foster edge habitats which attracts nest predators (Weakland and Wood 2002).

GARI is also home to many hemlock ecosystems. These ecosystems support many avian species dependent on conifer habitats (Tingley et al. 2002, Wood et al. 2009), including the Acadian flycatcher (*Empidonax virescens*) and the black-throated green warbler (*Setophaga virens*). The ongoing threat of HWA infestation, first documented in the park in 2007 (Strickler 2014), represents a significant issue for these plant and avian communities in GARI. After a hemlock ecosystem is infested, it often changes in community type to one dominated by hardwood species (Orwig and Foster 1998, Wood et al. 2009), and such a change in vegetation would also change the avian species that would be found in that area. GARI has documented baseline bird species richness and abundance levels in many of the hemlock communities in the park, and managers remain concerned about potential changes in community structure as a result of the infestations.

In total, GARI has nearly 150 species of birds that are confirmed as present in the park (NPS 2016d) (Appendix E). GARI is located between two important migratory crossover locations for the Atlantic Flyway, as species cross over to the Atlantic Coast from the Mississippi River Flyway. Several migratory species cross through the park in the spring and fall on their way to and from breeding grounds in northern North America. The summer breeding bird community in GARI also includes a large influx of migratory songbirds. The winter community of the park includes some migratory waterfowl that utilize the riparian habitats of the park.

Additionally, GARI has confirmed the presence of 22 species identified as species of concern by the West Virginia Wildlife Diversity Program (WVWDP) (Table 22). These species represent approximately 15% of all confirmed species in the park. Species are ranked on how imperiled/rare that species is in West Virginia, and are classified at six levels:

- **S1 – Critically Imperiled –** Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically five or fewer occurrences and very few remaining individuals (<1,000);

- **S2 – Imperiled –** Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically six to 20 occurrences of few remaining individuals (1,000 to 3,000);

- **S3 – Vulnerable –** Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals;

- **S4 – Apparently Secure –** Uncommon, but not rare, and usually widespread in the state. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals;

- **S5 – Secure –** Common, widespread, and abundant in the state. Essentially ineradicable under present conditions. Typically considerably more than 100 occurrences and more than 10,000 individuals;

- **SH – State Historical –** Species occurred historically in the state and there is some expectation that it may be rediscovered. Its presences may not have been verified in the past 20 years (WVDNR 2017b).

Table 22. Avian species identified as Species of Conservation Concern by the West Virginia Wildlife Diversity Program (WVDNR 2017b). N = Non-breeding population; B = Breeding population. Other acronyms defined in the bullet points above.

Scientific Name	Common Name	WVNHP Classification
Anas rubripes	American black duck	S2B, S2N
Fulica americana	American coot	SHB, S2N
Haliaeetus leucocephalus	bald eagle	S3B, S3N
Setophaga fusca	Blackburnian warbler	S3B
Nycticorax nycticorax	black-crowned night heron	SHB
Buteo platypterus	broad-winged hawk	S3B
Petrochelidon pyrrhonota	cliff swallow	S3B
Vermivora chrysoptera	golden-winged warbler	S1B
Ardea herodias	great blue heron	S3B, S4N
Circus cyaneus	northern harrier	S1B, S3N
Parkesia noveboracensis	northern waterthrush	S2B
Lophodytes cucullatus	hooded merganser	S1B, S4N
Pandion haliaetus	osprey	S2B
Falco peregrinus	peregrine falcon	S2B, S2N
Melanerpes erythrocephalus	red-headed woodpecker	S3B, S3N

Table 22 (continued). Avian species identified as Species of Conservation Concern by the West Virginia Wildlife Diversity Program (WVDNR 2017b). N = Non-breeding population; B = Breeding population. Other acronyms defined in the bullet points above.

Scientific Name	Common Name	WVNHP Classification
Podilymbus podiceps	pied-billed grebe	S2B, S4N
Catharus ustulatus	Swainson's thrush	S3B
Limnothlypis swainsonii	Swainson's warbler	S3B
Bartramia longicauda	upland sandpiper	SHB, S1N
Pooecetes gramineus	vesper sparrow	S2B, S2N
Zonotrichia albicollis	white-throated sparrow	SHB, S5N
Sphyrapicus varius	yellow-bellied sapsucker	S2B, S3N

4.5.2. Measures

- Species richness
- Species abundance
- Species distribution
- Bird Community Index (BCI)

4.5.3. Reference Condition/Values

Due to a lack of historic surveys or inventories in the park, an appropriate quantitative reference condition does not exist for this component at this time. The GARI area was historically covered in continuous, mature forests. While logging removed many trees from the area in the 1800s, the area has returned to a landscape that is largely unfragmented and densely forested. For this assessment, a reference condition of a 'rich and diverse breeding forest bird community' will be used. Because there are no historic data from forest bird communities in the area, the best professional judgement of the identified subject matter experts and NPS staff was used to assess current condition. Future assessments of condition may be able to utilize this summary as a baseline for comparison.

4.5.4. Data and Methods

NPS Certified Species List (NPS 2016)

The NPS Certified Bird Species List (NPS 2016d) for GARI was used for this assessment, as this list represents all of the confirmed bird species present in the park. The list is populated by the various bird inventories and surveys that occur in the park's area, and in the case of parks with limited bird work, will likely resemble the overall species list of the primary bird inventory effort for the park.

NPS Point Count Surveys

Beginning in 1998, NPS staff initiated annual avian fixed-radius point count surveys (PCS) in GARI, BLUE, and NERI. The PCS route in GARI follows much of the Meadow River in the southern portion of the unit, and consists of 20 points that are spaced approximately 250 m (820 ft) apart

(Figure 22). Observers begin survey efforts within 3 hours after sunrise, and stop at each point for 10 minutes. Each individual that is heard or seen within a 20 m (66 ft) radius from the point is identified to species and recorded. Data from these PCS efforts are current in GARI through 2017.

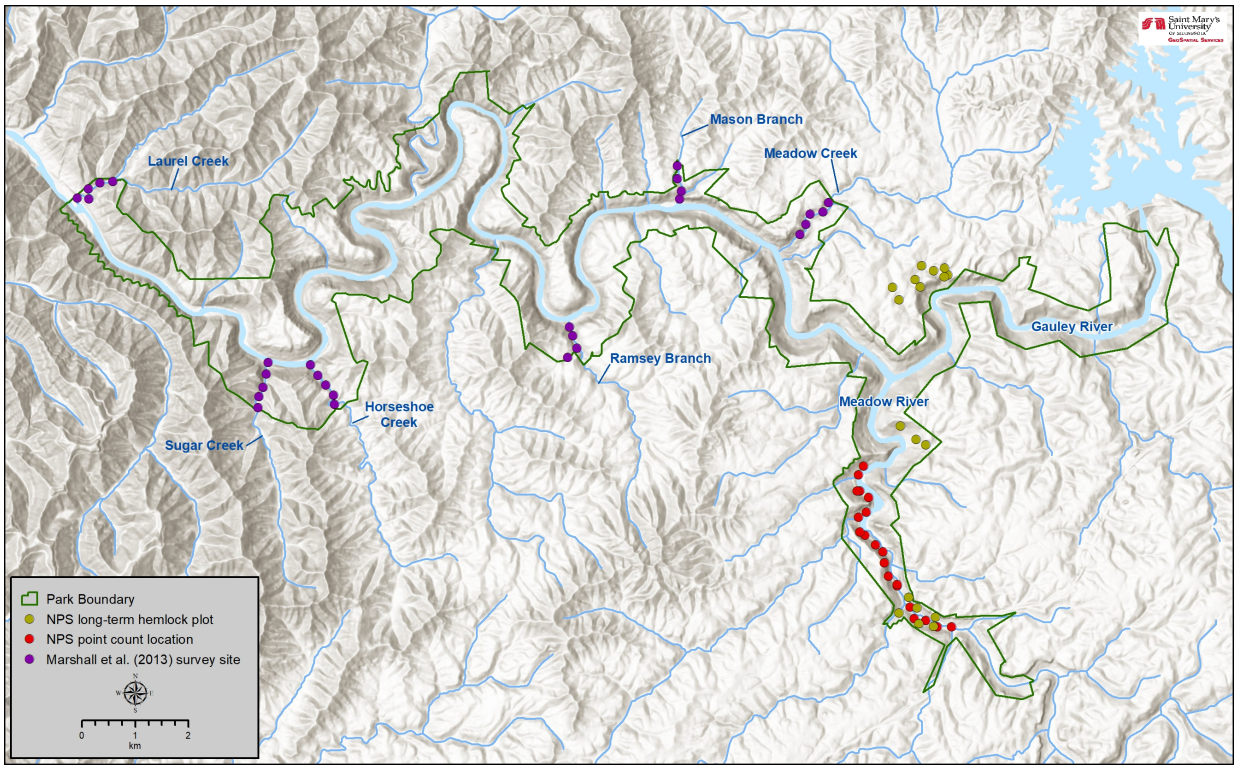


Figure 22. Sampling locations in Gauley River National Recreation Area utilized during the NPS-led point count surveys, the Wood et al. (2009) hemlock monitoring, and the Marshall et al. (2013) streamside bird monitoring efforts.

In one instance, SMUMN GSS slightly adjusted some of the PCS data when compiling the report. Records of the solitary vireo were combined with observations of the blue-headed vireo (*Vireo solitarius*) to reflect current taxonomic classification (Cicero and Johnson 1998); the raw PCS data identified these birds as two separate species.

Wood et al. (2009)

In an effort to document the avian species composition of hemlock ecosystems prior to infestation by adelgid, Wood et al. (2009) surveyed several hemlock ecosystems in GARI and NERI during the summers of 1999-2008. A specific objective of Wood et al. (2009, p. 1) was to "quantify avian richness and abundance to relate these songbird metrics to structural changes in vegetation characteristics in a variety of hemlock habitats within NERI and GARI."

Avian point count locations overlapped with hemlock vegetation monitoring plots utilized by Wood et al. (2009), and observers recorded all birds within a 50 m (164 ft) plot. All songbird species that were seen or heard during a 10 minute count were documented; observers also recorded species that were encountered at an unlimited radius (i.e., outside of the count circle). Each point count location

was surveyed twice each year, with one count occurring during early June, and a second occurring in late June, with at least 1 week separating the two counts (Wood 2004). Species richness and species abundance for songbird species were estimated using the protocols outlined by Ralph et al. (1993). Abundance estimates used the maximum number of individuals of a species observed during the two yearly point counts for a site.

The Wood et al. (2009) monitoring plots have continued to be surveyed following the 2009 publication. Surveys have continued through the 2017 field season, but the data have not been summarized to date. These data will be highly informative in future condition assessments, as they will provide park managers with a long-term, continuous data set related to a critical habitat type in the GARI area.

Pauley et al. (2005)

As part of a park-wide inventory effort, Pauley et al. (2005) inventoried the bird community of GARI from 2000-2001. Specific objectives of Pauley et al. (2005) were to document approximately 90% of bird species in the park and to document the habitat that they occupied. Inventory efforts in the park utilized point counts, line transects, singing male counts, and general opportunistic bird surveys.

During the breeding (Jun-mid July) and winter (Nov-Feb) seasons of 2000-2001, Pauley et al. (2005) utilized 12 point count locations, and followed the protocol outlined by Ralph et al. (1993). Each point count location was centered in a fixed-radius 50 m (164 ft) plot, with the observer documenting all species observed within that plot during a 10-minute window. The fall migratory period (Aug-Oct) of 2000 was inventoried using 12 line transects. Each line transect measured 300 m (984 ft) and was surveyed for 30 minutes.

The 2001-2002 field season for Pauley et al. (2005) utilized a series of 10 upland and 10 lowland point counts during both the breeding (Mar-May) and fall migratory (Aug-Oct) periods, resulting in a total of 20 point count locations for each period. Winter (Nov-Dec) point counts were also conducted, and utilized the same 12 point count methodology as the 2000-2001 field season. In addition to the point count survey efforts, Pauley et al. (2005) also conducted nocturnal callback surveys at 30 point count locations in the park. These survey efforts used species-specific calls to elicit vocal responses from nocturnal and diurnal raptor species. Additionally, Pauley et al. (2005) completed opportunistic surveys that focused primarily on waterfowl species. Species observed along the shores of the Gauley and Meadow Rivers were documented five times from 20 October to 31 December 2001.

Marshall et al. (2013)

The ERMN identified “streamside birds” as a key natural resource network-wide, and initiated a long-term monitoring program in 2007 (Marshall et al. 2012). The term “streamside bird” was chosen as the monitoring protocol calls for avian sampling along a specific habitat corridor: forested, closed canopy streams. It is this sampled area – the closed canopy streams – that calls for distinction; ERMN monitoring samples the breeding bird community of this habitat type, and the data collected are analogous to data collected by other NPS monitoring programs in regard to “breeding birds”,

"landbirds", or other labels for bird communities (Marshall et al. 2012, 2013). Marshall et al. (2013, p. 3) identified the following objectives prior to initiating annual point counts:

1. Estimate occupancy, density, and/or indices of abundance annually for select bird species and guilds at the park (target stream network) and stream reach scale;
2. Estimate trends among years in occupancy, density, and/or indices of abundance for select bird species and guilds at the park (target stream network) and stream reach scale;
3. Calculate the Bird Community Index [BCI] of biotic integrity annually at the park (target stream network) and stream reach scale; and
4. Compare trends in occupancy, density, and/or indices of abundance for select bird species and guilds within ERMN parks to regional and continental trends.

The ERMN streamside bird monitoring efforts in GARI used the methodology outlined by Marshall et al. (2012). Sampling sites consist of closed canopy, wadeable stream reaches within a park's administrative boundary, and ranged between 250 m (820 ft) and 1 km (0.6 mi) in length. Selected stream reaches had between two and five point count locations, with each station being spaced at least 250 m (820 ft) apart and up to 25 m (82 ft) upslope from the stream (Marshall et al. 2012).

In GARI, six stream sites were identified that met the monitoring criteria of Marshall et al. (2012). However, when monitoring began in 2007, only three sites were randomly selected for inclusion (Laurel Creek, Horseshoe Creek, and Meadow Creek) (Figure 22). Beginning in 2012, all six candidate monitoring sites were included for monitoring, as it was determined that GARI did not have enough candidate monitoring sites to utilize a random approach for selection (Marshall et al. 2013). The three sites that were added included Sugar Creek, Ramsey Branch, and Mason Branch (Table 23).

Table 23. Streamside sampling sites in Gauley River National Recreation Area selected for annual monitoring by Marshall et al. (2013). Table reproduced from Marshall et al. (2013).

Site Name	Site ID	Year Established	Reach Length (m)	# of Point Count Stations
Laurel Creek	GARI. 1001	2007	1000	5
Horseshoe Creek	GARI. 1002	2007	1000	5
Meadow Creek	GARI. 1003	2007	1000	5
Sugar Creek	GARI. 1004	2012	1000	5
Ramsey Branch	GARI. 1005	2012	750	4
Mason Branch	GARI. 1006	2012	750	4

Each point count location was visited twice per year, typically between May and July. During a visit, observers documented all bird species seen or heard during a 10-minute window and recorded

species identity, type of detection, the distance of detection, the time frame of detection (e.g., minute-4 of observation window), life stage of the species (i.e., if the species was a juvenile or not), and whether or not the species was flying over the canopy (Marshall et al. 2012). Observers conducted two "passes" of a stream reach during a visit, conducting an upstream pass and a downstream pass separated by at least 10 minutes to allow for each pass to be treated as an independent observation (i.e., each visit consisted of two passes).

4.5.5. Current Condition and Trend

Species Richness

The species richness measure in this component refers to the total number of species present in a given study, survey, or other monitoring effort. This definition is in line with the traditional definition in published literature, and is the same used by Wood et al. (2009) during monitoring efforts in GARI from 1999-2008.

It is important to note that a higher species richness estimate does not always correlate to a "healthier community". This is particularly true in the mature, largely unfragmented forests typical of the GARI/NERI/BLUE areas in West Virginia. These areas often have highly specialized avian guilds that depend upon the interior forest communities for breeding. Accordingly, these ecosystems may exhibit lower species richness estimates but still be considered in good condition as they provide and sustain critical habitat for these specialized groups of birds. The fragmentation of these forests may encourage generalist bird species or guilds to move in, which would increase the species richness estimate, but would lower the overall condition of the measure. In instances where trends or ecosystem function was unclear, the best professional judgement of NPS managers was used for this measure.

NPS Certified Species List (NPS 2016d)

The NPS Certified Bird Species List contains 148 species that are confirmed in the park (Appendix E). One species, the eastern kingbird (*Tyrannus tyrannus*), was identified as unconfirmed. The designation of unconfirmed indicates that the species has been attributed to the park, but little or no evidence to support its presence exists.

Unlike annual bird surveys, NPS (2016) is not well suited for an analysis of annual species richness, as no data are collected yearly. The NPS Certified Species List documents the presence (or historic presence) of the identified species and serves as a useful point of comparison to determine which species have been documented in the park.

NPS Point Count Surveys

The NPS has conducted annual avian point counts in GARI since 1998. The total number of species observed from 1998-2017 was 45 (Appendix E). Annual species richness estimates have varied over the 18 years of the surveys, with species richness estimates ranging from six species (2016) to 26 species (1998) (Figure 23). The average number of species observed along the GARI PCS route from 1998-2016 was 17.17 species (Figure 23).

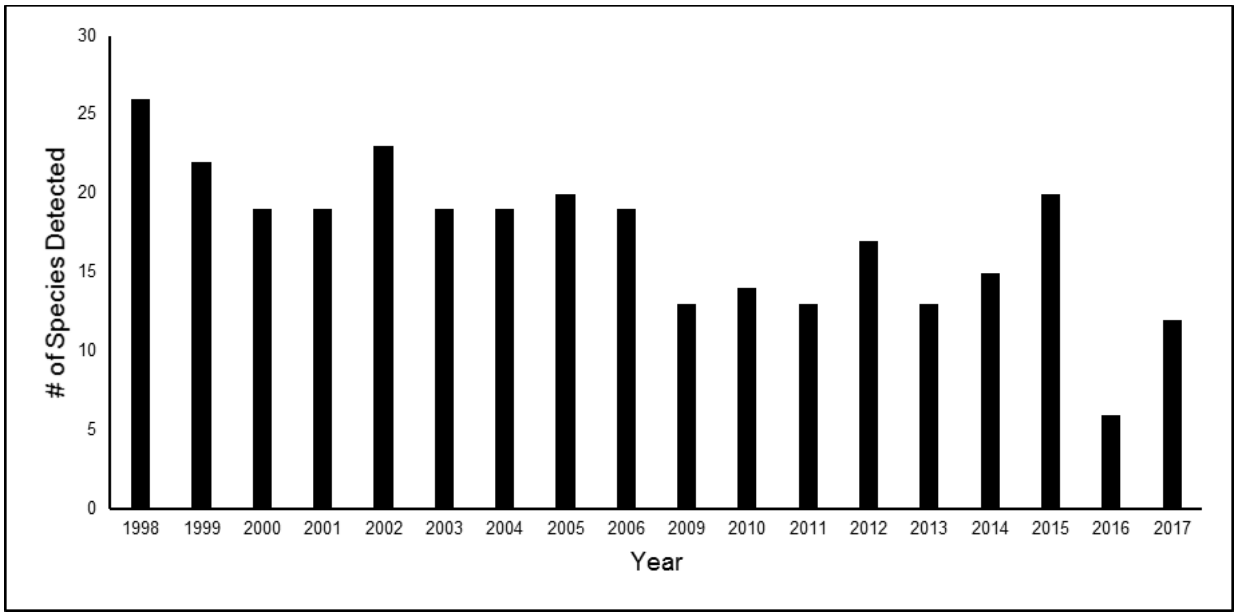


Figure 23. Annual species richness at Gauley River National Recreation Area during yearly point count survey (PCS) (NPS unpublished data). The dashed red line indicates the 18-year species richness average for the PCS (17.17 species). Note that in 2016 only eight of the 20 point count locations were surveyed as the other locations were inaccessible due to floodwaters.

Within the last 5 years (2013-2017), the average species richness along the PCS route in GARI has been 13.2 species, which is slightly below the 18-year average. However, surveys in 2016 were cut short because count locations were inaccessible due to floodwaters; only eight of the 20 point count locations were surveyed. This resulted in a drastically reduced species richness estimate that likely does not accurately reflect the actual richness during the 2016 season. When excluding the 2016 results from the 2013-2017 survey period, the 5-year average species richness along the route in GARI was 15.0 species. Species richness estimates for 2017 were the lowest of all PCS efforts in GARI (excluding 2016; 12 species), and fell well below the long-term and 5-year species richness averages for the route (Figure 23).

Pauley et al. (2005)

During avian inventory efforts in GARI from 2000-2001, Pauley et al. (2005) recorded 129 bird species (Appendix E). Survey efforts of Pauley et al. (2005) were split into year one (2000-winter 2001) and year two (remainder of 2001). In year one, 83 species were observed during point count efforts in the breeding season (June to mid-July), 69 species were observed during line transect surveys during the migration period (August to October), and 36 species were observed during point counts from November to February (Table 24).

Table 24. Total number of species observed in Gauley River National Recreation Area during three seasons in Year 1 of Pauley et al. (2005) surveys.

Parameter	Breeding Season (June - mid July)	Migration Period (August- October)	November - February
# of Species	83	69	36

Year two survey efforts focused on both upland and lowland point count locations, and also used winter and nocturnal point counts. Spring point counts (March-May) identified 85 species in the upland habitats and 68 species in the lowland habitats. Summer point counts (August-October) identified 73 species in upland habitats and 49 species in lowland habitats (Table 25). Winter point counts in GARI from November to December 2001 identified 27 avian species, while nocturnal point counts identified eight species.

Table 25. Total number of species observed in the upland and lowland areas of Gauley River National Recreation Area during spring and summer point count survey in Year 2 of Pauley et al. (2005).

	Upland Point Counts		Lowland Point Counts	
Parameter	Spring	Summer	Spring	Summer
# of Species	85	73	68	49

Wood et al. (2009)

Monitoring of the hemlock ecosystems in NERI and GARI from 1998-2008 documented 76 bird species (Appendix E). Wood et al. (2009) noted that the majority of the species observed (65 species; 85.5%) were songbirds, with the remaining species consisting of waterfowl, raptors, or corvid species. Annual species richness, per point count location, for songbirds in the Wood et al. (2009) study plots slightly declined from 1999-2008 (Figure 24, indicated by diamonds).

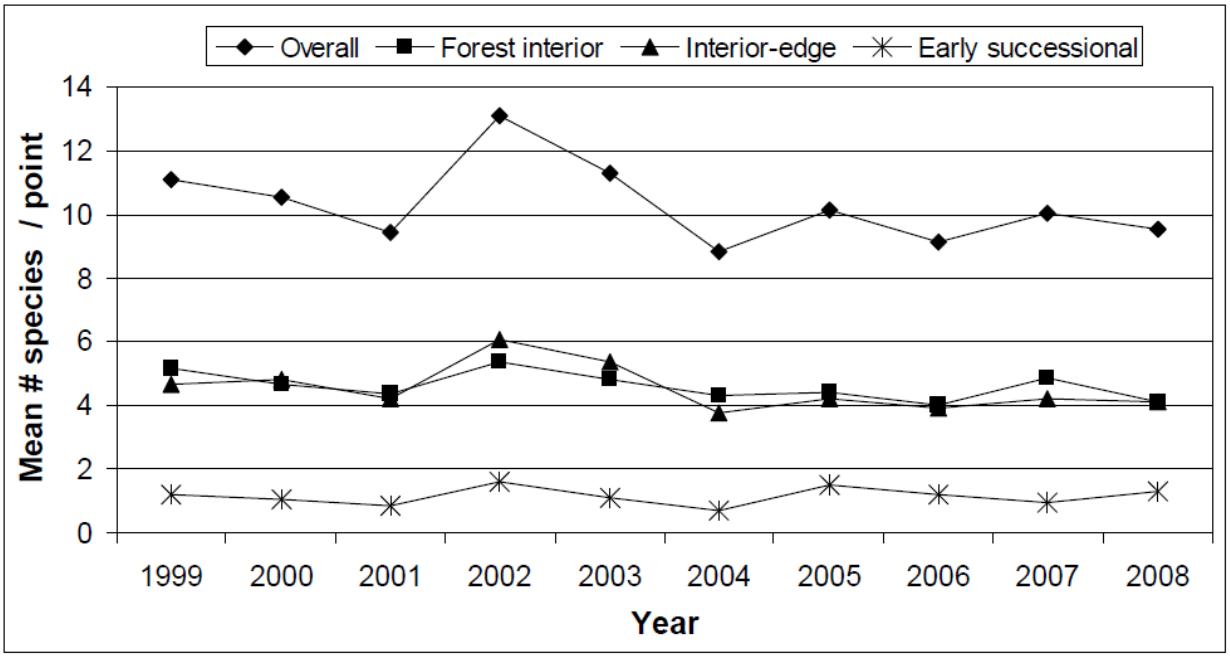


Figure 24. Annual trends in overall species richness and species richness for habitat guilds (reproduced from Wood et al. (2009).

Marshall et al. (2013)

The ERMN streamside bird monitoring efforts in GARI sampled six sites in the park from 2007-2012 (Figure 22) While monitoring efforts in the park lasted from 2007-2012, three sites were not surveyed for the first time until the 2012 season (Sugar, Ramsey, and Mason Creeks). Marshall et al. (2013) documented 66 bird species during the six years of streamside bird monitoring (Appendix E); this species richness total should be interpreted with a degree of caution, as only areas along streams and rivers were sampled.

As mentioned previously, a higher species richness estimate may not be truly indicative of good condition in an ecosystem. Marshall et al. (2013) observed an unexpected relationship between species richness and BCI scores at two ERMN parks (Delaware Water Gap National Recreation Area [DEWA] and NERI) where BCI scores for a site were negatively correlated to species richness (i.e., higher BCI scores corresponded to lower species richness). An explanation for this trend is that areas have higher species richness estimates when more generalist species are present than specialist species. A higher percentage of generalist species generally reduce an area's BCI score. The BCI scoring process is much more nuanced than a simple species richness tally for a given year, as the BCI weights each species encountered differently, depending upon avian guilds. An explicit reference condition also exists for the BCI (mature forests). A more detailed look at BCI results in GARI is presented later on in this component.

<u>Species Abundance</u>

Species abundance refers to how many individuals are documented in a given survey/monitoring period. It needs to be noted, however, that all species have different detection probabilities, and

measures of abundance reported here should be considered "naïve" estimates, as they do not account for these variable detection probabilities.

NPS Point Count Surveys

The NPS-organized avian PCS in GARI have identified 1,264 individuals of 45 species between 1998 and 2017. The total number of individuals observed each year has been variable, ranging from seven individuals in 2016 to 156 individuals in 1998; the average number of birds detected during PCS from 1998-2017 was 70.2 (NPS unpublished data). However, surveys during 2016 were cut short due to elevated floodwaters; only eight of the 20 point count locations could be accessed by researchers. Because of this, species abundance estimates were likely greatly reduced compared to what their actual abundance was along the route. When removing 2016 results, the lowest number of individuals detected during a survey year was 38 (2013), and the average number of individual detections from 1998-2017 increased to 73.9.

The most commonly detected species during the 18 field seasons were the red-eyed vireo (*Vireo olivaceus*; 224 detections), hooded warbler (*Setophaga citrina*; 139 detections), scarlet tanager (*Piranga olivacea*; 116 detections), Swainson's warbler (*Limnothlypis swainsonii*; 110 detections), and the blue jay (*Cyanocitta cristata*; 106 detections). These five species have accounted for 55% of all observations during the NPS PCS surveys in GARI. All five of these species were detected during every year of the PCS (Table 26).

Table 26. The five most frequently detected bird species during National Park Service monitoring form 1998-2016. All five species were detected in every year of the point count surveys (NPS unpublished data).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
red-eyed vireo	33	22	17	18	14	11	9	9	14	7	10	9	11	2	11	18	2	7	224
hooded warbler	17	14	4	8	5	2	9	8	8	5	8	7	9	6	11	6	1	11	139
scarlet tanager	3	10	2	10	5	8	4	4	4	5	5	13	8	10	11	8	1	5	116
Swainson's warbler	3	7	8	10	14	5	8	7	8	8	5	5	7	2	4	3	1	5	110
blue jay	11	5	1	1	7	7	11	8	8	7	6	5	7	3	8	5	1	5	106

The birds that were detected in the highest numbers, perhaps with the exception of the blue jay, are all species dependent upon intact, dense forests. The scarlet tanager is particularly sensitive to changes in forests in regards to fragmentation, and the Swainson's warbler is a secretive, forest-dependent species that is a species of conservation concern and is not easily observed. The fact that these species were detected frequently highlights the importance of the largely intact forests of GARI and are indicative of the overall health of these communities.

Pauley et al. (2005)

The Pauley et al. (2005) inventory efforts reported species abundance as the highest daily number of bird species observed at any of the point count locations during the period of survey. Annual abundance estimates summarized below represent the sum of the peak number of individuals observed at each point count location and not the total number of individuals observed during the counts.

In year one of Pauley et al. (2005), 826 individuals were observed during point counts and line transect efforts. Point count efforts in the breeding season estimated peak abundance at 256 individuals, while fall migration period line transects recorded 425 individuals (Table 27). Winter point count efforts documented 145 individuals during survey peaks. The American crow (*Corvus brachyrhynchos*) was among the three most abundant species during all three surveys in year one of Pauley et al. (2005) (Table 28). The red-eyed vireo was observed in highest numbers during the breeding season of year one, while the common grackle was the most abundant species during the migration period (Table 28).

Table 27. Peak daily abundance estimates of birds observed in Gauley River National Recreation Area during three seasons in Year 1 of Pauley et al. (2005) surveys.

Parameter	Breeding Season (June - mid July)	Migration Period (August- October)	November - February
Peak daily abundance	256	425	145

Table 28. The most frequently detected species observed during Year 1 and Year 2 of Pauley et al. (2005). Bolded numbers indicate the three most frequently detected species in each column.

Species	Year 1			Year 2			
	Breeding Season	**Migration Period**	**Winter**	**Uploand Point Counts: Spring**	**Upland Point Counts: Summer**	**Lowland Point Counts: Spring**	**Lowland Point Counts: Summer**
Acadian flycatcher	**10**	–	–	–	–	4	–
American crow	**9**	**22**	**33**	15	20	11	18
American goldfinch	3	**23**	7	15	**48**	4	15
American robin	3	14	8	**25**	**23**	8	–
Canada goose	5	–	**11**	9	–	**46**	**82**
cliff swallow	–	–	–	–	–	–	**63**
common grackle	5	**45**	–	5	12	**13**	–
dark-eyed junco	–	6	**9**	9	–	–	–
European starling	–	–	–	**27**	**90**	–	–
red-eyed vireo	**15**	6	–	12	12	**15**	12
song sparrow	4	1	2	**25**	14	4	2
tree swallow	2	–	–	6	9	4	**47**
turkey vulture	5	9	–	**36**	20	12	14

Year two survey efforts focused on both the upland and lowland habitats of GARI, and also utilized winter point counts and nocturnal point counts. Spring point counts (March to May) had peak abundance estimates of 535 individuals in the upland habitats and 342 individuals in the lowland habitats (Table 29). Summer point counts (August to October) had peak abundance estimates of 524 individuals in the upland habitats and 519 in the lowland habitats (Table 29). Winter point counts in GARI from November to December in 2001 identified 103 individuals, while nocturnal point counts identified 33 individuals.

Table 29. Peak daily abundance of birds observed in the upland and lowland areas of Gauley River National Recreation Area during spring and summer point count survey in Year 2 of Pauley et al. (2005).

Parameter	Upland Point Counts		Lowland Point Counts	
	Spring	Summer	Spring	Summer
Peak daily abundance	535	524	342	519

Wood et al. (2009)

Survey locations utilized by Wood et al. (2009) were located in hemlock-dominated habitats, and because of this, species that were not associated with this particular habitat type were either not documented or were documented in low numbers. Of the 76 bird species observed by Wood et al. (2009) from 1999-2008, the ovenbird (*Seiurus aurocapilla*), red-eyed vireo, wood thrush (*Hylocichla mustelina*), hooded warbler, and scarlet tanager had the highest mean annual number of detections (Appendix F). Eighty-one red-eyed vireos were observed in a single field season, which was the highest number of any species observed during a survey (Table 30).

Table 30. The 10 most commonly observed species at Gauley River National Recreation Area during the Wood et al. (2009) bird surveys. SE=Standard Error.

Scientific Name	Common Name	# of Annual Detections			
		Mean	SE	Min	Max
Seiurus aurocapillus	ovenbird	52.1	2.18	43	62
Vireo olivaceus	red-eyed vireo	48.6	4.68	34	81
Hylocichla mustelina	wood thrush	47.0	2.95	32	69
Setophaga citrina	hooded warbler	45.8	2.33	34	56
Piranga olivacea	scarlet tanager	37.4	1.89	29	47
Corvus brachyrhynchos	American crow	29.3	2.56	16	41
Vireo solitarius	blue-headed vireo	23.8	1.76	14	32
Setophaga virens	black-throated green warbler	20.8	2.36	13	32
Cyanocitta cristata	blue jay	20.7	1.37	16	31
Empidonax virescens	Acadian flycatcher	20.5	3.10	12	44

Marshall et al. (2013)

Streamside bird monitoring efforts in GARI from 2007-2012 identified 2,618 individuals (Appendix G) (Marshall et al. 2013). The most frequently detected species during the 6 years of monitoring was the hooded warbler, with 296 detections. The hooded warbler was followed by the red-eyed vireo, which had 191 individuals observed (Table 31). The five most commonly detected species during Marshall et al. (2013) made up 37.3% of all observations (Table 31). As previously mentioned, Marshall et al. (2013) sampled in streamside habitats, and likely observed streamside birds in higher numbers than bird species that may depend on other habitats.

Table 31. The five most commonly observed bird species during Marshall et al. (2013) monitoring in Gauley River National Recreation Area from 2007-2012.

Common Name	Total # individuals observed from 2007-2012
hooded warbler	296
red-eyed vireo	191
Acadian flycatcher	174
ovenbird	158
Louisiana waterthrush	157

One of the focal specialist species in the ERMN is the Louisiana waterthrush (*Parkesia motacilla*). This species is a migratory warbler that is a forest interior obligate species (Mattsson and Cooper 2006) that breeds along streams in the Appalachian region (the only such species in the Eastern U.S.). The ERMN documents Louisiana waterthrush occupancy network-wide, as the species is considered an indicator of overall riparian ecological condition (Mattsson and Cooper 2006, Latta and Mulvihill 2010, Marshall et al. 2013). The species' possible utility as an indicator of overall stream health is part of the reason that the ERMN selected streamside birds for monitoring (Marshall et al. 2013). Marshall et al. (2013) documented 157 Louisiana waterthrushes in GARI from 2007-2012 (Table 31).

Species Distribution

Species distribution was defined by NPS staff as the number of species encountered at each survey point. Of the data sources that have been summarized in this component, only the Wood et al. (2009) surveys reported the total number of species detected at each survey point. Because of this, only the Wood et al. (2009) data are discussed below. However, the Wood et al. (2009) survey efforts focused on a specific habitat type (hemlock stands) and only reported songbird species data.

Wood et al. (2009) detected an average of 10.31 species/point between 1999-2008 and observed an overall decreasing trend for the duration of the study. Of the three habitat guilds identified and monitored by Wood et al. (2009), the forest interior guild had the highest mean number of songbird species detected per point in GARI from 1999-2008 (4.62 species/point; Table 32). The interior edge guild had similar, albeit slightly smaller, species detections per point over the same period (4.53 species/point). The early successional habitat had the lowest number of species observed per point

(1.15 species/point), although this guild was the only guild to exhibit an increasing trend in species richness/point during Wood et al. (2009). The increasing trend observed in the early successional habitat did not appear to be tied to changes in the vegetation structure of the point count locations, and instead was likely due to other, unidentified factors.

Table 32. Average annual songbird species richness (total number of species detected per point) and the direction of annual trend of songbird detections from 1999-2008 (Table modified from Wood et al. 2009). "-" trend indicates decline, while "+" trend indicates increase.

Guild Group	Guild	Mean # of Species/Point	SE	Yearly Trend			
				R^2	F	p	Trend Direction
Habitat Guilds	Forest Interior	4.62	0.09	0.39	3.40	<0.001	Negative
	Interior-edge	4.53	0.10	0.44	8.26	<0.0001	Negative
	Early Successional	1.15	0.06	0.49	3.33	<0.001	Positive
Nesting Guilds	Subcanopy	2.86	0.06	0.48	2.40	0.012	Negative
	Canopy	2.24	0.06	0.48	5.75	<0.0001	Negative
	Shrub	1.46	0.05	0.47	2.62	0.006	Positive
	Ground	1.72	0.05	0.32	2.23	0.020	Negative
	Cavity	1.98	0.07	0.45	6.96	<0.0001	Negative
Overall	Species Richness	10.31	0.17	0.55	10.14	<0.0001	Negative

Five nesting guilds were identified during Wood et al. (2009): subcanopy, canopy, shrub, ground, and cavity nesting species. The subcanopy nesting species were detected most frequently at each point, with a mean of 2.86 species detected per point (Table 28). Shrub nesting species were detected in the lowest numbers (1.46 species/point) but were the only nesting g uild that exhibited an increasing species richness trend from 1999-2008 (Table 28).

Bird Community Index (BCI)

Bird Community Indices have been developed to better understand the health and biotic integrity of bird communities in specific regions, communities, or habitats. For streamside bird monitoring in the ERMN, Marshall et al. (2013) utilized a BCI developed by O'Connell et al. (1998a, b, 2000) that was based on the breeding bird communities of the central Appalachians. As described by Marshall et al. (2013, p. 23), the O'Connell et al. (1998a, b, 2000) BCI is

> *...based on 16 response guilds with each guild broadly classified as 'specialist' or 'generalist' depending on each guild's relationship to specific elements or biotic integrity (Table 33). Each species is assigned to a response guild and the BCI ranks the overall bird community detected at a site according to the proportional representation of the species in the response guilds.*

Table 33. Biotic integrity elements, guild categories, response guilds, and guild interpretations used in the O'Connell et al. (1998a, b, 2000) Bird Community Index of ecological integrity.

Biotic Integrity Element	Guild Category	Response Guild	Specialist	Generalist
Functional	trophic	omnivore	–	X
Functional	insectivore foraging behavior	bark prober	X	–
Functional	insectivore foraging behavior	ground gleaner	X	–
Functional	insectivore foraging behavior	upper-canopy forager	X	–
Functional	insectivore foraging behavior	lower-canopy forager	X	–
Compositional	origin	exotic/nonnative	–	X
Compositional	migratory	resident	–	X
Compositional	migratory	temperate migrant	–	X
Compositional	number of broods	single-brooded	X	–
Compositional	population limiting	nest predator/brood parasite	–	X
Structural	nest placement	canopy nester	X	–
Structural	nest placement	shrub nester	–	X
Structural	nest placement	forest-ground nester	X	–
Structural	nest placement	open-ground nester	X	–
Structural	primary habitat	forest generalist	–	X
Structural	primary habitat	interior forest obligate	X	–

BCI scores were broken down into four ecological condition categories: highest integrity (60.1-77.0), high integrity (52.1-60.0), medium integrity (40.1-52.0), and low integrity (20.5-40.0). A high BCI score (i.e., the higher ecological condition categories) corresponds to communities that have a higher proportion of specialist avian species relative to generalist species.

BCI scores in GARI from 2007-2012 were all high, with average values falling into either the "highest" or "high" ecological condition categories (Figure 25). The park-wide average BCI score was 60 ± 2.4, which was above the threshold for the 'highest' ecological integrity category. GARI had among the highest BCI scores of any park in the ERMN (with BLUE having the highest). These high scores reflect the overall quality of the largely unfragmented forests of the park, and the fact that the park is home to a robust group of forest interior specialist species for much of the year.

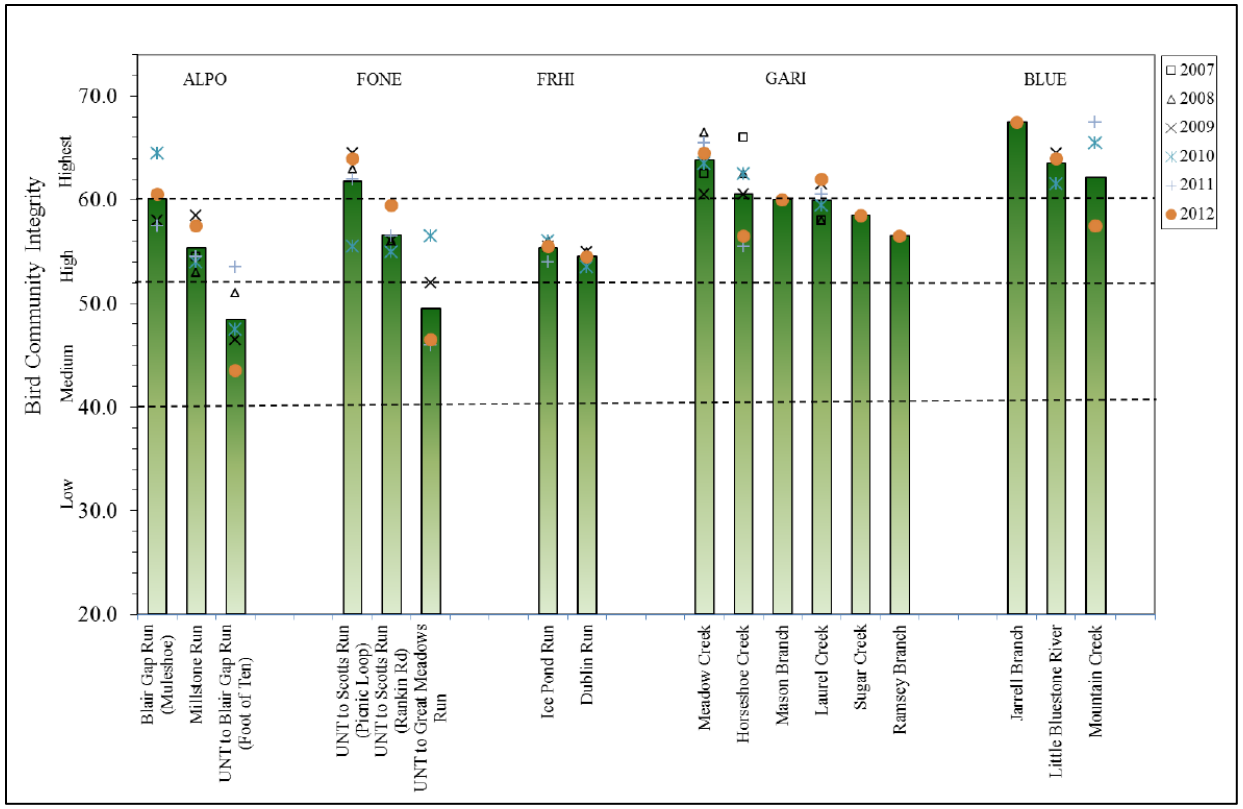


Figure 25. Bird community index (BCI) of biotic integrity (O'Connell et al. 2000) for several Eastern Rivers and Mountains Network parks. BCI results for Gauley River National Recreation Area are depicted on the mid-right of the graph. Bar height represents the mean of 1-6 years of sampling. Points depict values for individual years. Higher values indicate higher ecological integrity. Dashed horizontal lines depict thresholds between low, medium, high, and highest ecological integrity (reproduced from Marshall et al. 2013). ALPO = Allegheny Portage Railroad National Historic Site, FONE = Fort Necessity National Battlefield, FRHI = Friendship Hill National Historic Site.

Threats and Stressor Factors

NPS staff identified several threats to GARI's bird communities, including climate change, water quality, timber plots outside of park, and cultivated agriculture upstream of the park. Climate change is one of the major forces affecting bird communities across the globe (NABCI 2010); this threat is becoming better understood as research and data continue to become available. Changes in the temperature and precipitation norms in the park could have both direct and indirect effects on the bird community of GARI. An example of a direct impact to the bird community in the park includes potential shifts in the timing of spring plant phenology, while indirect impacts resulting from shifts in temperature and precipitation could include effects on the frequency, extent, and severity of insect outbreaks. These insect outbreaks often have lasting effects on communities, particularly the hemlock groves of the park, as tree mortality can influence the overall habitat structure and species composition of forest areas for many years (Wood et al. 2009).

Another climate-related threat facing breeding landbird populations is the shifting of species' reproductive phenology. Several bird species depend on temperature ranges or weather cycles to cue

their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins (*Turdus migratorius*) in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success and population declines (Jones and Cresswell 2010).

Migratory bird species face deteriorating habitat conditions along their migratory routes and on wintering grounds. Most of the birds that breed in the U.S. overwinter in the Neotropics (MacArthur 1959); deforestation in these wintering grounds has occurred at an annual rate up to 3.5% (Lanly 1982). While forest and habitat degradation does occur in the United States, it does not approach the level of degradation seen in the tropics (WRI 1989). Furthermore, Robbins et al. (1989) supported the suggestion that deforestation in the tropics has a more direct impact on Neotropical migrant populations than deforestation and habitat loss in the U.S.

In forested areas surrounding GARI, most of the timber is considered harvestable, and active logging occurs near and adjacent to the park (Purvis 2002). Logging, and the roads associated with logging activity, increase soil exposure and erosion, which in turn increases sedimentation of streams in the area (Hebner 1991, Purvis 2002), and opens the potential for transport and establishment of non-native plant species. Additionally, the removal of mature timber trees eliminates nesting and foraging habitat for many forest interior species, and creates additional edge habitats.

Degradation of the park's water quality could have impacts on GARI's bird population, especially with the high observed levels of biotic integrity in these areas reported by Marshall et al. (2013). As previously discussed, logging activities increase sedimentation in area streams, and contributes to a reduction in overall stream quality. Coal mining activity also represents a threat to the park's water quality, as the Peters Creek watershed has been particularly affected by coal mining activity (Chambers and Messinger 2001). Reductions in aquatic invertebrate species, especially as related to water quality changes, could affect forage success of various wading and waterfowl species. An additional water quality threat in the area are the agricultural practices that occur within the GARI region.

Data Needs/Gaps

Continuation of both the annual NPS-led PCS efforts and the ERMN streamside bird monitoring (Marshall et al. 2013) in the park would allow for long-term trend analysis for many observed species, and would allow managers to better monitor the health of the park's avian and vegetation communities. The NPS-led PCS efforts are especially important to continue as it represents the longest avian survey to take place in the park, with almost 20 years of data, and it also covers a much broader range of habitats than the ERMN streamside monitoring.

Expansion of survey efforts could include sampling of the raptor communities in the park, as these species are often under-represented during traditional point count methodologies. Additionally,

surveys of overwintering species could provide managers with a greater insight into the overall health of the resident and overwintering migrant species.

The Wood et al. (2009) monitoring plots have continued to be surveyed following the 2009 publication. Surveys have continued through the 2017 field season, but the data have not been summarized to date. These data need to be summarized, and doing so will be highly informative for future condition assessments, as they will provide park managers with a long-term, continuous data set related to a critical habitat type in the GARI area.

Overall Condition

Species Richness

The GARI project team assigned the species richness measure a *Significance Level* of 3 during project scoping. Determining the species richness condition is a bit unique, as higher species richness estimates do not always correlate to higher indices of quality. The presence of non-native species, generalist species, or vagrant species may increase the species richness estimate while not truly increasing the overall condition of the avian community. Instead, species richness must be assessed based on the expected species in the park, as well as making sure that focal communities and guilds (e.g., forest-dwelling species) remain intact and free from excessive generalist species.

Species richness estimates from surveys in GARI indicate that annual species richness levels are about what is to be expected based on the size and location of the park. Yearly species richness estimates remained relatively constant throughout the NPS-led PCS, with the exception of 2016 when flood waters altered the sampling frequency. Similarly, results from Pauley et al. (2005) and Wood et al. (2009) indicated relatively stable species richness estimates for the park

The species richness estimates of forest dwelling species remained high throughout the duration of all surveys, indicating that the forest community in GARI is in good condition. The most common and frequently observed species during the NPS PCS efforts were nearly universally forest-dwelling species. For these reasons, the *Condition Level* of species richness in GARI was determined to be 0, indicating no current concern.

Species Abundance

The species abundance measure for GARI was assigned a *Significance Level* of 2. Abundance estimates obtained during NPS-led PCS efforts were variable, but overall species abundance estimates did not indicate any major declines or problematic trends. The majority of the most frequently detected bird species during the NPS PCS efforts were interior forest obligates, such as the scarlet tanager, Swainson's warbler, and red-eyed vireo. Similarly, the Wood et al. (2009) hemlock habitat surveys detected forest-dependent species in high numbers.

The persistent abundance of these species again highlights the overall health of both the forest communities and the forest-dependent species in the park. The absence of these species, or a dramatic reduction in annual abundance would likely indicate a shift in the overall health of the interior forest communities, and no such trend was apparent from 1998-2017.

At present, there does not appear to be any major concern regarding the annual abundance of birds in GARI. However, there is a lack of recent data available outside of the NPS-led PCS efforts. While ERMN streamside bird monitoring is still ongoing, the results from 2012-2018 are yet to be summarized. A *Condition Level* of 1 was assigned for species abundance at this time; however, expansion of survey efforts and the summarization of recent ERMN monitoring data is needed to assign higher confidence in this assessment

Species Distribution

A *Significance Level* of 2 was assigned to the species distribution measure. Only the Wood et al. (2009) surveys documented the number of species detected at each survey point, although those survey efforts focused on a specific habitat type (hemlock stands) and only reported songbird species data. While it is possible to recognize potential trends in the hemlock communities from the Wood et al. (2009) data, distribution trends from the other data are not discernable. Current condition designation for this measure relies largely on professional judgement of NPS staff and interpretation of existing data where appropriate.

Wood et al. (2009) detected an average of 10.31 species/point between 1999-2008, and observed an overall decreasing trend for the duration of the study. Of the three habitat guilds identified and monitored by Wood et al. (2009), the forest interior guild had the highest mean number of songbird species detected per point in GARI from 1999-2008 (Table 32). The interior edge guild had similar, albeit slightly smaller, species detections per point over the same period (Table 32). The early successional habitat had the lowest number of species observed per point, although this guild was the only guild to exhibit an increasing trend in species richness/point during Wood et al. (2009). The increasing trend observed in the early successional habitat did not appear to be tied to changes in the vegetation structure of the point count locations, and instead was likely due to other, unidentified factors.

The hemlock-specific data from Wood et al. (2009), combined with the abundance and richness estimates reported previously by the NPS PCS efforts, Pauley et al. (2005), and Marshall et al. (2013), appear to indicate there is currently low concern in regards to avian distribution in the park. It is very apparent that the dense forests of the park support many species and in high numbers. At this time, the species distribution measure is assigned a *Condition Level* of 1, indicating low current concern.

Bird Community Index (BCI)

The bird community index measure was assigned a *Significance Level* of 3 during project scoping. As determined at project scoping, this measure was to deal primarily with the work of Marshall et al. (2013), as this was the only study in GARI that had reported a BCI. Overall, BCI scores in GARI were high from 2007-2012, with average values falling into either the “highest” or “high” ecological integrity categories for all sites. The BCI values for GARI were among some of the highest values obtained ERMN-wide by Marshall et al. (2013), indicating very high ecological integrity at GARI. For these reasons, the bird community index measure was assigned a *Condition Level* of 0, indicating no current concern for this metric.

Weighted Condition Score

The birds component was assigned a *Weighted Condition Score* of 0.13 (Table 34), indicating good current condition. The number of species and individuals associated with intact forests remained high throughout the period of record, indicating that the critical forest community remains healthy and is supporting many birds. Confidence in this assessment is high, and the current trend for this resource appears to be stable at present.

Table 34. Current condition of Gauley River National Recreation Area's Bird Community.

Measures	Significance Level	Condition Level	WCS = 0.13
Species Richness	3	0	
Species Abundance	2	1	
Species Distribution	2	1	
Bird Community Index	3	0	

4.5.6. Sources of Expertise

- Lenza Paul, GARI Biological Science Technician
- Matt Marshall, ERMN Program Manager

4.6. Mammals

4.6.1. Description

Mammals are some of the most visible and recognizable wildlife in eastern national parks. The mature forests, cliffs, and riparian areas of GARI provide favorable habitat for many species, including common forest mammals such as white-tailed deer, raccoons, and squirrels. These same habitats are critically important foraging and summer roosting areas for many bat species in the park (Castleberry et al. 2007). Bat activity in the region is often associated with riparian zones, but edge habitats are also important, as insects are often abundant and the relatively open nature allows for clearer flight and echolocation paths (Schirmacher et al. 2007). GARI supports several mammal species of conservation concern (NPS 2016d) (Table 35). Two of these species are federally protected, the Indiana bat (*Myotis sodalis,* Figure 26) as an endangered species and the northern myotis (*M. septentrionalis*) as a threatened species.

Table 35. Mammal species of concern occurring within Gauley River National Recreation Area, along with their West Virginia state ranks (WVDNR 2015).

Scientific Name	Common Name	State Rank[A]
Lasionycteris noctivagans	silver-haired bat	S2
Myotis leibii	eastern small-footed myotis	S1
Myotis septentrionalis	northern myotis/long-eared bat	S3
Myotis sodalis	Indiana bat	S1
Neotoma magister	Allegheny woodrat	S3
Cryptotis parva	least shrew	S2
Sorex dispar	long-tailed shrew	S2S3

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation



Figure 26. The Indiana bat (left, USFWS photo by Adam Mann) and Allegheny woodrat (right, photo by Steven B. Castleberry) are two mammal species of conservation concern found at Gauley River National Recreation Area.

4.6.2. Measures

- Species richness
- Bat species richness
- Allegheny woodrat presence/absence
- Annual harvest numbers

4.6.3. Reference Condition/Values

Historic literature pertaining to West Virginia's mammals is scarce, and no information specific to GARI's mammal populations was published until 2005 (Pauley et al. 2005). As a result, the reference condition for this component is currently undefined. The information presented in this assessment may be used as a baseline for assessing the condition of this resource in the future.

4.6.4. Data and Methods

From 2000-2001, Pauley et al. (2005) conducted a park-wide mammal inventory at GARI utilizing various methods. Small mammals were captured with Sherman live traps, pitfalls, tomahawk traps, and snap traps. Pitfall traps consisted of half gallon buckets set flush with the ground on wooded slopes, in riparian areas, and along rock outcrops (Pauley et al. 2005). Bats were sampled with mist nets, beginning one hour before dusk and continuing throughout the night (Pauley et al. 2005).

Beginning in 1999, Wood (2001) conducted searches for Allegheny woodrats (*Neotoma magister*) at several locations in the park. Suitable rocky habitat was first searched for woodrat sign (e.g., middens or latrine areas) to identify sites for trapping. Some sites with prime habitat but no sign of woodrats were also trapped. Six sites at GARI were selected for trapping, four on the Gauley River and two on the Meadow River. Each site was trapped for two consecutive nights using Tomahawk live traps baited with apple (Wood 2001).

Johnson et al. (2003) surveyed abandoned mine portals at GARI for bat species in the fall of 2002. Two mine locations were monitored from sunset until midnight using Anabat II acoustic detectors; 11 mines were sampled using mist nests or harp traps. Castleberry et al. (2007) surveyed natural habitats at GARI for bat species during the summers of 2003 and 2004. Both acoustic monitoring and live capture techniques were utilized. Mist net surveys were conducted in four areas of concentrated bat activity, such as above water sources or along flight corridors (roads and trails). Sampling began at sunset and continued for approximately 5 hours (Castleberry et al. 2007). Acoustic surveys were conducted with an Anabat II detector during the 2-3 hours right after sunset at 63 locations in 2003 (July-Sept) and 80 locations in 2004 (May-Aug). However, considering that is difficult to distinguish between several *Myotis* species with similar echolocation call structures during acoustic surveys (Castleberry et al. 2007), this NRCA will focus on the more reliable mist net survey results.

Hunting harvest data for white-tailed deer and black bears (*Ursus americanus*) are reported at the county level by the WVDNR in annual Big Game Reports (WVDNR 2011, 2016) and, more recently, in online press releases (WVDNR 2017e, 2018).

4.6.5. Current Condition and Trend

Species Richness

The species richness measures in this component refers to the total number of species present in a given study, survey, or other monitoring effort. It is important to note that a higher species richness estimate does not always correlate to a "healthier" community. The mature, largely unfragmented forests typical of the GARI area may exhibit lower species richness estimates but could still be considered in good condition, as they provide and sustain critical habitat for some specialized species of wildlife. The fragmentation of these forests may encourage non-native species to move in, which would increase the species richness, but could lower the overall condition of the community.

According to NPSpecies (NPS 2016d), 43 mammal species have been confirmed as present in the park with one unconfirmed species, Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) (Appendix H). Three species are non-native to North America: the house mouse (*Mus musculus*), Norway rat (*Rattus norvegicus*), and feral cat (*Felis catus*). Thirty-eight of the confirmed species, including the three non-natives, were observed by Pauley et al. (2005) from 2000-2001. The river otter (*Lontra canadensis*) and fisher (*Martes pennanti*) were successfully reintroduced to the state in the 1990s (Evans 2005) and may have expanded into the GARI area but have not yet been documented in the park. Given that West Virginia as a whole supports 66 native mammal species and GARI does not contain the same number and type of habitats as the entire state, this species richness is about what would be expected for the park.

Historically, several additional large mammals occurred in West Virginia and may have been present in what is now GARI. These include eastern elk (*Cervus elaphus canadensis*), bison (*Bison bison*), eastern cougars (*Puma concolor couguar*), and gray wolves (*Canis lupus*). However, the last known sightings of native individuals of these species in the state (excluding reintroduction attempts) were all prior to 1900 (WVDNR 2001, 2008).

Bat Species Richness

NPSpecies (NPS 2016d) lists nine bat species as present within GARI and one species as unconfirmed (Appendix H). Pauley et al. (2005) observed six species, including the only known report of Rafinesque's big-eared bat for the park (Table 36, Figure 27). Given that Rafinesque's big-eared bat populations have reportedly been declining in West Virginia and that GARI appears to be outside the most recently updated range map for the species (IUCN 2017), it seems unlikely that the species currently occurs at the park. In a survey of abandoned mines at GARI, Johnson et al. (2003) documented four species utilizing this man-made habitat. Castleberry et al. (2007) captured five species during mist netting. Acoustic surveys by Castleberry et al. (2007) detected the apparent calls of four additional bat species, but the presence of these species within park boundaries was not confirmed by physical captures. Rafinesque's big-eared bats can be difficult to detect with acoustic monitoring due to their low intensity calls and have a lower probability of being captured by mist netting because of their relatively short foraging distances (Castleberry et al. 2007).

Table 36. Bat species documented by various surveys at Gauley River National Recreation Area, 2001-2004.

Scientific Name	Common Name	Pauley et al. (2005)	Johnson et al. (2003)	Castleberry et al. (2007)
Eptesicus fuscus	big brown bat	x	–	x
Lasionycteris noctivagans	silver-haired bat	–	–	a[A]
Lasiurus borealis	eastern red bat	x	–	x
Lasiurus cinereus	hoary bat	x	–	a
Myotis leibii	eastern small-footed myotis	x	x	a
Myotis lucifugus	little brown bat	x	x	x
Myotis septentrionalis	northern myotis	–	x	x
Myotis sodalis	Indiana bat	–	–	a
Perimyotis subflavus	tricolored bat	x	x	x
Corynorhinus rafinesquii	Rafinesque's big-eared bat	x	–	–

[A] a = acoustic detection only; not confirmed by physical capture.




Figure 27. Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)(left, USFWS photo) and silver-haired bat (*Lasionycteris noctivagans*) (right, NPS photo by Sally King).

Allegheny Woodrat Presence/Absence

The Allegheny woodrat is a nocturnal rodent associated with rock outcrops, caves, and cliff and talus slopes in the central and southern Appalachians (Wood 2001, Castleberry et al. 2006). In recent decades, the species has experienced declines in large portions of its range, possibly associated with declines in key forage species such as the American chestnut (*Castanea dentata*) and oaks (*Quercus* spp.) (Castleberry et al. 2006, Manjerovic et al. 2009). At GARI, Allegheny woodrats have been documented at several locations in the eastern portion of the park. In the summer of 1999, Wood (2001) captured individuals at four locations: south of Carnifex Ferry Battlefield State Park, south of the Summersville Dam, near Mt. Lookout east of the Meadow River, and near Underwood Road just north of the Meadow River (Table 37). Two of these locations (Summersville Dam and Underwood) have been revisited for trapping in subsequent years. Allegheny woodrats were detected at Summersville Dam site 1 on five additional visits, most recently in September 2011, and were not setected on three occasions (NPS 2014a). At Underwood, woodrats were captured during eight additional visits (most recently in August 2014) and were not detected on two occasions (Table 37).

Table 37. Presence/absence of Allegheny woodrats at Gauley River National Recreation Area sites (NPS 2014a).

Location	# of Visits	Times Detected	Times Not Detected
Carnifex Ferry 1	1	Aug 1999	–
Carnifex Ferry 2	1	–	Aug 1999
Summersville Dam 1	9	July 1999, Aug 2001, Aug 2002, June 2003, Oct 2005, Sept 2011	June 2004, July 2007, Sept 2010
Summersville Dam 2	1	July 1999	–
Mt. Lookout	1	June 1999	–
Underwood	11	July 1999, July 2001, Aug 2002, Aug 2005, July 2007, Sept 2010, July 2011, Aug 2012, Aug 2014	Aug 2003, July 2004

Annual Harvest Numbers

In the absence of population size monitoring, harvest numbers and trends provide some insight into the condition of wildlife populations. In West Virginia, black bear and white-tailed deer harvest statistics are reported by county on an annual basis. Statewide, black bear harvest has generally increased since the mid-1980s (Figure 28). Harvests exceeded 3,000 individuals in 2015 (3,201 bears), 2016 (3,012 bears), and 2017 (3,160 bears) (WVDNR 2016, 2017d, 2018).

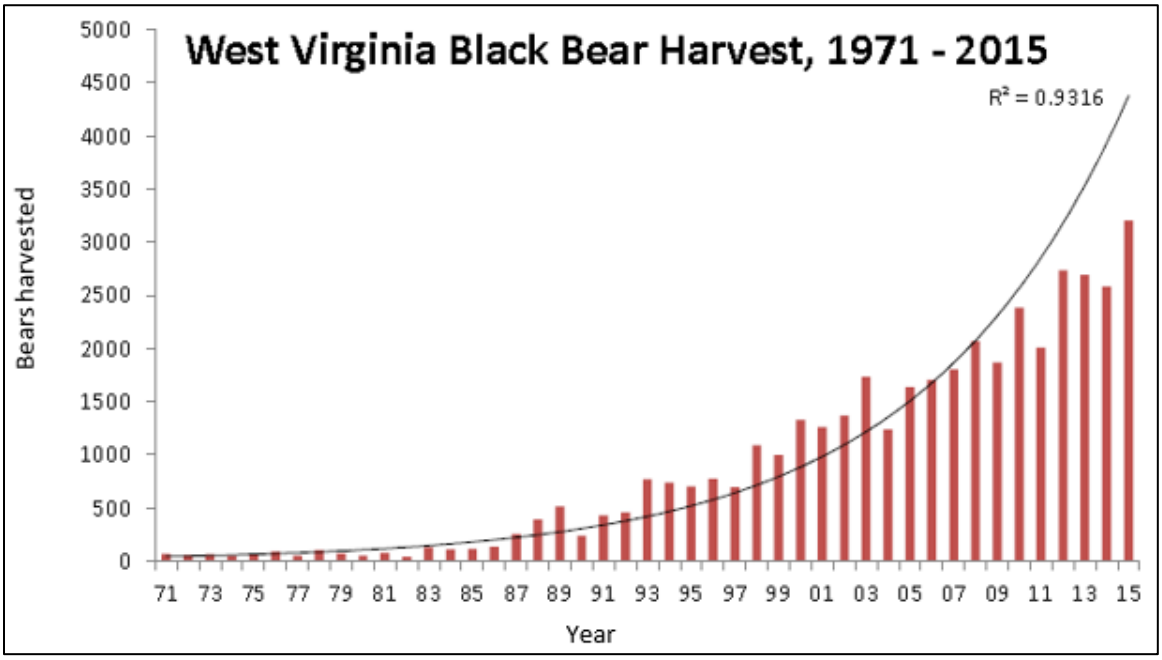


Figure 28. West Virginia black bear harvest, 1971-2015 (reproduced from WVDNR 2016).

The counties that include GARI (Nicholas and Fayette) have also experienced relatively stable or slightly above average black bear harvest numbers in recent years (Table 38). In Nicholas County,

harvest peaked at 266 bears in 2015 and remained above 200 bears in 2016 and 2017 (WVDNR 2016, 2017d, 2018). Fayette County harvest numbers peaked in 2012 at 192 bears but was also high in 2015 (162 bears) and 2016 (147 bears). While numbers have fluctuated somewhat between years, these statistics do not raise any particular cause for concern regarding black bear population size in the GARI region.

Table 38. Black bear harvest within the counties that include Gauley River National Recreation Area, 2011-2017 (WVDNR 2016, 2017d, 2018).

County	2011	2012	2013	2014	2015	2016	2017
Nicholas	120	149	146	164	266	213	240
Fayette	98	192	138	111	162	147	109

White-tailed deer harvest in West Virginia increased from the 1970s through the 1990s, peaking in 2002 (Figure 29). Numbers declined during the mid-2000s but appear to have stabilized between 100,000 and 150,000 deer harvested annually (WVDNR 2016).

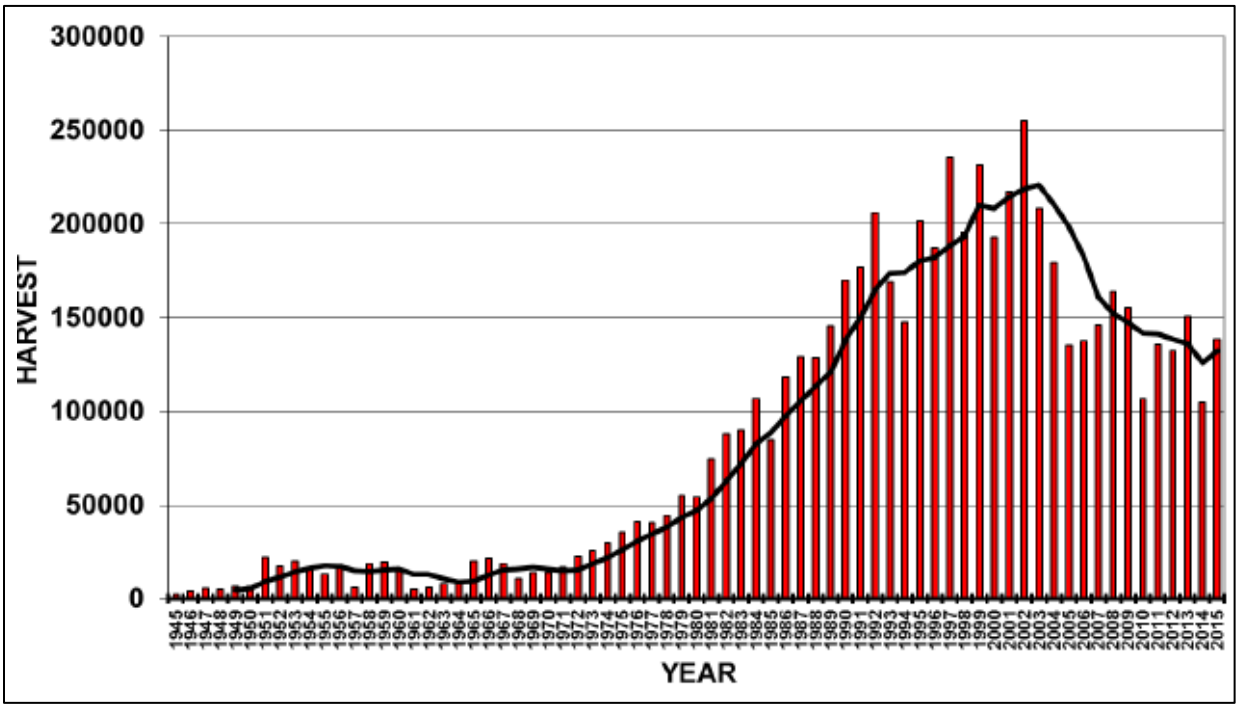


Figure 29. White-tailed deer harvest in West Virginia from 1945-2015 (reproduced from WVDNR 2016).

In Nicholas County, annual white-tailed deer harvest over the past 10 years (2007-2016) has ranged from 1,731 in 2010 to 2,944 in 2015, with an average of 2,380 deer (Table 39). The annual deer harvest in Fayette County ranged from 1,349 in 2010 to 2,665 in 2008, with an average of 2,134 deer (WVDNR 2011, 2016, 2017e). In general, harvest numbers likely fluctuate naturally over time, but

current numbers and trends for the GARI region do not raise any particular concerns with regards to the deer population.

Table 39. White-tailed deer harvest within the counties that include Gauley River National Recreation Area, 2007-2016 (WVDNR 2011, 2016, 2017e).

County	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Nicholas	2,248	2,158	2,318	1,731	2,556	2,746	2,372	2,214	2,944	2,511
Fayette	2,546	2,665	2,180	1,349	2,020	2,319	1,818	1,851	2,590	1,997

Threats and Stressor Factors

Threats to mammals at GARI include habitat fragmentation, recreational uses, development on neighboring private lands, invasive species, climate change, hunting pressure, and white-nose syndrome (WNS). As described in Chapter 4.1, fragmentation has been occurring in the GARI region since logging began in the late 1800s (Streets and Vanderhorst 2010). Other human uses, such as gas extraction development and recreational/residential development also contribute to habitat fragmentation. Such fragmentation often limits mammal species' movements and dispersal, influencing species abundance and density, genetic diversity, and interspecific interactions (Rentch 2006). Fragmentation also creates more "edge" areas, where wildlife are potentially vulnerable to increased predation, exposure to pathogens, and competition with non-native species (Wood 2001, Rentch 2006). The effects of fragmentation have likely contributed to the decline of Allegheny woodrats in large portions of their range (Wood 2001, Monty and Feldhamer 2002, Manjerovic et al. 2009). Non-native mammals known to occur at GARI that could compete with or prey upon native species include the house mouse, Norway rat, and feral cats (NPS 2016d). Although feral hogs (*Sus scrofa*) have not been detected in the counties surrounding GARI, they do occur in the state and would pose a threat to wildlife and habitat if they reached the park (McCoy 2016; Lenza Paul, NERI/GARI/BLUE Biological Science Technician, written communication, May 2018).

Allegheny woodrat declines may also be linked to reduced food availability as a result of changes in forest composition and productivity. American chestnut blight (*Cryphonectria parasitica*), gypsy moth infestation, continued logging, and reduced acorn production have negatively impacted common mast-producing trees of eastern forests (Monty and Feldhamer 2002, Manjerovic et al. 2009). These changes in food availability likely impact other mammal species as well. In addition, Allegheny woodrats are vulnerable to infection by the nematode parasite *Baylisascaris procyonis* (Monty and Feldhamer 2002). This parasite is carried by raccoons and may be picked up by woodrats exposed to raccoon feces while foraging. Woodrats that ingest the nematode eggs contract the parasite, become lethargic and lose muscle control, eventually leading to death (Monty and Feldhamer 2002).

Climate change could impact mammal populations directly (e.g., heat and/or water stress) and indirectly (e.g., altered habitats, food availability, pathogen presence/strength). Climate change may also impact seasonal cues that some mammals depend on to trigger behaviors (e.g., hibernation, breeding) (Bronson 2009). In a statewide assessment, Byers and Norris (2011) concluded that two

West Virginia species of special concern at GARI are particularly vulnerable to climate change: the Indiana bat and the Allegheny woodrat. Due to its similar habitat needs, the northern myotis is also likely vulnerable to climate change (Sheila Colwell, NPS Wildlife Biologist, written communication, 26 April 2018).

Although not currently a concern, hunting pressure may pose a threat to the park's mammal populations. Hunting is allowed on park lands in accordance with WVDNR state regulations. Deer and bear hunting seasons generally extend from October through December, and some smaller mammals may be hunted throughout the fall and winter (squirrels, foxes, cottontail rabbits [*Sylvilagus floridanus*]), or year-round (skunk [*Mephitis mephitis*], Virginia opossum [*Didelphis virginiana*], woodchuck [*Marmota monax*], coyote [*Canis latrans*]) (WVDNR 2017a). Given the remoteness of GARI and the challenges it creates for enforcing hunting regulations, poaching (i.e., illegal hunting) may also be occurring (Paul, written communication, May 2018).

Recreational uses of park lands may cause stress or disturbance to some of the park's sensitive mammal species, including bats and Allegheny woodrats. These include legal activities (e.g., rock climbing in approved areas) and illegal activities (ORV use). Additional trail development and use could contribute to further habitat fragmentation and disturbance. Higher impact activities, such as ORV use, frequently cause disturbances that change the behavior of wildlife, which can increase the animals' energy expenditure and/or cause them to abandon suitable habitat areas (Knight and Cole 1995). A study in northern California found that even quiet, non-consumptive human recreation may negatively impact mammalian carnivore species (Reed and Merenlender 2008).

White-nose syndrome, caused by the fungus *Pseudogymnoascus destructans*, has emerged as the greatest threat to bats in North America in the past decade (Blehert et al. 2008, Castle and Cryan 2010, Cryan et al. 2010). First detected in upstate New York in 2006, WNS has spread rapidly across the U.S., reaching as far west as Oklahoma and Nebraska in just 10 years (an isolated case was confirmed in Washington State in 2015-2016; it is unknown how the disease traversed to the west coast and affected only an isolated county) (Figure 30) (USFWS 2018b). Affected bats exhibit a white fungal growth on their external body surface, usually around the muzzle, ears, or wings, and experience frequent winter arousal when hibernating. These arousals deplete the bat's body fat prematurely and cause them to experience dehydration, wing damage, starvation, and frequently, death (Foley et al. 2011). It is estimated that WNS has killed more than 6 million bats in the eastern U.S. and Canada since 2006 (Baker et al. 2015). In 2015, the northern myotis was listed as a federally threatened species due to population declines caused by WNS (USFWS 2018a). Transmission primarily occurs from bat-to-bat during the winter months, as the fungus that causes the disease thrives in cold temperatures; it is unknown, however, how long the fungal spores can persist. Anthropogenic spread of WNS is also possible, as contaminated caving gear, clothing, or recreational equipment (e.g., ropes, packs) may facilitate spread of the fungus (Baker et al. 2015, USGS 2017a).

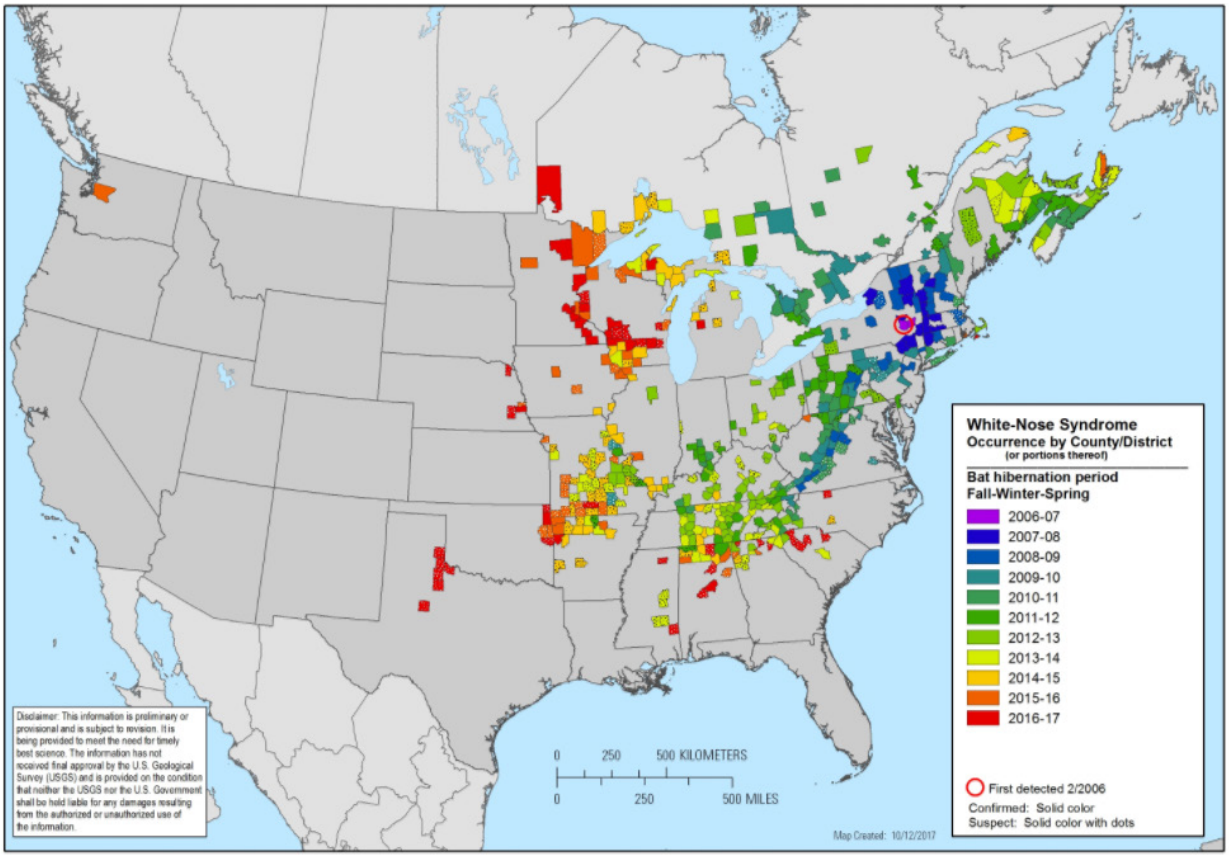


Figure 30. Counties and districts across the continental U.S. where white-nose syndrome has been confirmed, as of October 2017 (Reproduced from USFWS 2018b). Colors represent the year in which the disease was first detected.

In West Virginia, WNS was first detected in Pendleton County in 2009 (WVDNR 2015). By 2012, the disease had spread across the karst regions of the state, affecting multiple bat species. In 2010, Francl et al. (2012) already noted dramatic declines in capture rates for little brown bats (*Myotis lucifugus*), northern myotises, eastern small-footed myotises (*M. leibii*), Indiana bats, and tricolored bats (*Perimyotis subflavus*). Based on winter 2014-2015 surveys in the state, little brown bats experienced a 97% population decline and Indiana bats an 85% decline (WVDNR 2015). It is not known if WNS has impacted bat populations in the GARI area, but it is highly likely, given the large declines in neighboring counties (Paul, written communication, May 2018).

Data Needs/Gaps

An updated inventory of GARI for mammal species would help to identify any trends in species richness or concerns regarding particular rare or sensitive species. Special attention is likely needed for bat species, given the impact of WNS on bat populations in other portions of the state. Bat inventory and monitoring efforts that utilize mist netting (i.e., physical captures) would be preferred, given the difficulties in distinguishing between several *Myotis* species with similar echolocation call structures during acoustic surveys. Additional study would also be needed to better understand the condition of GARI's Allegheny woodrat populations. This should include not only trapping surveys

but also studies of how the species interacts with the surrounding environment as well as any influence from human activities (Wood 2001).

Overall Condition

Species Richness

The project team assigned this measure a *Significance Level* of 3. Forty-three mammal species have been confirmed as present at GARI, along with one unconfirmed bat species (NPS 2016d). This represents 65% of all mammal species known to occur in the state of West Virginia. Only three confirmed species are considered non-native. Given the relatively small size of the park, this species richness is considered good. Therefore, this measure is assigned a *Condition Level* of 0.

Bat Species Richness

The bat species richness measure was also assigned a *Significance Level* of 3. GARI supports nine known bat species, with one additional species (Rafinesque's big-eared bat) considered unconfirmed (NPS 2016d). However, no bat survey results have been published since 2007 and, particularly given the presence of WNS in the region, it is unclear whether all of these species are still present within the park. As a result, a *Condition Level* cannot be assigned for this measure.

Allegheny Woodrat Presence/Absence

A *Significance Level* of 3 was assigned for this measure. Trapping during the summer of 1999 detected Allegheny woodrats at five locations within GARI. Two of these locations have been subsequently revisited for additional trapping. While woodrats have not been found on every visit, they have been detected more often than not (Table 39). However, given the limited sampling effort (two sites, most recent data from 2014), there is not enough information to assign a *Condition Level* for this measure at this time.

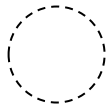
Annual Harvest Numbers

This measure was also assigned a *Significance Level* of 3. Although available harvest data are county-wide and not specific to GARI boundaries, they can provide some insight into the condition of the park's wildlife populations. At this time, the trends in harvest numbers do not indicate any cause for concern (*Condition Level* = 0).

Weighted Condition Score

A *Weighted Condition Score* was not assigned for GARI's mammals (Table 40), given the limited information for several of the selected measures. The current condition and trend of the park's mammal populations is unknown.

Table 40. Current condition of Gauley River National Recreation Area's Mammal Community.

Measures	Significance Level	Condition Level	WCS = N/A
Species Richness	3	0	
Bat Species Richness	3	n/a	
Allegheny Woodrat Presence/Absence	3	n/a	
Annual Harvest Numbers	3	0	

4.6.6. Sources of Expertise

- Sheila Colwell, NPS Wildlife Biologist
- Lenza Paul, NERI/GARI/BLUE Biological Science Technician

4.7. Herpetofauna

4.7.1. Description

Herpetofauna species are often used as indicator species in assessments of environmental health, particularly amphibian species that are highly sensitive to environmental change and degradation (Welsh and Ollivier 1998, Rentch 2006). Many herpetofauna species around the world are also in decline due to environmental stressors (Gibbons et al. 2000, Rentch 2006). Reptiles and amphibians are often understudied in protected areas, and have become a focal topic as protecting biodiversity has become a critical goal in NPS units (Scott and Seigel 1992).

The forests and aquatic habitats of GARI support a diversity of herpetofauna species, including three reptile species and four salamander species that are of special concern within the State of West Virginia (Pauley et al. 2005). All of these species of special concern are known to breed within the park (Pauley et al. 2005, NPS 2016d). Three of GARI's salamander species are endemic to the Appalachian Mountains: the black-bellied salamander (*Desmognathus quadramaculatus*), green salamander (*Aneides aeneus*), and Wehrle's salamander (*Plethodon wehrlei*) (WVDNR 2015). These endemic salamanders and several other species found at GARI lack lungs and "breathe" through their skin and mouth lining, making them very sensitive to environmental contaminants and changes in moisture levels. Terrestrial salamanders typically have specific temperature, moisture, and humidity requirements that limit their distribution within the landscape (WVDNR 2015).





The green salamander (*Aneides aeneus*) (left, USGS photo by Alan Cressler) and Wehrle's salamander (*Plethodon wehrlei*) (right, photo by Todd Pierson) are two of the Appalachian endemics that occur at Gauley River National Recreation Area.

Most amphibians require standing water for breeding habitat (WVDNR 2015). Due to the steep topography at GARI, natural pools suitable for breeding are somewhat rare. However, artificial pools that form in ruts in or along roads and trails (i.e., as a result of human activity) have become important breeding habitats for amphibians within GARI (Pauley et al. 2005). During vertebrate surveys, Pauley et al. (2005) observed egg masses from several frog and salamander species in these "road-rut pools". Habitats with rocks and/or large open areas, including roads and railroads, are valuable for reptiles and some amphibians that rely on solar radiation to warm their ectothermic (i.e., "cold-blooded) bodies (Pauley et al. 2005).



Egg masses from the wood frog (*Lithobates sylvaticus*, left), spotted salamander (*Ambystoma maculatum*, middle), and mountain chorus frog (*Pseudacris brachyphona*, right) were found in road-rut pools at Gauley River National Recreation Area. (WVDNR photos by Mark B. Watson).

4.7.2. Measures

- Species richness
- Species abundance
- Species distribution

4.7.3. Reference Condition/Values

Very little is known about the herpetofauna community within GARI. However, the most comprehensive source for the state (Green and Pauley 1987) lists 27 amphibian and 19 reptile species as occurring in Fayette and Nicholas Counties, where GARI is located. GARI may not contain all the habitats that are found across both counties and therefore may not support all of these species; however, the number of species identified by Green and Pauley (1987) will serve as an informal reference condition for the species richness measure. The reference conditions for species abundance and distribution are undefined at this time. Information presented in the current condition section of this report may be used as a baseline for assessing condition in the future.

4.7.4. Data and Methods

A herpetofaunal inventory of GARI was conducted from 1999-2004 by a team from Marshall University (Pauley et al. 2005). The objectives of this inventory were to document reptile and amphibian species, describe their habitats, and present management recommendations for park staff. Day and night-time searches were conducted across terrestrial and aquatic habitats in both upland and riparian areas throughout GARI. In addition to simple ground searches, team members utilized dip nets in pools and ponds, turtle traps in streams, and roadside breeding chorus surveys for frogs and toads (Pauley et al. 2005). A total of 597 sites were inventoried across 19 different habitat types.

4.7.5. Current Condition and Trend

Species Richness

During an extensive inventory of GARI, Pauley et al. (2005) documented 27 amphibian species and 19 reptile species (Appendix I). The amphibians documented included seven frog species, two toad species, and 18 salamander species. Reptiles included three lizard species, four turtle species, and 12

snake species. These inventory results match the number of amphibian and reptile species known to occur within Fayette and Nicholas Counties, as documented by Green and Pauley (1987).




The eastern worm snake (*Carphophis a. amoenus*) (left, photo by Mark B. Watson) and timber rattlesnake (*Crotalus horridus*) (right, NPS photo by Kent Walters) are special concern reptile species found at Gauley River National Recreation Area.

Species Abundance

Pauley et al. (2005) observed a total of 1,152 individual reptiles and amphibians throughout their inventory period. The majority of individuals observed (~80%) were amphibians (Table 41). Among amphibians, salamanders were most abundant (67% of amphibian individuals), followed by frogs (28% of individuals). Among reptiles, snakes were most abundant (43% of reptile individuals), followed by lizards (35% of reptile individuals) (Pauley et al. 2005). Five or fewer individuals were documented for six different amphibian species (primarily salamanders) and for seven reptile species (primarily snakes). However, Pauley et al. (2005) noted that many reptiles and amphibians are naturally secretive, and some individuals may not have been detected despite thorough searching. As a result, it is possible that some species are more abundant at GARI than the results of this survey suggest. Species abundances by habitat type are provided in Appendix J (terrestrial habitats) and Appendix K (aquatic habitats).

Table 41. The abundance of herpetofaunal categories documented at Gauley River National Recreation Area by Pauley et al. (2005), along with the most abundant species in each category.

Species	Individuals
Total reptiles	**230**
Total turtles	51
Eastern box turtle (Terrapene carolina carolina)	39
Total lizards	80
Five-lined skink (*Eumeces fasciatus*)	49

Table 41 (continued). The abundance of herpetofaunal categories documented at Gauley River National Recreation Area by Pauley et al. (2005), along with the most abundant species in each category.

Species	Individuals
Total snakes	99
Northern copperhead (Agkistrodon contortrix mokasen)	19
Total amphibians	**922**
Total toads	39
Eastern American toad (Anaxyrus americanus americanus)	34
Total frogs	262
Cope's gray treefrog (*Hyla chrysoscelis*)	91
Total salamanders	621
Seal salamander (Desmognathus monticola)	146

Species Distribution

Pauley et al. (2005) found more herpetofauna species and individuals in GARI's aquatic habitats (39 species, 586 individuals) than in terrestrial habitats (34 species, 426 individuals), despite sampling a slightly greater number of terrestrial sites (Table 42). Road-rut pools supported the highest number of amphibian species (22) and individuals (268) of any single habitat type. Trails/roads and banks supported the highest number of reptile species (10) and individuals (46) as well as the second highest amphibian species richness (13). Species richness was also high in deciduous forests, fields and rights-of-way, and rock outcrops (Pauley et al. 2005).

Table 42. Number of herpetofauna species and total individuals observed by habitat type within Gauley River National Recreation Area (Pauley et al. 2005).

Habitat Type	Total Sites	Species Richness		Total Individuals	
		Reptiles	Amphibians	Reptiles	Amphibians
Terrestrial	**290**	**13**	**21**	**167**	**259**
Trails/roads and banks	77	10	13	46	71
Deciduous forest	81	7	13	24	103
Fields and rights-of-way	19	7	9	25	11
Rock outcrops	51	5	10	7	57
Rock piles	20	6	2	18	2
Railroads	12	5	0	45	0
Emergent rocks or boulder fields	27	1	4	2	8
Railroad tunnels	3	0	5	0	7

Table 42 (continued). Number of herpetofauna species and total individuals observed by habitat type within Gauley River National Recreation Area (Pauley et al. 2005).

Habitat Type	Total Sites	Species Richness		Total Individuals	
		Reptiles	Amphibians	Reptiles	Amphibians
Aquatic	**266**	**15**	**24**	**41**	**538**
Road-rut pools	135	7	22	16	268
First-order streams	38	1	10	2	119
Second-order streams	16	2	8	2	30
Springs/seeps	15	1	9	1	47
Riparian floodplains	9	3	4	4	7
Wet rock faces	9	3	4	4	16
Gauley/Meadow Rivers	11	6	1	14	1
Ephemeral pools	12	0	7	0	14
Third-order streams	7	0	5	0	28
Flood scar depressions	8	2	3	3	7
Permanent pools	6	2	1	2	2

The number and diversity of habitat types where a species was observed provides some insight into their distribution. Species found in a greater number of habitats, and in both terrestrial and aquatic types, likely have a wider distribution. At GARI, the most widely distributed reptile was the eastern fence lizard (*Sceloporus undulatus*), found in eight of the 19 habitat types (seven terrestrial, one aquatic) (Appendix L). The eastern box turtle (*Terrapene c. carolina*) and five-lined skink (*Eumeces fasciatus*) were also widely distributed among terrestrial and aquatic habitat types (Pauley et al. 2005). Reptiles that were found in a single habitat type included two snake species, two turtle species, and the broad-headed skink (*Eumeces laticeps*), a state species of conservation concern (Appendix L).

Among amphibians, the most widely distributed species was the red-spotted newt (*Notophthalmus v. viridescens*), which was found in 10 habitat types (five terrestrial, five aquatic). The northern green frog (*Lithobates clamitans melanota*) and northern dusky salamander (*Desmognathus fuscus*) were also found in a high number of habitats (nine and eight, respectively), but the majority of these habitat types were aquatic (Pauley et al. 2005). The four amphibian species that were limited to a single habitat type were all salamanders (Appendix L).

Maps of the sampling locations where each herpetofauna species was encountered by Pauley et al. (2005) are included in Appendix M. While many species were distributed throughout the park, some were more common in the western, downstream portion of the park (e.g., timber rattlesnake [*Crotalus horridus*], eastern milk snake [*Lampropeltis t. triangulum*], northern map turtle [*Graptemys geographica*]), or in the eastern, upstream portion (e.g., northern ringneck snake

[*Diadophis punctatus edwardsii*], American bullfrog [*Lithobates catesbeianus*], northern red salamander [*Pseudotriton r. ruber*]).

Threats and Stressor Factors

Threats to GARI's herpetofauna include habitat fragmentation, land development, impaired water quality, pathogens, recreational use, bait collection and release, illegal moss harvest, pesticides, and climate change. Habitat loss and alteration are considered primary threats to herpetofauna populations. In North America, the loss of freshwater wetlands has been substantial (Dahl 2000). A reduction in these important aquatic habitats, along with an increase in landscape fragmentation, have been implicated in declining trends in aquatic biodiversity, particularly aquatic reptile and amphibian taxa (Bates et al. 2008). At GARI, deciduous forests also support a high diversity of herpetofauna but are impacted by fragmentation, which impacts species movement/migration (Pauley et al. 2005). As mentioned in Chapter 4.1, fragmentation due to logging has been occurring in the GARI region since the late 1800s (Streets and Vanderhorst 2010). Some of the tracts currently owned by the NPS were logged shortly before their acquisition, and some private holdings within the park boundary have been logged more recently (Streets and Vanderhorst 2010). Recreational trails, transportation corridors (roads and railways), and gas extraction structures also fragment the park landscape, exposing forest edges to additional threats such as exotic species invasion, alteration of temperature/moisture regimes, and exposure to harsh weather conditions (Pauley et al. 2005, Rentch 2006).

With many of GARI's herpetofauna species dependent on aquatic habitat at some stage in their life cycles, drought is a major threat to these populations. Climate change has been implicated in widespread drought events, which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and occasional flooding that damage riparian areas and other important aquatic habitats, as well as degrading water quality (Bates et al. 2008). Riparian flooding during the summer may destroy vegetative cover utilized by young herpetofauna and could wash away larval amphibians and/or turtle nests (Purvis 2002). An overall increase in global temperatures associated with climate change, which contributes to extended periods of drought, will have a combined effect on biota by causing temperature and water stress (Bates et al. 2008). In West Virginia, amphibians have been identified as one of the taxonomic groups most vulnerable to climate change (Byers and Norris 2011), with some species already being negatively impacted within the state (Pauley 2006).

Ranavirus is a genus in the family Iridoviridae which can infect multiple species of amphibians and some reptiles (e.g., box turtles) (USGS 2016b). These viruses have been associated with die-offs of more than 20 species of amphibians and turtles in over 25 states across the U.S, and they are known to be present in West Virginia (WVDNR 2015, USGS 2016b). Mortality due to ranaviruses occurs mostly in larval amphibians, true frogs, and chorus frogs. Infected individuals may exhibit subtle or severe hemorrhages in ventral skin, often appearing as an irregular rash; onset of illness is sudden and frequently affects most individuals within a wetland (up to or exceeding 90%) (USGS 2016b). Observed outbreaks have often been within wetland ecosystems and cause mass die-off of frogs and salamanders, with the highest mortality rates occurring in juveniles (USGS 2016b).

Chytrid fungus, specifically *Batrachochytrium dendrobatidis* (*Bd*), is an amphibian pathogen that could potentially affect GARI's amphibian populations. The pathogen has been identified as the cause of severe population declines on several continents, including North America (Piotrowski et al. 2004). A similar fungus, *Batrachochytrium salamandrivorans* (*Bsal*), impacts salamanders specifically but has not yet been documented in North America (Yap et al. 2015). Amphibians infected by *Bd* or *Bsal* develop chytridiomycosis, an infectious non-hyphal zoosporic fungus that causes roughening and reddening of the skin, convulsions, ulcers and hemorrhages, and sporadic death. Not all amphibians infected with *Bd* develop chytridiomycosis or die; environmental factors, such as pH of the environment, drought, and temperature at time of infection, may affect mortality rates. Some research indicates that *Bd* growth is inhibited by high temperatures (28°C [82°F]) and exposure of infected individuals to high temperatures may kill the fungus (Woodhams et al. 2003). If this is the case, the threat of chytrid at GARI may abate somewhat during warmer summers or as average temperatures rise with global climate change. To date, chytrid fungus has not been detected in or near GARI, but a black-bellied salamander captured near Quinnimont in the vicinity of NERI tested positive for the fungus in 2008 (Bartkus 2009).

Activities related to recreational fishing can threaten herpetofauna populations in several ways. Some salamanders, such as the black-bellied salamander, are collected for use as bait (Purvis 2002). Many amphibian species face competition or predation from non-native bait species (e.g., fish, crayfish) that are released, accidentally or intentionally, into aquatic habitats by visiting anglers. When bait species are introduced to smaller water bodies where they previously were not present, amphibians and their eggs are often exposed to a novel predation source that they are not adapted to (Kats and Ferrer 2003, WVDNR 2015). Introduced bait species that are not predators may still compete with native herpetofauna for habitat and food resources and may spread pathogens (WVDNR 2015). Other recreational activities, particularly ORV use, can negatively impact herpetofauna species. ORV use, which can do significant damage to wildlife habitat, has increased in West Virginia and across the country over time (Pauley et al. 2003, Andrews et al. 2006). These vehicles disturb and destroy road-rut pools and can crush herpetofauna eggs, larvae, and adults (Pauley et al. 2003, Andrews et al. 2006).

As discussed in Chapter 4.1, commercial moss harvest is common in the Appalachian Mountains, and although not permitted on NPS property, moss poaching occurs within GARI boundaries (John Perez, NERI/GARI/BLUE Biologist, written communication, April 2018). Mosses provide a favorable, moist habitat for many salamanders and some other amphibians (Pauley et al. 2005, Studlar and Peck 2007). Four-toed salamanders (*Hemidactylium scutatum*), for example, lay and guard their eggs under sphagnum moss (Pauley et al. 2005). Moss poaching can result in habitat loss for amphibians, and some small individuals may even be accidentally collected and removed.

Water quality impairment due to human activities often impacts aquatic herpetofauna. These impairments include contaminants (e.g., pesticides, mining waste, endocrine disrupting chemicals) and siltation/sedimentation (WVDNR 2015). Contaminants have been shown to significantly affect herpetofauna development, growth, reproduction, and immune system functions (Gibbons et al. 2000, Hayes et al. 2006). Pesticides and other chemicals may be ingested by herpetofauna if their

prey species are contaminated (e.g., insects, other invertebrates) and can be absorbed directly through the skin of some amphibians (Smith et al. 2007, WVDNR 2015). Excess silt and sediment in water bodies can degrade aquatic habitat and may destroy food resources (Bilotta and Brazier 2008, WVDNR 2015).

Data Needs/Gaps

Information regarding GARI's herpetofauna populations is largely limited to a single study from nearly 15 years ago (Pauley et al. 2005). Rentch (2006) recommended regular herpetofauna sampling within ERMN parks, particularly since the environmental sensitivity of many species could provide park managers with an "early warning" of environmental degradation. Sampling could be stratified by vegetative cover type and staggered over 3-5 years so that not all herpetofauna species are targeted every year (Rentch 2006). Each year in the rotation could focus on certain species with similar habitats that could be inventoried with similar methods. Given the difficulties in herpetofauna study (e.g., small size, seasonal and/or secretive behavior), focus should be on relative diversity and density/abundance rather than exact population numbers and distributions (Rentch 2006). In addition, regular disease surveillance would help managers detect the presence and potential impacts of pathogens such as chytrid fungus and ranavirus (WVDNR 2015).

Overall Condition

Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3. Pauley et al. (2005) documented 27 amphibian and 19 reptile species at GARI during 1999-2004 intensive surveys. This matches the number of herpetofauna species known to occur within Fayette and Nicholas Counties (Green and Pauley 1987). However, no systematic surveys have occurred since to determine if herpetofauna species richness has changed over time. As a result, a *Condition Level* cannot be assigned.

Species Abundance

The abundance measure was also assigned a *Significance Level* of 3. Pauley et al. (2005) surveys showed that some herpetofauna species were relatively abundant at GARI (Table 41) while others were rare. As with species richness, more recent data is not available to determine if species abundances have shifted since that time. Therefore, a *Condition Level* cannot currently be assigned for this measure.

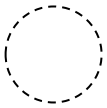
Species Distribution

A *Significance Level* of 3 was also assigned for the distribution measure. Many of the park's herpetofauna were well distributed throughout the park and across habitat types, but some species appear to show limited distributions (Appendix M). Given the limited data, it is unclear if restricted distributions are related to limited habitat availability within GARI or are simply due to species rarity. As with previous measures, a *Condition Level* could not be assigned, given the lack of recent data.

Weighted Condition Score

A *Weighted Condition Score* could not be calculated for GARI's herpetofauna due to a lack of recent data and information. The current condition and trend for the component are considered unknown at this time.

Table 43. Current condition of Gauley River National Recreation Area's Herpetofauna Community.

Measures	Significance Level	Condition Level	WCS = N/A
Species Richness	3	n/a	
Species Abundance	3	n/a	
Species Distribution	3	n/a	

4.7.6. Sources of Expertise

- Lenza Paul, NERI/GARI/BLUE Biological Science Technician (Wildlife)
- John Perez, NERI/GARI/BLUE Biologist

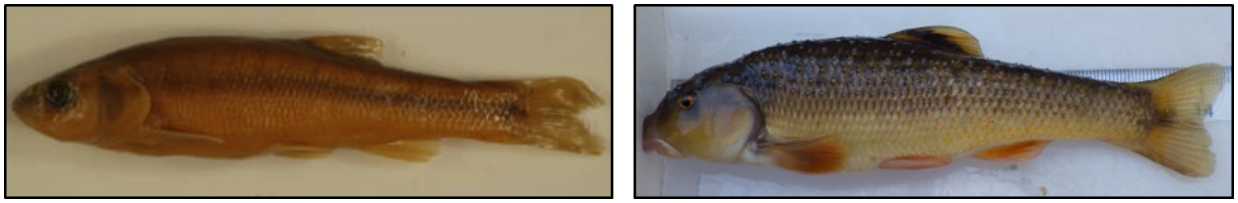
4.8. Aquatic Wildlife Community

4.8.1. Description

The aquatic wildlife community of GARI includes aquatic animals that rely upon the park's rivers and streams, such as fish and aquatic macroinvertebrates. Aquatic macroinvertebrates are invertebrates that can be seen without the aid of a microscope (e.g., insects and their larvae, mussels, crayfish) (Marshall and Piekielek 2007a, WVDEP 2016a). Fish and aquatic macroinvertebrates have both been used as bioindicators of stream ecosystem health (Marshall et al. 2006, Faulk 2015, Tzilkowski et al. 2015). Since fish are more mobile and generally longer-lived than invertebrates, they are considered better indicators of watershed-scale health, while macroinvertebrates are more indicative of localized conditions (Marshall et al. 2006, Anderson and Petty 2015).

Benthic macroinvertebrates (BMI), which live on or within the stream bottom, have frequently been included in water quality monitoring efforts because they are very common, relatively easy to collect, and have consistent responses to human impacts on aquatic systems (Marshall et al. 2006, WVDEP 2016a). BMI are also vital components of stream ecosystems, as they are an important link in the food web, serving as a food source for many other organisms such as fish, herpetofauna, and birds (Tzilkowski et al. 2015, WVDEP 2016a). As a result, BMI were chosen as a Vital Sign for ERMN parks, including GARI (Marshall and Piekielek 2007a).

Like BMI, fish are also relatively easy to collect and identify, and they are important within the food web, as both predators and prey (Marshall et al. 2006). The fish community of GARI has been described as "relatively depauperate of native species", compared to neighboring watersheds (Welsh et al. 2004, p. 166). The low native species richness is likely due to migration barriers downstream from the park, particularly the 7.0-7.6 m (23-25 ft) high Kanawha Falls (Messinger and Chambers 2001, Purvis 2002). These falls have likely prevented the migration of additional fish species that are common further downstream in the Upper Ohio River System (Cincotta and Chambers 1999).



The native fish of Gauley River National Recreation Area include creek chub (*Semotilus atromaculatus*) (left, USFWS photo) and central stoneroller (*Campostoma anomalum*) (right, NPS photo courtesy of Evan Faulk).

4.8.2. Measures

- Fish species richness
- Percent native fish species
- Fish species relative abundance

- Aquatic macroinvertebrate species richness
- Benthic macroinvertebrate multimetric index of biotic integrity (MIBI)

4.8.3. Reference Condition/Values

The reference conditions for this component will vary between measures. For the three fish measures, information reported in Welsh et al. (2004) will serve as the reference. No reference condition could be identified for aquatic macroinvertebrate species richness, but reference ranges have been developed by Herlihy et al. (2008) and adopted by the EPA for the regional MIBI utilized by ERMN monitoring (described below). For the Southern Appalachian region where GARI is located, streams with MIBI scores above 51 are considered in good condition, scores of 37-51 are fair condition, and scores below 37 are poor condition (Herlihy et al. 2008). Because the MIBI was calibrated for wadeable streams (i.e., small and shallow enough to adequately sample without a boat [EPA 2006]), these ranges are applicable to tributaries of the Gauley River in the GARI region, but not the Gauley River itself. For the purpose of this assessment, good condition will serve as the reference condition for GARI.

4.8.4. Data and Methods

Hocutt et al. (1979) surveyed streams throughout the Gauley River watershed for fish during 1976. Streams were sampled with seine nets and electrofishing (in lower reaches only). Seven of the sites sampled by Hocutt et al. (1979) were within or near current GARI boundaries (Sites 6,7,8, 25,32, 33, and 49).

In the late 1990s, the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program studied the effects of environmental factors on the fish and BMI communities of the Kanawha River Basin, which includes the Gauley River system (Chambers and Messinger 2001, Messinger and Chambers 2001). The study sampled fish and BMI at two sets of locations: fixed, indicator sites to reflect overall watershed conditions and synoptic sites to investigate the impacts of coal mining in the West Virginia portion of the Kanawha Basin (Chambers and Messinger 2001). A fixed sampling site was located on Peters Creek near Lockwood, and a synoptic site was located on Miller Creek, a tributary of the Meadow River, at Nallen (Figure 31). Fish and macroinvertebrate samples were collected at fixed sites in 1997 and at synoptic sites in 1998 (Chambers and Messinger 2001, Messinger and Chambers 2001). Fish were collected through electrofishing and macroinvertebrates were sampled by disturbing substrate immediately upstream of a slack sampler (a fine-meshed net) (Figure 32). Macroinvertebrate sampling results were used to calculate modified Hilsenhoff Biotic Index (HBI) scores for each location to assess stream degradation (higher scores = more impairment) (Hilsenhoff 1988, Chambers and Messinger 2001). HBI scores are based on the average pollution tolerance values of the taxa present, on a scale of 0-10 (i.e., the most sensitive taxa have a value of zero and the least sensitive taxa have values closer to 10).

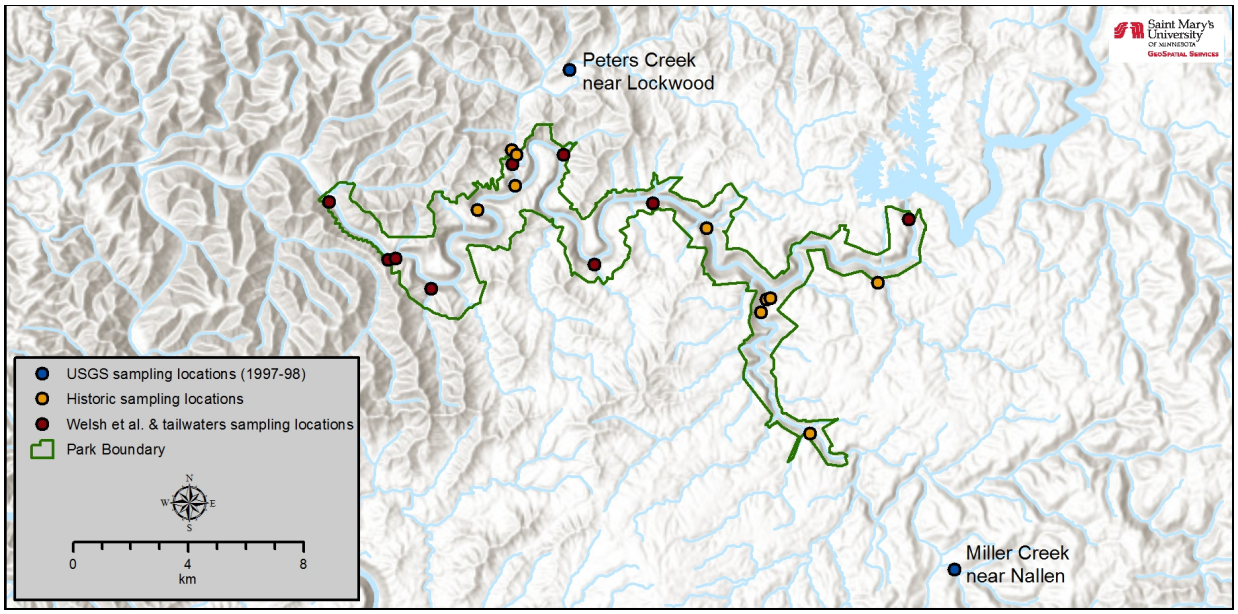


Figure 31. Locations of USGS NAWQA sampling sites near Gauley River National Recreation Area and fish sampling locations with results reported in Welsh et al. (2004). Historic (1965-1980) sampling locations include Hocutt et al. (1979) survey sites.



Figure 32. USGS researchers sampling benthic macroinvertebrates with a slack sampler (USGS photo by Dennis Sun).

Welsh et al. (2004) compiled historic fish community information and conducted sampling by electrofishing within the Gauley River watershed from June-September 2003. Sampling on the mainstem and larger tributaries was limited by above average rainfall and stream flows at the time. Eight of the sites sampled by Welsh et al. (2004) fell within or near current GARI boundaries (Sites 6-8, 15, 18, 19, 37, 38) (Figure 31). Welsh et al. (2004) also reported on the results of fish sampling at the Summersville Dam tailwaters by the WVDNR in September 2002.

From 2009-2012, the ERMN sampled BMI at GARI as part of a wadeable streams monitoring protocol (Tzilkowski et al. 2010, 2015). Four tributary stream reaches were included in this monitoring: Laurel Creek, Horseshoe Creek, Meadow Creek, and Peters Creek (Figure 33). BMI sampling was conducted in the spring, as researchers realized that many mid-sized streams in the region frequently dry up in the fall (Tzilkowski et al. 2010). BMI samples were collected using the USGS richest-targeted habitat (RTH) method (Moulton et al. 2002). An RTH is a habitat that is typically rich in BMI taxa (Tzilkowski et al. 2015); at GARI, the RTH is riffle habitat (Andrew Weber, ERMN Hydrologic Technician, written communication, February 2018). This involves disturbance-removal sampling, similar to that used by Chambers and Messinger (2001). The data collected were used to calculate a regional MIBI designed for the Mid-Atlantic Highlands Region, where upland and lowland streams are often dominated by riffle habitat (Klemm et al. 2003). This MIBI consists of seven metrics, shown in Table 44.

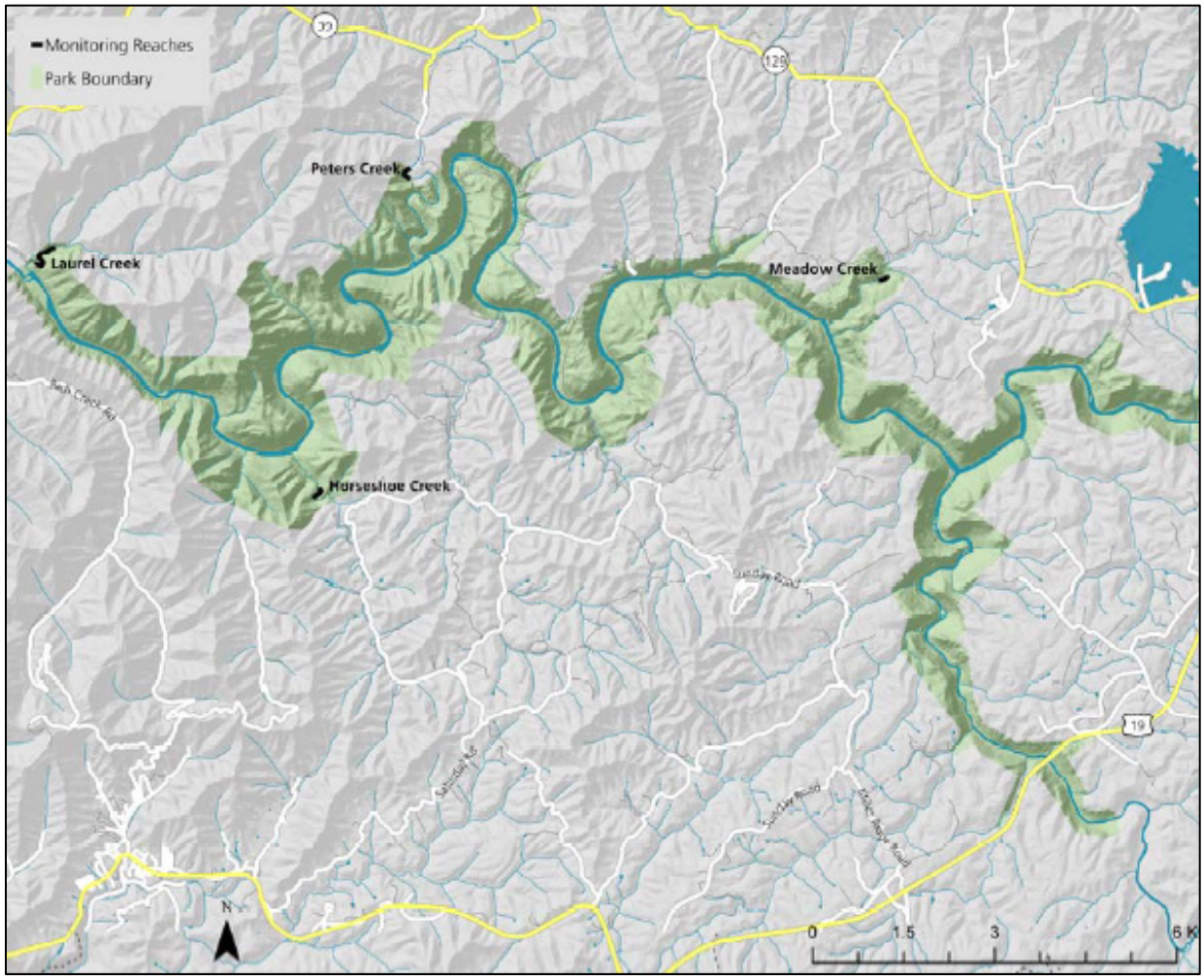


Figure 33. Stream reaches within Gauley River National Recreation Area monitored by Eastern Rivers and Mountains Network (reproduced from Tzilkowski et al. 2015).

Table 44. Metrics included in the multimetric index of biotic integrity (MIBI) utilized by Eastern Rivers and Mountains Network benthic macroinvertebrates sampling (Tzilkowski et al. 2015).

Metric	Response to Decreasing Biotic Integrity
Ephemeroptera taxa richness	decrease
Plecoptera taxa richness	decrease
Trichoptera taxa richness	decrease
Collector-Filterer (feeding strategy) taxa richness	decrease
% of non-insect individuals	increase
Macroinvertebrate tolerance index (MTI) (abundance-weighted mean tolerance)	increase
% of individuals in the five most dominant taxa	increase

4.8.5. Current Condition and Trend

Fish Species Richness

Given the relatively low native fish species richness at GARI (Welsh et al. 2004), low numbers of species alone are not necessarily indicative of poor condition. Rather, changes in species richness may indicate a cause for concern or need for further investigation. The NPS certified species list for GARI (NPS 2016d) includes 33 confirmed species, four species considered "probably present" or "unconfirmed", and two species that occurred historically but are considered no longer present (Table 45). Two confirmed species (bigmouth chub [*Nocomis platyrhynchus*], candy darter [*Etheostoma osburni*]) and one historical species (New River shiner [*Notropis scabriceps*]) are considered endemic (i.e., native to a limited geographic area). According to Welsh et al. (2004), 26 species were documented within or near GARI boundaries by surveys conducted from 1965-1980 (including Hocutt et al. 1979). This included two species (channel catfish [*Ictalurus punctatus*], brown bullhead [*Ameiurus nebulosus*]) that were documented in the Gauley River near the Meadow River confluence in 1967 that are not currently on the park's certified species list. Sampling by the WVDNR at the Summersville Dam tailwaters in 2002 (as reported by Welsh et al. 2004) recorded 13 species, including several not previously documented within park boundaries (Table 45). During 2003 sampling, Welsh et al. (2004) documented 24 species within or near park boundaries. This included five species not previously observed during historic surveys. However, nine species that had been present historically (eight of them native) were not found in 2003 (Welsh et al. 2004).

Percent Native Fish Species

Of the 33 fish species confirmed present according to the GARI certified species list, 79% are native (NPS 2016d). Two of the four species considered "probably present" or "unconfirmed" are native (Table 45). According to historic records (as reported by Welsh et al. 2004), 88% of the species documented within or near GARI boundaries were native. Of the 24 fish species observed by Welsh et al. (2004) during 2003 sampling, 79% were native (Table 45).

Table 45. Fish species present, probably present, unconfirmed, or historically present within Gauley River National Recreation Area, according to NPSpecies (NPS 2016d). The last three columns indicate which species were documented by historic surveys (1965-1980, as reported by Welsh et al. 2004), during 2002 sampling at the Summersville Dam tailwaters by the WVDNR (as reported by Welsh et al. 2004), and during 2003 sampling by Welsh et al. (2004).

Status in Park	Scientific Name	Common Name	Historic (1965-1980)	Tailwaters 2002	Welsh et al. 2004
Confirmed present	*Catostomus commersoni*	white sucker	X	–	X
	Hypentelium nigricans	northern hog sucker	X	–	X
	Campostoma anomalum	central stoneroller	X	X	X
	Cyprinella galactura[A]	whitetail shiner	–	–	X
	Cyprinella spiloptera	spotfin shiner	–	–	X
	Luxilus albeolus	white shiner	X	–	X
	Nocomis platyrhynchus[B]	bigmouth chub	X	X	X
	Notemigonus crysoleucas	golden shiner	X	–	–
	Notropis atherinoides[A,C]	emerald shiner	–	X	–
	Notropis buccatus	silverjaw minnow	X	–	X
	Notropis photogenis	silver shiner	–	–	–
	Notropis rubellus	rosyface shiner	X	X	X
	Notropis stramineus	sand shiner	X	–	X
	Notropis telescopus	telescope shiner	–	–	X
	Notropis volucellus	mimic shiner	X	X	–
	Pimephales notatus	bluntnose minnow	X	X	X
	Rhinichthys atratulus	blacknose dace	X	–	X
	Rhinichthys cataractae	longnose dace	X	X	X
	Semotilus atromaculatus	creek chub	X	–	X
	Ambloplites rupestris	rock bass	X	X	X
	Lepomis cyanellus	green sunfish	X	–	X
	Lepomis macrochirus[A]	bluegill	X	–	X
	Micropterus dolomieu[A]	smallmouth bass	X	–	X
	Micropterus salmoides[A]	largemouth bass	–	–	–
	Etheostoma blennioides	greenside darter	X	–	–
	Etheostoma caeruleum[A]	rainbow darter	–	–	X
	Etheostoma flabellare	fantail darter	X	–	X
	Etheostoma nigrum	johnny darter	X	X	X
	Etheostoma osburni[B]	candy darter	–	X	–

[A] Non-native

[B] Endemic

[C] Not on park's certified species list

Table 45 (continued). Fish species present, probably present, unconfirmed, or historically present within Gauley River National Recreation Area, according to NPSpecies (NPS 2016d). The last three columns indicate which species were documented by historic surveys (1965-1980, as reported by Welsh et al. 2004), during 2002 sampling at the Summersville Dam tailwaters by the WVDNR (as reported by Welsh et al. 2004), and during 2003 sampling by Welsh et al. (2004).

Status in Park	Scientific Name	Common Name	Historic (1965-1980)	Tailwaters 2002	Welsh et al. 2004
Confirmed Present (continued)	*Percina caprodes*	logperch	–	X	–
	Percina oxyrhynchus	sharpnose darter	X	X	–
	Oncorhynchus mykiss[A]	rainbow trout	–	–	–
	Cottus bairdi	mottled sculpin	X	–	X
	Pylodictis olivaris	flathead catfish	X	–	–
Probably present	*Luxilus chrysocephalus*	striped shiner	–	X	–
	Sander vitreus[A]	walleye	X	–	–
	Noturus flavus	stonecat	–	–	–
Unconfirmed	*Chrosomus erythrogaster*[A]	southern redbelly dace	–	–	X
Historical	*Anguilla rostrata*	American eel	X	–	–
	Notropis scabriceps[B]	New River shiner	–	–	–
	Ictalurus punctatus[C]	channel catfish	X (1967)	–	–
	Ameiurus nebulosus[C]	brown bullhead	X (1967)	–	–

[A] Non-native

[B] Endemic

[C] Not on park's certified species list

Fish Species Relative Abundance

Hocutt et al. (1979) reported the number of individuals of each species documented by sampling location, allowing for calculations of relative abundance. The most abundant species were mimic shiner (*Notropis volucellus*) with 24.3%, bluntnose minnow (*Pimephales notatus*) with 15.5%, and the endemic bigmouth chub with 13.8% (Table 46). Together, these species comprised 53.6% of all fish sampled. Nine species were rarely captured, comprising ≤0.1% of observed individuals.

Table 46. Fish species abundance from Gauley River National Recreation Area sampling sites, 1976 (Hocutt et al. 1979).

Species	# of Sites (out of 7)	Total Individuals	% Relative Abundance
mimic shiner	2	979	24.3
bluntnose minnow	7	622	15.5
bigmouth chub[B]	5	555	13.8
longnose dace	5	272	6.8
rosyface shiner	6	249	6.2
northern hog sucker	6	224	5.6
johnny darter	4	210	5.2
smallmouth bass[A]	6	163	4.1
sharpnose darter	5	113	2.8
white shiner	2	59	1.5
greenside darter	5	56	1.4
blacknose dace	1	54	1.3
white sucker	4	47	1.2
silverjaw minnow	4	42	1.0
rock bass	4	40	1.0
central stoneroller	5	27	0.7
silver shiner	1	25	0.6
sand shiner	1	23	0.6
creek chub	5	22	0.5
telescope shiner	1	15	0.4
candy darter	2	14	0.3
rainbow darter[A]	1	9	0.2
stonecat	1	8	0.2
fantail darter	1	6	0.1
flathead catfish	1	5	0.1
green sunfish	1	4	0.1
logperch	1	4	0.1
American eel	1	1	<0.1
Bluegill[A]	1	1	<0.1
spotted bass[A,C]	1	1	<0.1
golden shiner	1	1	<0.1
Walleye[A]	1	1	<0.1

[A] Non-native

[B] Endemic

[C] Not on park's certified species list (captured just outside park boundary)




The endemic bigmouth chub (left, NPS photo) and the non-native rainbow darter (right, USFWS photo).

Welsh et al. (2004) also reported the number of individuals sampled by species and location. The species with the highest relative abundances were central stoneroller at 27.3%, creek chub at 16.5%, and the non-native rainbow darter (*Etheostoma caeruleum*) at 12.8% (Table 47). These species together comprised 56.6% of all fish sampled. Five species had low relative abundances, comprising 0.1% or less of fish sampled.

Table 47. Fish species abundance from Gauley River National Recreation Area sampling sites, 2003 (Welsh et al. 2004).

Species	# of Sites (out of 6)	Total Individuals	% Relative Abundance
central stoneroller	5	348	27.3
creek chub	5	210	16.5
rainbow darter[A]	1	163	12.8
telescope shiner	2	121	9.5
blacknose dace	4	113	8.9
mottled sculpin	5	94	7.4
rosyface shiner	1	55	4.3
bigmouth chub[B]	3	36	2.8
northern hog sucker	2	35	2.7
whitetail shiner[A]	2	27	2.1
bluntnose minnow	1	16	1.2
white shiner	2	14	1.1
sand shiner	1	13	1.0
rock bass	2	7	0.5
silverjaw minnow	2	4	0.3
white sucker	3	4	0.3
smallmouth bass[A]	3	4	0.3
longnose dace	1	2	0.2
green sunfish	2	2	0.2

[A] Non-native

[B] Endemic

Table 47 (continued). Fish species abundance from Gauley River National Recreation Area sampling sites, 2003 (Welsh et al. 2004).

Species	# of Sites (out of 6)	Total Individuals	% Relative Abundance
spotfin shiner	1	1	0.1
southern redbelly dace[A]	1	1	0.1
Bluegill[A]	1	1	0.1
fantail darter	1	1	0.1
johnny darter	1	1	0.1

[A] Non-native

[B] Endemic

Aquatic Macroinvertebrate Species Richness

Information regarding aquatic macroinvertebrate species richness within GARI streams is somewhat limited. A comprehensive macroinvertebrate survey has not been conducted. The only data currently available are from ERMN BMI sampling. Two tributaries of the Gauley River (Meadow and Laurel Creeks) were sampled consistently from 2009-2012, while two additional tributaries (Horseshoe and Peters Creeks) were sampled three times during those years. Laurel Creek, at the western (downstream) end of GARI, showed the lowest average BMI taxa richness at 27.8 (range: 24-32) (Table 48). However, the lowest average Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness was 15.7 from Peters Creek, a watershed with historic and current coal mining activity. Horseshoe Creek exhibited the highest average taxa richness at 38.7 (range: 37-42) and the highest average EPT taxa richness with 21 (NPS unpublished data). No clear trends in total or EPT taxa richness were apparent over time.

Table 48. Benthic macroinvertebrate taxa richness at sampling stream reaches within Gauley River National Recreation Area (NPS unpublished data, received from the Eastern Rivers and Mountains Network).

Site	Year	Taxa Richness	EPT Taxa Richness
Meadow Creek	2009	32	16
	2010	27	18
	2011	28	13
	2012	31	17
	Average	**29.5**	**16.0**
Laurel Creek	2009	26	18
	2010	24	16
	2011	32	23
	2012	29	18
	Average	**27.8**	**18.8**

Table 48 (continued). Benthic macroinvertebrate taxa richness at sampling stream reaches within Gauley River National Recreation Area (NPS unpublished data, received from the Eastern Rivers and Mountains Network).

Site	Year	Taxa Richness	EPT Taxa Richness
Horseshoe Creek	2009	37	19
	2011	42	23
	2012	37	21
	Average	**38.7**	**21.0**
Peters Creek	2010	30	17
	2011	23	11
	2012	34	19
	Average	**29.0**	**15.7**

Benthic Macroinvertebrate Multimetric Index of Biotic Integrity (MIBI)

Aquatic macroinvertebrate communities can be described or characterized in several ways. For example, communities may be assessed based on the presence or percentage of particularly sensitive or tolerant taxa, by taxa food-resource use (e.g., filterers, predators, shredders), or through a mathematical index of multiple attributes or metrics (Chambers and Messinger 2001). During the USGS study of the Kanawha Basin during the late 1990s, BMI sampling results were used to calculate modified HBI scores for each study site (Chambers and Messinger 2001). Lower HBI scores indicate low levels of stream degradation while higher scores indicate higher degradation. HBI scores throughout the Basin ranged from 2.84 to 5.80 with a mean of 4.44 (Chambers and Messinger 2001). The HBI score for Peters Creek near Lockwood was slightly above this mean, likely due to degradation from coal mining (Figure 34). The score for Miller Creek at Nallen, where coal mining has not occurred in the watershed, was just above 3.0, indicating lower degradation (Figure 35).

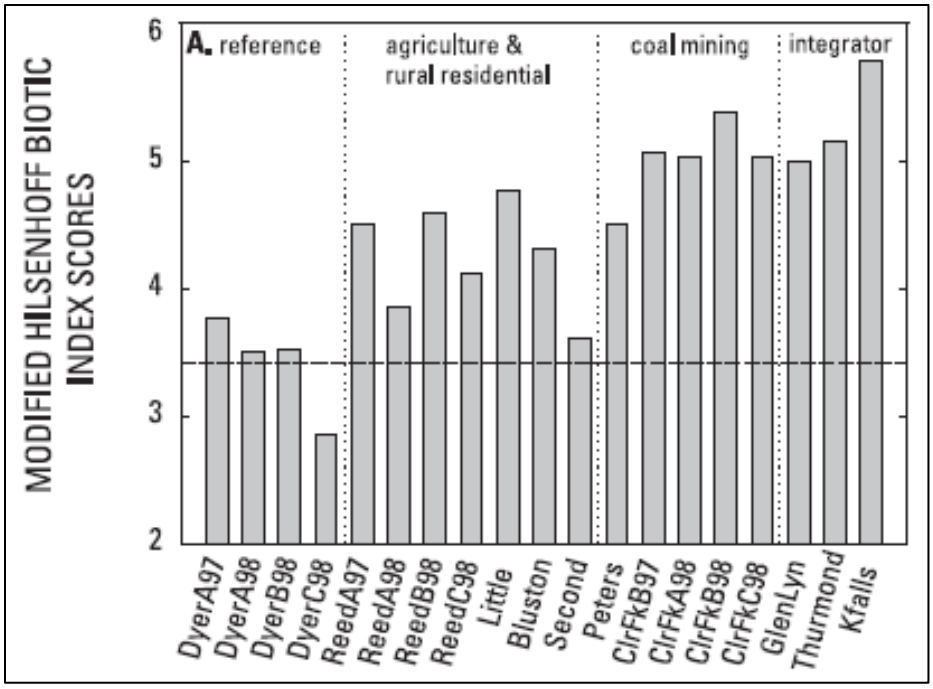


Figure 34. Modified Hilsenhoff Biotic Index (HBI) scores for fixed sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). “Peters”, near the center of the graph, represents the Peters Creek near Lockwood location. The text above the columns shows land use in the watershed around each location.

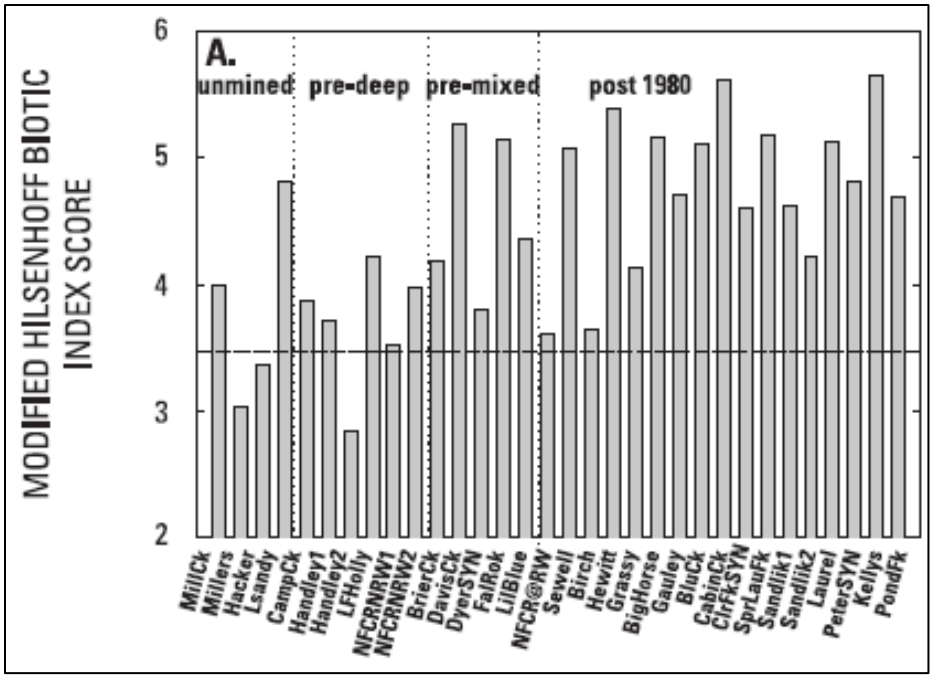


Figure 35. Modified Hilsenhoff Biotic Index (HBI) scores for synoptic sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). “Millers”, towards the left of the graph, represents the Miller Creek at Nallen location. The text above the columns shows coal mining history (pre-mixed = deep and surface mining before 1980).

MIBI scores were calculated for the four ERMN sampling reaches within GARI based on 3 or 4 years of data (2009-2012) (Tzilkowski et al. 2015). Overall, MIBI scores across all four sites ranged from 40.8 (Peters Creek, 2010) to 67.1 (Horseshoe Creek, 2011) (Figure 36, Table 49). The site on Horseshoe Creek showed the narrowest range of MIBI scores (59.1-67.1) and the widest range of scores occurred at Peters Creek (27.9-56.1). The reach averages ranged from 41.6 (Peters Creek) to 62.8 (Horseshoe Creek). Based on these average MIBI scores, Peters Creek and Laurel Creek fall in the fair condition range (37-51) while Meadow Creek and Horseshoe Creek fall in the good condition range (>51).

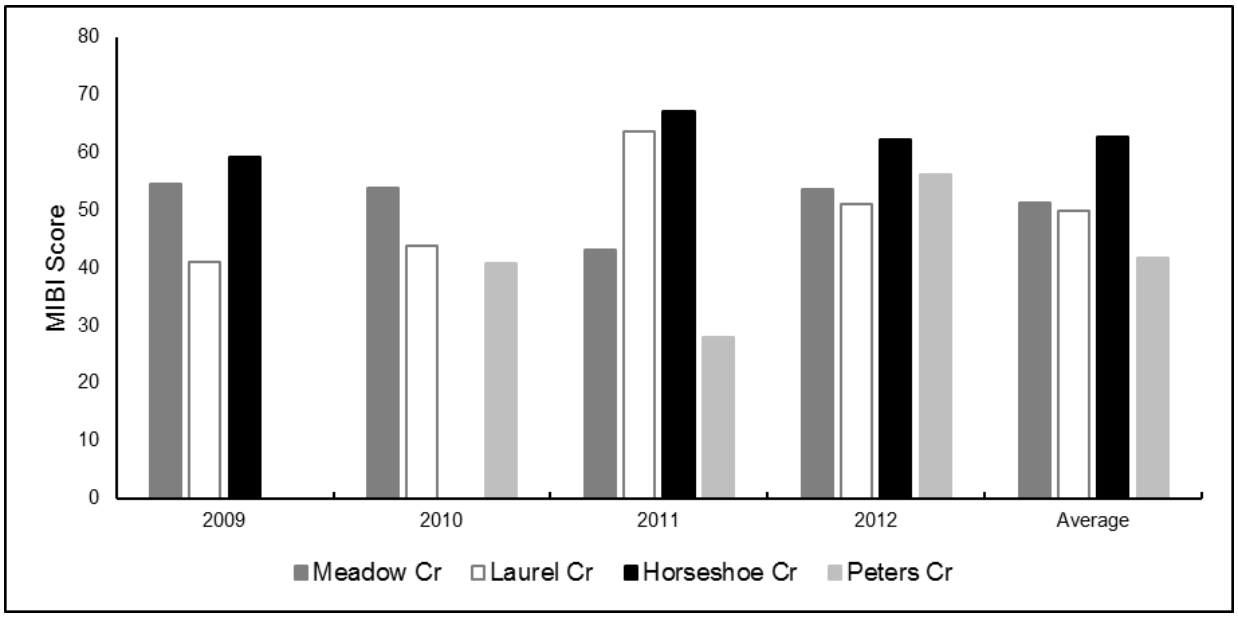


Figure 36. Multimetric index of biotic integrity (MIBI) scores for Gauley River National Recreation Area sampling reaches, 2009-2012 and averages for the period (Tzilkowski et al. 2015).

Table 49. Multimetric Index of Biotic Integrity (MIBI) scores and constituent metric results for samples from Gauley River National Recreation Area, 2009-2012 (Tzilkowski et al. 2015). E = Ephemeroptera richness, P = Plecoptera richness, T = Trichoptera richness, CF = Collector-filterer richness, %NI = Percent non-insect individuals, %D5 = Percent of five most dominant taxa, MTI = Macroinvertebrate Tolerance Index.

Reach	Date	E	P	T	CF	% NI	% D5	MTI	MIBI
Meadow Creek	4/1/2009	7	3	6	7	4.6	62	3.61	54.5
	4/5/2010	5	6	7	4	0.7	69	3.59	53.8
	3/29/2011	5	2	6	6	1.3	76	4.11	43.2
	3/11/2012	6	4	7	6	0.3	69	3.84	53.5
	Average	5.8	3.8	6.5	5.8	1.7	69.0	3.79	51.3

Table 49 (continued). Multimetric Index of Biotic Integrity (MIBI) scores and constituent metric results for samples from Gauley River National Recreation Area, 2009-2012 (Tzilkowski et al. 2015). E = Ephemeroptera richness, P = Plecoptera richness, T = Trichoptera richness, CF = Collector-filterer richness, %NI = Percent non-insect individuals, %D5 = Percent of five most dominant taxa, MTI = Macroinvertebrate Tolerance Index.

Reach	Date	E	P	T	CF	% NI	% D5	MTI	MIBI
Laurel Creek	3/30/2009	7	6	5	3	5.0	83	4.03	41.0
	4/5/2010	7	6	3	2	0.7	78	2.50	43.7
	3/22/2011	9	7	7	5	2.9	66	2.97	63.6
	3/11/2012	7	7	4	3	4.2	63	3.27	51.1
	Average	7.5	6.5	4.8	3.3	3.2	72.5	3.19	49.9
Horseshoe Creek	3/30/2009	7	4	8	5	4.6	48	3.47	59.1
	3/22/2011	9	6	8	5	2.5	2.5	3.72	67.1
	3/11/2012	8	6	7	4	1.9	1.9	3.67	62.2
	Average	8	5.3	7.7	4.7	3.0	17.5	3.62	62.8
Peters Creek	4/5/2010	9	3	5	5	2.4	76	4.44	40.8
	3/29/2011	6	2	3	5	1.0	82	4.81	27.9
	3/11/2012	8	6	5	6	2.4	61	4.07	56.1
	Average	7.7	3.7	4.3	5.3	1.9	73	4.44	41.6

Threats and Stressor Factors

Threats to the aquatic wildlife community of GARI include non-native fish stocking, bait bucket releases, invasive aquatic plants, boat traffic, Summersville Dam operations, extreme hydrologic/weather events, oil and gas extraction, coal mining activity, pesticides, and upstream land use/development (e.g., agriculture, sewage discharge, logging, development). Land use/development and gas extraction are primarily threats to aquatic life because of their impacts on water quality, which will be discussed in Chapter 4.7. However, the excess sediment often contributed to streams by logging, agriculture, and development can also fill in pools or small spaces that provide habitat for aquatic wildlife (Chambers and Messinger 2001, Purvis 2002, Bilotta and Brazier 2008). When suspended in the water, excess sediment can irritate and clog the respiratory organs of fish and aquatic invertebrates, stressing and potentially killing these organisms (Bilotta and Brazier 2008, WVDNR 2015). In the Kanawha Basin, Chambers and Messinger (2001) found that aquatic invertebrate communities in watersheds with agricultural land use showed slight impairment over reference streams. Pollution tolerance varies among fish species, with some showing more sensitivity to change than others. Native fish occurring within GARI that are considered intolerant of pollution include the candy darter, greenside darter (*Etheostoma blennioides*), and rosyface shiner (*Notropis rubellus*) (Anderson and Petty 2015).

Coal mining activity is a particular threat to the park's aquatic wildlife community. Coal mining has significant impacts on water quality (discussed in Chapter 4.7), including increased sedimentation

and elevated specific conductance, which can linger for decades after mining concludes (Chambers and Messinger 2001). Chambers and Messinger (2001) found that BMI communities in streams with recent mining activity showed impairment, and impairment increased as mining intensity increased (Figure 34, Figure 35). EPT taxa richness, in particular, decreased with increases in specific conductance and decreases in median streambed-particle size, an indicator of excess sedimentation (Figure 37) (Chambers and Messinger 2001). Within GARI, the Peters Creek watershed has been particularly affected by coal mining and mining activity still continues in the watershed (see Chapter 4.7).

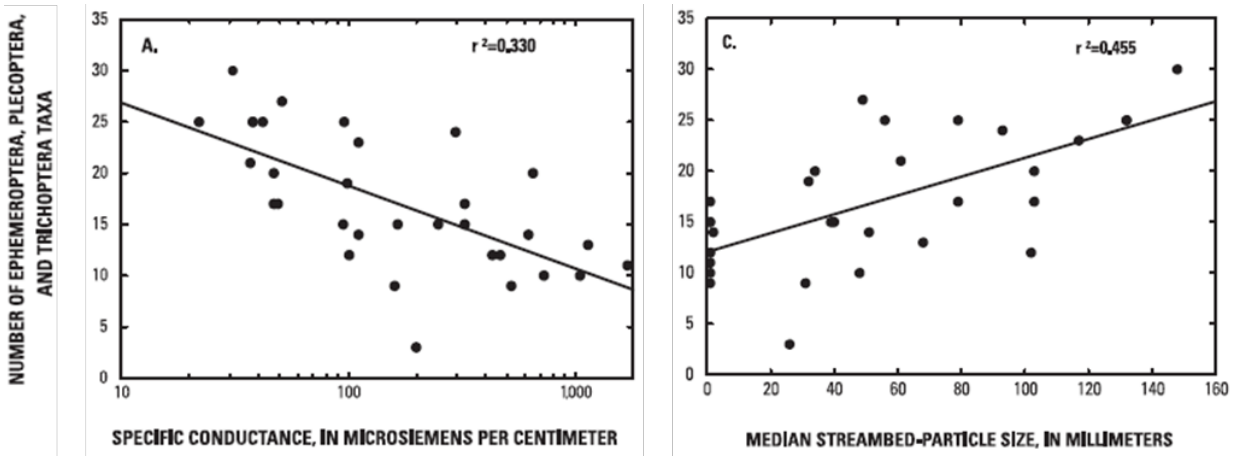


Figure 37. The number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness within Kanawha Basin streams compared to specific conductance (left) and streambed-particle size (right) (Chambers and Messinger 2001).

Recreational fishing in and around the Gauley River has contributed to non-native species introductions in several ways. First is the intentional introduction of game fish such as bass and trout to "improve" recreational opportunities (Cincotta and Chambers 1999, Purvis 2002). The WVDNR has been stocking trout at the Summersville Dam tailwaters for many years. Stocking is conducted once in February, once every 2 weeks from March through May, and twice in mid-October (WVDNR 2003; Lisa Wilson, NPS Biological Science Technician, written communication, February 2018). In recent years, an additional 600-1,500 lbs of rainbow trout (*Oncorhynchus mykiss*) have been stocked by helicopter in June (WVDNR 2010, 2013, 2017c). Non-native species have also been introduced through bait-bucket releases (i.e., anglers dumping out remaining bait at the end of the day) (Cincotta and Chambers 1999). Smaller fish within GARI that are likely present due to bait-bucket introductions, either within park boundaries or downstream, include the whitetail shiner (*Cyprinella galactura*) and emerald shiner (*Notropis atherinoides*) (Purvis 2002, Welsh et al. 2004). Although it has not been documented, it is likely that these non-native fish are having a negative impact on native species and may even out-compete some of the local endemics (Messinger and Chambers 2001, Purvis 2002). Bait-bucket releases are not only responsible for fish introductions but are also thought to be the source for non-native crayfish in the New River system (Purvis 2002, Swecker 2012). Lastly, boating can lead to non-native plant and invertebrate introductions if boats are not cleaned properly when moved between sites (Johnson et al. 2001, WVDNR 2014). Invasive

species transferred by boats that threaten GARI include non-native mussels and hydrilla (*Hydrilla verticillata*), a mat-forming aquatic plant (WVISWG 2011). Invasive aquatic plants and invertebrates can alter habitats and/or ecosystem processes in ways that could negatively impact native aquatic wildlife (Strayer 2010).

The release of water from the Summersville Lake Reservoir through the Summersville Dam (Figure 38) may be impacting aquatic wildlife communities. Water released from the dam comes from the bottom of the lake and is typically colder than water in the rest of the Gauley River and its tributaries (WVDNR 2015). Coldwater releases from reservoirs have been shown to alter downstream thermal regimes of rivers (Troxler and Thackston 1977, as cited by Caissie 2006). Thermal regime influences the distribution and growth rates of aquatic organisms, as well as the overall health of aquatic ecosystems (Robinson and Childs 2001, Caissie 2006). Water temperatures are also important in the timing of fish reproduction and movements (Albanese et al. 2004, Caissie 2006).



Figure 38. Summersville Dam and tailwaters (SMUMN GSS photo by Hannah Hutchins).

Extreme weather events, such as droughts or heavy rain, can cause extremely low or high water levels, which may stress aquatic wildlife communities. While heavy rain and droughts are natural events in the GARI region, these events may increase in frequency or intensity due to climate change and/or human activities (e.g., development, water diversions, land use change). Flooding, which may also contribute to landslides, can alter aquatic habitat by scouring away habitat features (e.g., gravel, woody debris, aquatic vegetation), eroding stream banks, or altering other stream morphology characteristics (Figure 39) (Purvis 2002). Droughts reduce habitat availability; smaller streams may

shrink to isolated pools or dry up completely, stranding any fish and aquatic invertebrates living there (Messinger and Chambers 2001, Boulton and Lake 2008). As water levels drop and pools become isolated, water quality often declines (e.g., higher water temperatures, lower dissolved oxygen, pH), which can further stress aquatic organisms (Boulton and Lake 2008). Previous research in West Virginia streams found that BMI density declined significantly during droughts (Kaller 2001). This decline could impact other wildlife that rely on BMI as a food source.



Figure 39. A landslide/bank failure caused by flooding on the Meadow River in June 2016 (NPS photo by John Perez).

Data Needs/Gaps

Although some information regarding fish species composition and relative abundance at GARI is available, the studies have not sampled consistent locations over time, making it difficult to

document any changes that may be occurring within the fish community with confidence. Re-sampling of the locations surveyed by Welsh et al. (2004) would help to identify any trends within the fish community. Welsh et al. (2004, p. 173) suggested that low darter numbers "may reflect sub-optimal water chemistry or sedimentation impacts", but studies are needed to test this hypothesis. In addition, further research is needed to explore how non-native species (plants and animals) are impacting native aquatic wildlife and habitats (Welsh et al. 2004).

With the exception of ERMN BMI sampling locations, little is known about the diversity of aquatic macroinvertebrates within GARI streams. An inventory of aquatic invertebrates within park boundaries would help managers better understand the park's biodiversity and may identify environmentally-sensitive organisms or species of conservation concern, such as mussels or crayfish. Mussels and crayfish are important components of West Virginia stream ecosystems, and many species are considered of conservation concern in the state (WVDNR 2015).

Overall Condition

Fish Species Richness

The NRCA project team assigned this measure a *Significance Level* of 2. While overall species richness in GARI waters remained similar over the Welsh et al. (2004) study period, species composition shifted somewhat. According to Welsh et al. (2004), nine fish species that had been present historically (1965-1980) were not found in 2003, and five species not previously observed were documented in 2003. However, no fish sampling has been conducted since 2003 and species richness may have shifted during this time. As a result, this measure has not been assigned a *Condition Level*.

Percent Native Fish Species

A *Significance Level* of 3 was assigned for this measure. The percent of native fish species at GARI appears to have declined over time. According to historic records, 88% of species documented were native, while 79% of species observed in 2003 were native (Welsh et al. 2004). No more recent information is available to determine whether this trend has continued. While the observed decline is certainly cause for concern the level of concern cannot be determined at this time and a *Condition Level* has not been assigned.

Fish Species Relative Abundance

The relative abundance measure was also assigned a *Significance Level* of 3. The three most abundant fish during 1976 sampling were native species and totaled a combined 54% of all individuals observed (Hocutt et al. 1979). During 2003 sampling, the two most abundant species were native but the third-most abundant species was non-native (Welsh et al. 2004). The three most abundant species at this time comprised 56.6% of all fish sampled. The increased dominance by a non-native species and the slight increase in dominance by just a few species is cause for concern. However, due to a lack of recent studies, it is unknown whether relative abundance has changed since 2003. As a result, a *Condition Level* has not been assigned.

Aquatic Macroinvertebrate Species Richness
This measure was assigned a *Significance Level* of 3. Information regarding aquatic macroinvertebrate species richness within GARI waters is limited to a few sampling locations and a relatively short period of time. There are also no reference points or ranges for comparison to assess condition. Therefore, a *Condition Level* cannot be assigned at this time.

Benthic Macroinvertebrate Multimetric Index of Biotic Integrity (MIBI)
A *Significance Level* of 3 was assigned for the MIBI measure. The average MIBI scores for two of the reaches sampled within GARI fell in the fair condition range (Laurel and Peters Creeks) and two reaches fell in the good condition range (Horseshoe and Meadow Creeks) (Tzilkowski et al. 2015). Because two of the four sampled reaches fell in the fair range, this measure is assigned a *Condition Level* of 2.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for GARI's aquatic wildlife community due to a lack of recent data for a majority of the measures (Table 50). The condition and trend for this park resource are currently unknown.

Table 50. Current condition of Gauley River National Recreation Area's Aquatic Wildlife Community

Measures	Significance Level	Condition Level	WCS = N/A
Fish species richness	2	n/a	
Percent native fish species	3	n/a	
Fish species relative abundance	3	n/a	
Aq macroinvertebrate species richness	3	n/a	
BMI MIBI	3	2	

4.8.6. Sources of Expertise

- Caleb Tzilkowski, ERMN Aquatic Ecologist
- Andrew Weber, ERMN Hydrologic Technician
- Lisa Wilson, NPS Biological Science Technician

4.9. Water Quality

4.9.1. Description

Surface water quality and hydrology were identified by the ERMN as high priorities both for Vital Signs monitoring and for park management (Marshall and Piekielek 2007a). Water quality and quantity have direct impacts on park wildlife and vegetation, including sensitive species (e.g., fish, aquatic invertebrates, amphibians), and also influence visitor use and enjoyment (e.g., water-based recreation) (Marshall and Piekielek 2007a).

The GARI boundary contains approximately 73.9 km (45.9 mi) of streams, 51.8 km (32.2 mi) of which have been identified by the State of West Virginia as Tier 3 or "outstanding national resource waters" (Sheeder et al. 2004, Tzilkowski et al. 2015). These include the Gauley River, Meadow Creek, Laurel Creek, and several additional smaller tributaries. However, 11.7 km (7.3 mi) of Gauley River tributaries within GARI are classified as 303d impaired (NPS 2014b). The entire length of the Meadow River is impaired due to fecal coliform bacteria, while the full length of Peters Creek is considered impaired by fecal coliform bacteria and iron (NPS 2014). The Meadow River typically meets the criteria to support fisheries, agricultural, and wildlife uses, but at times coliform bacteria levels are considered unsafe for water contact recreation (Sheeder et al. 2004, Tzilkowski et al. 2015). Peters Creek meets the criteria for agricultural and wildlife uses but does not support trout fisheries or water contact recreation uses.

4.9.2. Measures

- Water temperature
- pH
- Dissolved oxygen
- Specific conductance
- Turbidity
- Fecal coliform bacteria

Water Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, but it also affects biological activity and growth within water systems (USGS 2015b). For example, water temperatures play a key role in the reproductive timing and success of river fish (Marshall et al. 2006). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2015b). As temperature increases or decreases too far past this range, the number of species and individuals able to survive eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water, making them more toxic to aquatic life (USGS 2015b).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2015b). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2015b). Chemicals in water can change the pH and harm animals and plants living in the water; monitoring pH can therefore be useful for detecting natural and human-caused changes in water chemistry (USGS 2015b).

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. In order to survive, fish and zooplankton filter out or "breathe" dissolved oxygen from the water (USGS 2015b). Oxygen enters water from the air, when atmospheric oxygen mixes with water at turbulent, shallow riffles in a waterway, or when released by algae and other plants as a byproduct of photosynthesis. As the concentration of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2015b). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than warm water (USGS 2015b). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2015b).

Specific Conductance

Specific conductance (SpC) is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved ions in the water (Allan and Castillo 2007). Water with low amounts of dissolved ions (such as purified or distilled water) will have a low SpC, while water with high amounts of dissolved solids (such as salty sea water) will have a higher SpC (Allan and Castillo 2007). SpC is an important water quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2015b).

Turbidity

Turbidity assesses the amount of fine particle matter (such as clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) that is suspended in water by measuring the scattering effect that solids have on light that passes through water (USGS 2015b). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature in waterways and reducing the concentration of dissolved oxygen in the water. The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (Bilotta and Brazier 2008). Suspended particles also irritate and clog the respiratory organs of many fish and aquatic invertebrates (e.g., mussels, crustaceans), stressing and potentially killing these organisms (Bilotta and Brazier 2008).

Fecal Coliform Bacteria

Bacteria are commonly found in surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals such as *E. coli*, can cause illness in humans (USGS 2011a). Fecal coliform bacteria are a subgroup of

coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. Bacteria densities can be determined by counting colonies that grow on 0.45 micron filters incubated at 44.5°C (112.1°F) for 22-24 hours.

4.9.3. Reference Condition/Values

The reference conditions for water quality will be the West Virginia state standards for water bodies with an aquatic life designated use, unless otherwise indicated (Table 51). Many of these water quality standards also apply to other designated uses (e.g., contact recreation, wildlife use) and are protective of human health (WVDEP 2014).

Table 51. West Virginia state water quality standards for the fish and aquatic life designated use (unless otherwise noted) (WVDEP 2014).

Parameter	West Virginia Standards
Water temperature	Temperature rise limited to no more than 2.8°C (5°F) above natural temperature, not to exceed 30.6°C (87°F) at any time during months of May through November and not to exceed 22.8°C (73°F) at any time during the months of December through April.
pH[A]	6.0-9.0; higher values due to photosynthetic activity may be tolerated
Dissolved oxygen[A]	≥5.0 mg/L
Turbidity	No more than 10 NTUs (nephelometric turbidity units) over background turbidity when the background is 50 NTU or less, or no more than a 10% increase in turbidity (plus 10 NTU minimum) when the background turbidity is more than 50 NTUs.
Fecal coliform bacteria[B]	≤200/100 ml as a monthly geometric mean based on not less than 5 samples per month; also, ≤400/100 ml in more than ten percent of all samples taken during the month.

[A] Standard for aquatic life, human health, and other designated uses

[B] Human health standard for contact recreation; aquatic life standard not established

State turbidity standards are based on "background turbidity" levels, but such levels have not been determined for GARI surface waters (Wilson, email communication, 27 January 2017). As a result, there is no numeric turbidity reference condition that can be used for this NRCA.

State and national standards are not available for SpC. However, SpC is related to concentration of total dissolved solids (TDS), and the EPA has recommended a TDS concentration <500 mg/L for drinking water (Sheeder et al. 2004). This recommended TDS concentration equates to an SpC of 325 µmhos or µS/cm. This value will be used as an informal reference condition for this NRCA, as values above this could indicate a need for further investigation and/or cause for concern.

4.9.4. Data and Methods

NPS (1995) presented the results of surface-water quality data retrievals for GARI using six of the EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS). Although many of the sampling sites identified were either single-event or one-year intensive sampling efforts, six stations

within GARI had longer-term water quality records: Gauley River (GARI 0043), Gauley River Below Summersville, WV (GARI 0044), Summersville Dam (GARI 0045), Meadow River Near Mt. Lookout, WV (GARI 0060), Mid Gauley (GARI 0069), and Peters Creek (GARI 0071) (Figure 40).

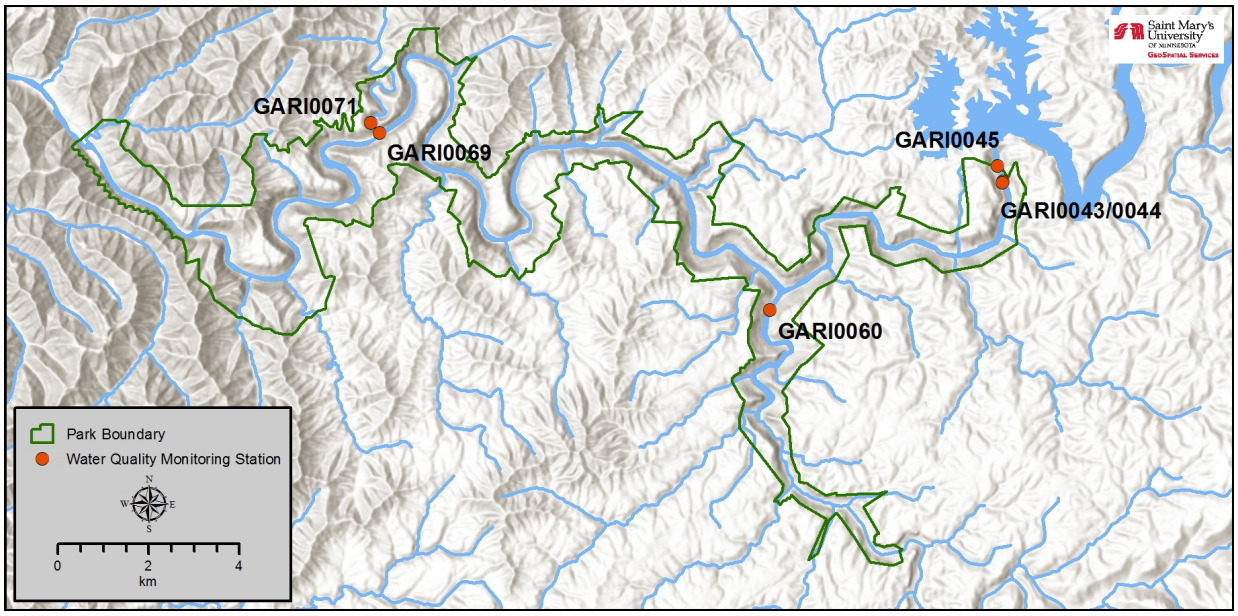


Figure 40. Locations of water quality monitoring stations with long-term records from Gauley River National Recreation Area's baseline report (NPS 1995).

Due to concerns over coliform bacteria levels, various water quality parameters have been monitored at GARI since the early 1990s (Wilson and Purvis 2003). Samples have consistently been gathered at five locations, four within GARI boundaries and one just southeast (upstream) of the park (Hebner 1991, Purvis 2009). Three sites are on the Gauley River, and two are on tributaries (Meadow River and Peters Creek) (Figure 41). Sampling typically occurred between April and October and included the summer recreational season, when bacteria levels are a particular concern (Purvis 2009, NPS 2017c). Parameters measured include temperature, pH, dissolved oxygen, conductivity, turbidity, and fecal coliform (Purvis and Wilson 2007). Sampling results, focused primarily on fecal coliform, were presented by Hebner (1991), Sullivan (1993), Wilson and Purvis (2000, 2003), Purvis and Wilson (2007), and Purvis (2009). A Microsoft Access database (NPS 2017c) containing monitoring results (1991-2016) was provided to SMUMN GSS by park staff. The park baseline water quality report (NPS 1995) included data through 1995; consequently, only data from 1996-2016 in this Access database were used for this analysis. Results from the most recent 5 years available (2012-2016) will provide the best insight into current water quality conditions.

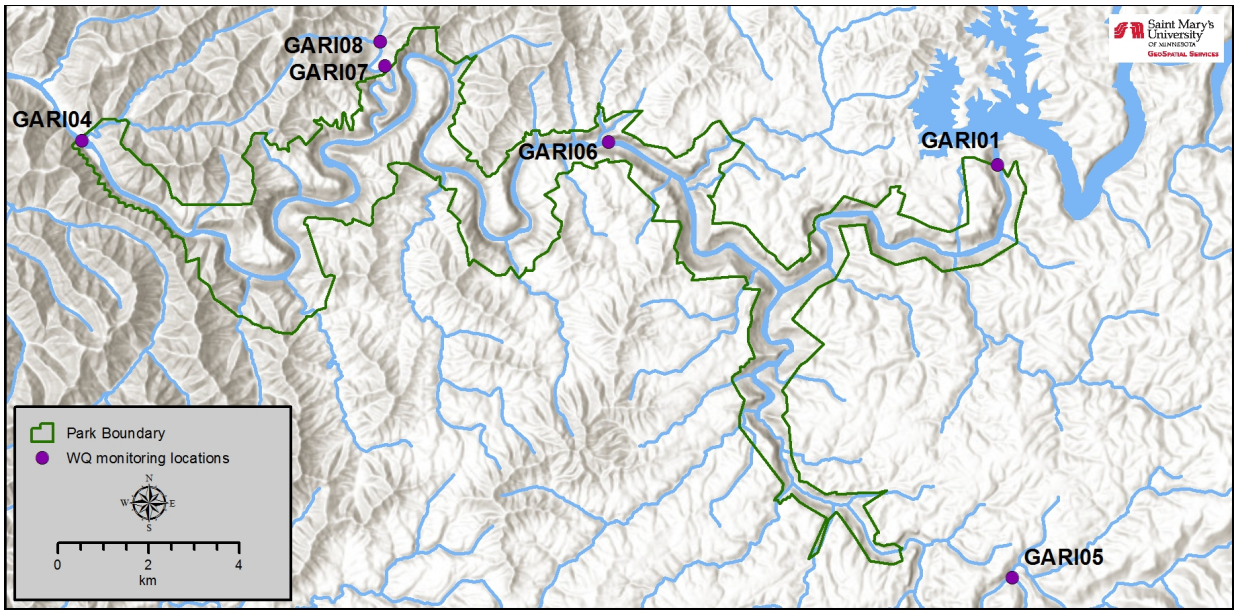


Figure 41. Locations of stations used in recent park water quality monitoring at Gauley River National Recreation Area. (NPS 2017c).

Since 2008, core water quality parameters (temperature, pH, DO, and SpC) have been sampled by ERMN as part of the wadeable stream monitoring program, in conjunction with benthic macroinvertebrate sampling (Tzilkowski et al. 2015). Four tributary stream reaches have been monitored at GARI: Meadow Creek, Peters Creek, Horseshoe Creek, and Laurel Creek (Figure 33). Water quality sampling methods are based on USGS procedures, as outlined in Tzilkowski et al. (2010). Monitoring has occurred primarily in the spring (March-April), although some early samples were taken in the fall. ERMN also deployed continuous water quality monitors at two locations on the Gauley River between August 2013 and October 2014. These monitors recorded water temperature and SpC observations every hour, although some gaps occurred when sensors malfunctioned or were exposed to the air due to low water levels (Caleb Tzilkowski, ERMN Aquatic Ecologist, written communication, 16 February 2017). The upstream sampling location was less than 1.0 km (0.6 mi) below the Summersville Dam and the downstream location was approximately 2 km (1.2 mi) upstream from Swiss, near the park's western boundary (NPS 2017a).

Webber (2012) collected data from two GARI streams (Laurel and Meadow Creeks) as part of a larger study to characterize water quality in in ERMN wadeable streams. Parameters including temperature, pH, DO, turbidity, nutrients, and major ions (e.g., sulfate, chloride) were measured six times at each site during seasonal baseflow conditions in 2010-2011 (Webber 2012). Webber (2012) classified each stream as reference (i.e., high quality), fair, or impaired, based on water chemistry and habitat criteria outlined by Waite et al. (2000).

4.9.5. Current Condition and Trend

Temperature

Historic observations (1966-1995) of water temperatures within GARI ranged from 0-27°C (32-80.6°F) (NPS 1995). Maximum temperatures were lower at stations near Summersville Dam and

higher further downstream (near and on Peters Creek) (Table 52). Since state temperature standards vary with season and exact sampling dates for these historical observations were not provided, it is uncertain whether exceedances of the lower December-April standard occurred. However, all observations met the May-November standard of 30.6°C (87°F).

Table 52. Historic (pre-1996) water temperature observations (°C) for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	62 (1991-1995)	1.5	21.0	13.2	13.8
Gauley River below Summersville (GARI0044)	141 (1966-1985)	0.5	24.0	9.0	10.7
Gauley River, 0.6 km below dam (GARI0043)	1,411 (1974-1993)	1.7	26.3	18.0	18.0
Mid Gauley, upstream of Peters Creek (GARI0069)	60 (1991-1995)	4.0	27.0	18.0	17.4
Meadow River near Mt. Lookout (GARI0060)	96 (1967-1983)	0	26.0	11.0	11.8
Peters Creek near mouth (GARI0071)	61 (1991-1995)	1.7	27.0	18.0	17.1

Temperature observations by Webber (2012) ranged from a low of 6.5°C (43.7°F) in the fall to a high of 22.1°C (71.8°F) in summer (Table 53). Both of these observations were from Meadow Creek; the water temperature range for Laurel Creek was slightly narrower, from 7.0-20.2°C (44.6-68.4°F). No observations exceeded either the December-April or May-November standards.

Table 53. Water temperature observations (°C) from Gauley River tributaries within Gauley River National Recreation Area, 2010-2011 (Webber 2012).

Site	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Laurel Creek	20.0	7.0	8.9	20.2	10.2
Meadow Creek	19.6	6.5	7.7	22.1	9.7

Tzilkowski et al. (2015) found that water temperatures on Gauley tributaries in the spring were generally in the 7-13°C (44.6-55.4°F) range, with the greatest range on Laurel Creek (Figure 42). All observations were well within state standards.

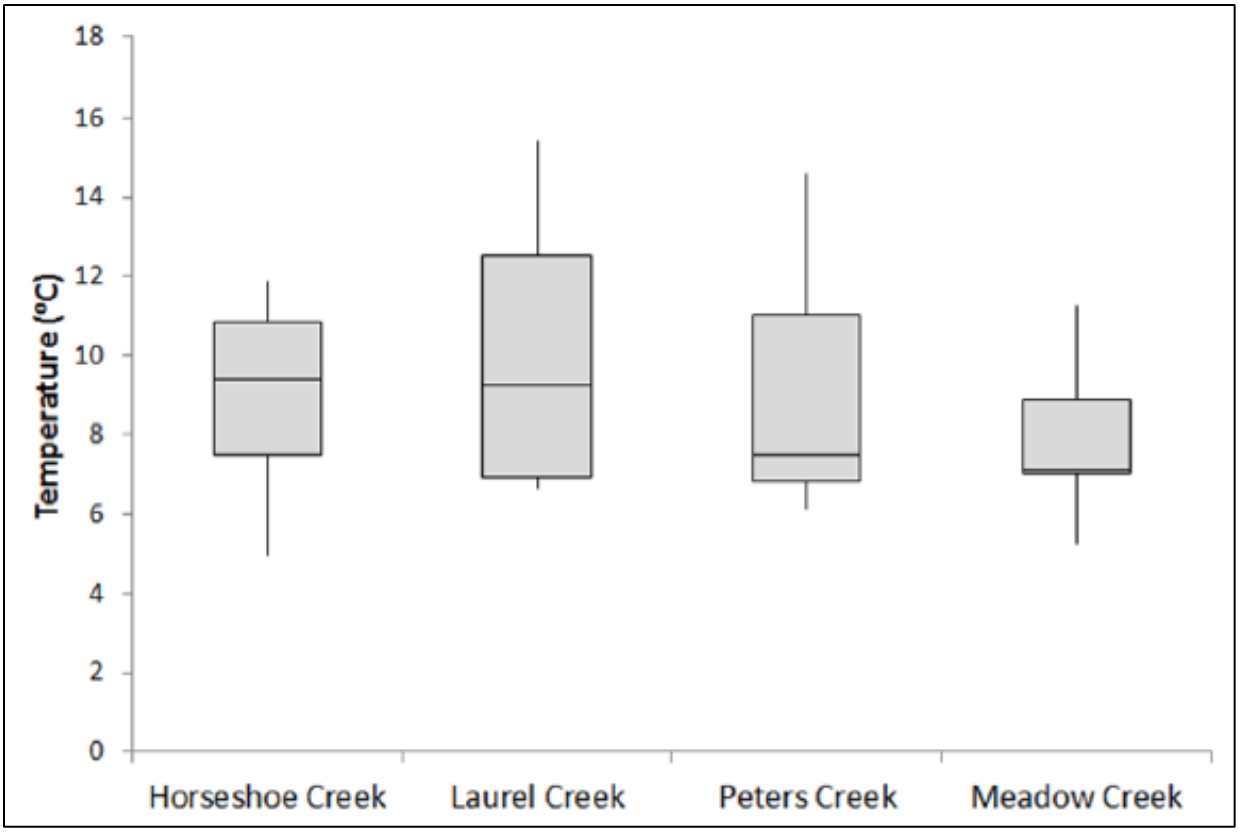


Figure 42. Water temperature ranges documented during Eastern Rivers and Mountains Network water quality sampling at Gauley River National Recreation Area, 2008-2013 (reproduced from Tzilkowski et al. 2015). Horseshoe and Laurel Creeks were sampled four times, Peters Creek three times, and Meadow Creek five times. The bottom and top of the boxes represent the 1st and 3rd quartiles respectively, whereas the band in each box is the median. "Whisker" ends represent minimum and maximum values.

Continuous water quality monitors deployed by ERMN in 2013-2014 recorded temperature ranges of 0.8-18.6°C (33.4-65.5°F) at the upstream location (below Summersville Dam) (Figure 43) and 0-28.4°C (32-83.1°F) at the downstream location (near Swiss) (Figure 44) (NPS 2017a). The range of water temperatures was narrower at the upstream location, where cooler water is regularly released from Summersville Dam.

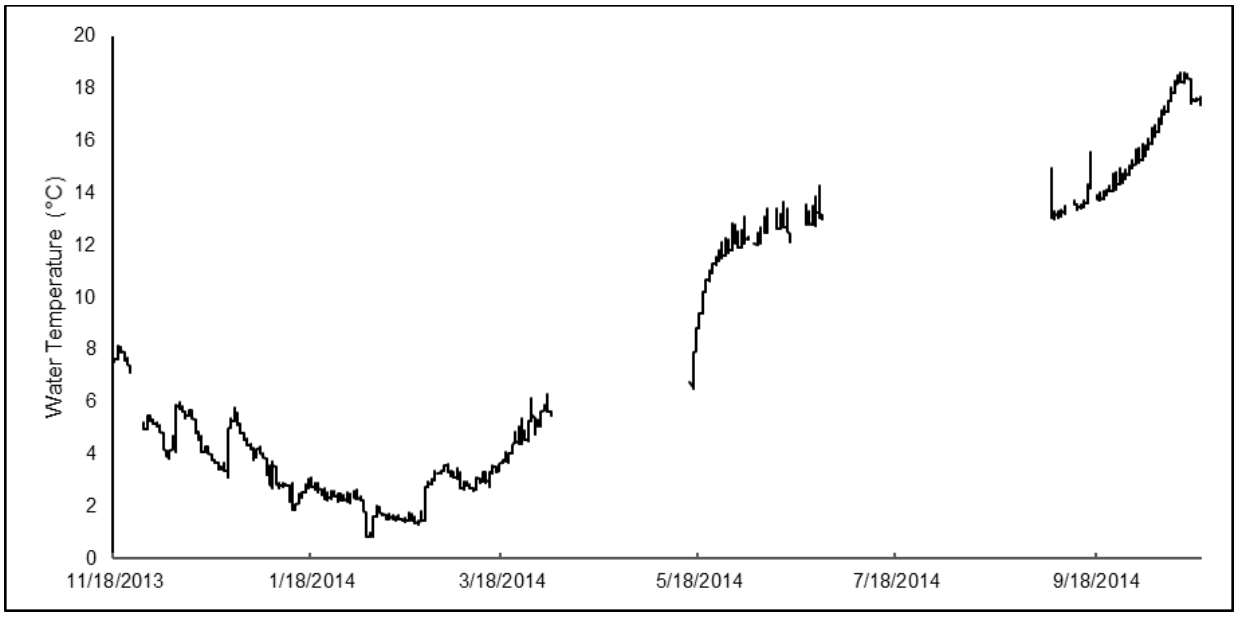


Figure 43. Continuous (hourly) water temperature observations at the upstream Gauley River location, 2013-2014 (NPS 2017a). Gaps represent periods when sensors malfunctioned or were exposed to the air due to low water levels.

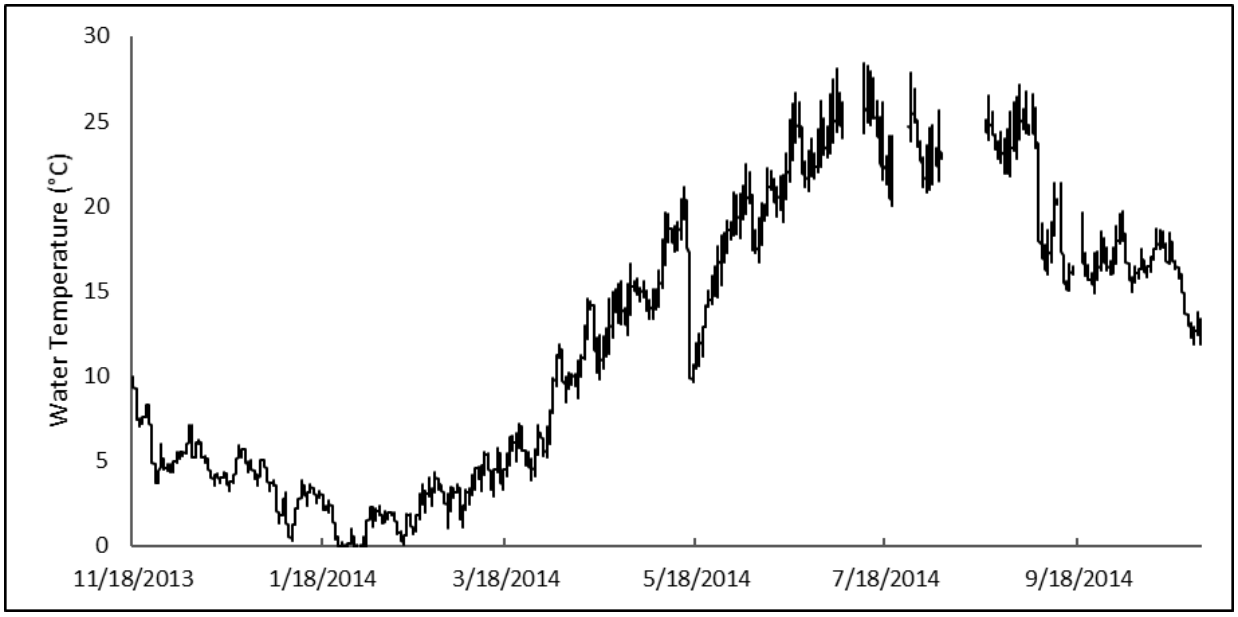


Figure 44. Continuous (hourly) water temperature observations at the upstream Gauley River location, 2013-2014 (NPS 2017a).

During 1996-2011 park monitoring, water temperatures on the Gauley River ranged from 3.1-28.5°C (37.6-83.3°F), with means from 13.3-16.7°C (55.9-62.1°F) (NPS 2017c). Meadow River water temperatures were 2.8-28.0°C (37.0-82.4°F) during this time, whereas Peters Creek temperatures ranged from 5.0-26.0°C (41.0-78.8°F) between 1996 and 2008 (Table 54). From 2012-2016, Gauley River water temperature observations ranged from 5.0-24.3°C (41.0-75.7°F), with annual means

between 11.4-18.0°C (52.5-64.4°F) (NPS 2017c). However, annual means can be influenced by the timing and number of samples taken each year and should be compared with caution. Mean and maximum water temperatures were consistently lower at the site just below the dam than at locations farther downstream. Water temperatures on the Meadow River during 2012-2016 ranged from 7.5-23.8 °C (45.5-74.8°F) with means from 15.0-17.2°C (59.0-63.0°F). Temperatures on Peters Creek (2011-2016) ranged from 8.6-24.2°C (47.5-75.6°F) with means from 13.5-18.8°C (56.3-65.8°F). All observations met the state standards.

Table 54. Water temperature results (°C) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River below Summersville Dam (G01)	1996-2011 (104, Feb-Oct)	3.1	21.6	13.3
	Apr-Oct 2012 (5)	11.5	18.0	14.7
	Apr-Sept 2013 (4)	5.0	19.5	12.8
	Apr-Oct 2014 (5)	5.9	13.7	11.4
	Apr-Oct 2015 (6)	9.1	19.7	14.4
	May-Oct 2016 (2)	13.4	16.4	14.9
Gauley River above Mason Branch (G06)	1996-2011 (104, Feb-Oct)	3.4	27.8	15.0
	Apr-Oct 2012 (5)	9.1	19.6	15.3
	Apr-Sept 2013 (4)	12.1	18.0	15.3
	Apr-Oct 2014 (5)	11.7	20.6	15.4
	Apr-Oct 2015 (6)	10.2	20.6	16.0
	May-Oct 2016 (2)	14.1	15.2	14.7
Gauley River above Swiss (G04)	1996-2011 (103, Feb-Oct)	3.8	28.5	16.7
	Apr-Oct 2012 (5)	12.3	24.1	17.7
	Apr-Sept 2013 (4)	12.3	20.1	16.2
	Apr-Oct 2014 (5)	11.9	24.3	18.0
	Apr-Oct 2015 (6)	10.4	20.9	18.0
	May-Oct 2016 (2)	15.0	15.5	15.3
Meadow River (G05)	1996-2011 (106, Feb-Oct)	2.8	28.0	16.5
	Apr-Oct 2012 (5)	7.5	21.3	15.0
	Apr-Sept 2013 (4)	11.4	20.3	15.5
	Apr-Oct 2014 (5)	9.2	23.8	17.1
	Apr-Oct 2015 (6)	8.6	23.8	17.2
	Apr-Oct 2016 (7)	10.7	22.9	16.1
Peters Creek at Ford (G07)	1996-2008 (99, Feb-Oct)	5.0	26.0	16.5

Table 54 (continued). Water temperature results (°C) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	11.5	24.2	18.8
	Apr-Oct 2012 (5)	9.1	21.6	15.8
	Apr-Sept 2013 (4)	12.7	21.9	16.6
	Apr-Oct 2014 (5)	8.6	22.8	17.3
	Apr-Oct 2015 (6)	8.6	23.2	16.8
	May-Oct 2016 (2)	11.1	15.8	13.5

pH

Historic pH observations on the Gauley River and its tributaries within GARI ranged from 4.0-8.7, with means from 6.7-7.9 (NPS 1995). The lowest measurement (4.0) occurred on the Meadow River and the highest measurement (8.7), as well as the highest mean, was on Peters Creek (Table 55). Minimum observations at four stations (GARI0043, GARI0044, GARI0045, GARI0060) fell below the state standard range of 6.0-9.0.

Table 55. Historic (pre-1996) pH observations for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	61 (1991-1995)	5.4	8.6	7.2	7.1
Gauley River below Summersville (GARI0044)	77 (1969-1985)	5.6	7.8	6.9	6.9
Gauley River, 0.6 km below dam (GARI0043)	72 (1974-1993)	5.1	7.9	6.8	6.7
Mid Gauley, upstream of Peters Creek (GARI0069)	61 (1991-1995)	6.0	8.2	7.3	7.2
Meadow River near Mt. Lookout (GARI0060)	57 (1969-1983)	4.0	8.4	7.0	7.0
Peters Creek near mouth (GARI0071)	61 (1991-1995)	6.5	8.7	8.0	7.9

Readings taken by Webber (2012) on Gauley tributaries ranged from 7.0 to 7.6, all within state standards (Table 56).

Table 56. pH observations from Gauley River tributaries within Gauley River National Recreation Area, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Laurel Creek	7.0	7.6	7.4	7.3	7.1	7.4
Meadow Creek	7.1	7.5	7.6	7.3	7.6	7.4

Observations by Tzilkowski et al. (2015) also fell within state standards, ranging from just above 6.0 to approximately 7.8 (Figure 45). Values were higher on Peters and Meadow Creeks and lower on Laurel and Horseshoe Creeks, with more variability.

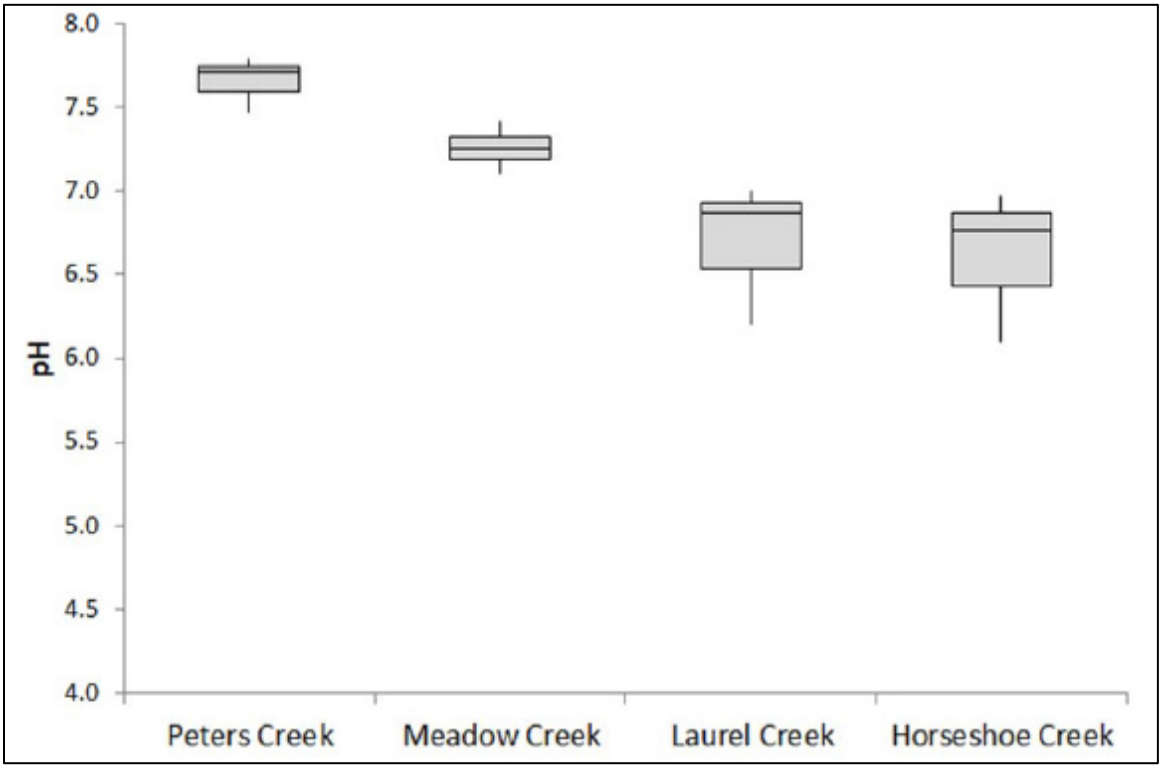


Figure 45. pH ranges documented during Eastern River and Mountain Network water quality sampling at Gauley River National Recreation Area, 2008-2013 (reproduced from Tzilkowski et al. 2015). "Whisker" ends represent minimum and maximum values.

Park monitoring on the Gauley River from 1996-2011 documented pH values between 5.7 and 9.5, with means in the 7.0-7.4 range (Table 57) (NPS 2017c). During this period there were four observations from the Gauley River below the state minimum (pH of 6) and just one observation above the state maximum (pH of 9). pH observations on tributaries from 1996-2011 ranged from 6.6-8.2, with means between 7.3 and 8.0 and no values outside state standards. More recently (2012-2016), pH observations from the Gauley River ranged from 6.6-8.0, with annual means between 7.0 and 7.8 (NPS 2017c). Tributary pH measurements during this time were between 7.0 and 8.4, with annual means in the 7.3-8.2 range. All observations from 2012-2016 met state standards.

Table 57. pH results from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River below Summersville Dam (G01)	1996-2011 (104)	5.72	9.5	7.00
	Apr-Oct 2012 (5)	7.03	7.37	7.19
	Apr-Sept 2013 (4)	6.65	7.61	7.04
	Apr-Oct 2014 (5)	6.78	7.54	7.16
	Apr-Oct 2015 (6)	6.88	7.48	7.18
	May-Oct 2016 (2)	6.97	7.05	7.01
Gauley River above Mason Branch (G06)	1996-2011 (103)	5.97	7.9	7.2
	Apr-Oct 2012 (5)	7.39	7.74	7.59
	Apr-Sept 2013 (4)	7.25	7.61	7.48
	Apr-Oct 2014 (5)	7.37	7.65	7.56
	Apr-Oct 2015 (6)	7.37	7.88	7.59
	May-Oct 2016 (2)	7.27	7.69	7.48
Gauley River above Swiss (G04)	1996-2011 (102)	6.8	8.0	7.37
	Apr-Oct 2012 (5)	7.59	7.93	7.71
	Apr-Sept 2013 (4)	7.38	7.62	7.53
	Apr-Oct 2014 (5)	7.61	7.77	7.71
	Apr-Oct 2015 (6)	7.52	7.97	7.78
	May-Oct 2016 (2)	7.62	7.82	7.72
Meadow River (G05)	1996-2011 (106)	6.6	7.98	7.34
	Apr-Oct 2012 (5)	7.35	8.1	7.61
	Apr-Sept 2013 (4)	7.09	7.73	7.39
	Apr-Oct 2014 (5)	7.17	7.76	7.53
	Apr-Oct 2015 (6)	7.41	7.85	7.70
	Apr-Oct 2016 (7)	7.41	8.22	7.71
Peters Creek at Ford (G07)	1996-2008 (99)	7.09	8.2	7.75
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	7.89	8.08	7.98
	Apr-Oct 2012 (5)	7.72	8.14	7.91
	Apr-Sept 2013 (4)	7.81	7.94	7.88
	Apr-Oct 2014 (5)	7.96	8.29	8.13
	Apr-Oct 2015 (6)	7.82	8.32	8.07
	May-Oct 2016 (2)	7.83	7.95	7.89

Dissolved Oxygen

Historic observations of DO within GARI ranged from 2.2-15.2 mg/L, with the lowest value occurring on the Meadow River (NPS 1995). With the exception of the Meadow River, all observations from the other sampling stations met the state standard of ≥5.0 mg/L (Table 58).

Table 58. Historic (pre-1996) DO (mg/L) observations for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	48 (1991-1995)	6.8	15.0	10.4	10.4
Gauley River below Summersville (GARI0044)	25 (1975-1983)	8.4	15.2	11	11.2
Gauley River, 0.6 km below dam (GARI0043)	70 (1975-1993)	5.9	13.0	9.7	9.7
Mid Gauley, upstream of Peters Creek (GARI0069)	48 (1991-1995)	8.1	14.0	9.4	9.6
Meadow River near Mt. Lookout (GARI0060)	30 (1973-1983)	2.2	14.4	10.2	10.3
Peters Creek near mouth (GARI0071)	48 (1991-1995)	6.2	13.0	9.1	9.4

All DO observations by Webber (2012) met the state standard, with lower values during summer when temperatures are warmer and higher values in the fall when temperatures begin to cool (Table 59).

Table 59. DO observations (mg/L) from Gauley River tributaries within Gauley River National Recreation Area, 2010-2011 (Webber 2012).

Site	Summer 2010	Fall 2010	Summer 2011	Fall 2011
Laurel Creek	8.8	11.9	9.5	11.9
Meadow Creek	8.7	12.2	8.7	12.2

Observations by Tzilkowski et al. (2015) also met the state standard of ≥5.0 mg/L, with values generally in the 10-13 mg/L range (Figure 46).

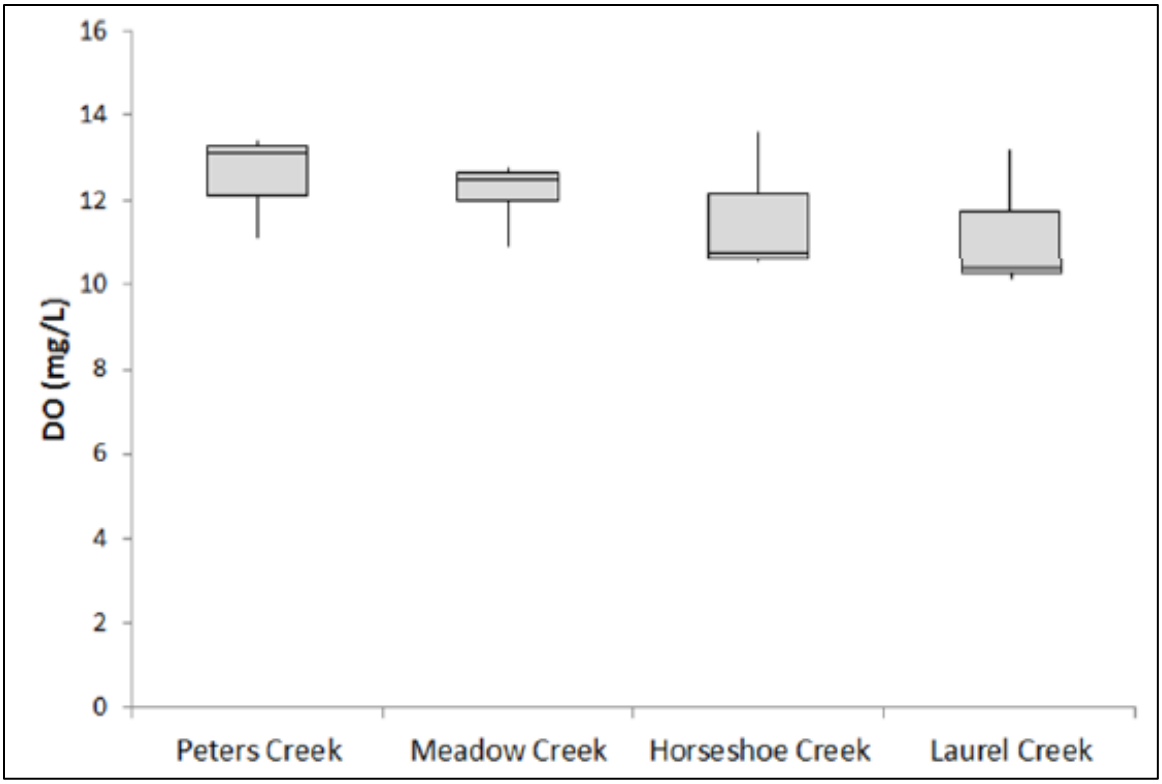


Figure 46. DO ranges documented during Eastern Rivers and Mountains Network water quality sampling at Gauley River National Recreation Area, 2008-2013 (reproduced from Tzilkowski et al. 2015).

From 1996-2011, park monitoring efforts recorded DO ranges on the Gauley River of 5.0-17.6 mg/L, with means of 9.2-9.9 mg/L (NPS 2017c). DO observations on tributaries during this period ranged from 3.3 mg/L on the Meadow River to 14.1 mg/L on Peters Creek, with means from 8.5 to 9.3 mg/L (Table 60). Only two observations from the Meadow River fell below the state standard during this time. From 2012-2016, DO observations on the Gauley River fell between 7.0 and 15.3 mg/L, with annual means typically in the 9-11 mg/L range (NPS 2017c). Tributary DO measurements ranged from 6.2-14.1 mg/L, with annual means between 8.6 and 10.1 mg/L. All observations since 2012 have met the state standard.

Table 60. DO results (mg/L) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River below Summersville Dam (G01)	1996-2011 (104)	5.0	17.6	9.9
	Apr-Oct 2012 (5)	8.5	12.3	10.4
	Apr-Sept 2013 (4)	8.3	15.3	11.2
	Apr-Oct 2014 (5)	8.8	12.4	9.9
	Apr-Oct 2015 (6)	8.1	11.6	9.6
	May-Oct 2016 (2)	8.2	10.1	9.2

Table 60 (continued). DO results (mg/L) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River above Mason Branch (G06)	1996-2011 (104)	5.8	13.4	9.8
	Apr-Oct 2012 (5)	9.0	11.6	10.2
	Apr-Sept 2013 (4)	9.0	13.2	10.4
	Apr-Oct 2014 (5)	7.0	10.7	9.1
	Apr-Oct 2015 (6)	7.5	11.1	9.6
	May-Oct 2016 (2)	10.1	10.1	10.1
Gauley River above Swiss (G04)	1996-2011 (103)	5.6	13.9	9.2
	Apr-Oct 2012 (5)	8.7	10.4	9.5
	Apr-Sept 2013 (4)	9.0	13.0	10.5
	Apr-Oct 2014 (5)	8.0	10.8	9.3
	Apr-Oct 2015 (6)	8.0	11.3	9.3
	May-Oct 2016 (2)	10.2	10.2	10.2
Meadow River (G05)	1996-2011 (104)	3.3	12.7	8.5
	Apr-Oct 2012 (5)	7.9	13.0	9.5
	Apr-Sept 2013 (4)	7.5	13.0	9.5
	Apr-Oct 2014 (5)	7.1	10.5	8.7
	Apr-Oct 2015 (6)	6.7	10.8	8.6
	Apr-Oct 2016 (7)	7.2	10.2	8.8
Peters Creek at Ford (G07)	1996-2008 (98)	6.2	14.1	9.3
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	7.4	10.9	8.6
	Apr-Oct 2012 (5)	7.9	10.6	8.9
	Apr-Sept 2013 (4)	7.8	12.9	9.7
	Apr-Oct 2014 (5)	7.8	10.9	9.3
	Apr-Oct 2015 (6)	7.4	10.3	8.9
	May-Oct 2016 (2)	9.6	10.7	10.1

Specific Conductance

Historic SpC measurements at GARI ranged from 11-535 µS/cm, with means from 53-324 µS/cm (NPS 1995). The highest single observation and mean were on Peters Creek (Table 61). Although no state standard exists for SpC, the informal reference condition of 325 µS/cm (based on EPA criteria for TDS in drinking water) was exceeded on Peters Creek and on the Gauley River 0.6 km (0.4 mi) below the dam (GARI0043).

Table 61. Historic (pre-1996) SpC (µS/cm) observations for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	59 (1991-1995)	11	130	50	53.3
Gauley River below Summersville (GARI0044)	87 (1969-1985)	25	90	57	58.7
Gauley River, 0.6 km below dam (GARI0043)	54 (1974-1993)	17	360	58	60.7
Mid Gauley, upstream of Peters Creek (GARI0069)	59 (1991-1995)	38	110	65	66.7
Meadow River near Mt. Lookout (GARI0060)	59 (1969-1983)	25	190	72	80.4
Peters Creek near mouth (GARI0071)	59 (1991-1995)	80	535	330	323.9

SpC observations by Webber (2012) were all below 180 µS/cm, well below the informal reference condition of 325 µS/cm (Table 62). Measurements from Meadow Creek were consistently higher than measurements from Laurel Creek.

Table 62. SpC observations (µS/cm) from Gauley River tributaries within Gauley River National Recreation Area, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Laurel Creek	68.4	95.9	100.9	70.1	101.1	80.7
Meadow Creek	176.4	126.4	171.6	160.8	159.6	112.8

Tzilkowski et al. (2015) measured substantially higher SpC values on Peters Creek than on the other three Gauley tributaries, ranging from 200 µS/cm to just over 300 µS/cm (Figure 47). Observations from Horseshoe and Laurel Creeks were below 100 µS/cm, while Meadow Creek measurements were in the 100-175 µS/cm range (Tzilkowski et al. 2015).

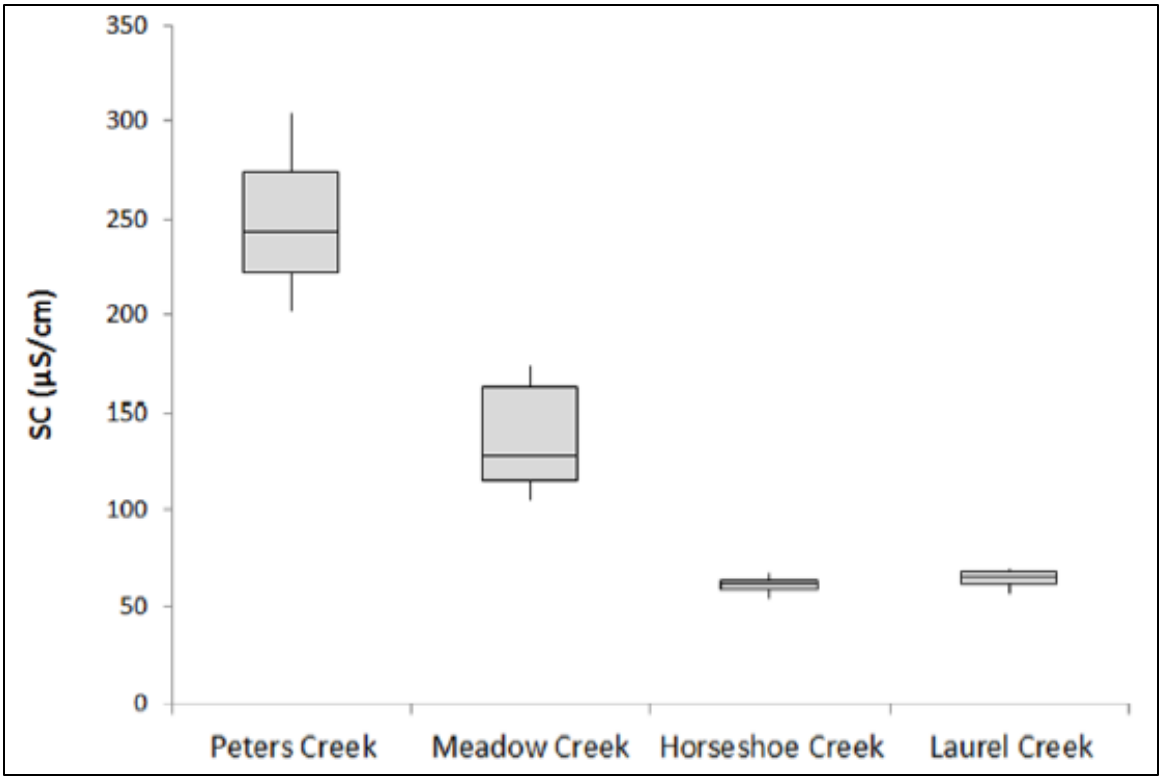


Figure 47. SpC ranges measured during Eastern Rivers and Mountains Network water quality sampling at Gauley River National Recreation Area, 2008-2013 (reproduced from Tzilkowski et al. 2015).

Continuous water quality monitors deployed by ERMN in 2013-2014 recorded SpC ranges of 31.5-134.6 µS/cm at the upstream sampling location (Figure 48) and 50.7-145.9 µS/cm at the downstream location (Figure 49) (NPS 2017a). No observations exceeded 200 µS/cm, which is well below the reference level of 325 µS/cm.

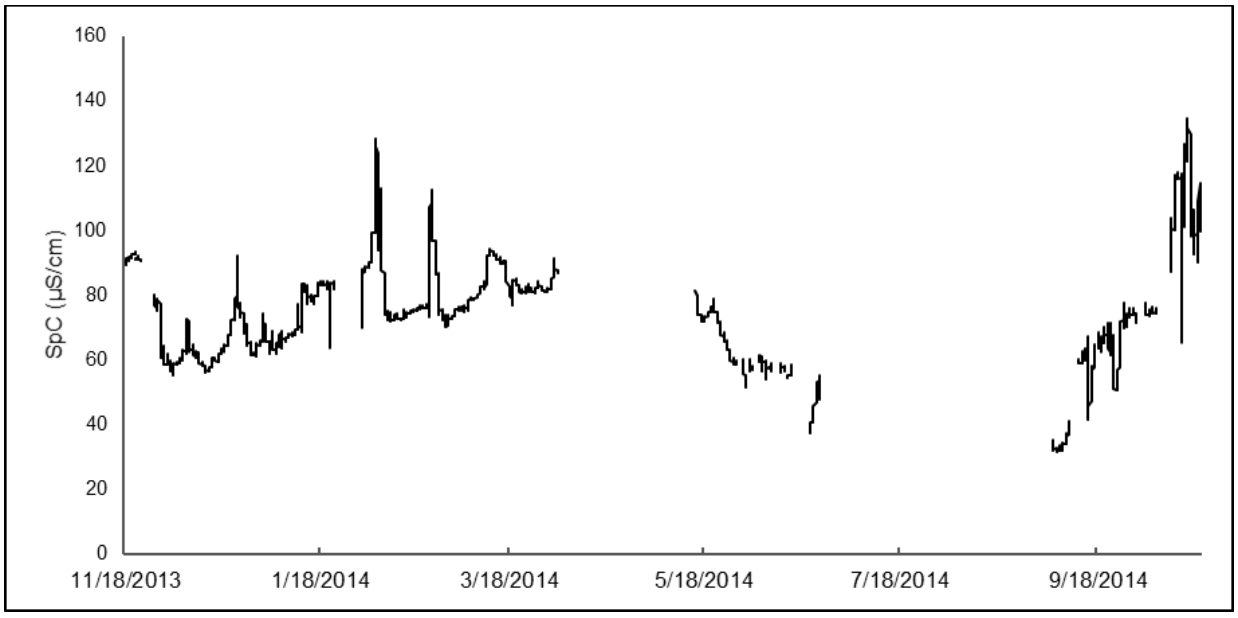


Figure 48. Continuous (hourly) SpC observations at the upstream Gauley River location, 2013-2014 (NPS 2017a). Gaps represent periods when sensors malfunctioned or were exposed to the air due to low water levels.

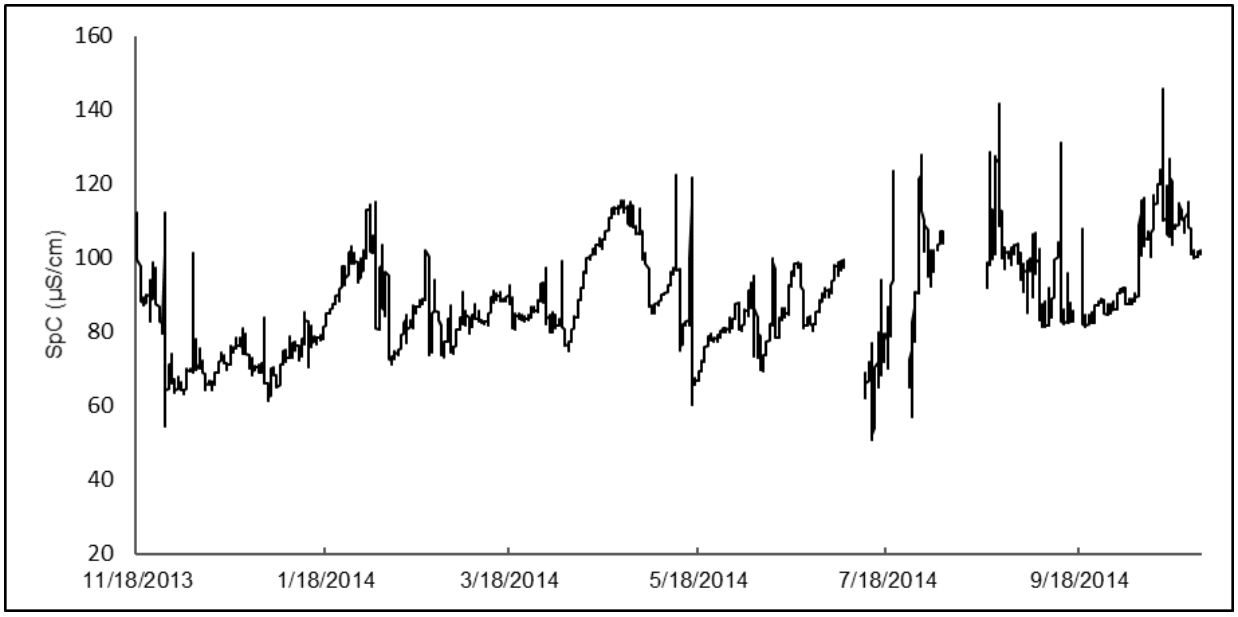


Figure 49. Continuous (hourly) SpC observations at the downstream Gauley River location, 2013-2014 (NPS 2017a).

During 1996-2011 park monitoring, SpC observations at Gauley River locations ranged from 5.0-180.0 µS/cm, with means in the 55-72 µS/cm range (NPS 2017c). SpC values on tributaries were between 12.0 and 585.0 µS/cm (Table 63). From 1996-2008, 37 of 99 observations on Peters Creek exceeded the informal reference condition of 325 µS/cm (NPS 2017c). More recently (2012-2016), Gauley River SpC observations fell between 35.8 and 117.3 µS/cm, with annual means in the 51-93

µS/cm range. Annual means are influenced by the timing and number of samples taken each year, as SpC may shift with heavy precipitation and flow levels. Meadow River SpC observations were slightly higher, ranging from 51.6-177.2 µS/cm, with annual means between 72 and 119 µS/cm. Peters Creek measurements have again been much higher, ranging from 144.9-551.0 µS/cm with annual means of 225-388 µS/cm (Table 63). From 2011-2016, 13 of 26 observations on Peters Creek have exceeded 325 µS/cm (NPS 2017c).

Table 63. Conductivity results (µS/cm) from Gauley River National Recreation Area monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River below Summersville Dam (G01)	1996-2011 (104)	5.0	120.0	54.9
	Apr-Oct 2012 (5)	52.5	98.0	67.0
	Apr-Sept 2013 (4)	40.0	85.3	56.3
	Apr-Oct 2014 (5)	39.8	76.7	51.2
	Apr-Oct 2015 (6)	44.4	109.3	63.9
	May-Oct 2016 (2)	56.9	99.0	78.0
Gauley River above Mason Branch (G06)	1996-2011 (103)	32.0	139.0	64.0
	Apr-Oct 2012 (5)	60.2	98.5	75.4
	Apr-Sept 2013 (4)	35.8	70.9	55.3
	Apr-Oct 2014 (5)	56.0	74.3	65.4
	Apr-Oct 2015 (6)	46.4	114.9	75.6
	May-Oct 2016 (2)	56.7	98.4	77.6
Gauley River above Swiss (G04)	1996-2011 (103)	41.5	180.0	72.0
	Apr-Oct 2012 (5)	68.9	112.2	92.5
	Apr-Sept 2013 (4)	60.0	80.9	67.4
	Apr-Oct 2014 (5)	68.6	96.7	84.5
	Apr-Oct 2015 (6)	49.0	117.3	84.2
	May-Oct 2016 (2)	59.9	104.5	82.2
Meadow River (G05)	1996-2011 (106)	12.0	228.5	103.8
	Apr-Oct 2012 (5)	54.7	148.2	101.0
	Apr-Sept 2013 (4)	52.9	86.2	72.4
	Apr-Oct 2014 (5)	52.1	170.3	99.0
	Apr-Oct 2015 (6)	51.6	168.8	118.3
	Apr-Oct 2016 (7)	56.0	177.2	108.4
Peters Creek at Ford (G07)	1996-2008 (99)	85.0	585.0	281.6

Table 63 (continued). Conductivity results (µS/cm) from Gauley River National Recreation Area monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	213.3	414.7	323.0
	Apr-Oct 2012 (5)	144.9	440.8	325.3
	Apr-Sept 2013 (4)	214.9	364.2	259.4
	Apr-Oct 2014 (5)	294.0	551.0	387.7
	Apr-Oct 2015 (6)	193.9	436.4	333.1
	May-Oct 2016 (2)	208.6	241.8	225.2

Turbidity

The units for turbidity measurements vary depending on the equipment used for sampling, although this distinction was not recognized until 2004 (USGS 2017b). Since 2004, measurements taken with a device using white or broadband light are presented in Nephelometric Turbidity Units (NTUs) while those taken with devices using infrared, monochromatic light are measured in Formazin Turbidity Units (FTU) (USGS 2017b). These two units are not directly comparable. Historically, the U.S. Army Corps of Engineers (USACE) measured turbidity in FTU while the NPS has used NTU (Wilson, written communication, April 2017). Historic observations of turbidity within GARI ranged from 0.5-240.0 NTU (NPS 1995). Mean values showed a much narrower range of 2.5-14.8 NTU (Table 64).

Table 64. Historic (pre-1996) turbidity observations for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	50 (1992-1995)	0.9 NTU	23.0 NTU	2.9 NTU	4.3 NTU
Gauley River, 0.6 km below dam (GARI0043)	11 (1974-1978)	0.5 NTU	7.4 NTU	2.1 NTU	2.5 NTU
Mid Gauley, upstream of Peters Creek (GARI0069)	50 (1992-1995)	1.0 NTU	22.0 NTU	2.8 NTU	4.7 NTU
Meadow River near Mt. Lookout (GARI0060)	1 (1980)	28 FTU	28 FTU	–	–
Peters Creek near mouth (GARI0071)	50 (1992-1995)	1.4 NTU	240.0 NTU	3.9 NTU	14.8 NTU

On Gauley River tributaries, Webber (2012) observed turbidities in the 0.4-180.0 FTU range, with all but one measurement below 15.0 FTU (Table 65). The single high observation from Laurel Creek occurred in the summer and may have followed a precipitation/runoff event. The difference between

maximum and minimum turbidity on Laurel Creek was >10 FTUs in 2011, as were the maximum and minimum turbidity on Meadow Creek in 2010 (Table 65).

Table 65. Turbidity observations (FTU) from Gauley River tributaries within Gauley River National Recreation Area, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Laurel Creek	0.8	2.54	0.45	10.4	180.0	0.5
Meadow Creek	0.8	13.1	2.2	10.3	14.7	0.7

Turbidities on the Gauley River during 1996-2011 park monitoring were variable, ranging from 0.2-228.0 NTU, with means between 7.9 and 10.1 NTU (Table 66) (NPS 2017c). Only seven observations exceeded 50 NTU. Tributary turbidities over this same period ranged from 0.6-662.0 NTU, with six observations from Peters Creek above 50 NTU and three observations above 500 NTU. More recently (2012-2016), Gauley River turbidity observations ranged from 0.8-12.1 NTU, with the majority of annual means in the 2-5 NTU range. Tributary turbidities were more variable, ranging from 0.8-37.6 NTU, but with most annual means below 10 NTU (NPS 2017c).

Table 66. Turbidity results (NTU) from Gauley River National Recreation Area monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Gauley River below Summersville Dam (G01)	1996-2011 (104)	0.2	228.0	8.7
	Apr-Oct 2012 (5)	1.3	3.7	2.1
	Apr-Sept 2013 (4)	2.5	10.0	5.0
	Apr-Oct 2014 (5)	2.0	11.7	5.2
	Apr-Oct 2015 (6)	1.9	7.6	4.2
	May-Oct 2016 (2)	3.0	7.3	5.2
Gauley River above Mason Branch (G06)	1996-2011 (104)	0.5	89.0	7.9
	Apr-Oct 2012 (5)	0.8	4.9	2.6
	Apr-Sept 2013 (4)	5.2	11.3	8.3
	Apr-Oct 2014 (5)	1.6	8.7	3.7
	Apr-Oct 2015 (6)	1.6	10.1	4.9
	May-Oct 2016 (2)	4.3	5.5	4.9
Gauley River above Swiss (G04)	1996-2011 (103)	0.2	91.4	10.1
	Apr-Oct 2012 (5)	1.1	3.1	1.8
	Apr-Sept 2013 (4)	3.1	12.1	7.4
	Apr-Oct 2014 (5)	1.4	7.4	3.1
	Apr-Oct 2015 (6)	1.1	10.1	4.5
	May-Oct 2016 (2)	4.2	5.0	4.6

Table 66 (continued). Turbidity results (NTU) from Gauley River National Recreation Area monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Meadow River (G05)	1996-2011 (106)	0.6	73.9	8.2
	Apr-Oct 2012 (5)	0.8	8.0	3.2
	Apr-Sept 2013 (4)	14.5	36.8	21.0
	Apr-Oct 2014 (5)	2.1	3.9	2.9
	Apr-Oct 2015 (6)	1.0	15.4	6.0
	Apr-Oct 2016 (7)	1.3	9.1	3.8
Peters Creek at Ford (G07)	1996-2008 (99)	0.6	662.0	29.4
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	2.3	4.8	3.9
	Apr-Oct 2012 (5)	1.5	37.6	11.3
	Apr-Sept 2013 (4)	2.2	6.7	4.5
	Apr-Oct 2014 (5)	1.1	4.2	2.6
	Apr-Oct 2015 (6)	0.9	28.3	9.9
	May-Oct 2016 (2)	1.4	4.9	3.2

Fecal Coliform Bacteria

Historic fecal coliform measurements from GARI waters have ranged widely from 0.4-1,867.0 FC/100ml, with means from 4.7-270.3 FC /100ml (NPS 1995). Only the Meadow River and Peters Creek had observations ≥400 FC/100ml (Table 67).

Table 67. Historic (pre-1996) fecal coliform observations (FC/100ml) for Gauley River National Recreation Area sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Gauley River at Summersville Dam (GARI0045)	26 (1991-1995)	0.4	164.0	3.5	22.0
Gauley River below Summersville (GARI0044)	7 (1981-1982)	0.5	90.0	1.0	32.2
Mid Gauley, upstream of Peters Creek (GARI0069)	28 (1991-1995)	1.0	22.0	2.8	4.7
Meadow River near Mt. Lookout (GARI0060)	7 (1981-1982)	11.0	400.0	220.0	184.1
Peters Creek near mouth (GARI0071)	32 (1991-1995)	18.0	1,867.0	111.0	270.3

Fecal coliform observations have also been highly variable during park monitoring, with values on the Gauley River between 1996 and 2011 ranging from 0-20,001 FC/100ml (Table 68) (NPS 2017c).

During this time, nearly 10% of observations (31 out of 315) exceeded 400 FC/100ml. Observations on the Meadow River during this time ranged from 2-4,000 FC/100ml, with 26 observations ≥400 FC/100ml. Peters Creek measurements (1996-2008) showed the greatest range, from 10-34,000 FC/100ml, with a mean of nearly 1,580 FC/100ml and 31 observations exceeding 400 FC/100ml (NPS 2017c). More recently (2012-2016), observations on the Gauley River ranged from 0-380 FC/100ml, with no measurements ≥400 FC/100ml and only four observations ≥200 FC/100ml (Table 68). During the same period, coliform observations on the Meadow River ranged from 6-630 FC/100ml, with just one measurement ≥400 FC/100ml and five measurements ≥200 FC/100ml. Peters Creek again showed the highest measurements, with observations between 10 and 1,400 FC/100ml (NPS 2017c). Four observations exceeded 400 FC/100ml and 11 exceeded 200 FC/100ml.

Table 68. Fecal coliform bacteria results (FC/100ml) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean	Samples ≥200	Samples ≥400
Gauley River below Summersville Dam (G01)	1996-2011 (105)	0	2,900	75.8	8	4
	Apr-Oct 2012 (5)	0	13	5.6	0	0
	Apr-Sept 2013 (4)	0	204	60.0	1	0
	Apr-Oct 2014 (5)	0	33	10.6	0	0
	Apr-Oct 2015 (6)	0	31	8.5	0	0
	May-Oct 2016 (2)	45	86	65.5	0	0
Gauley River above Mason Branch (G06)	1996-2011 (107)	1	2,670	157.0	18	13
	Apr-Oct 2012 (5)	2	66	25.0	0	0
	Apr-Sept 2013 (4)	9	273	95.5	1	0
	Apr-Oct 2014 (5)	2	17	8.4	0	0
	Apr-Oct 2015 (6)	1	58	29.2	0	0
	May-Oct 2016 (2)	42	102	72	0	0
Gauley River above Swiss (G04)	1996-2011 (103)	0	20,001	362.9	22	14
	Apr-Oct 2012 (5)	6	29	14.4	0	0
	Apr-Sept 2013 (4)	8	380	119.5	1	0
	Apr-Oct 2014 (5)	2	19	8.6	0	0
	Apr-Oct 2015 (6)	2	283	61.3	1	0
	May-Oct 2016 (2)	10	52	31	0	0
Meadow River (G05)	1996-2011 (106)	2	4,000	341.0	34	26
	Apr-Oct 2012 (5)	6	85	38.8	0	0
	Apr-Sept 2013 (4)	40	630	271.8	2	1
	Apr-Oct 2014 (5)	12	33	22.2	0	0
	Apr-Oct 2015 (6)	16	237	95.8	2	0
	Apr-Oct 2016 (7)	7	397	86.9	1	0

Table 68 (continued). Fecal coliform bacteria results (FC/100ml) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean	Samples ≥200	Samples ≥400
Peters Creek at Ford (G07)	1996-2008 (99)	10	34,000	1,578.6	44	31
Peters Creek below Stillhouse Branch (G08)	June-Oct 2011 (4)	79	363	187.3	1	0
	Apr-Oct 2012 (5)	57	1,400	421.6	3	1
	Apr-Sept 2013 (4)	73	745	279.5	2	1
	Apr-Oct 2014 (5)	10	298	98.8	1	0
	Apr-Oct 2015 (6)	49	817	284.5	3	2
	May-Oct 2016 (2)	49	233	141.0	1	0

Threats and Stressor Factors

Threats to GARI's water quality include upstream agricultural use and logging; residential and other development; inadequately treated sewage; coal mining and transport (by rail); oil and gas exploration/development; pesticides, road de-icers, and industrial chemicals (e.g., fracking waste disposal sites); bilge waste from boats on Summersville Lake; cold water influx from the reservoir; and atmospheric deposition. One of the greatest water quality concerns is high fecal coliform bacteria levels, which led to the 303d impaired listing for the Meadow River and Peters Creek (Tzilkowski et al. 2015). While some bacteria may originate from livestock and wildlife, it is likely that the primary contributor is inadequately treated sewage (i.e., human waste) (Purvis and Wilson 2007). Many communities and households in the region around the park lack adequate septic or sewage systems for the proper treatment of human and other domestic wastes (Purvis 2002, 2009). This is largely due to the longstanding poverty in the area and the high cost of building sewer lines in rocky, densely forested terrain (Purvis 2002).

There are still active coal mines in the watersheds that flow into GARI, primarily in the Peters Creek watershed north of the park (Figure 50) (WVDEP 2017). One very large, active mountaintop removal (MTR) operation is just 3.2 km (2 mi) north of the GARI boundary, near Lockwood, WV (Figure 51) (Claire Rozdilski, GARI Outdoor Recreation Planner, Acting Chief of Natural Resources, written communication, April 2017). Mining activity not only contributes sediment to stream ecosystems, it also increases certain mineral concentrations (e.g., sulfate, calcium, magnesium) and overall SpC (Bernhardt et al. 2012). In a study of southern West Virginia watersheds, Bernhardt et al. (2012) found a direct relationship between stream conductivity, sulfate concentration, and the percent of a watershed that is mined for coal. These elevated mineral concentrations and conductivities can negatively impact aquatic wildlife communities. Coal is typically transported by rail, and a set of railroad tracks used for transporting coal runs parallel to a portion of the Gauley River downstream of Peters Creek. Coal may give off "fugitive dust" during transport, if not covered properly (Lazo and McClain 1996), which could run off into nearby surface waters during precipitation events. Train derailments are not uncommon in the U.S., with over 4,000 occurring on main rail lines nationwide

between 2001-2010 (Liu et al. 2012). If a coal train were to derail and spill its cargo or fuel in the vicinity of GARI, water quality could be impacted.

According to the WVDEP, there are currently four active gas wells within GARI boundaries and an additional 25 active wells within 1 km (0.6 mi) of park boundaries (WVDEP 2016b). Many of these are near surface waters (Figure 52). During drilling and extraction, there is a risk that drilling fluids, gas, or waste fluids may spill or leak, potentially contaminating nearby waters (Purvis 2002, NPS 2009). Trucks, pipelines, and pumping stations required for the transportation of gas and waste products may spill or leak as well. There are also four abandoned (unmaintained) gas wells within GARI boundaries and 11 abandoned wells nearby that may threaten park resources (Figure 52) (WVDEP 2016b). The liquid wastes from oil and gas extraction operations (primarily brine) are often pumped back into the ground by separate injection wells (EPA 2016b). Although these wells are designed to carry the waste fluids to deep underground formations that are isolated from groundwater sources, there is a risk of leaks or spills at or near the surface, which could contaminate surface waters and/or shallow groundwater. Currently, the closest injection well to the park is just over 16 km (10 mi) to the northwest (Figure 53). Given that the park lies on the southeastern edge of the Marcellus Shale, a major gas-bearing rock formation, there is a potential for new gas exploration and development near the park (NPS 2009).

Surrounding land use can have a significant impact on the surface water quality of protected areas, especially at GARI, where the majority of the watershed lies outside park boundaries (Marshall and Piekielek 2007a). Land cover within the GARI watershed is primarily forested, with a small amount of hay/pasture and cropland near the park (Figure 54) (Sheeder et al. 2004). Agricultural land uses can contribute pollutants (e.g., chemicals, nutrients, fecal bacteria from livestock) and excess sediment to streams (Purvis 2002). In forested areas around GARI, most of the timber is considered harvestable, and active logging occurs near, adjacent to, and sometimes within park boundaries (Purvis 2002). This logging, and the roads associated with logging activity, increase soil exposure and erosion, which in turn increases sedimentation of streams in the area (Hebner 1991, Purvis 2002).

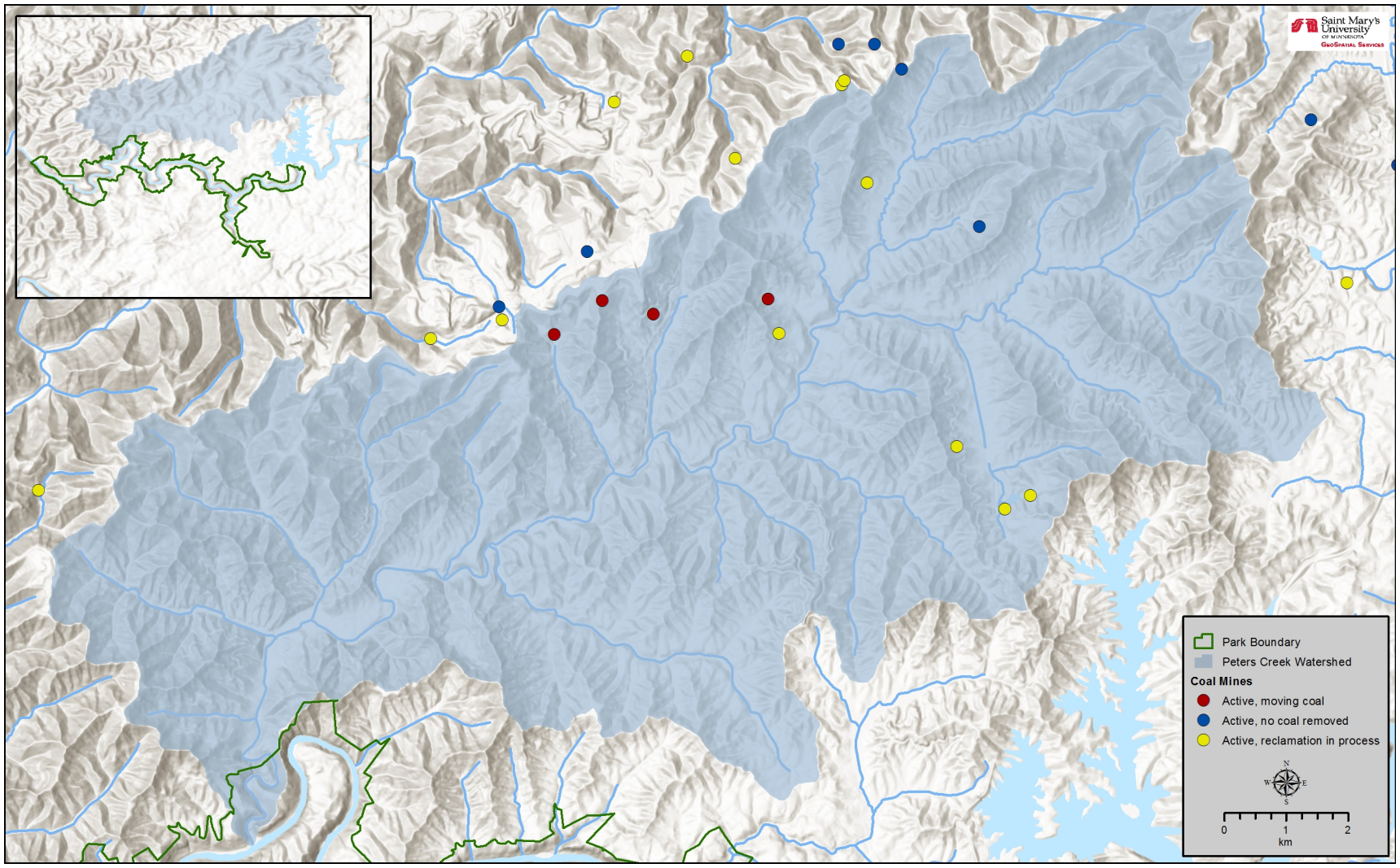


Figure 50. Locations of active coal mines within the Peters Creek watershed, which drains into Gauley River National Recreation Area (WVDEP 2017).

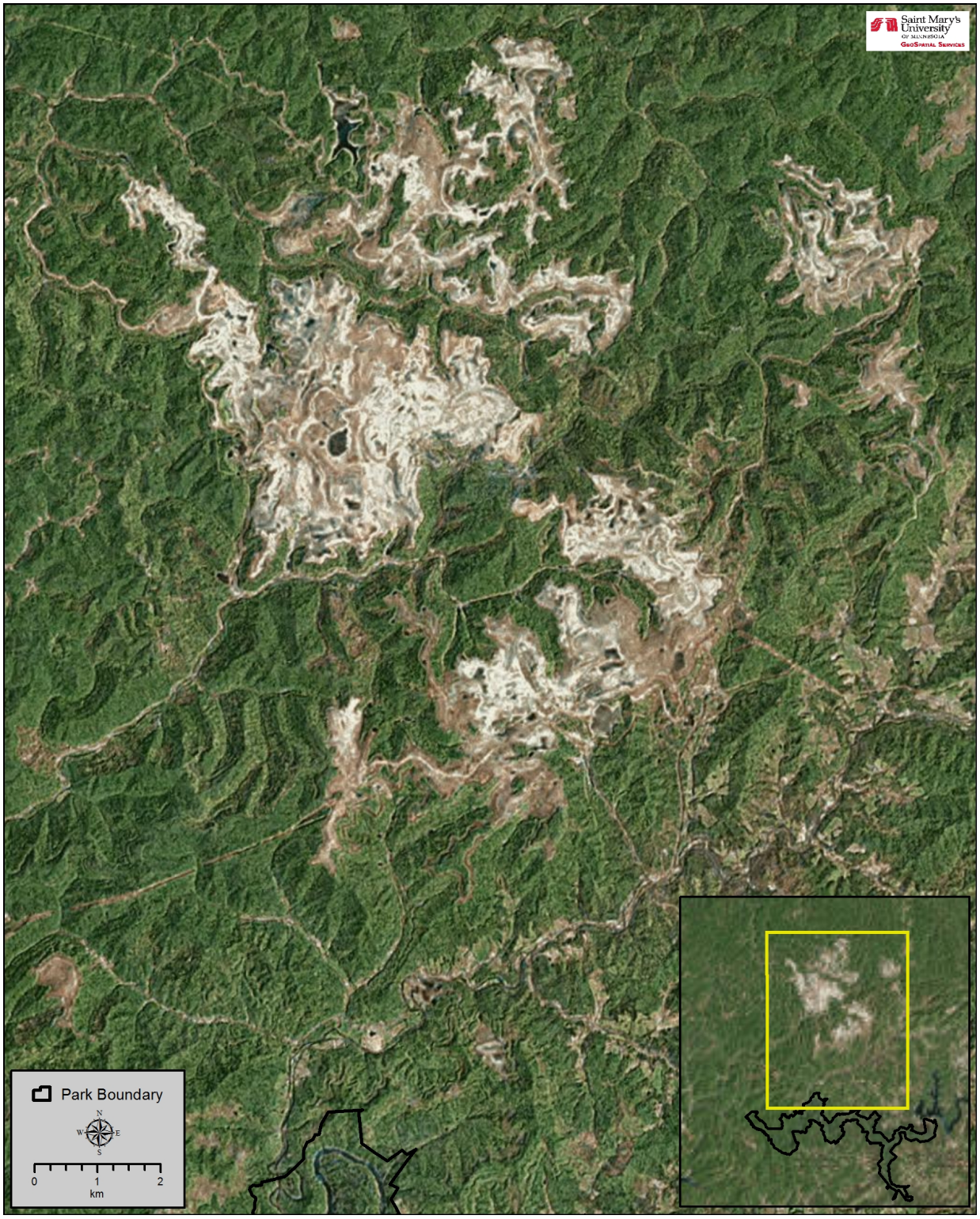


Figure 51. A large active MTR coal mining site north of Gauley River National Recreation Area in the Peters Creek watershed.

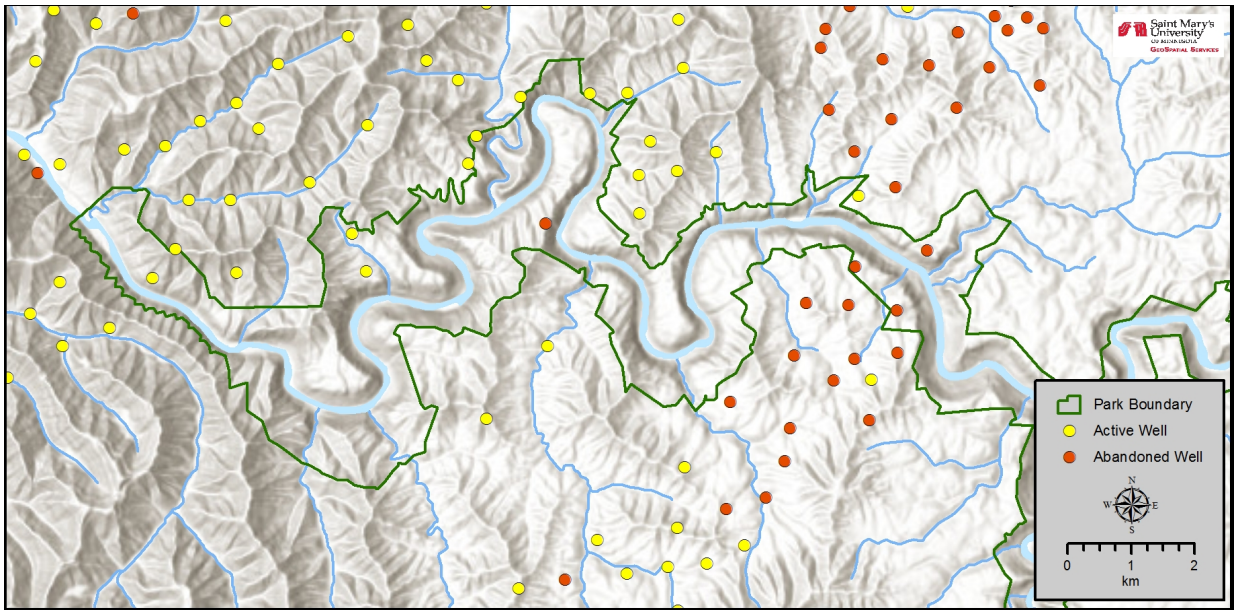


Figure 52. Active and abandoned gas production wells within and near Gauley River National Recreation Area (WVDEP 2016b).

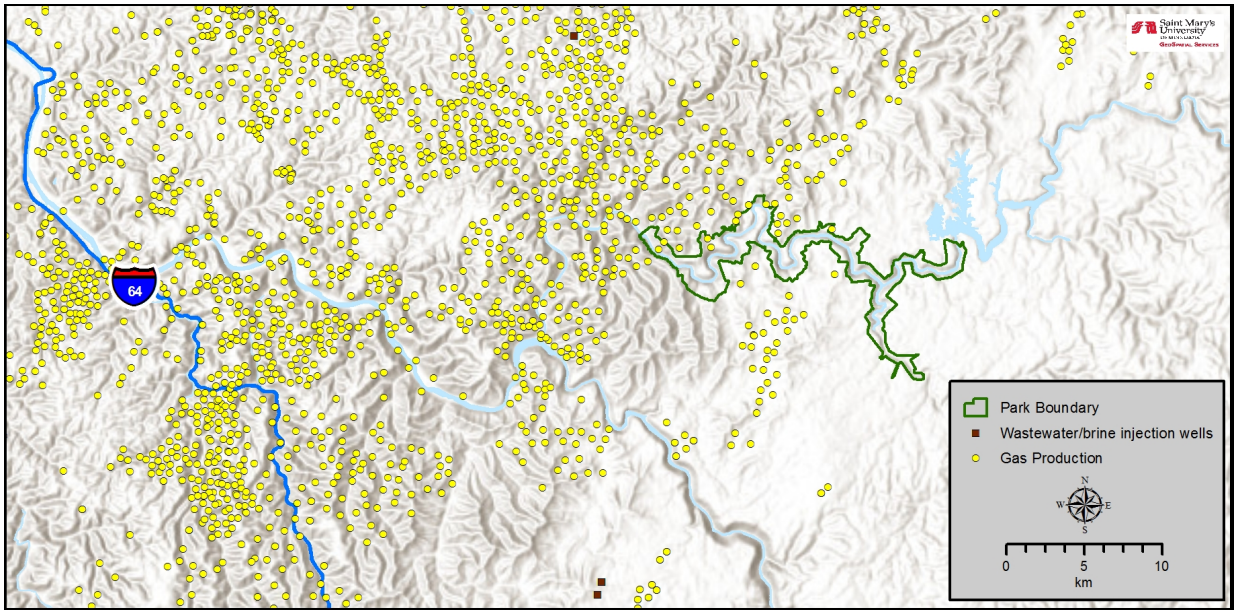


Figure 53. Active gas production and wastewater/brine injection wells in the vicinity of Gauley River National Recreation Area (WVDEP 2016b).

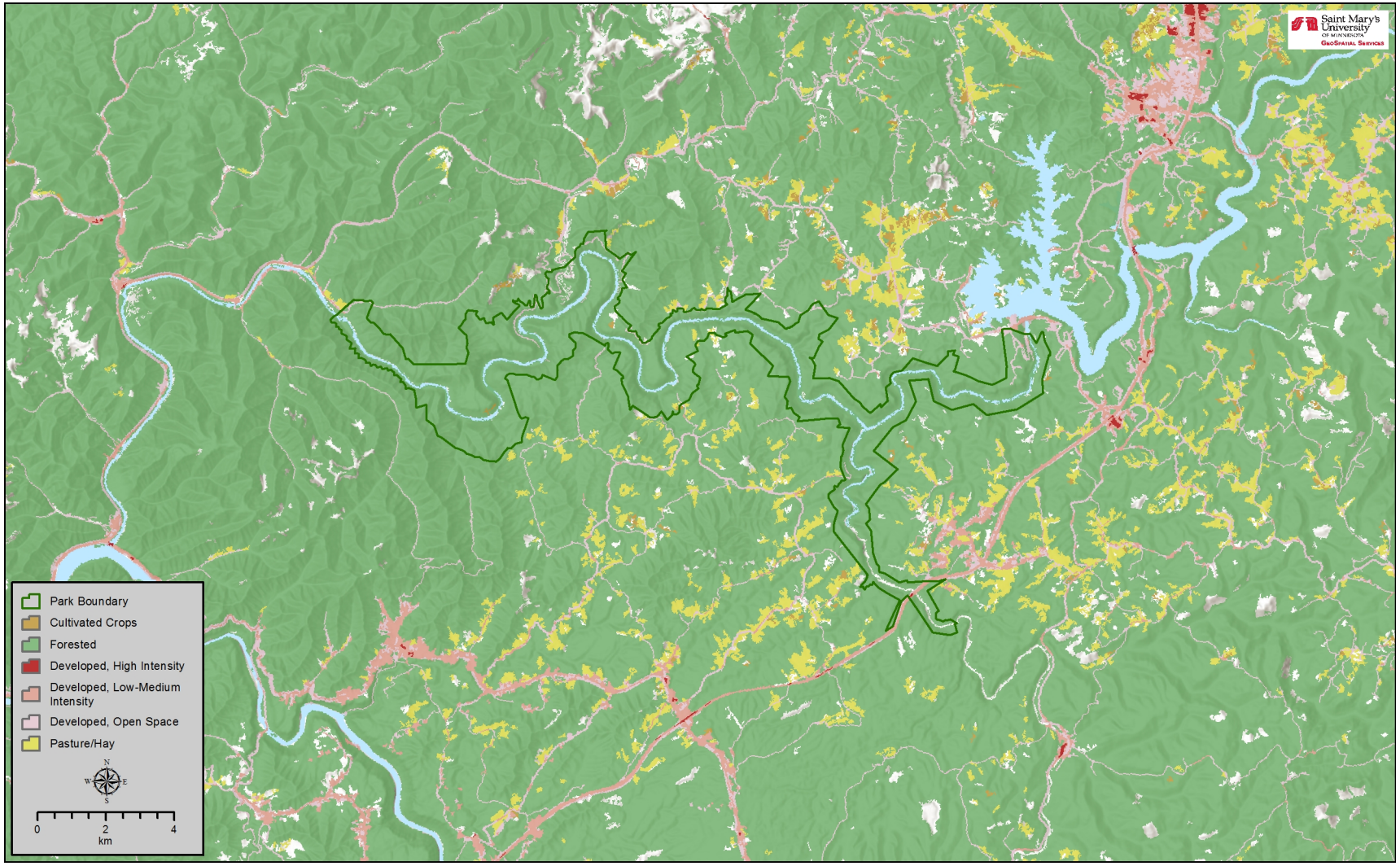


Figure 54. Land use in and around Gauley River National Recreation Area, 2011 (USGS 2011b).

Increasing residential and recreational development is a concern in the area, due to interest in vacation homes and recreational infrastructure (Marshall and Piekielek 2007a). Construction and clearing for these developments can increase runoff, contributing sediment to surface waters. De-icing solutions (e.g., salts) used on roads associated with developments may pollute park waters as well, particularly with chloride (Webber 2012).

Summersville Lake, the reservoir above the dam and just upstream of the park boundary, is a popular site for recreational boating. Bilge and other wastes from boats can contaminate the lake's waters (Milliken and Lee 1990) and subsequently flow into the Gauley River within park boundaries. Water released from the reservoir into the Gauley River is colder than water on uncontrolled portions of the river, which can impact water quality parameters and aquatic organisms just downstream of the dam (Caissie 2006).

Atmospheric wet deposition (e.g., rain, snow, fog) in the region around GARI is likely acidic. The mean annual pH of wet deposition measured at Babcock State Park (approximately 42 km [26 mi] north of GARI) in 2014-2015 was below 5.1 (Figure 55) (NADP 2016b). The normal pH of rain is around 5.6 (NADP 2014). The low pH of precipitation/deposition in the region may decrease the pH of (i.e., acidify) the park's surface waters. Human-related contributors to acidic deposition include motor vehicles, electric power generation (e.g., coal-burning facilities), and industrial/chemical plants (NADP 2014).

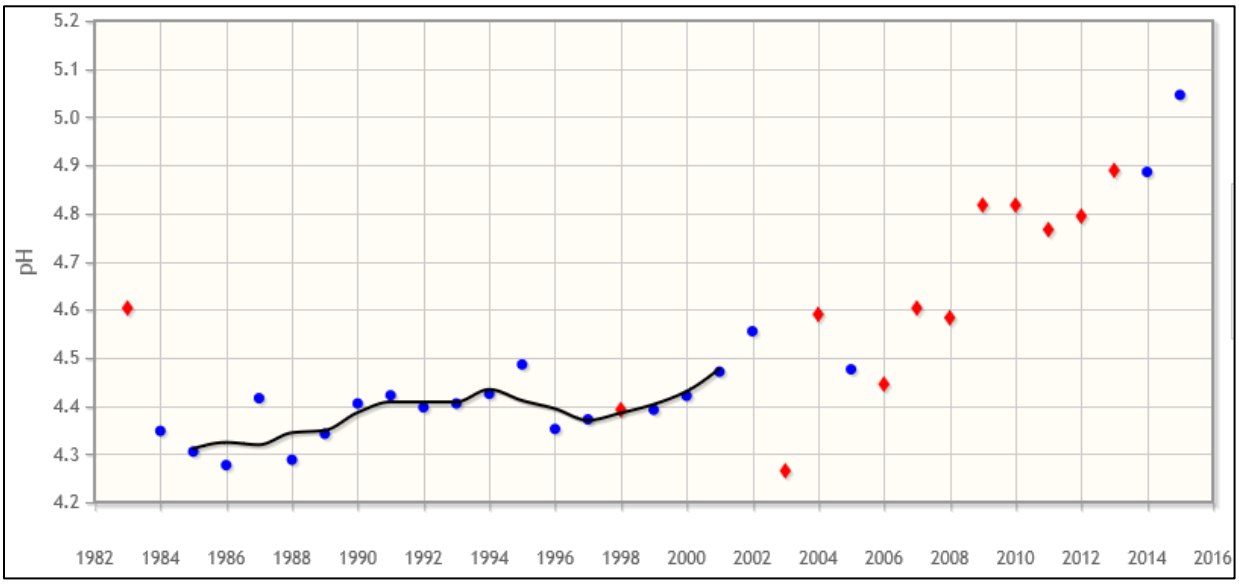


Figure 55. Annual mean pH of wet atmospheric deposition at NTN Site WV04, Babcock State Park (NADP 2016b). Red diamonds represent years when NADP's data completeness criteria (valid samples and precipitation amounts for 75% of time period) were not met. The black line represents a smoothed 3-yr moving average.

Data Needs/Gaps

While some data are available for all selected water quality measures, more frequent and consistent monitoring would provide further insight into current water quality conditions and any changes over time. However, this is challenging given the terrain and limited access to many areas of the park. If budgets allow, the deployment of additional automated water quality monitoring equipment to collect continuous data (similar to the ERMN 2013-2014 temperature and SpC observations) would be particularly useful. This could enable researchers to link fluctuations in water quality parameters to seasonal changes or particular events (e.g., precipitation events). For example, continuous monitoring on Peters Creek, particularly of SpC, could be valuable, especially given concerns over mining activity in the watershed. In addition, existing water quality data could be compared to stream flow/discharge data and to park geologic maps to look for any patterns or relationships between these factors. Bedrock geology has been shown to influence water quality, particularly pH and specific conductance, in other areas of the Appalachians (Johnson and Reynolds 1977, Silsbee and Larson 1982).

Overall Condition

Temperature

The NRCA project team assigned this measure a *Significance Level* of 2. All water temperature observations taken during park monitoring (1996-2016) have met state water quality standards, as did observations by Webber (2012) and Tzilkowski et al. (2015). Therefore, this measure is currently of no concern (*Condition Level* = 0).

pH

This measure was assigned a *Significance Level* of 3. Historically, some pH readings from the Gauley and Meadow Rivers have fallen outside the state standard range of 6.0-9.0 (NPS 1995, 2017c). However, all park monitoring observations since 2012, along with Webber (2012) and Tzilkowski et al. (2015) observations, have met state standards. As a result, pH is assigned a *Condition Level* of 0.

Dissolved Oxygen

A *Significance Level* of 3 was assigned for the DO measure. Sufficient DO levels are critical for the survival of aquatic organisms (USGS 2015b). All park monitoring observations since 2012, as well as measurements by Webber (2012) and Tzilkowski et al. (2015), met the state standard of ≥5.0 mg/L. Therefore, DO is also currently of no concern (*Condition Level* = 0).

Specific Conductance

This measure was assigned a *Significance Level* of 3. SpC observations from the Gauley and Meadow Rivers during recent park monitoring (2012-2016) and from ERMN continuous monitoring all met the informal reference condition of 325 µS/cm (based on EPA criteria for TDS in drinking water) (NPS 2017c). However, measurements from Peters Creek are much higher, with 13 of 26 observations during this period exceeding 325 µS/cm. For this reason, SpC is assigned a *Condition Level* of 2, indicating moderate concern.

Turbidity

The turbidity measure was also assigned a *Significance Level* of 3. A numeric turbidity reference condition could not be determined for GARI surface waters, since the "background turbidity" is unknown. While turbidities on the Gauley River have been have relatively stable and rarely exceeded 10 NTU during 2012-2016 park monitoring, measurements on tributaries were occasionally elevated, exceeding 35 NTU on both the Meadow River and Peters Creek (NPS 2017c). A turbidity of 180 FTU was measured on Laurel Creek during summer 2011 (Webber 2012). Due to these results and the concerns of park staff, this measure is assigned a *Condition Level* of 2.

Fecal Coliform Bacteria

The NRCA project team assigned this measure a *Significance Level* of 3. Elevated coliform bacteria levels can pose a threat to the health of park visitors and staff. From 2012-2016, only four measurements from the Gauley River exceeded 200 FC/100 ml (NPS 2017c). The Meadow River experienced one measurement ≥400 FC/100ml and five measurements ≥200 FC/100ml. Peters Creek showed the highest coliform bacteria levels, with four observations exceeding 400 FC/100ml and 11 above 200 FC/100ml. As a result of these elevated observations on tributaries, this measure is assigned a *Condition Level* of 2.

Weighted Condition Score

The *Weighted Condition Score* for GARI's water quality is 0.35, indicating moderate concern. Although water temperatures, pH, and DO are well within state standards and currently of no concern, the remaining measures have shown levels of concern during recent (2012-2016) park monitoring. SpC observations on the Peters Creek and turbidity observations on both Peters Creek and the Meadow River have exceeded informal reference conditions on occasion. Sporadic elevated coliform bacteria levels on the Meadow River and Peters Creek may pose a threat to human health. As there is no clear or consistent decline or improvement in the selected measures, a stable/unchanging trend is assigned.

Table 69. Current condition of Gauley River National Recreation Area's Water Quality.

Measures	Significance Level	Condition Level	WCS = 0.35
Temperature	2	0	
pH	3	0	
Dissolved Oxygen	3	0	
Specific Conductance	3	2	
Turbidity	3	2	
Fecal coliform bacteria	3	2	

4.9.6. Sources of Expertise

- Caleb Tzilkowski, ERMN Aquatic Ecologist
- Lisa Wilson, NPS Biological Science Technician

4.10. Air Quality

4.10.1. Description

Air pollution can significantly affect natural resources, their associated ecological processes, and the health of park visitors. In the Clean Air Act (CAA), Congress set a national goal "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic or historic value" (42 U.S.C. §7470(2)). This goal applies to all units of the National Park System. The act includes special provisions for 48 park units, called "Class I" areas under the CAA; all other NPS areas are designated as Class II, including GARI. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas which can allow for more development (NPS 2004). Additional authority to consider and protect air quality in Class II parks is provided by Title 54 (54 USC 100101(a) et seq.), commonly known as the NPS Organic Act.

Parks designated as Class I and II airsheds use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA standards are designed to protect human health and the health of natural resources (EPA 2016d). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008). In addition, the ERMN has identified ozone and atmospheric deposition as Vital Signs for all network parks, including GARI (Marshall and Piekielek 2007a).

4.10.2. Measures

- Nitrogen deposition
- Sulfur deposition
- Mercury deposition
- Ozone
- Visibility

Atmospheric Deposition of Sulfur and Nitrogen

Sulfur and nitrogen are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012). While in the atmosphere, these emissions form compounds that may be transported long distances, eventually settling out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (NPS 2008, EPA 2012). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in

the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water and vegetation (NPS 2008, reviewed in Sullivan et al. 2011b, 2011d).

Atmospheric Deposition of Mercury

Sources of atmospheric mercury include anthropogenic sources such as fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, along with natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008). Atmospheric deposition of mercury from coal-burning power plants has been identified as a major source of mercury to remote ecosystems (Landers et al. 2008). Mercury is a potential problem for ecosystems in regions with heavy current or historic coal use.

Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species, resulting in exposure to wildlife and humans that consume them (EPA 2008). Mercury exposure can cause liver, kidney, and brain (neurological and developmental) damage (EPA 2008). High concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success (Mast et al. 2010, Eagles-Smith et al. 2014).

Ozone

Ozone occurs naturally in the earth's upper atmosphere where it protects the earth's surface against ultraviolet radiation (EPA 2012). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides (NO_x) and VOCs in the presence of heat and sunlight (NPS 2008). Ozone precursors are emitted from both anthropogenic and natural source types, including power plants, industry, motor vehicles, oil and gas development, forest fires, and other sources (Beitler 2006, EPA 2008).

Ozone is one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth defects for sensitive plants in natural ecosystems. Specific defects include reduced photosynthesis, premature leaf loss, and reduced biomass; prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). Plant species occurring in GARI that are known to be sensitive to ozone include green ash, white ash, tulip tree, American sycamore, and Virginia pine (*Pinus virginiana*) (Kohut 2007).

At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans through reduced lung function, increased acute respiratory problems, and elevated susceptibility to respiratory infections (EPA 2016c). Visitors and staff engaging in aerobic activities in the park (e.g., hiking), as well as children, the elderly, and people with heart and lung diseases are especially sensitive to elevated ozone concentrations.

Visibility (Particulate Matter)

Air pollution, especially PM, influences a visitor's ability to view scenic vistas and landscapes at parks (NPS 2007). Particulate matter is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2016e). There are two particle

size classes of concern: $PM_{2.5}$ – fine particles found in smoke and haze, which are 2.5 micrometers or less in diameter; and PM_{10} – coarse particles found in wind-blown dust, which have diameters between 2.5 and 10 micrometers (EPA 2012). Fine particles are a major cause of reduced visibility (haze) in many national parks and wilderness areas (EPA 2012). $PM_{2.5}$ can either be directly emitted from sources (e.g., forest fires) or they can form when gas emissions from power plants, industry, and/or vehicles react in the air (EPA 2016e). Particulate matter can either absorb or scatter light, causing the clarity, color, and distance seen by humans to decrease, especially during humid conditions when additional moisture is present in the air. $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2016e). Exposure to these particles can cause airway irritation, coughing, and difficulty breathing (EPA 2016e).

4.10.3. Reference Condition/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (NPS 2015b). This approach is discussed by indicator in the following paragraphs and the ratings are summarized in Table 70 and Table 71.

Table 70. National Park Service Air Resources Division air quality index values for wet deposition of nitrogen or sulfur, ozone, particulate matter, and visibility (NPS 2015b).

Condition Level	Human Health Risk from Ozone (ppb)	Vegetation Health Risk from Ozone (ppm-hrs)	Wet Deposition of N or S (kg/ha-yr)	Visibility (dv[A] above natural conditions)
Significant Concern	≥71	>13	>3	>8
Moderate Concern	55–70	7-13	1–3	2–8
Good Condition	≤55	<7	<1	<2

[A] a unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview (dv) represents the minimal perceptible change in visibility to the human eye.

Table 71. National Park Service Air Resources Division air quality assessment matrix for mercury status (NPS 2015b). GC = Good Condition (green), MC = Moderate Concern (yellow), and SC = Significant Concern (red).

Predicted Methylmercury Concentration Rating	Mercury Wet Deposition Rating				
	Very Low (<3 µg/m²/yr)	Low (≥3–<6 µg/m²/yr)	Moderate (≥6–<9 µg/m²/yr)	High (≥9–<12 µg/m²/yr)	Very High (≥ 12 µg/m²/yr)
Very Low (< 0.038 ng/L)	GC	GC	GC	MC	MC
Low (≥0.038–< 0.053 ng/L)	GC	GC	MC	MC	MC
Moderate (≥0.053–<0.075 ng/L)	GC	MC	MC	MC	SC
High (≥0.075–<0.12 ng/L)	MC	MC	MC	SC	SC
Very High (≥0.12 ng/L)	MC	MC	SC	SC	SC

Ozone

The primary NAAQS for ground-level ozone is set by the EPA, and is based on human health effects. The 2008 NAAQS for ozone was a 3-year average 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb) (NPS 2015b). On 1 October 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb (EPA 2015). The NPS ARD recommends a benchmark for *Good Condition* ozone status in line with the updated Air Quality Index (AQI) breakpoints (NPS 2015b).

Current condition for human health risk from ozone is based on the estimated 5-year average 4th-highest daily maximum 8-hour ozone average concentration in ppb (NPS 2015b). Ozone concentrations ≥71 ppb are assigned a *Significant Concern*, from 55–70 ppb are assigned *Moderate Concern*, and <55ppb are assigned a *Good Condition* (NPS 2015b).

In addition to being a concern to human health, long-term exposures to ozone can cause injury to ozone-sensitive plants (EPA 2014). The W126 metric relates plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the primary (human-health based) standard (EPA 2014). The W126 metric measures cumulative ozone exposure over the growing season in "parts per million-hours" (ppm-hrs) and is used for assessing the vegetation health risk from ozone levels (EPA 2014).

The W126 condition thresholds are based on information in the EPA's Policy Assessment for the Review of the Ozone NAAQS (EPA 2014). Research has found that for a W126 value of:

- ≤7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10% per year in sensitive species.

The NPS ARD recommends a W126 of <7 ppm-hrs to protect most sensitive trees and vegetation. Levels below this guideline are considered *Good Condition*, 7-13 ppm-hrs is *Moderate Condition*, and >13 ppm-hrs is considered to be of *Significant Concern* (NPS 2015b).

Atmospheric Deposition of Sulfur and Nitrogen

Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Wet deposition is used as a surrogate for total deposition (wet plus dry), because wet deposition is the only nationally available monitored source of nitrogen and sulfur deposition data (NPS 2015b). Values for nitrogen (from ammonium and nitrate) and sulfur (from sulfate) wet deposition are expressed as amount of nitrogen or sulfur in kilograms deposited over a 1 ha (2.5 ac) area in 1 year (kg/ha/yr). The NPS ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This is based on studies linking early stages of aquatic health decline correlated with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Sheibley et al. 2014). Parks with ≤1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned *Good Condition*, those with 1-3 kg/ha/yr are assigned *Moderate Concern*, and parks with depositions ≥3 kg/ha/yr are assigned *Significant Concern* (NPS 2015b).

Mercury Deposition

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (micrograms per m^2 per year [$\mu g/m^2/yr$]) and the predicted surface water methylmercury concentrations (nanograms per liter [ng/L]) at NPS I&M parks (NPS 2015b). It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition because atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and able to accumulate in food webs (NPS 2015b). Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors, like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH), must also be considered (NPS 2015b). Mercury wet deposition and predicted methylmercury concentration are considered concurrently in the mercury status assessment matrix displayed previously (Table 71) to determine park-specific mercury/toxics status (NPS 2015b).

Visibility

Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews [dv]) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2013b). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier (NPS 2013b). The NPS ARD assesses visibility condition status based on the deviation of the estimated current visibility on mid-range days from estimated natural visibility on mid-range days (i.e., those estimated for a given area in the absence of human- caused visibility impairment, EPA-454/B003-005) (NPS 2015b). The NPS ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network. Visibility on mid-range days is defined as the mean of the visibility observations falling within the 40th and 60th percentiles (NPS 2015b). A visibility condition estimate of <2 dv above estimated natural conditions indicates a *Good Condition*,

estimates ranging from 2-8 dv above natural conditions indicate *Moderate Concern*, and estimates >8 dv above natural conditions indicate *Significant Concern* (NPS 2015b).

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days (NPS 2015b). Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend (NPS 2015b).

4.10.4. Data and Methods

NPS Data Resources

Although data on air quality parameters have not been actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in GARI. NPS ARD provides estimates of ozone, wet deposition (nitrogen, sulfur, and mercury), and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2011–2015). Estimates and condition data for GARI were obtained from the NPS Air Quality by park data products page (http://www.nature.nps.gov/air/data/products/parks/index.cfm).

On-site or nearby data are needed for a statistically valid trends analysis. There are no on-site or near-enough representative monitors for such an assessment of ozone, $PM_{2.5}$, and nitrogen, sulfur and mercury deposition trends at this time. For visibility trend analysis, monitoring data from an Interagency Monitoring of Protected Visual Environments Program (IMPROVE) station is required (NPS 2015b). An IMPROVE monitoring site considered representative of a Class II park has to be within ± 30.48 m (100 ft) or 10% of maximum and minimum elevation of the park and 150 km (93 mi) of the park (NPS 2015b). The IMPROVE visibility monitor in the James River Face Wilderness Area (Monitor ID: JARI1) near Natural Bridge, VA, is approximately 137 km (85 mi) southeast of GARI and is considered representative for the park (Figure 56).

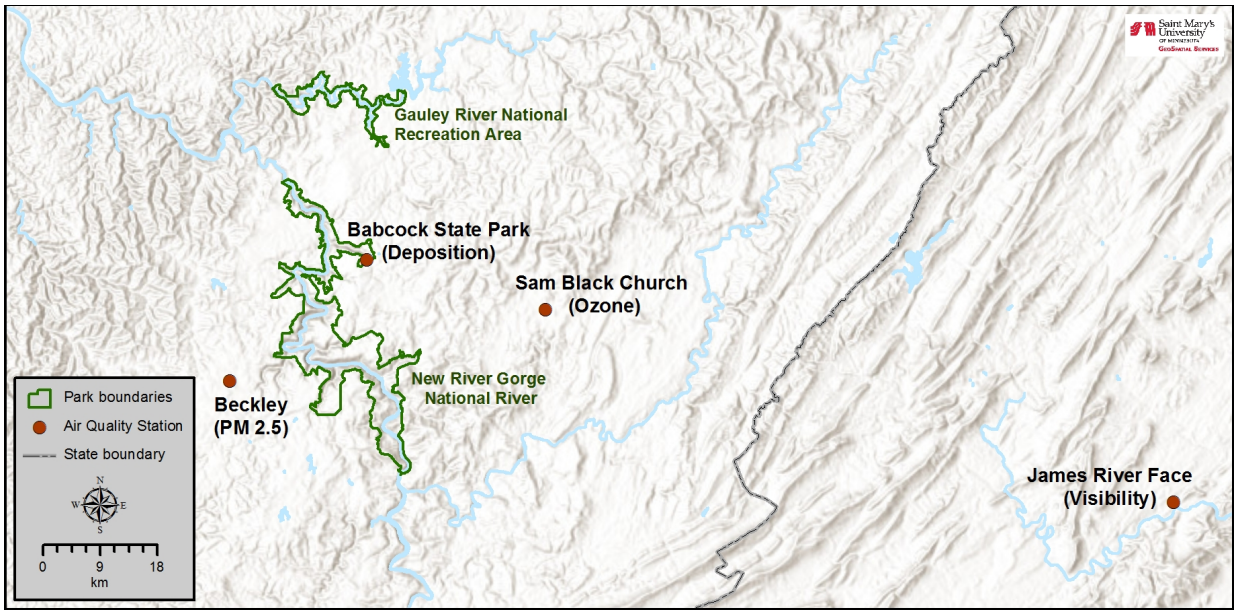


Figure 56. Locations of air quality monitoring stations in relation to Gauley River National Recreation Area.

Other Air Quality Data Resources

The EPA Air Trends Database provides annual average summary data for ozone and $PM_{2.5}$ concentrations near GARI (EPA 2016a). The nearest $PM_{2.5}$ monitor is located in Beckley, WV (Site ID: 54-081-0002; Figure 56) and data were collected at this site by the West Virginia Air Pollution Control Commission through March 2015. This station is located approximately 46 km (28.5 mi) south of the southwest portion of GARI. The nearest active ozone monitor is in the small town of Sam Black Church, WV (Site ID: 54-025-0003), around 39 km (24 mi) southeast of GARI's southernmost point, and has been active since 1999 (Figure 56).

The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database provides annual average summary data for nitrogen and sulfur concentration and deposition across the U.S. (NADP 2016b). The NADP-NTN monitoring site closest to GARI is located at Babcock State Park (site ID: WV04), just over 18 km (11 mi) south of the southernmost portion of GARI (Figure 56). This site has collected deposition data for the region since 1983 and is currently active in monitoring (NADP 2016b). Data summaries for this monitor are available on the NADP-NTN website (NADP 2016b).

The NADP Mercury Deposition Network (MDN) provides weekly summary data for mercury deposition and concentration (NADP 2016a). Wet mercury deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses. Trends are computed for parks with a representative NADP-MDN wet deposition monitor that is within 16 km (10 mi) of park boundaries (NPS 2015b). GARI does not have any NADP-MDN monitors within 140 km (87 mi). Predicted methylmercury concentrations in surface water were obtained from a model that predicts surface water methylmercury concentrations for hydrologic units throughout the U.S. based on relevant

water quality characteristics (pH, sulfate, and total organic carbon) and wetland abundance (USGS 2015a).

Special Air Quality Studies

Kohut (2007) employed a biologically-based method to evaluate the risk of foliar injury from ozone at parks within the 32 Vital Signs Networks, the Appalachian National Scenic Trail, and the Natchez Trace National Scenic Trail. The assessment allowed resource managers at each park to better understand the risk of ozone injury to vegetation within their park and permits them to make a better informed decision regarding the need to monitor the impacts of ozone on plants.

Sullivan et al. (2011b, 2011d) identified ecosystems and resources at risk to acidification and excess nitrogen enrichment in national parks. These reports provided a relative risk assessment of acidification and nutrient enrichment impacts from atmospheric nitrogen and sulfur deposition for parks in 32 I&M networks. Ecosystem sensitivity ratings to acidification from atmospheric deposition were based on percent sensitive vegetation types, number of high-elevation lakes, length of low-order streams, length of high-elevation streams, average slope, and acid-sensitive areas within the park (Sullivan et al. 2011b). Ecosystem sensitivity ratings to nutrient enrichment effects were based on percent sensitive vegetation types and number of high-elevation lakes within the park (Sullivan et al. 2011d).

Pardo et al. (2011) synthesized current research relating atmospheric nitrogen deposition to effects on terrestrial and aquatic ecosystems in the U.S. and identified empirical critical loads for atmospheric nitrogen deposition.

4.10.5. Current Condition and Trend

Nitrogen Deposition

Five-year interpolated averages of nitrogen (from nitrate and ammonium) wet deposition are used to estimate condition for deposition. The most recent 5-year (2011–2015) estimate for nitrogen deposition at GARI is 3.7 kg/ha/yr (NPS 2015a). Based on the NPS ratings for air quality conditions (see Table 70), this falls in the *Significant Concern* range. A comparison to previous 5-year estimates shows that nitrogen deposition decreased slightly and then stabilized over recent years (Figure 57).

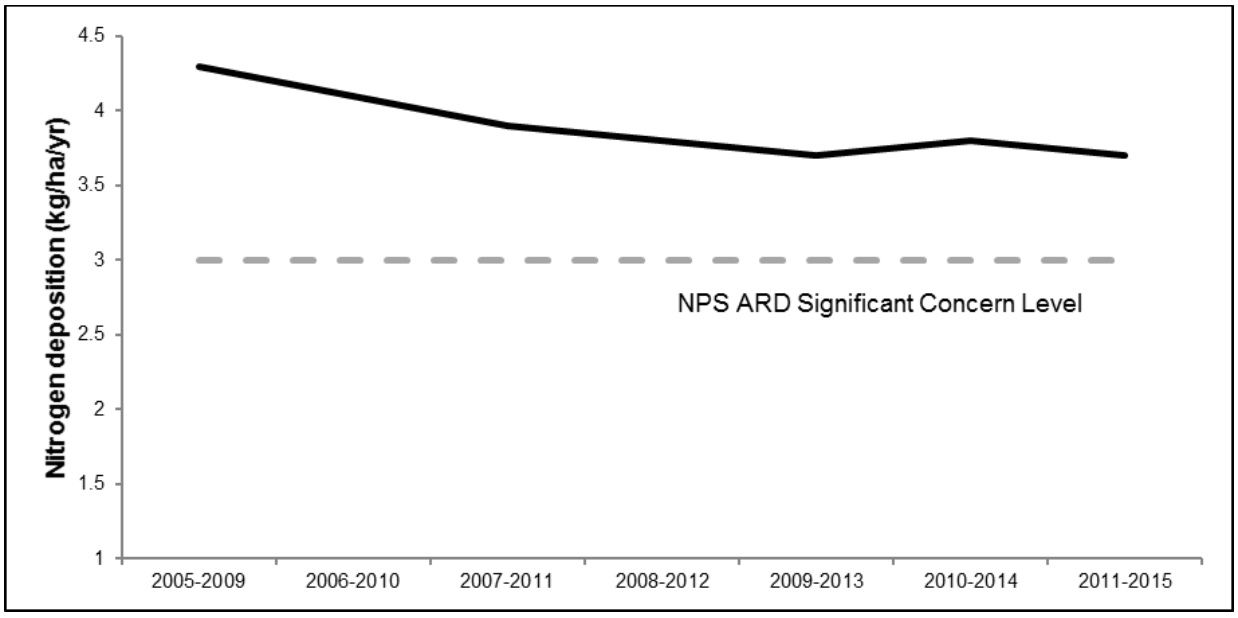


Figure 57. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at Gauley River National Recreation Area (NPS 2015a).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to park resources (Pardo et al. 2011). A critical load is defined as the level of deposition below which harmful effects to the ecosystem are not expected (Pardo et al. 2011). For the Eastern Temperate Forest, the ecoregion where GARI is located, Pardo et al. (2011) suggested critical loads for total nitrogen deposition (wet plus dry) of 4-8 kg/ha/yr to protect lichen, 8 kg/ha/yr to protect hardwood forests, and <17.5 kg/ha/yr to protect herbaceous species. The lowest critical load level (4.0 kg/ha/yr) is identified as an appropriate management goal because it will protect the full range of vegetation in the park (Pardo et al. 2011). The 2011-2015 estimated deposition at GARI of 3.7 kg/ha/yr was just below the minimum ecosystem critical load for the ecoregion, suggesting that sensitive vegetation elements may not be at risk for harmful effects. Similarly, Sullivan et al. (2011c) ranked GARI as at low risk of nutrient enrichment from nitrogen deposition, due to high pollutant exposure but very low levels of ecosystem sensitivity.

Concentrations (mg/L) of nitrogen compounds in wet deposition can also be used to evaluate overall trends in deposition. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Figure 58 shows that nitrate concentrations fluctuated but were somewhat stable during the 1980s and 1990s, and then decreased during the 2000s (NADP 2016b). Ammonium concentrations appear relatively stable from the 1980s through 2002. Levels have fluctuated since that time, showing no clear increasing or decreasing trend (Figure 59) (NADP 2016b).

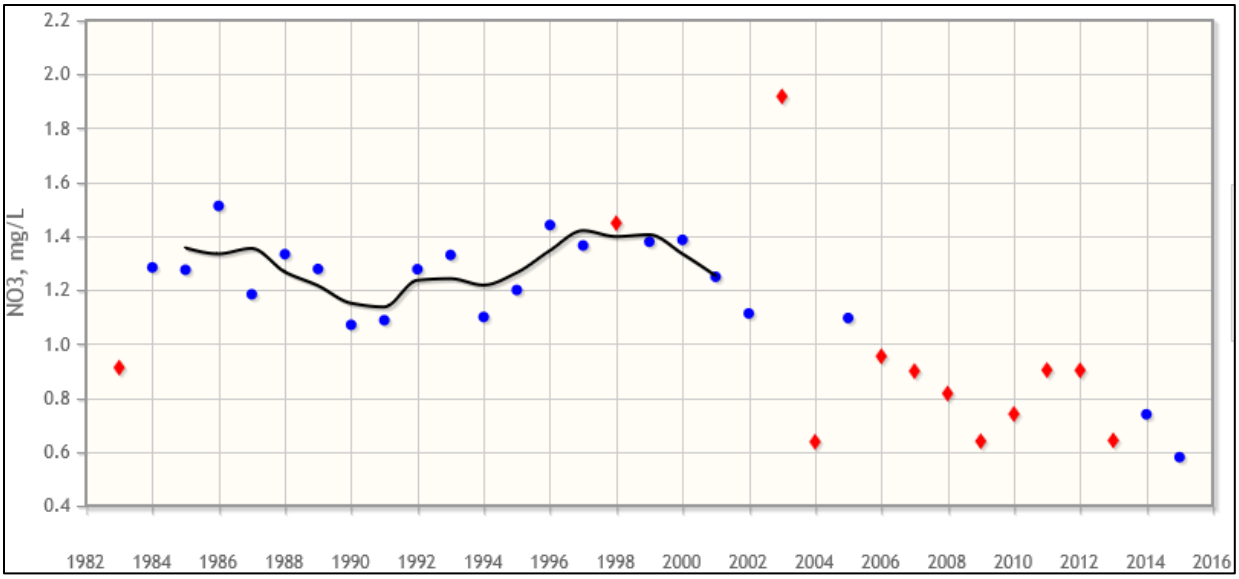


Figure 58. Annual weighted mean concentration of nitrate in wet deposition from Babcock State Park (NTN Site WV04) (NADP 2016b). The black line represents a smoothed 3-yr moving average. Red diamonds represent years when NADP's data completeness criteria (valid samples for 75% of the period) were not met and, therefore, were not included in trend line calculations.

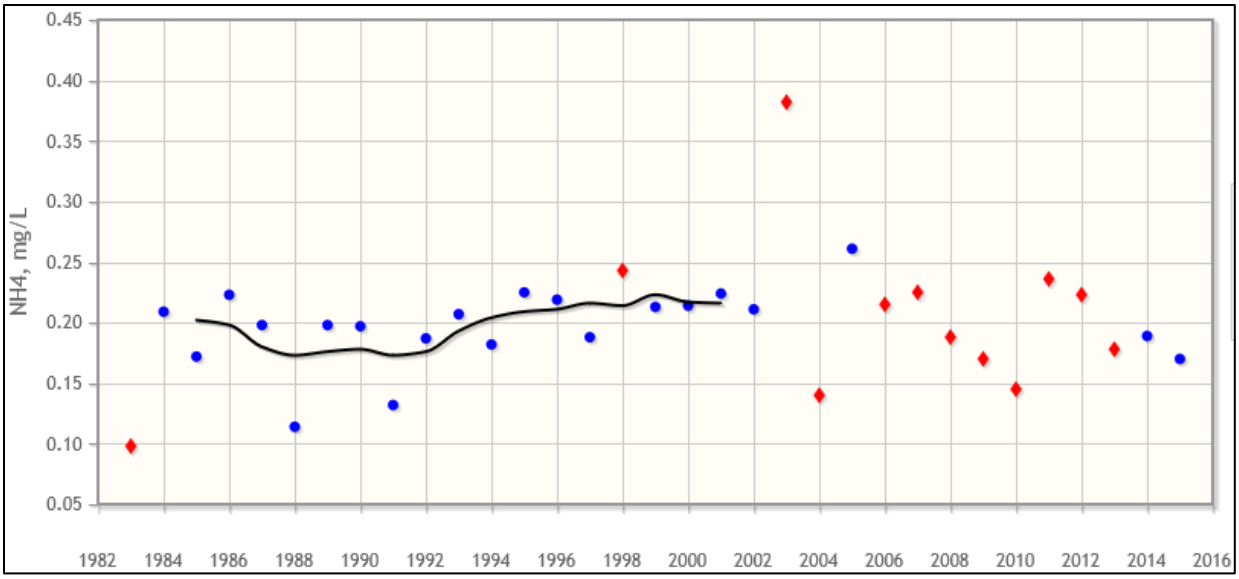


Figure 59. Annual weighted mean concentration of ammonium in wet deposition from Babcock State Park (NTN Site WV04) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

In contrast to the nutrient enrichment assessment discussed previously, Sullivan et al. (2011a) ranked GARI as being at a very high risk of acidification from acidic (nitrogen and sulfur) deposition, due to very high pollutant exposure and very high levels of ecosystem sensitivity.

Sulfur Deposition

Five-year interpolated averages of sulfur (from sulfate) wet deposition are used to estimate condition for deposition. The most recent 5-year (2011–2015) estimate for sulfur wet deposition at GARI is 2.9 kg/ha/yr (NPS 2015a). While this normally falls in the Moderate Concern range, the NPS ARD has elevated GARI to *Significant Concern* due to very high ecosystem sensitivity to acidification effects (according to Sullivan et al. 2011a). A comparison to previous estimates suggests that sulfur deposition is decreasing at GARI and could potentially drop below the significant concern level in the near future (Figure 60).

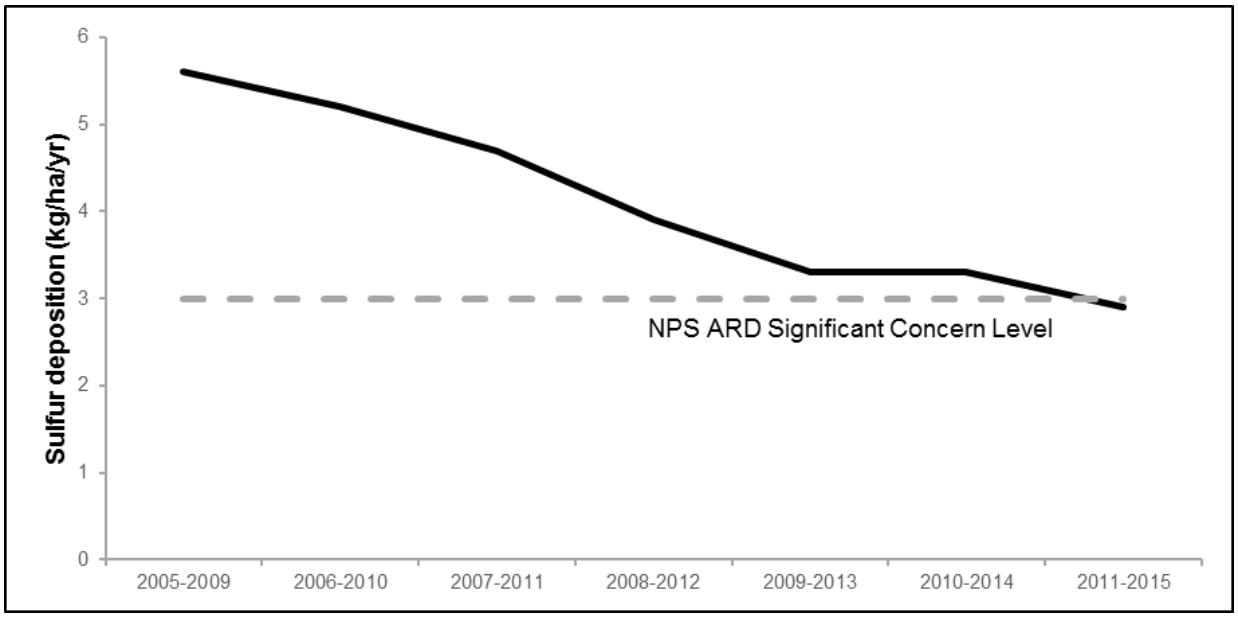


Figure 60. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at Gauley River National Recreation Area (NPS 2015a).

As with nitrogen, concentrations (mg/L) of sulfur compounds in wet deposition can also be used to evaluate overall trends in deposition. Figure 61 shows that the sulfate concentration in the GARI region has declined over time, dropping to 0.5 mg/L in 2015 (NADP 2016b).

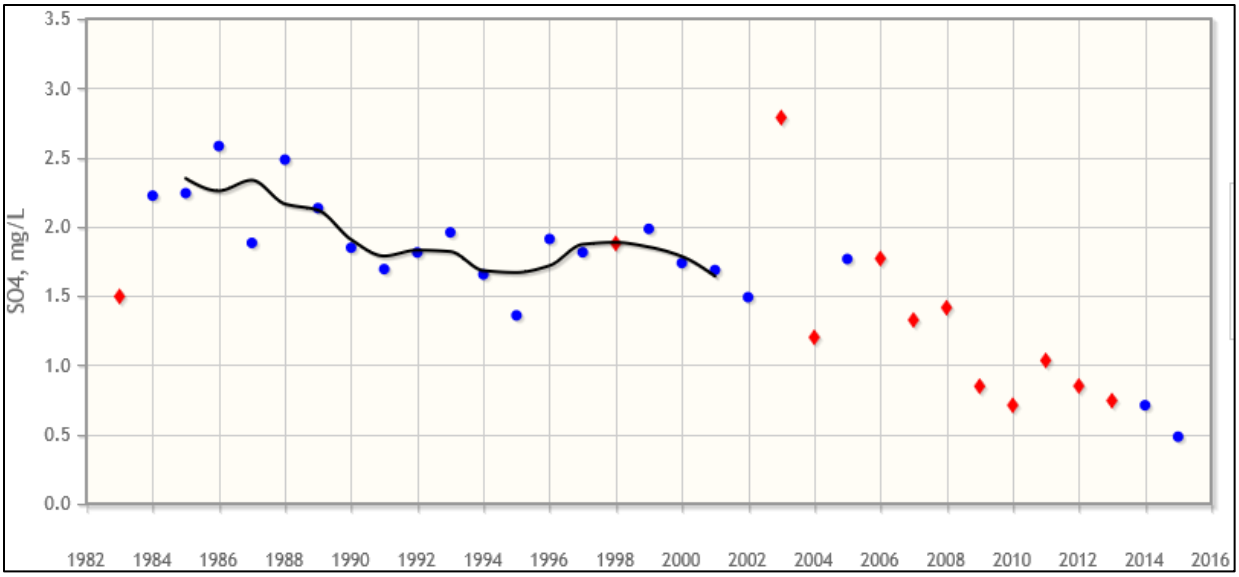


Figure 61. Annual weighted mean concentration of sulfate in wet deposition from Babcock State Park (NTN Site WV04) (NTN Site AL99) (NADP 2016b). The black line represents a smoothed 3-yr moving average. Red diamonds represent years when NADP's data completeness criteria (valid samples for 75% of the period) were not met and, therefore, were not included in trend line calculations.

Mercury Deposition

The 2012-2014 wet mercury deposition estimate was high for GARI, ranging from 9.5-9.7 µg/m^2/yr, but predicted methylmercury concentrations in surface waters were low, estimated at 0.04 ng/l (NPS 2016a). When compared to the NPS ARD mercury status assessment matrix (Table 71), these estimates result in a condition of *Moderate Concern*. However, confidence in this assignment is low, given a lack of park-specific contaminant data.

Based on interpolations by the MDN, mercury deposition levels in the GARI area in 2014 were likely in the 8-12 µg/m^2 range (Figure 62) (NADP 2017).

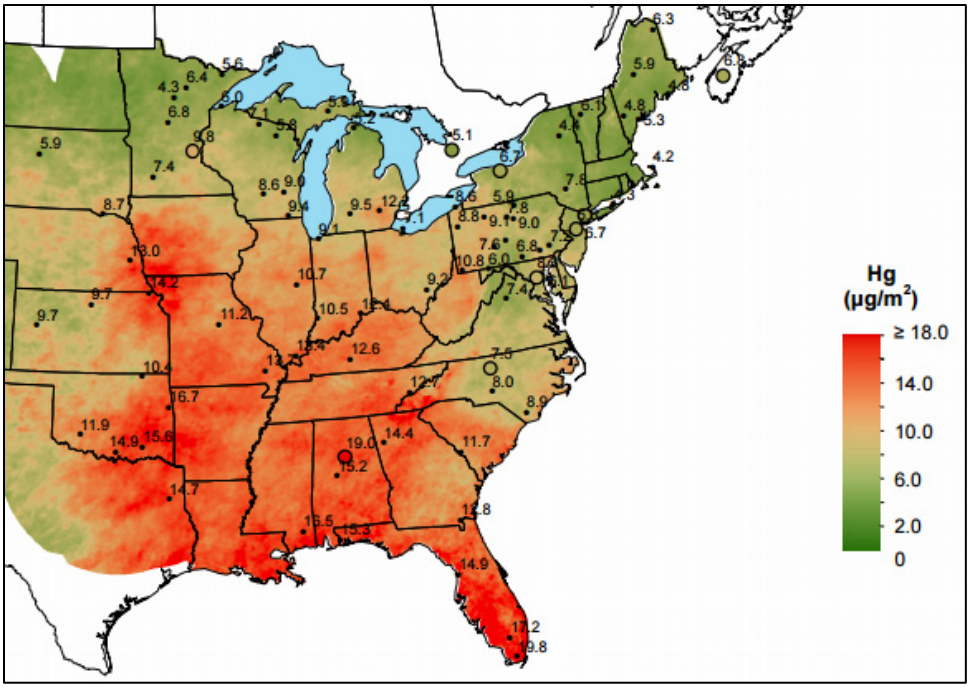


Figure 62. Total annual mercury wet deposition in 2015 (NADP 2017).

Based on interpolations displayed in Figure 63, total mercury concentrations in the GARI area were likely 7-10 ng/L (NADP 2017).

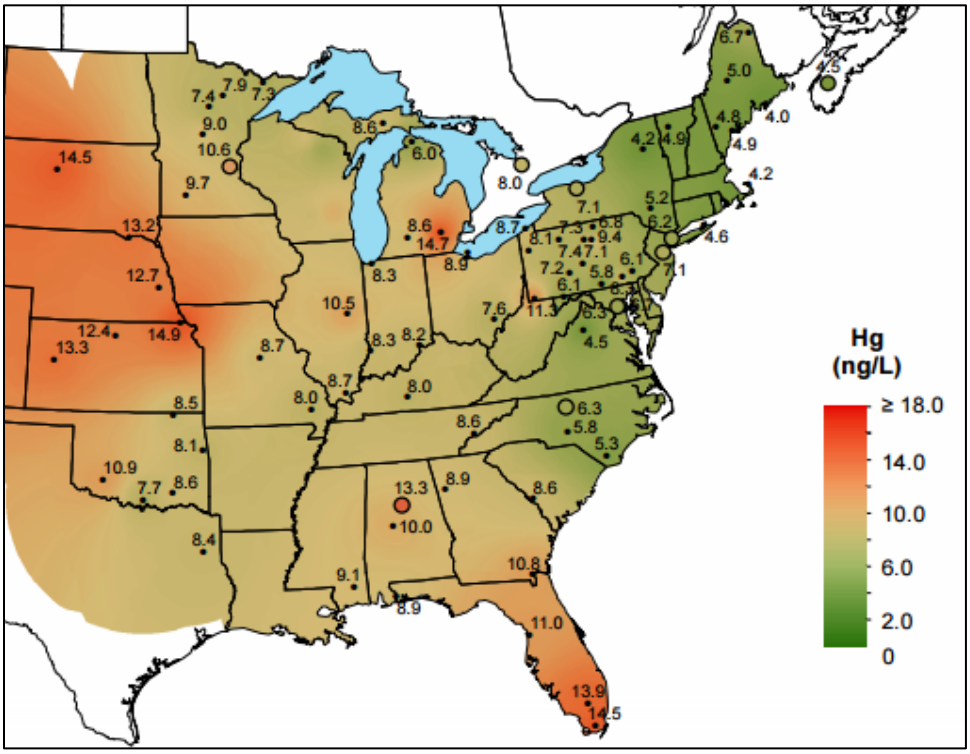


Figure 63. Total mercury concentrations in 2015 (NADP 2017).

The NPS ARD has measured mercury wet deposition at 16 parks across the U.S. (NPS 2013a). The location closest to GARI where monitoring has occurred is Shenandoah National Park (SHEN), approximately 210 km (130 mi) east of GARI. According to an analysis of mercury concentrations in precipitation, concentrations at SHEN have been relatively stable, increasing by an average of just 0.1 ng/l/yr from 2000-2009 (NPS 2013a).

Ozone

Historically, ozone has been somewhat of a concern in the GARI region. Kohut (2007) determined that the risk of ozone exposure at the park was moderate, with concentrations estimated (through kriging) to exceed 80 ppb many times annually between 1995 and 1999. During these same years, the estimated W126 value remained above 25 ppm-hrs, and exceeded 45 ppm-hrs in 1998 and 1999 (Kohut 2007).

The condition of human risk from ozone in NPS units is determined by calculating the 5-year average of the 4th-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2013b). The most recent 5-year (2011–2015) estimated average for 4th-highest 8-hour ozone concentration at GARI was 65.7 ppb (NPS 2015a). This is within the *Moderate Concern* range (Figure 64). A comparison to previous estimates suggests that ozone conditions are improving at GARI, as 5-year average estimates have declined from a high of 72.3 ppb for 2005-2009 (NPS 2015a).

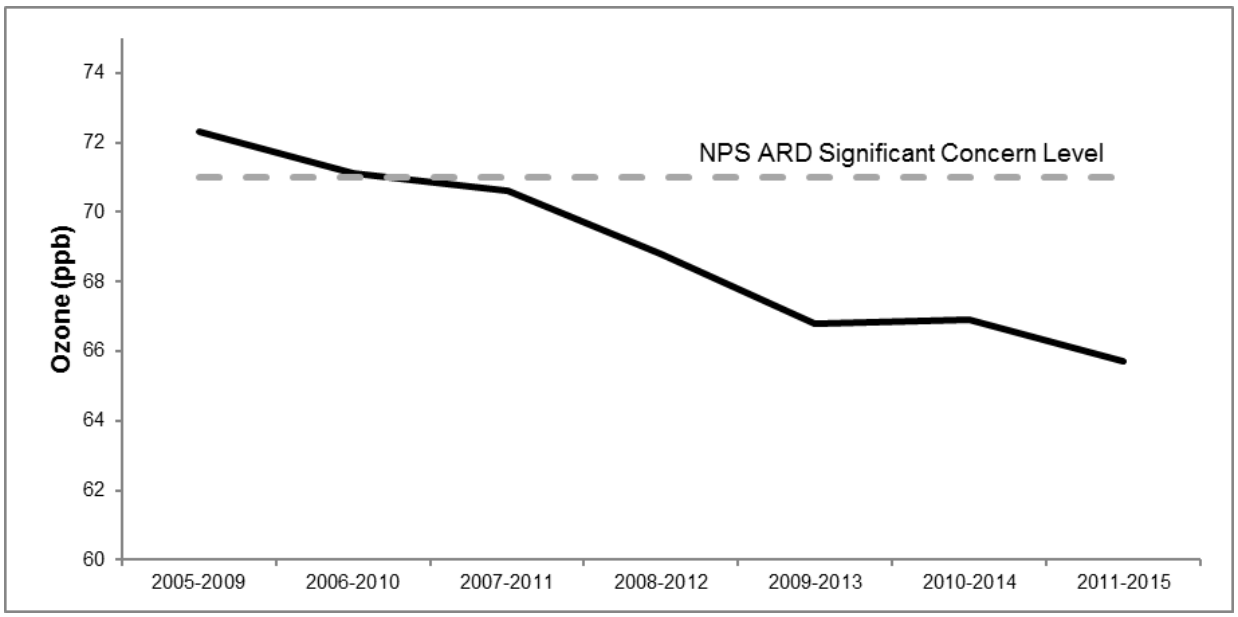


Figure 64. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for Gauley River National Recreation Area (NPS 2015a).

The apparent improvement in ozone condition is supported by data from the nearest year-round ozone monitor (in Sam Black Church, WV), which show ozone concentrations fluctuating over time but with a general decreasing trend (Figure 65) (EPA 2016a).

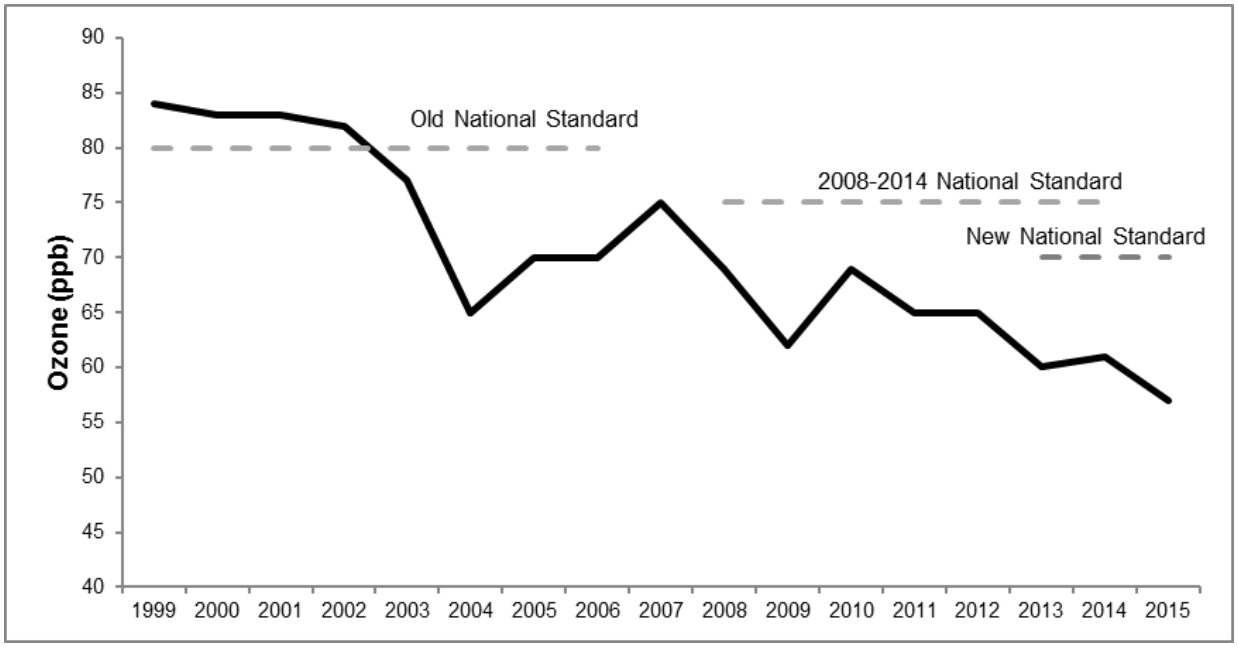


Figure 65. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Sam Black Church, WV monitoring site (Site ID: 54-025-0003), 1999-2015 (EPA 2016a).

Vegetation health risk from ground-level ozone condition is determined by estimating a 5-year average of annual maximum 3-month, 12-hour W126 values. The 2011–2015 estimated W126 metric of 7.6 ppm-hrs falls in the *Moderate Concern* category (NPS 2015a). Again, a comparison to previous estimates suggests that ozone conditions are improving, decreasing from a high of 10.4 for 2005-2009 (Figure 66).

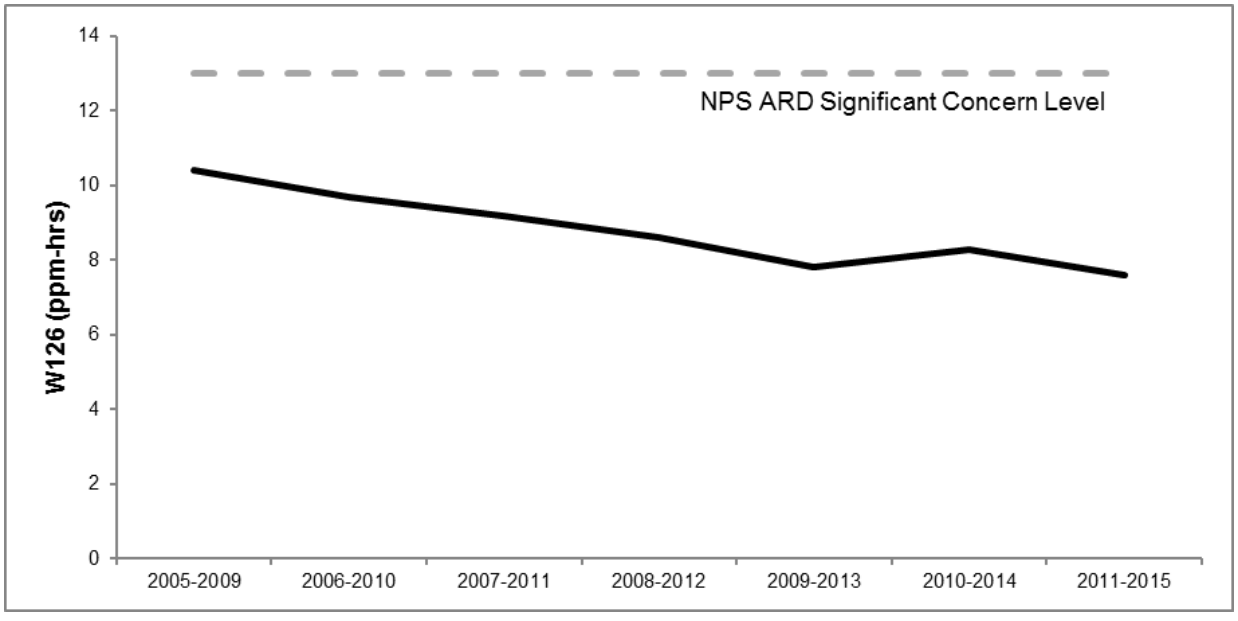


Figure 66. Estimated 5-year averages of the W126 ozone metric for Gauley River National Recreation Area (NPS 2015a).

Visibility

Five-year estimated averages of visibility on mid-range days minus natural condition visibility on mid-range days are used to estimate condition for visibility. The 2011–2015 estimated visibility on mid-range days for GARI was 8.4 dv above estimated natural conditions (NPS 2015a). This estimate falls into the *Significant Concern* category based on NPS criteria for air quality assessment.

Comparing the most recent mid-range estimate to previous NPS ARD estimates of visibility suggests that conditions may be improving at GARI. The 2005-2009 estimated visibility was 12.1 dv above estimated natural conditions; the 5-year average has declined every year since, although it is still above the significant concern threshold (>8 dv) (Figure 67) (NPS 2015a). Based on monitoring data from the nearby JARI1 station, conditions also appear to be improving over time on the 20% haziest and 20% clearest days (Figure 68) (NPS 2015a).

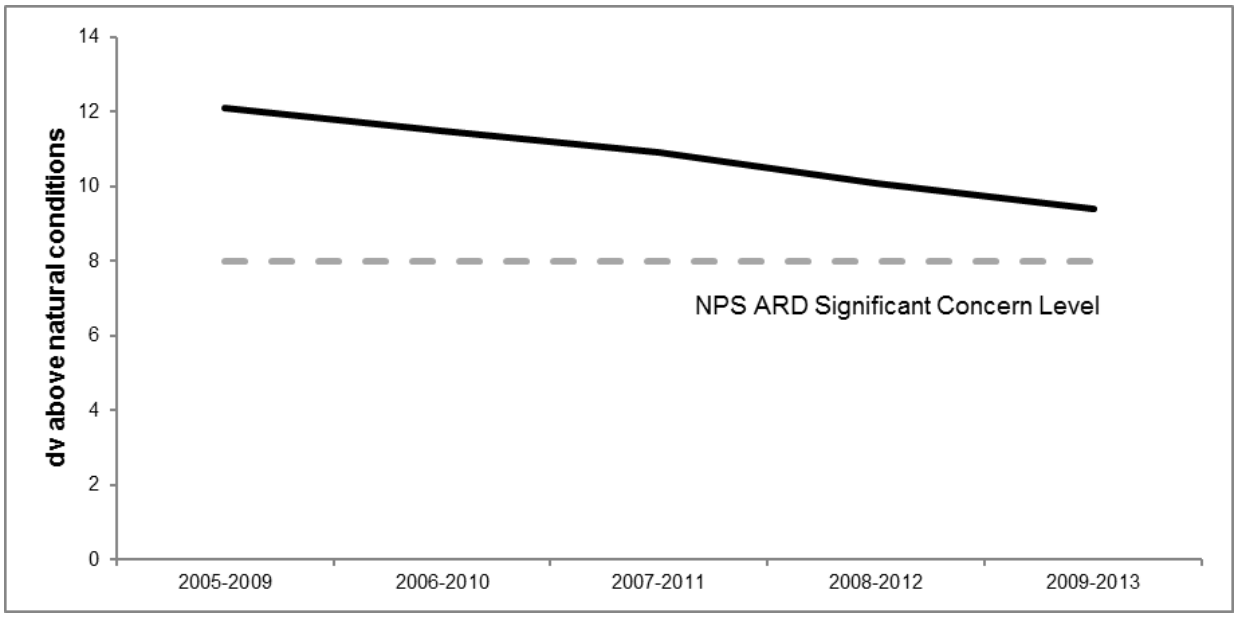


Figure 67. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at Gauley River National Recreation Area (NPS 2015a).

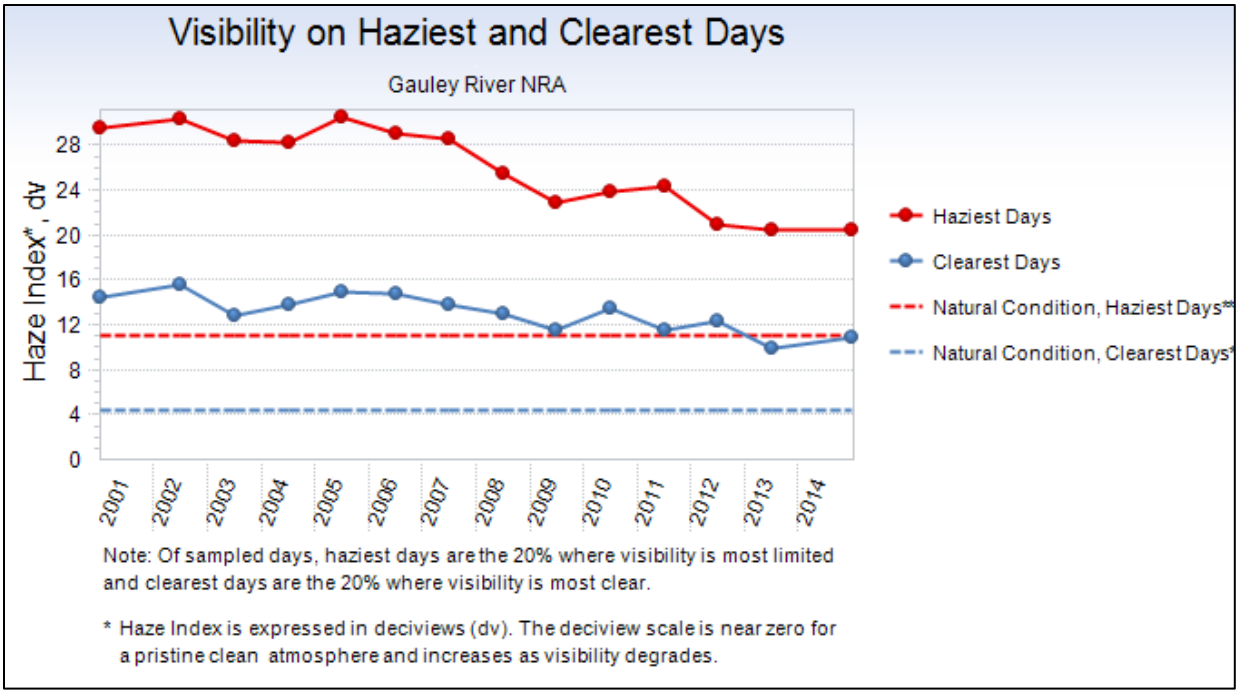


Figure 68. Long-term trends in visibility in the Gauley River National Recreation Area region, based on measurements from the JARI1 monitoring station in western Virginia (reproduced from NPS 2015a).

$PM_{2.5}$ is a major contributor to visibility impairment. Annual average 24-hour $PM_{2.5}$ concentrations are available from a station in Beckley, WV for 1999-2015. This station is located south of the western portion of GARI. Observations from the station suggest that $PM_{2.5}$ concentrations have decreased in the region (Figure 69). The EPA NAAQS for $PM_{2.5}$ uses the 3-year average 98th percentile 24-hour $PM_{2.5}$ concentration to assess human health risk. The station's most recent 3-year average (2013-2015) 98th percentile 24-hour $PM_{2.5}$ concentration of 11.2 µ/m^3 meets the EPA standard of <35 µg/m^3 (EPA 2016d).

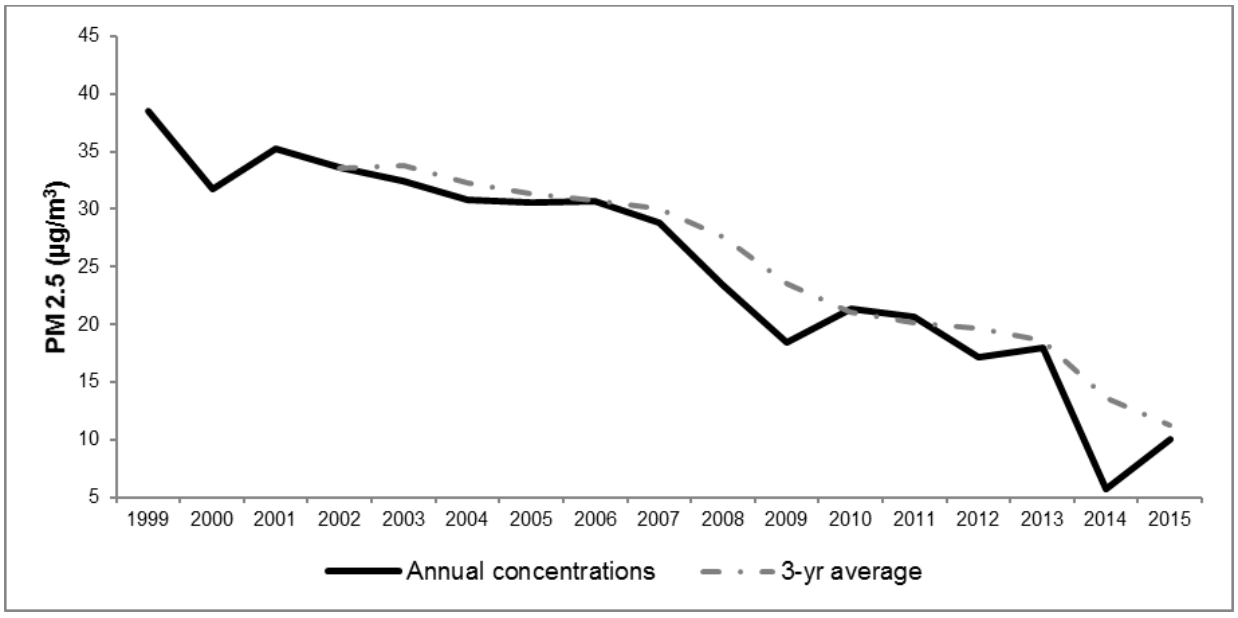


Figure 69. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) for the Gauley River National Recreation Area region, 1999-2015 (EPA 2016a). The monitoring station is located in Beckley, WV (Site ID: 54-081-0002).

Threats and Stressor Factors

Threats to GARI's air quality include power plant and vehicle emissions, railroad traffic, dust from mountaintop removal mining, and prescribed burning. Power plants are a major source of greenhouse gas emissions in the U.S. (EPA 2012). Coal-fired power plants also produce mercury, sulfur dioxide, and PM, which can cause a visible haze in the air (EPA 2012, NPS 2013a). The use of coal for power generation is declining across the country, with numerous facilities converting to natural gas, but a coal-burning power plant is still active near St. Paul, Virginia, approximately 180 km (112 mi) southwest of GARI (Dominion 2016).

Transportation sources account for a significant portion of nitrogen oxide and VOC emissions in the U.S. and also produce some particulate pollution and sulfur dioxides (Small and Kazimi 1995). These emissions can contribute to ozone formation and impact visibility. Although vehicle traffic within the park is minimal, Highway 19 does pass just southeast of GARI (Figure 70). There are also active railroad tracks within the park, along Peters Creek and on the Gauley from Peters Junction to beyond the park's western boundary. Many trains are pulled by diesel-powered locomotives, which produce exhaust that contains over 40 toxic air pollutants, including ozone-forming compounds, PM, and carcinogens (RHA 2016). In addition, some rail cargos (e.g., coal, sand) can give off "fugitive dust" during transport, if not covered properly (Lazo and McClain 1996). This dust is considered PM and can impact visibility.

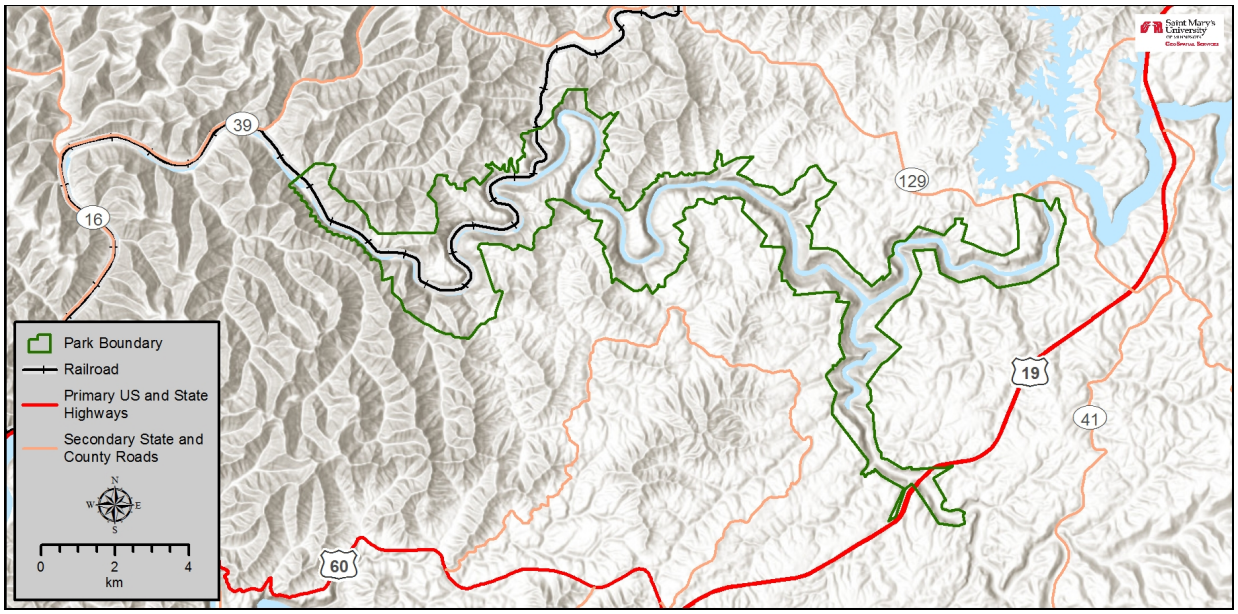


Figure 70. Roads and active railroads in the vicinity of Gauley River National Recreation Area.

Mountaintop removal coal mining uses heavy excavation equipment and explosives to remove vegetation, dirt, and rock in order to access coal seams (Kurth et al. 2014). This blasting and equipment operation generates PM (e.g., rock and coal dust) that can impair air quality. Fuel use by vehicles and equipment at the site, often diesel-powered, also generates air pollutants, including PM and VOCs (Kurth et al. 2014). While mining companies are required to "reclaim" sites following MTR, the result is nearly always open, grassy fields rather than the diverse forests that existed previously (EPA 2011). This forest loss alone can impact air quality, as trees are known to capture and store carbon dioxide and can remove pollutants such as sulfur dioxides, nitrogen dioxides, and ozone from the atmosphere (McPherson et al. 1994, Wickham et al. 2013). As of 2016, numerous surface coal mines were active in the vicinity of GARI (Figure 71), including a large MTR site just 3.2 km (2 mi) north of the GARI boundary (Rozdilski, written communication, April 2017).

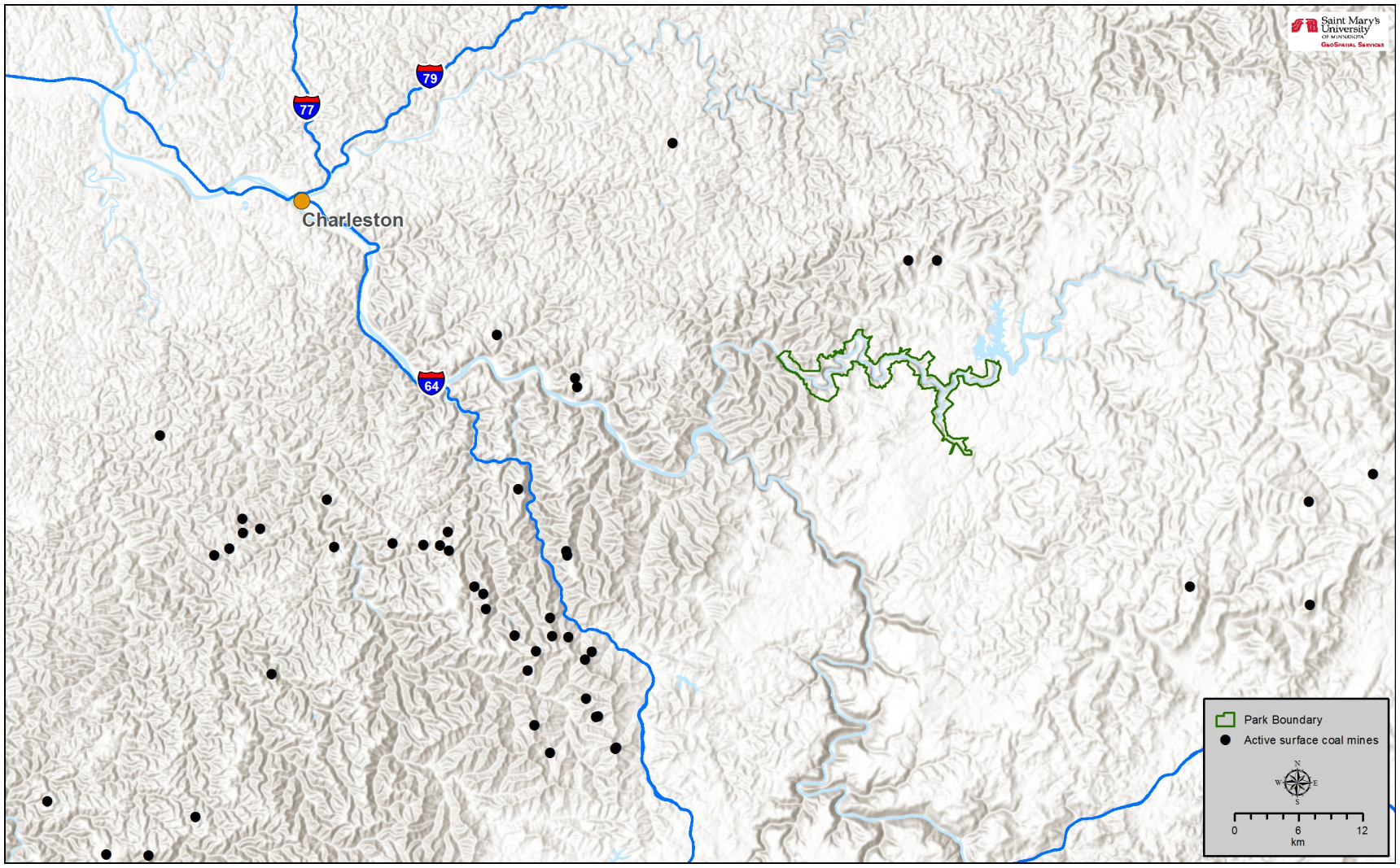


Figure 71. Surface coal mines (active as of 2016) in the Gauley River National Recreation Area region (WVDEP 2017).

Prescribed burning and wildfires produce air pollutants, including PM, carbon monoxide, and VOCs, which can contribute to ozone formation (Wotawa and Trainer 2000, Lee et al. 2005). Air pollution from fires typically impairs visibility and can travel long distances. For example, forest fires in Canada have been shown to impact air quality in the eastern U.S., including as far south as Tennessee (Wotawa and Trainer 2000, Lee et al. 2005).

Air pollutants such as ozone and particulates are strongly influenced by weather shifts (e.g., heat waves, droughts) (EPA 2012). According to the EPA and Intergovernmental Panel on Climate Change (IPCC), warmer temperatures associated with global climate change are expected to negatively affect air quality (EPA 2012). For example, the EPA (2012) projects that climate change could increase summertime average ground-level ozone concentrations in many areas by 2-8 ppb.

Data Needs/Gaps

If budget and personnel limitations allow, on-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury) and visibility will help managers better understand air quality conditions in the park. Studies of mercury concentrations in park waters and wildlife (e.g., fish, birds, bats) may also provide insight into the impact this contaminant is having on the park.

Overall Condition

Nitrogen Deposition

The project team assigned this measure a *Significance Level* of 3. The most recent 5-year nitrogen deposition estimate (2011–2015) for the park fell within the NPS ARD's *Significant Concern* range. Five-year averages have been decreasing slightly over time (Figure 57), as have nitrate concentrations in wet deposition (Figure 58). While GARI is considered to be at low risk of nutrient enrichment from nitrogen deposition, it is at very high risk of acidification from acidic (nitrogen and sulfur) deposition, due to very high pollutant exposure and ecosystem sensitivity (Sullivan et al. 2011a, 2011c). As a result, nitrogen deposition is assigned a *Condition Level* of 3.

Sulfur Deposition

Sulfur deposition was also assigned a *Significance Level* of 3. Although the most recent 5-year sulfur deposition estimate for GARI fell within the Moderate Concern range, the NPS ARD elevated the rating to *Significant Concern*, due to very high ecosystem sensitivity. While five-year deposition averages, as well as sulfate concentrations in wet deposition, have been decreasing in recent years, the current condition of this measure warrants a *Condition Level* of 3 at this time.

Mercury Deposition

A *Significance Level* of 3 was assigned for mercury deposition. Based on the NPS ARD mercury status assessment matrix (Table 71), which incorporates estimated mercury wet deposition and predicted methylmercury concentrations, GARI is currently in the *Moderate Concern* range. Therefore, a *Condition Level* of 2 is assigned for this measure.

Ozone

The project team also assigned this measure a *Significance Level* of 3. The most recent 5-year estimated average for 4th-highest 8-hour ozone concentration for GARI was in the *Moderate Concern*

range. Ozone concentrations appear to be improving (decreasing) in the region (Figure 64, Figure 65). Vegetation health risk (as measured by W126 values) is also of *Moderate Concern*. As a result, ozone is assigned a *Condition Level* of 2.

Visibility

Visibility was assigned a *Significance Level* of 3. The most recent estimated visibility average for mid-range days for GARI fell in the *Significant Concern* range. Five-year averages have been improving slightly since 2009 (Figure 67), but visibility is still assigned a *Condition Level* of 3.

Weighted Condition Score

The *Weighted Condition Score* for GARI's air quality is 0.87, indicating significant concern. Conditions appear to be improving among all the selected measures, but nitrogen and sulfur deposition, as well as visibility, are still of high concern. A medium confidence border is used due to the use of estimates/interpolations, as park-specific data is lacking.

Table 72. Current condition of Gauley River National Recreation Area's Air Quality.

Measures	Significance Level	Condition Level	WCS = 0.87
Nitrogen Deposition	3	3	
Sulfur Deposition	3	3	
Mercury Deposition	3	2	
Ozone	3	2	
Visibility	3	3	

4.10.6. Sources of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.11. Dark Night Skies

4.11.1. Description

A lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS NSNSD 2015). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, NPS NSNSD 2015). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS NSNSD 2015). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

GARI is located in central West Virginia and falls within both Nicholas and Fayette Counties; the middle of the Gauley and Meadow Rivers as they occur in the park represents the boundary of the two counties. GARI is surrounded by many small communities, most of which are unincorporated and are within close proximity to the park (Figure 72). Larger West Virginia cities (those with populations between 1,000-4,000) within an hour's drive from the park include Ansted, Fayetteville, and Summerville. Major cities (>10,000 people) such as Charleston (49,138 people) and Beckley (16,972 people) are located over an hour away by car travel.

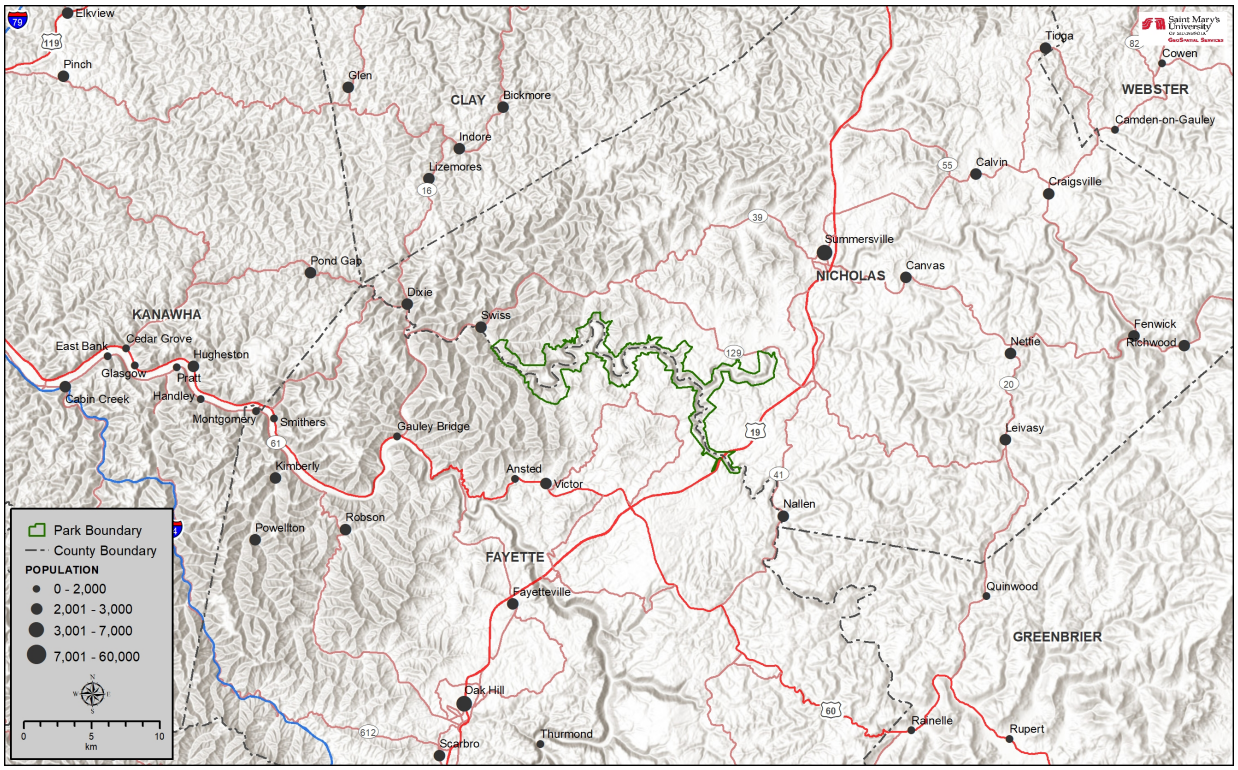


Figure 72. Location of Gauley River National Recreation Area and nearby communities and roads that may contribute anthropogenic light to the night sky.

The resource of a dark night sky is important to the NPS for a variety of reasons. First, the preservation of natural lightscapes (the intensity and distribution of light on the landscape at night) will keep the nocturnal photic environment within the range of natural variability. Excursions outside this natural range may result in a modification to natural ecosystem function, especially to systems involving the behavior and survival of nocturnal animals (NPS NSNSD 2015). The natural night sky is therefore one of the physical resources under which natural ecosystems have evolved. Second, the "scenery" of national park areas does not just include the daytime hours (NPS NSNSD 2015). Third, the history and culture of many civilizations are steeped in interpretations of night sky observations, whether for scientific, religious, or time-keeping purposes (NPS NSNSD 2015). As such, the natural night sky may be a very important cultural resource, especially in areas where evidence of aboriginal cultures is present. Fourth, the recreational value of dark night skies is important to campers and backpackers, allowing the experience of having a campfire or "sleeping under the stars" (NPS NSNSD 2015). And lastly, night sky quality is an important wilderness value, contributing to the ability to experience a feeling of solitude in a landscape free from signs of human occupation and technology (NPS NSNSD 2015).

4.11.2. Measures

The dark night sky at GARI was assessed using the suite of measures that the NPS Natural Sounds and Night Sky Division (NSNSD) uses to define the night sky conditions in a park unit. Selection of the standard NSNSD measures ensures that this assessment aligns with NSNSD standards. The suite of measures that the NSNSD typically uses to define the condition of dark night skies include:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second [mag/arcsec^2] or milli-candela per square meter [mCd/m^2]) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude (mags) is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a "Johnson-Cousins V" filter. It is similar to the "CIE photopic" broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);

- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;

- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;

- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;

- Visual observations by a human observer, such as Bortle Class and Zenith limiting magnitude (ZLM);

- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter (SQM), in mag/arcsec^2.

The NPS NSNSD has not conducted a field visit to GARI as of this writing. In the absence of these data, the NPS NSNSD recommends the use of the anthropogenic light ratio (ALR) as a measure of the quality of the photic environment and lightscape within a park (Moore et al. 2013). The ALR measures the average anthropogenic sky luminance as a ratio of natural conditions. This measure is easily modeled using GIS and provides a robust and descriptive metric (Moore et al. 2013). For this assessment, the ALR model for the GARI area will be used to assess current condition.

4.11.3. Reference Condition/Values

NPS staff identified the absence of anthropogenic light as the preferred reference condition. This condition can be defined as the absence of artificial light in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> *No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated the naturally dark zone* (Dan Duriscoe, NPS NSNSD, pers. comm., 2011).

Achieving this reference condition for preserving natural night skies is well summarized in the NPS Management Policies (NPS 2006, p. 7) in section 4.10 as follows:

> *The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.*

Implementing this directive in GARI requires that facilities within the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;

- be of an intensity that meets the minimum requirement for the task, but does not excessively exceed that requirement;

- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;

- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

4.11.4. Data and Methods

The NPS NSNSD has developed a geographic information system (GIS) model derived from data from the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001), which depicts *zenith* sky brightness (the brightness of the sky directly above the observer) (Moore et al. 2013). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the *entire* sky. Anthropogenic light up to 200 km (124 m) from parks can have an impact on a park's night sky quality. Finally, the modeled anthropogenic light over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Dursicoe 2016).

4.11.5. Current Condition and Trend

Background for NPS Night Sky Division's Suite of Measures

Anthropogenic light in the night environment can be very significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a "detector" or a measuring device, or entering the observer's pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English), and is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen/m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified (Ryer 1997).

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as "sky glow". This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional. When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a

distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a "full cutoff" design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 73 and Figure 74, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NSNSD.



Figure 73. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Figure provided by Dan Duriscoe, NPS NSNSD).

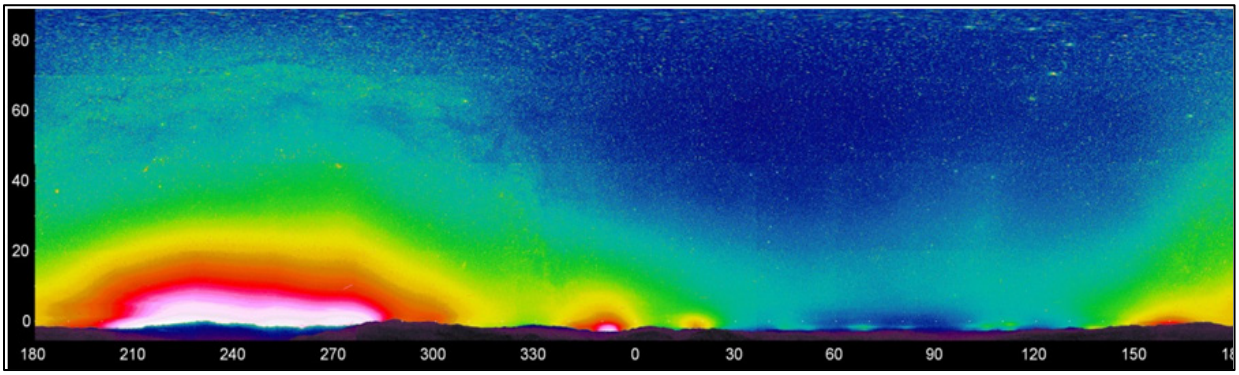


Figure 74. False color representation of Figure 73 after a logarithmic stretch of pixel values (Figure provided by Dan Duriscoe, NPS NSNSD).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NSNSD utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 73 and Figure 74 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called “permanent aurora” which varies in intensity over time) (Roach and Gordon 1973). The NSNSD has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 75). Figure 74 represents “total sky brightness” while Figure 75 displays “anthropogenic sky glow” or “net light pollution.” This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

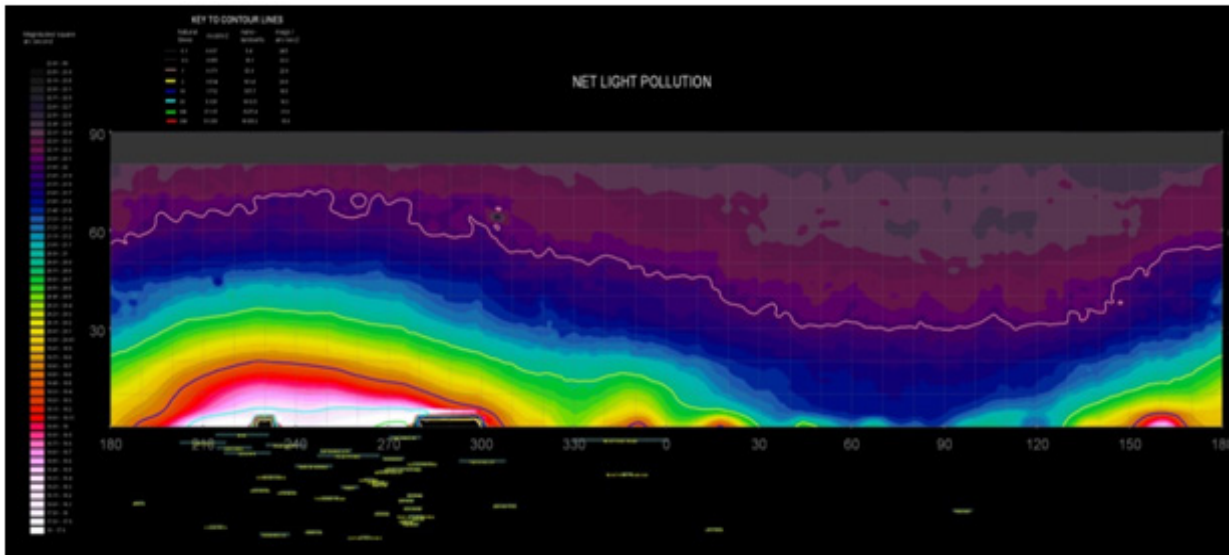


Figure 75. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 74 with natural sources of light subtracted (Figure provided by Dan Duriscoe, NPS Night Sky Division).

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric

of the resource condition - a ratio of anthropogenic to natural light, the ALR identified previously (Moore et al. 2013). Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2010). This so-called "light pollution ratio" is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NSNSD data, the atmospheric conditions determined from each individual data set. The ALR is derived from ground–based measurements when available, or from a GIS model (calibrated to ground-based measurements in the park) when field based data are measures are not available (Moore et al. 2013).

A quick and moderately accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron SQM. The Unihedron SQM is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Because the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NSNSD produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron SQM. The performance of the SQM has been tested and reviewed by Cinzano et al. (2001). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered "pristine", providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken (Moore et al. 2013).

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a "pristine sky" filled with easily observable features and class 9 represents an "inner city sky" where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

Another visual method for assessing sky quality is the ZLM, which is the apparent brightness or magnitude of the faintest star observable to the unaided human eye, which usually occurs near the Zenith. This method involves many factors, the most important of which is variability from observer to observer. A ZLM of 7.0-7.2 is usually considered "pristine" or representing what should be observed under natural conditions; observation of ZLM is one of the factors included in the Bortle Dark Sky Scale. The ZLM is often referenced in literature on the quality of the night sky, and is the basis for the international "Globe at Night" citizen-scientist program (see http://www.globeatnight.org/index.html). The NSNSD has experimented with the use of this observation in predicting sky quality, and has found that it is a much coarser measure and prone to

much greater error than accurate photometric measures over the entire sky. For these reasons, it is not included in the reference conditions section.

NPS Night Sky Division Suite of Measures

The NSNSD has not made a field visit to GARI. However, the NSNSD was able to use GIS-modeling to show ALR values for the Eastern U.S. and GARI (Figure 76, Figure 77). A condition level can be assigned to the modeled ALR data, based on a threshold applied spatially to the park (Moore et al. 2013). This threshold is dependent on whether the park is considered to be urban or non-urban (Moore et al. 2013). The distinction between urban (Level 2) and non-urban (Level 1) parks is based on the relative proximity of the park (and its borders) to Urban Areas as defined by the 2010 U.S. Census (Moore et al. 2013). For parks managed as wilderness, the designated condition is based on ALR level that exists in more than 90% of the wilderness area (Moore et al. 2013). As 90% of GARI's property occurs outside of urban areas, the park is classified as a non-urban (Level 1) park.

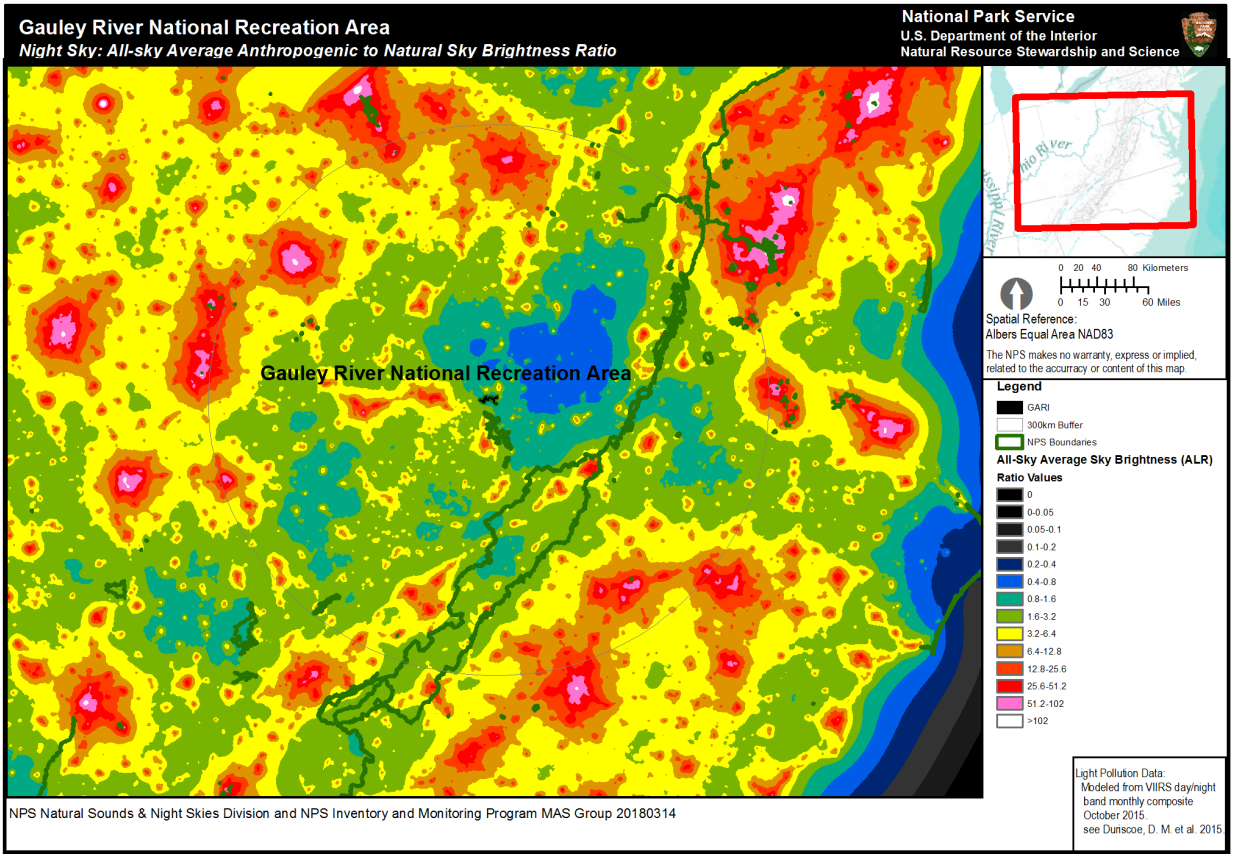


Figure 76. Modeled all-sky average sky brightness (ALR) in and around Gauley River National Recreation Area (GARI). GARI's boundary is outlined in black and is below the text label for the park. Figure provided by NPS NSNSD.

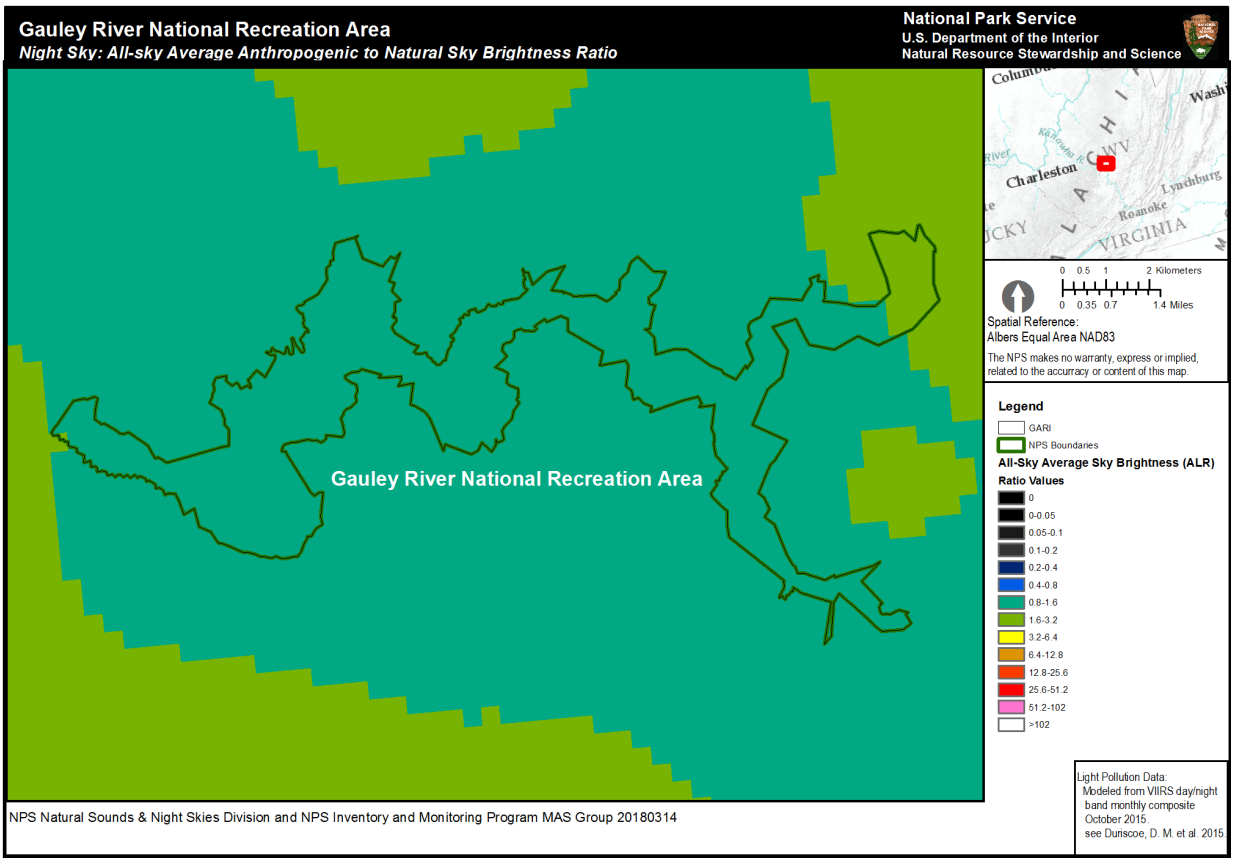


Figure 77. Modeled all-sky average sky brightness (ALR) for Gauley River National Recreation Area (GARI). This figure is a close up visual of the park as displayed in Figure 76. Figure provided by NPS NSNSD.

In interpreting the results of the model, for both urban and non-urban parks, the condition (green, amber, red) corresponds to the ALR level that represents the median condition (in at least half the park's area) for the park's landscape (Moore et al. 2013). This median condition reflects the probable night sky quality that park visitors will experience at any location within the park (Moore et al. 2013). It is also probable that the majority of wildlife and habitats within the park exist under this quality of night sky (Moore et al. 2013). The NPS NSNSD recommendations for ALR condition are given in Table 73. The median ALR value for GARI is 1.38, which puts the park in the moderate condition category for non-urban (Level 1) parks (Moore et al. 2013, NPS 2015). These ALR values and condition levels are the product of a model, and may not be fully accurate representations of current night sky conditions in the park. A NSNSD team visit is needed to accurately quantify the quality of night skies in GARI.

Table 73. National Park Service Natural Sounds and Night Sky Division recommendations for condition levels for modeled Anthropogenic Light Ratio (ALR) values (Moore et al. 2013).

Landscapes	Good Condition (Green)	Moderate Condition (Amber)	Poor Condition (Red)
Non-urban (Level 1) parks	< 0.33	0.33–2.00	> 2.00
Urban (Level 2) parks	< 2.00	2.00–18.00	> 18.00
Areas Managed as Wilderness	< 0.33	0.33–2.00	> 2.00

Threats and Stressor Factors

Light trespass from nearby cities, developments, and lack of planning information for local lighting within nearby communities and developments are considered the most concerning threat to night sky quality of a park. Examples of nearby sources of light trespass in the GARI area include park campgrounds, Carnifex Ferry Battlefield State Park and Summersville Lake, land developments surrounding the park, and lighting facilities at the Gauley tailwaters. Other sources of light pollution in the GARI area include traffic lights from highways and local roads (including Meadow River Gorge Bridge), cell phone tower lights, and power line lighting. Contributing to these typical light sources are air transparency (haze, smoke) conditions, which are often degraded in the area due to local weather patterns and proximity to the mountains which trap and concentrate air contaminants from coal-fired power plants and vehicle emissions (Emmott et al. 2005, Emmott and Porter 2008).

Data Needs/Gaps

The NPS NSNSD has never visited GARI to collect data. The night sky condition data collected by the NPS NSNSD would provide a more comprehensive suite of measures that are more conducive to developing desired conditions or making management decisions than the modeled data currently available for GARI. Along with periodic park monitoring visits, the NPS NSNSD could assess and track external light source impacts within GARI.

Overall Condition

Anthropogenic light ratio (ALR)

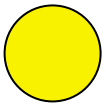
During scoping meetings, the NRCA team assigned the NPS NSNSD suite of measures a *Significance Level* of 3. While NPS NSNSD has not conducted a field visit to GARI, ALR data modeled by the NPS NSNSD can be used as a surrogate for the Average Natural Sky Luminance data collected during their field visits (Moore et al. 2013). The modeled ALR data for GARI was 1.38, which places it at the moderate condition level, as recommended by Moore et al. (2013). To align the *Condition Level* for this measure with what was suggested in Moore et al. (2013), a *Condition Level* of 2 was assigned to this measure.

Weighted Condition Score

A *Weighted Condition Score* of 0.67 was calculated for the dark night sky component, which, when following the scoring benchmark defined in Chapter 3, indicates significant concern (Table 74). However, due to only one measure being scored for this component, and because the *Condition Level* of that measure aligned with a Moderate Concern designation by Moore et al. (2013), the condition

graphic for this component has been adjusted to one of moderate concern. No current trend could be identified for this component, as all the data available were the result of modeling and not on-the-ground surveys. A visit to the park by the NPS NSNSD is needed to accurately measure the current condition of night skies in the park, and to elevate the confidence in condition designation (currently condition designation is of medium confidence).

Table 74. Current condition of Gauley River National Recreation Area's Dark Night Skies.

Measures	Significance Level	Condition Level	WCS = 0.67
Anthropogenic Light Ratio	3	2	

4.11.6. Sources of Expertise

National Park Service Night Sky Division members Dan Duriscoe and Jeremy White were instrumental in putting together much of the background narrative for this component. Sharolyn Anderson, also of the NPS NSNSD, provided the modeled ALR figures and data used in this assessment.

4.12. Surficial Geologic Features

4.12.1. Description

One of the primary reasons for the establishment of GARI was to protect the scenic and geologic resources of the Gauley River and its tributaries (Public Law 100-534). The geology of the river valley, with its rock falls and boulders, has directly contributed to its recreational value as a whitewater rafting destination (Kite 2011). Over time, the Gauley and Meadow Rivers have carved an impressive 100-300 m (328-984 ft) deep gorge into the surrounding bedrock. This bedrock consists of Pennsylvanian-aged (~300 million years ago) New River and Kanawha formations, which are nearly horizontal strata of sedimentary rock (Vanderhorst et al. 2010, Kite 2011). The New River formation is older and lies below the Kanawha formation. Both formations are comprised of sandstone with some shale, siltstone, and coal, but the New River formation contains a greater proportion of sandstone, including a capping layer of resistant, cliff-forming Nuttall sandstone (Vanderhorst et al. 2010). The New River formation is exposed in the eastern portion of GARI and has weathered into "rolling plateaus dissected by shallow, steep-sided gorges with prominent cliff bands overlooking bedrock and boulder controlled rapids in the river channels" (Vanderhorst et al. 2010, p. 3). Kanawha formation exposures are more extensive in the western part of the park; its landforms show greater topographic relief, characterized by ridges rather than plateaus.



Cliffs along the Gauley River near Koontz Bend (SMUMN GSS photo by Andy Nadeau).

Understanding the connections between the biological resources and physical components of an area, such as surficial geological features, is important for the successful management and protection of natural resources (NPS 2016c). Geologic resources include both physical features of the earth (e.g., mountains, canyons, rocks, beaches, fossils) and the processes that act upon them (e.g., erosion, sedimentation, landslides, rockfalls). Surficial geology resources of particular interest at GARI include cliffs, boulders, algific areas, and mass movements (e.g., rock fall, debris slide, debris flow).

However, several characteristics of these resources make it inappropriate to assess them as the other natural resources in this NRCA are assessed. For example, change is natural and normal for these geological resources, but the rates and magnitudes of change are highly variable. Some geological changes are slow and gradual while others are sudden and dramatic. Cliffs and boulders may appear unchanged for decades or centuries and then be suddenly modified by mass movements or floods. As a result, measurements and comparisons over regular time intervals may not be an efficient or effective monitoring/assessment method. The NRCA project team felt it would not be appropriate to evaluate or assign conditions for these resources; therefore, this component will simply summarize the known information about GARI's surficial geologic features, threats to these features, and data needs. There will be no scoring or condition assignment for this component.

4.12.2. Features of Interest

- Cliffs
- Boulders
- Algific areas
- Mass movements

4.12.3. Data and Methods

Literature and data sources on GARI's surficial geologic features are limited. The NPS Geologic Resources Inventory Program recently created a digital surficial geologic map of GARI. This map divides the surface of GARI into 15 map units, such as bouldery floodplain, colluvial fan, entrenched stream channel, and high terrace (NPS 2016c). The descriptions of these map units include information on composition (e.g., alluvium vs. colluvium), slope, and the prevalence of landslides. Some information on the vegetation communities supported by GARI's cliffs, boulders, and algific talus slopes can be found in Vanderhorst et al. (2010).

Mahan (2016) provided information on the geology and flora of the cliff resources at NERI, as well as discussing visitor use of cliffs. Although the document does not address GARI, similarities between the geology of the two parks means that some information from NERI will also apply to GARI's surficial geologic features, including threats to the resources from visitor use. A study of the role of mass movement debris in the formation of rapids at NERI by Moore (1999) also contains background information that could apply to GARI. Details on different types of mass movements and monitoring such events was found in a Geological Society of America manual on geological monitoring (Wieczorek and Snyder 2009).

4.12.4. Current Knowledge

Cliffs

The high cliffs along the Gauley River and some of its tributaries contribute greatly to the scenic beauty that led to the establishment of GARI. The cliffs are scattered throughout the park but are primarily associated with New River formation sandstone outcrops in the eastern two-thirds of GARI

(Figure 78). Soils occurring in crevices or at the base of the cliffs are highly acidic (pH = 4.0-4.4) (Vanderhorst et al. 2010).

Despite the inhospitable appearance of these cliffs, some plants and wildlife are able to utilize them as habitat. Cliff structure, including macro- and micro-topographic surface features (e.g., angle, ledge/crevice frequency), create habitat variety that influences the species occupying each cliff (Mahan 2016). Lichens and non-vascular plants (e.g., mosses and liverworts) can grow on sterile surfaces like bare rock and are often some of the first pioneer species to establish on cliff faces. These species offer a potential substrate for vascular plant seedling establishment, promoting habitat succession (Pauley and Clebsch 1990, Mahan 2016). During GARI vegetation classification and mapping efforts, cliff faces were divided into two vegetation associations: the Dry Cliff Face Association and the Common Rock Tripe Cliff Face Community (Vanderhorst et al. 2010).

The Dry Cliff Face Association occurs on vertical or overhanging sandstone cliffs that are somewhat sheltered from sunlight, rain, and seepage (Vanderhorst et al. 2010). The sparse vegetation on these cliffs is typically dominated by crustose lichens, with smaller amounts of moss (Figure 79). Lichens identified on GARI's dry cliff faces include reindeer lichen (*Cladina rangiferina*), cup lichen (*Cladonia squamosa*), dust lichens (*Lepraria* and *Chrysothrix* spp.), blistered naval lichen (*Lasallia papulosa*), and rock beard lichen (*Usnea amblyoclada*) (Vanderhorst et al. 2010). Occasional vascular plants growing from cracks or crevices include great laurel (*Rhododendron maximum*), sweet birch, red maple (*Acer rubrum*), white wood aster (*Eurybia divaricata*), and rock polypody (*Polypodium virginianum*). The cliffs and overhangs create unique dry areas that provide habitat for Allegheny woodrats and antlions (insect larvae of the family Myrmeleontidae) (Vanderhorst et al. 2010).

The Common Rock Tripe Cliff Face Community occurs on sandstone cliffs that are less than vertical and receive more sunlight and rain than vertical faces (Vanderhorst et al. 2010). The vegetation on these cliff faces is dominated by rock tripe (*Umbilicaria mammulata*), a macrolichen, with Andreaea moss (*Andreaea rothii*) (Figure 80). Occasional woody plants growing in crevices include red maple, eastern hemlock, great laurel, and Catawba rosebay (*Rhododendron catawbiense*) (Vanderhorst et al. 2010).

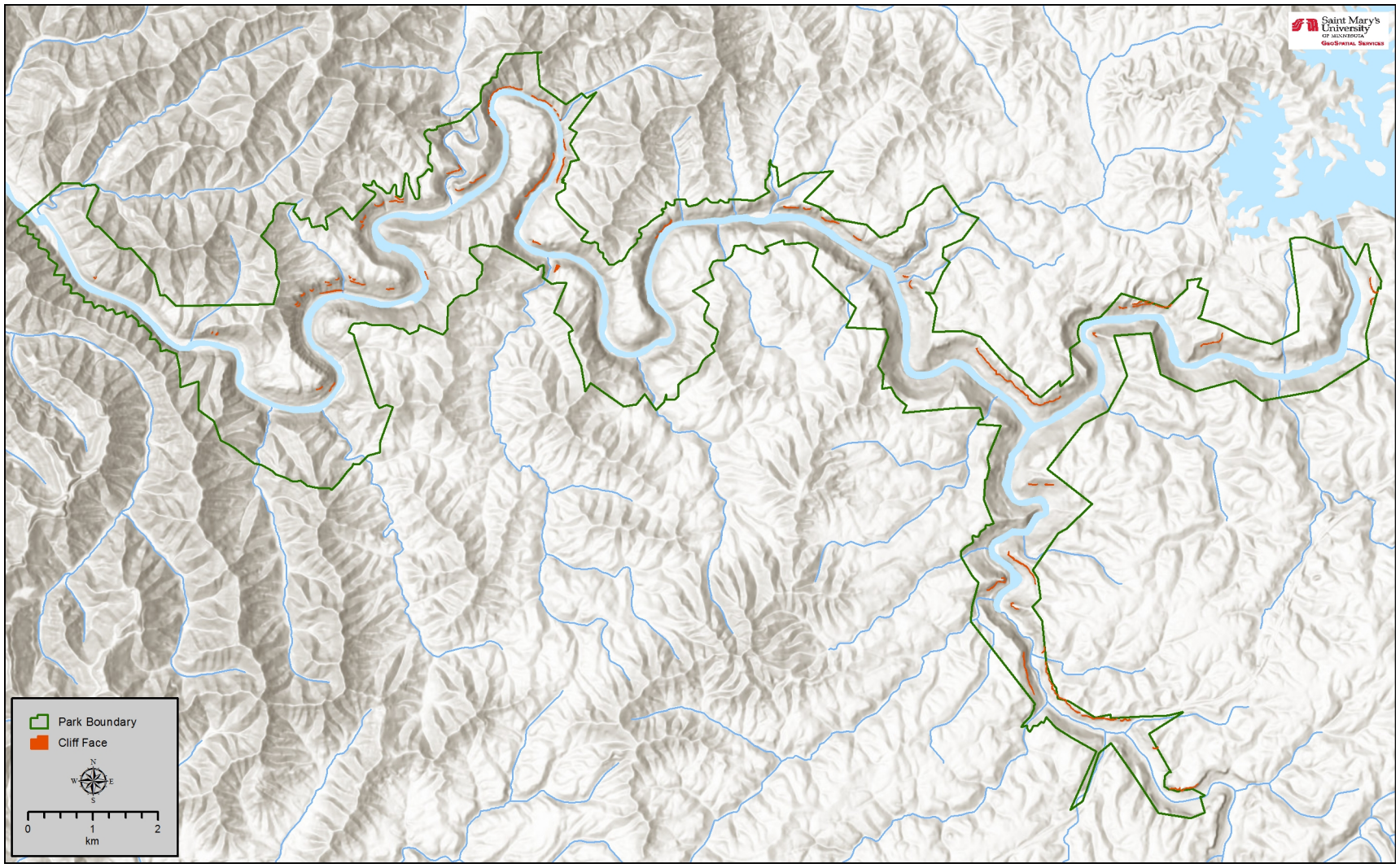


Figure 78. The locations of cliff face vegetation associations within Gauley River National Recreation Area (Vanderhorst et al. 2010).



Figure 79. A photo of dry cliff face community at Gauley River National Recreation Area, showing lichen on bare rock (Vanderhorst et al. 2010).



Figure 80. The common rock tripe cliff face association at Gauley River National Recreation Area (left, Vanderhorst et al. 2010) and a close-up of common rock tripe (right, Mahan 2016).

The Nuttall Sandstone that caps the New River formation forms cliffs and blocks that are preferred by recreational climbers over other sandstone types in the region (Mahan 2016). Nuttall Sandstone consists of homogenous quartz arenite with goethite, an iron-bearing mineral, as secondary cement along vertical tectonic joints (Mahan 2016, NPS 2016c). Goethite, an iron-bearing mineral, makes the rock layer more resistant to weathering and safer for climbing (Mahan 2016). The quartz arenite has been described as "well-indurated" (NPS 2016c), meaning the rock has been well-hardened by heat, compaction, or cementation. Between quartz arenite layers within the Nuttall Sandstone are bands of shale and basal conglomerate that are less resistant to erosion than the arenite (Mahan 2016). When these bands weather, they often create spherical surface depressions called "huecos", which provide convenient foot or handholds for climbers. At GARI, the Nuttall Sandstone has been classified into an 18-30 m (60-100 ft) thick upper layer and a 24-33 m (80-110 ft) thick lower layer (Figure 81) (NPS 2016c). The Lower Nuttall Sandstone has been described as "generally more massive and conglomeratic than the Upper Nuttall, often forming overhanging cliffs with an undulating base" (NPS 2016c, p. 6).

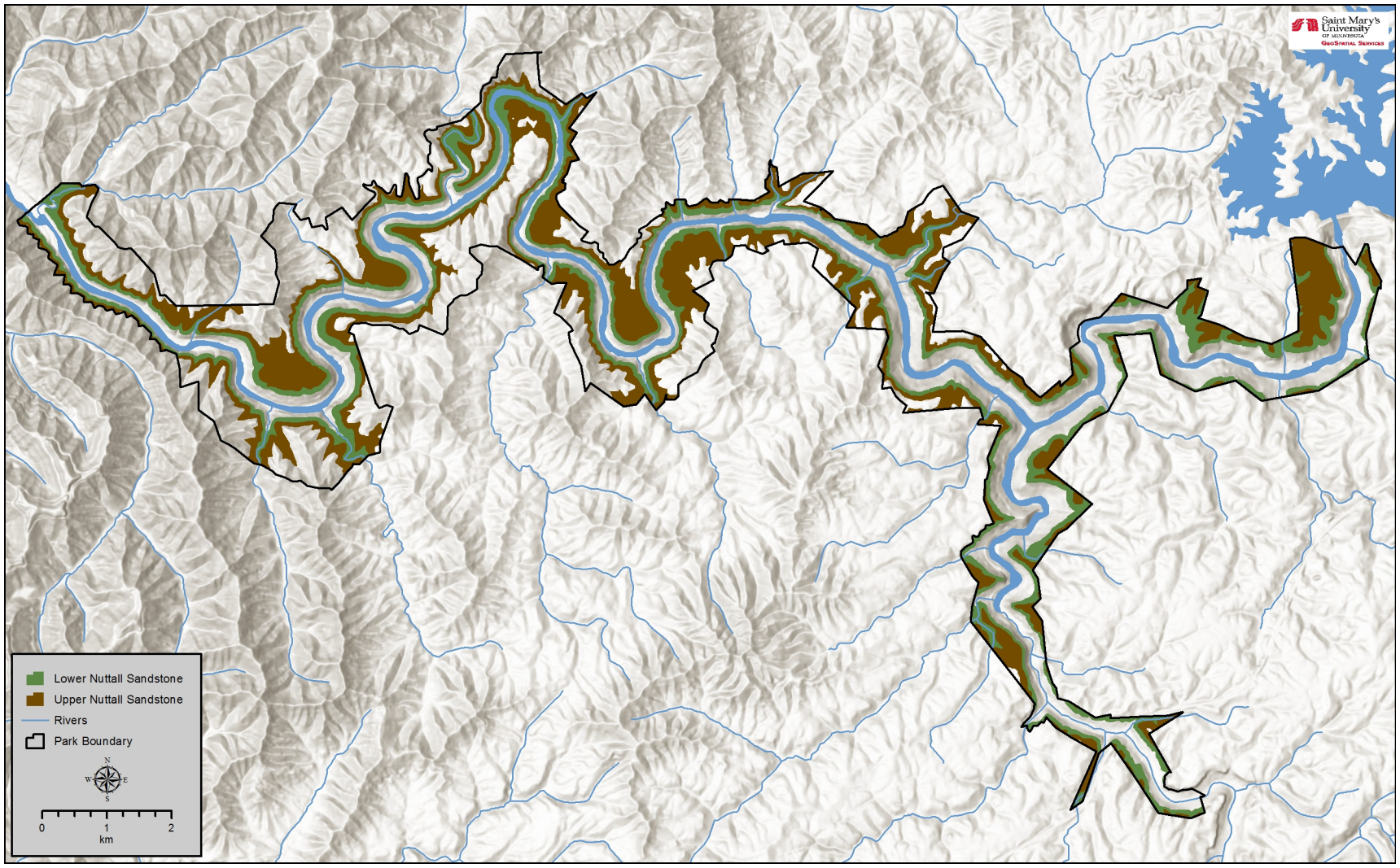


Figure 81. The locations of Upper and Lower Nuttall Sandstone within the Gauley River National Recreation Area boundary, based on a bedrock geology map of the park (NPS 2010).

Boulders

Large boulders, sometimes referred to as colluvial block, are common along and within the Gauley River (Figure 82). Smaller boulders (1-2 m [3.3-6.6 ft] in diameter) may be moved by strong floods (Kite 2011) but larger boulders often remain in place for decades or even centuries. These boulders have contributed to the formation of more than 100 rapids on the Gauley River, including six rated as Class V (extremely difficult) rapids (Figure 83) (Kite 2011, NPS 2016g).



Figure 82. Large boulders in and along the Gauley River create rapids that attract whitewater rafters and kayakers (NPS photo by Shari Quinn).

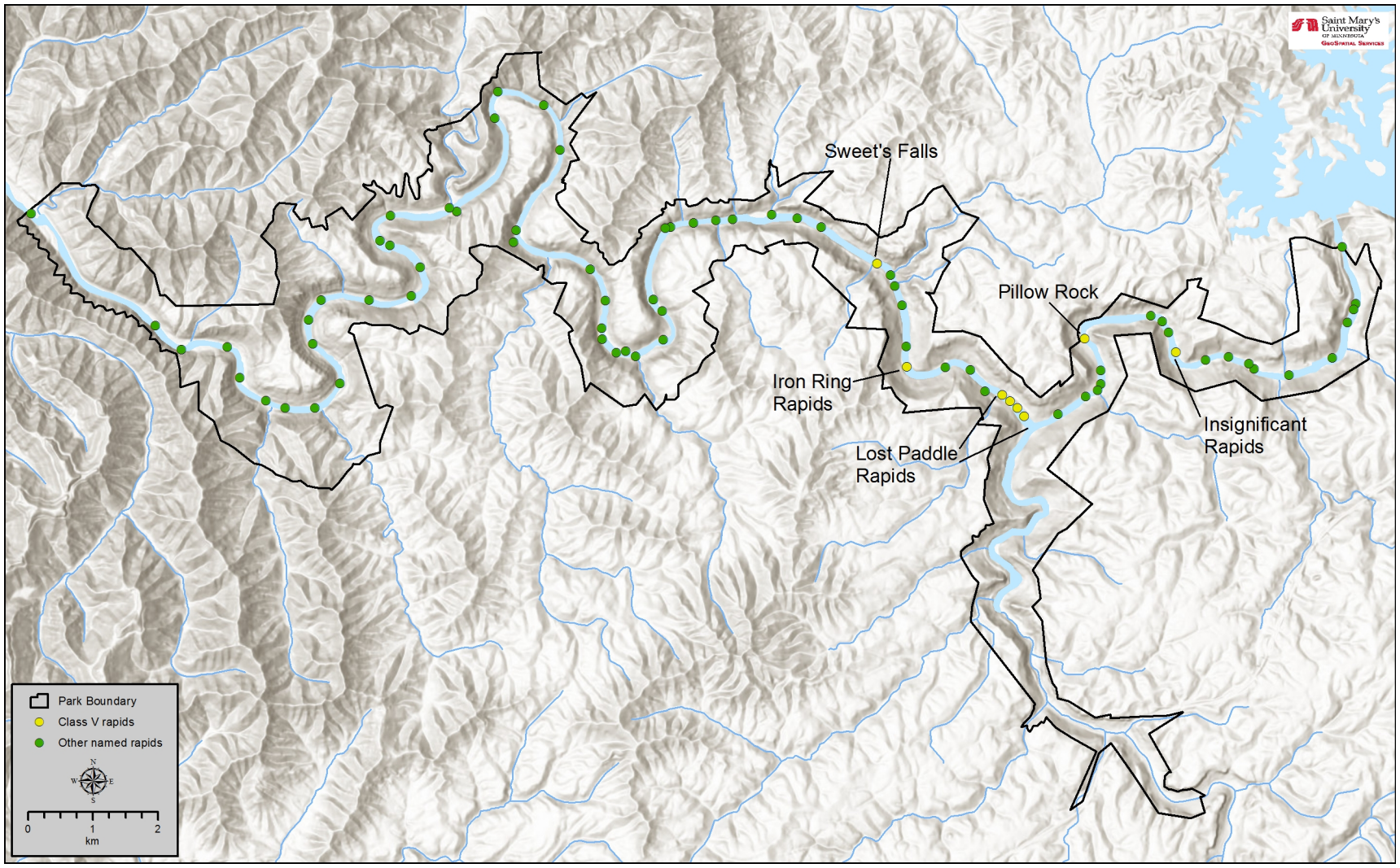


Figure 83. Named rapids, including Class V rapids, on the Gauley River within Gauley River National Recreation Area.

Surface geologic map units where boulders are common include Bouldery Floodplain and Entrenched Stream Channel (Figure 84). Bouldery Floodplain is described as "Floodplain bottom land, episodically inundated by floods, largely composed of boulders, cobbles, and blocks of alluvially or colluvially transported boulders" (NPS 2016c, p. 21). In the Entrenched Stream Channel map unit, banks commonly consist of boulders and blocks from adjacent very coarse colluvial sediment (NPS 2016c). Large boulders can protect vegetation from high-energy stream flows (Vanderhorst et al. 2010). For example, herbaceous marsh vegetation occurs on sandy alluvium behind bedrock and boulders along the riverbank. The downstream side of boulders may also support lichens such as *Xanthoparmelia conspersa* and a *Phlyctis* species (Vanderhorst et al. 2010).

Algific Areas

According to the Oxford Dictionaries (2017), "algific" means "that makes cold; cooling, chilling". It has been used to describe areas or geologic features that "have a chilling effect on the microclimate of the area." The term is most known from describing algific talus slopes. These rare, north-facing rocky habitats produce cold air during the warm season and are known to occur in the Driftless Area of the upper Midwest and in West Virginia (Darmody and Hayek 2014, Coffey 2015). The cold air and resulting cooler microclimate are produced when air circulates over ice deposits deep within the fissures and interconnected vents of the talus material (Coffey 2015). These ice deposits form during the cold season and are preserved by the shading of the talus material and their north-facing aspect. The cold air lowers the ambient growing-season temperature in these areas, influencing the vegetation that occurs there (Cottrell and Strode 2005, Darmody and Hayek 2014). Algific slopes often support unique biological communities and high biodiversity (Norris and Lewis 2006, Coffey 2015). However, the soils in these areas may be thin and the rocks and soils have crusts of non-vascular plants, which are sensitive to human activity and other disturbances (Coffey 2015).

At GARI, only one algific talus slope area on the Meadow River has been described and studied. The blocks/boulders comprising this talus are much larger than at most known algific talus slopes (Dr. Steve Kite, WVU Associate Professor of Geology and Geography, personal communication, 5 October 2017). When temperatures at this site were first measured in August 2010, they were approximately 10°C (18°F) below surrounding ambient temperatures (Kite 2011). Two continuous temperature data loggers were placed at this talus slope area along the Meadow River. From August 2010 through March 2014, site temperatures were 3.5-4.5°C (6.3-8.1°F) cooler than regional mean annual surface temperatures (Figure 85) (Kite, personal communication, 5 October 2017). However, this cooling effect was not as strong as at other known algific talus slopes, such as Ice Mountain in northeastern West Virginia, where temperatures were approximately 7.5°C (13.5°F) cooler than mean surface temperatures. There was also no evidence of persistent ice presence at the Meadow River site (Kite, personal communication, 5 October 2017).

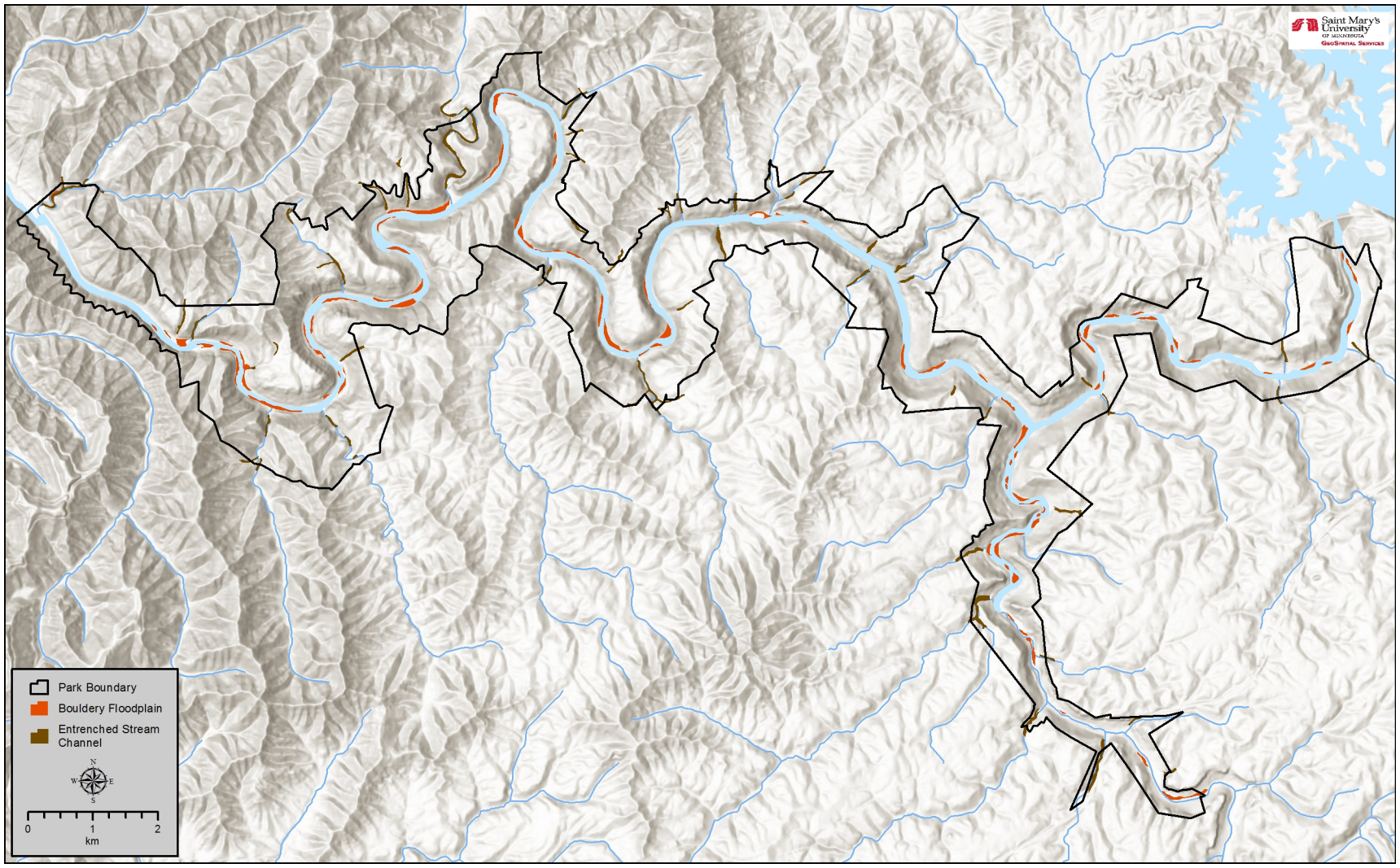


Figure 84. The locations of Bouldery Floodplain and Entrenched Stream Channel surficial geology map units within Gauley River National Recreation Area (NPS 2016f).

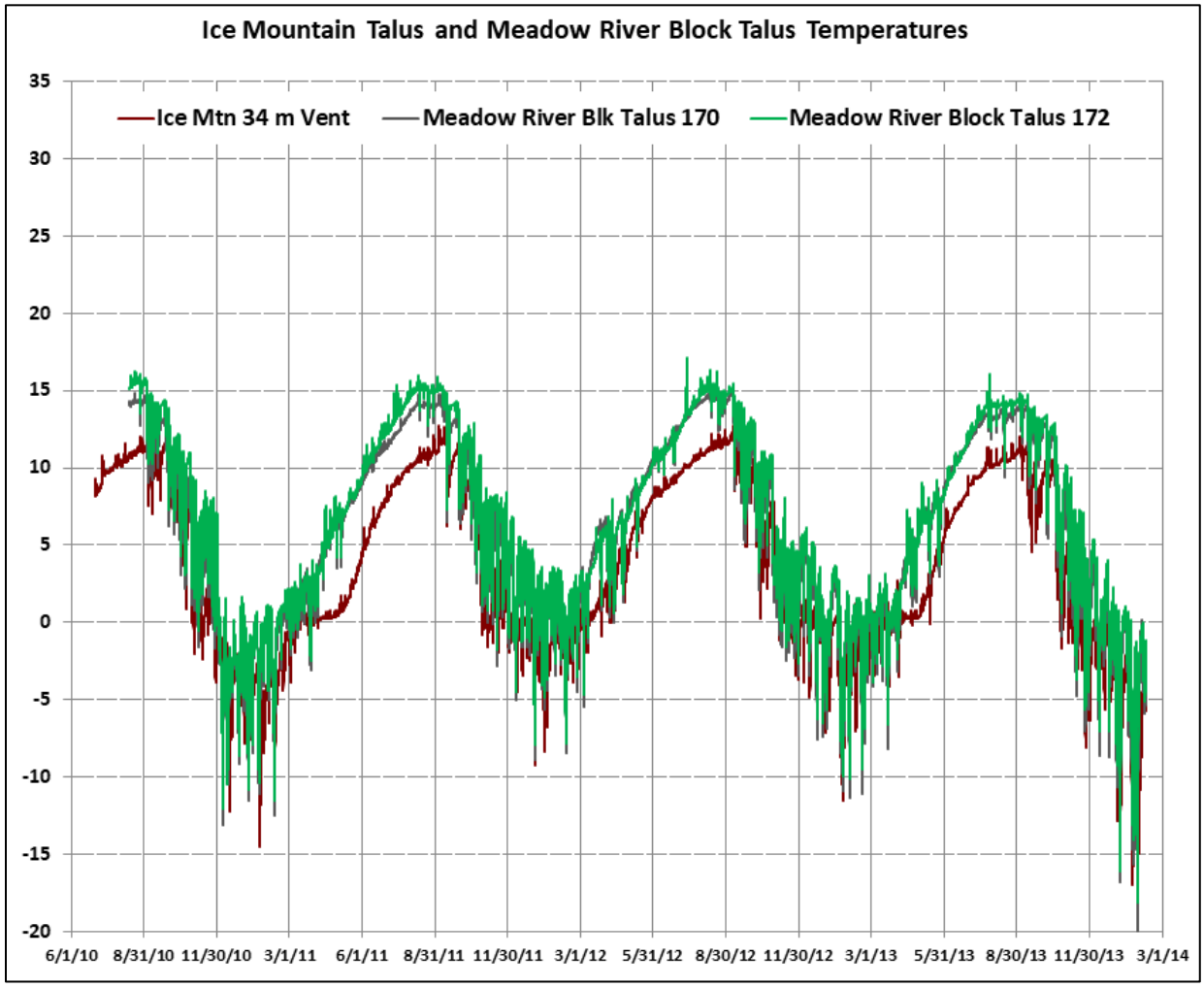


Figure 85. Temperatures (°C) at Meadow River algific talus sites, 2010-2014, compared to temperatures at Ice Mountain, a known algific talus slope in West Virginia. Graphic provided by Dr. Steve Kite (unpublished data).

The algific talus slope on the Meadow River occurs in an area mapped as Yellow Birch Cold Cove Forest by Vanderhorst et al. (2010) (Figure 86). This forest association is limited to a few locations on steep lower gorge slopes with northeasterly aspects and extremely low solar exposure (Vanderhorst et al. 2010). The substrate is boulder colluvium, and soils, where present, are very acidic with high organic matter content. The forest contains a large yellow birch (*Betula alleghaniensis* var. *alleghaniensis*) component, along with mountain magnolia (*Magnolia fraseri*), tuliptree, and eastern hemlock (Vanderhorst et al. 2010). Ferns and moss were common, including Christmas fern (*Polystichum acrostichoides*), delicate thuidium moss (*Thuidium delicatulum*), and hypnum moss (*Hypnum imponens*). Another yellow birch cold cove forest occurs on the Gauley River near Iron Ring Rapids, but it is not known if any algific talus slopes occur in this area (Figure 86).

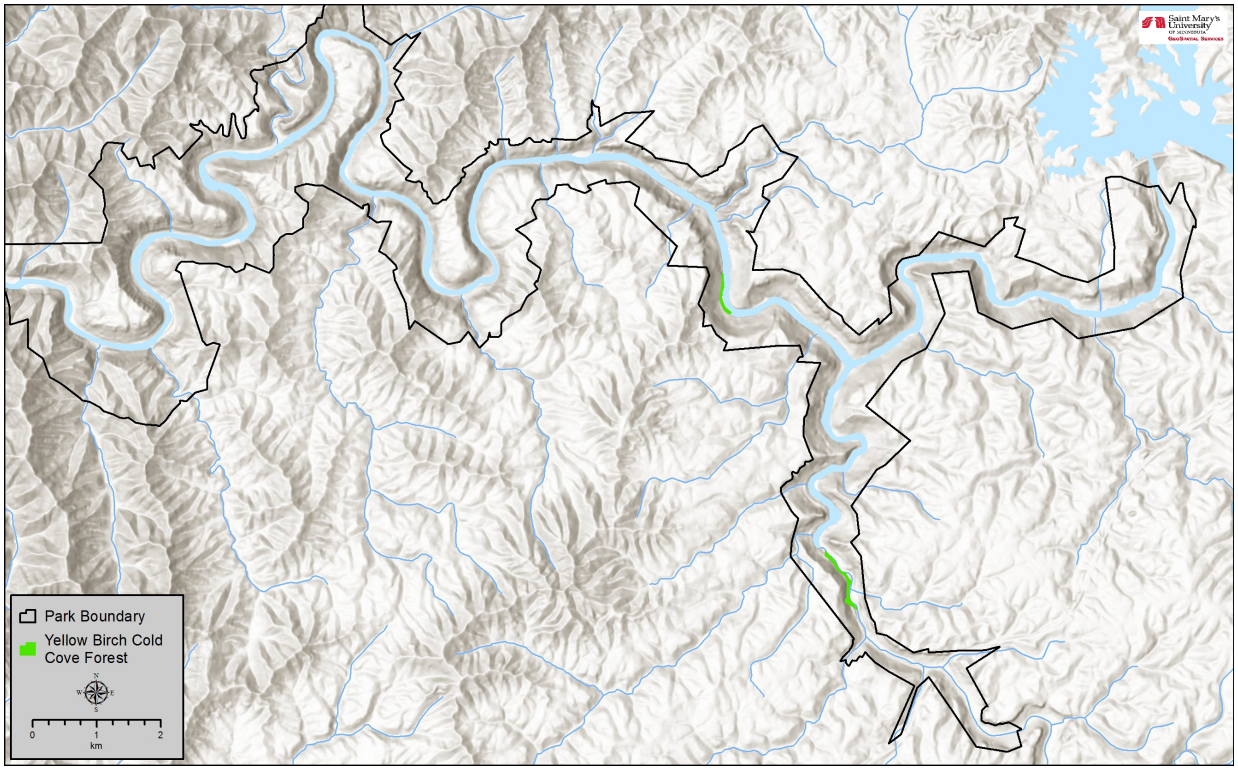


Figure 86. Yellow Birch Cold Cove Forest vegetation association locations within Gauley River National Recreation Area (Vanderhorst et al. 2010). The southern location on the Meadow River is where the known algific talus slope site occurs.



Photos of the algific talus slope site along the Meadow River within Gauley River National Recreation Area (photos provided by Dr. Steve Kite).

Mass Movements

Mass movement or mass wasting refers to any "gravity driven down-slope movement of earth materials" (NPS 2003). Mass movements are distinguished or described by the type of material involved, the speed with which it moves, and the mechanics involved in its motion. Geologic characteristics, climatic conditions, and human factors can all contribute to mass movement occurrences (NPS 2003, Wieczorek and Snyder 2009). Mass movements, also called "slope failures", from both natural and human-induced causes are a significant geologic issue at GARI (Figure 87) (Covington 2005). Although general information is available regarding the processes and factors involved in mass movements, no official documentation or studies of mass movements have occurred at the park.



Figure 87. A bank along the Meadow River within Gauley River National Recreation Area that experienced a mass movement (NPS photo).

The types of mass movement common to the geologic formations found at GARI include rock fall, rock topple, debris slide, debris flow, or complex (i.e., a combination of movement types) (Figure 88)

(Moore 1999). Rock fall and topple both involve large, detached rock masses, but rock topple involves an "overturning movement about a pivot point" while rock fall is generally "free fall with subsequent bouncing or rolling" (Moore 1999, p. 14). However, rock topples may subsequently transform into rock falls or slides. Debris flows and slides typically involve a mix of coarse material and fine-grained matrix. A slide is defined as "shear displacement of a detached mass that remains in constant sliding contact with the underlying, stable, slope materials" (Moore 1999, p. 14). Flows occur when debris mixes with a liquid component to form a slurry that then moves downslope.

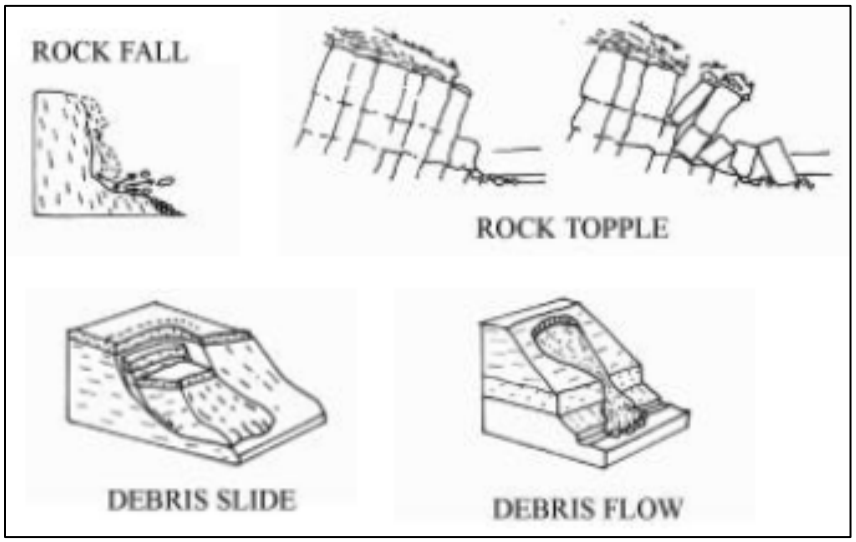


Figure 88. Generalized diagrams illustrating common types of mass movement in the Gauley River National Recreation Area region (Moore 1999, modified from Varnes 1978).

Geologic factors that influence the likelihood of mass wasting events, as well as their frequency and magnitude, include slope steepness and bedrock lithology (Moore 1999, NPS 2003). Lithology refers not only to the rock type but also to physical features such as fractures, joints, and bedding planes (e.g., where different rock layers meet). Fractures and joints may allow for water flow between rocks, increasing pressure or stresses that eventually weaken the slope or cliff (Moore 1999). Mass movements are often triggered by heavy precipitation or snowmelt (Wieczorek and Snyder 2009). While the Nuttall Sandstone at GARI is predominantly sandstone, it also contains some shale. When this shale becomes saturated, the water lubricates glide planes in the rock, which allows slippage and slope failure (Covington 2005). If there is sandstone overlying this shale, the sandstone will often collapse after the shale, sometimes generating large mass movements.

Threats and Stressor Factors

Threats to GARI's surficial geologic features include oil and gas exploration and development, recreation (particularly rock climbing), climate change, and extreme weather events (e.g., flooding). The impact of oil and gas exploration and developments on the surficial geologic features within the Appalachians is unknown at this time. However, it is possible that changes caused by drilling (e.g., vibrations, fractures) may influence the geologic stability of the surrounding region.

Since many mass movements are triggered by excess moisture, such as heavy precipitation events, climate change may impact GARI's surficial geologic features. According to Horton et al. (2014), the northeastern U.S. has already seen a 70% increase from 1958-2010 in the amount of precipitation falling in very heavy events. The frequency of heavy rain events is projected to increase even further over the remainder of this century (Horton et al. 2014). River flooding subsequent to heavy precipitation could undermine cliffs and river banks, contributing to slope failure and collapse.

Climate change may also cause shifts in the freeze-thaw cycles that influence geologic features. Alternating freeze and thaw events in temperate climates can weaken rocks and contribute to mass movements (NPS 2003). When moisture in rock fractures freezes, it expands and puts pressure on the rock, typically expanding those fractures. Repeated freezing and thawing can break apart even the strongest rocks (NPS 2003). The most recent available 30-year normal temperatures from the Summersville Lake weather station show winter (December-February) monthly mean temperatures around freezing (-1.0-0.8°C [30-33°F]) (NCEI 2015). At these temperatures, most ice would likely stay frozen throughout the season, especially in gorge areas with little sun exposure during winter months. If winter temperatures increase as predicted by climate change models, ice may thaw and re-freeze more frequently throughout the winter, potentially increasing stress on rocks.

Climate change is particularly a threat to algific talus slope communities. Temperatures are projected to increase across the eastern U.S. over the next century (Horton et al. 2014). As surrounding air temperatures warm, the cold-air producing capability of talus slopes and the cooler microclimate will be threatened (Coffey 2015). Any snow or ice that accumulates within the talus will be likely to melt earlier in the season. Shifts in precipitation and storm frequency and magnitude could also threaten site stability. The increased moisture from heavy rain could destabilize the talus or trigger additional mass movements that may fill in or bury the existing talus (Jakob and Lambert 2009, Coffey 2015). Storms with high winds could cause tree blowdowns, which may expose the moist talus slopes to additional warming sunlight (Coffey 2015).

Some cliffs in the park are used for recreational rock climbing (Vanderhorst et al. 2010). The potential impacts of climbing on the cliffs, boulders, and other geologic resources of GARI have not been investigated. However, Mahan (2016) suggested that climbing at nearby NERI may impact sensitive cliff vegetation (e.g., lichens, bryophytes) directly through their removal from climbing routes and indirectly through trampling or exposure to climbing chalk. These threats likely apply to GARI's cliffs as well. It is not clear if the types of climbing activity occurring at GARI could cause significant erosion or other physical changes to the actual rocks and cliffs.

Data Needs/Gaps

Little is known about the surficial geologic features of GARI. The park's cliff resources have never been explored or studied in detail from an ecological or a recreational perspective. An inventory and monitoring program for cliff resources has been initiated at nearby NERI to determine any effects that climbing and other recreational activities may be having on park resources (Mahan 2016). A cliff ecology monitoring manual for NERI is included in an Appendix to the Mahan (2016) report and could be adapted to gather information at GARI. Recommendations in the manual include the use of

referenced photo points to assess condition over time (Mahan 2016). A survey of cliffs for rare organisms, including non-vascular plants, lichens, and invertebrates, is also needed.

Scientific knowledge of algific slopes in general is primarily limited to site-specific biological inventories, primarily in the upper Midwest (Darmody and Hayek 2014). Only one algific talus slope has been located and described at GARI. Potential locations (e.g., north-facing talus slopes), such as the yellow birch cold cove forest on the Gauley River, could be searched for additional algific sites. The soils and geology of algific talus slopes, particularly in West Virginia, have not been studied.

No official documentation of mass movements at GARI has taken place. An inventory of areas where mass movements have occurred and identification of susceptible areas is needed (Covington 2005). This process could be initiated by comparing historic and current aerial photos to locate some areas where mass movements have occurred. Wieczorek and Snyder (2009) recommend including five elements in mass movement inventory and monitoring efforts: 1) determination of mass movement type; 2) monitoring of movement triggers and causes; 3) determination of geologic materials involved in movements; 4) measurement and assessment of mass movement; and 5) regional assessment of mass movement hazards and risks. In any assessment of hazards or susceptible areas, evaluating joint properties in rocks is an important factor. The steepness and direction of joints relative to the slope surface are key in determining what type of mass movement is most likely to occur (Wieczorek and Snyder 2009). For example, extremely steep joints may contribute to rock topple. Additional pertinent characteristics for evaluation include the opening size, smoothness, and filling of joints (Wieczorek and Snyder 2009).

4.12.5. Sources of Expertise

- Dr. Steve Kite, West Virginia University Associate Professor of Geology and Geography

5. Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1. Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 75 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 75. Identified data gaps or needs for the featured components in Gauley River National Recreation Area.

Component	Data Gaps/Needs
Upland Forest Communities	➢ Continuation and expansion of monitoring efforts aimed at monitoring vegetation communities in GARI. ➢ Additional research is needed into the current poor oak regeneration in the park and factors that may be contributing. ➢ More information is needed regarding the area's soil biota and the role they play in ecological processes that influence the health of GARI's upland forests.
Riparian Vegetation Communities	➢ Continuation of the ERMN vegetation monitoring program and expansion to monitor forested riparian areas is needed. ➢ Additional surveys are needed to document the numbers, locations, and status of rare plants in GARI's riparian areas.
Birds	➢ Continuation of the annual NPS PCS efforts and the ERMN streamside bird monitoring is recommended. ➢ Expansion of existing survey efforts to sample unique habitats and species groups (e.g., cliff habitats, raptors) is needed. ➢ Summarization of the Wood et al. (2009) monitoring plots through the 2017 field season is needed in order to provide long-term, continuous datasets for managers. ➢ No surveys for overwintering species currently are in place.
Mammals	➢ An updated inventory of mammalian species in GARI is needed. ➢ Additional research is needed on the park's bat population, particularly investigating the impacts of WNS and the presence of rare or sensitive species.

Table 75 (continued). Identified data gaps or needs for the featured components in Gauley River National Recreation Area.

Component	Data Gaps/Needs
Herpetofauna	➢ Information regarding the park's herpetofauna is limited to a single, 15-year old study. Regular sampling intervals within the park is needed. ➢ Investigation into the prevalence of disease (e.g, chytrid fungus, ranavirus) in the park would allow managers to better understand the current health of herpetofauna species in GARI.
Aquatic Wildlife Community	➢ Re-sampling of the locations surveyed by Welsh et al. (2004) would help to identify any trends within the fish community. ➢ Little is known about the diversity of aquatic macroinvertebrates within park boundaries. An inventory of BMI species would help better understand park biodiversity and stream health.
Water Quality	➢ More frequent and consistent water quality monitoring would provide further insight into current conditions and any changes that may occur over time. ➢ Additional automated water quality monitoring equipment, although expensive, would allow for continuous data collection in the future.
Air Quality	➢ On-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury) and visibility, as budget and personnel limitations allow ➢ Studies of mercury concentrations in park waters and wildlife (e.g., fish, birds, bats) to identify any impacts this contaminant may be having on the park
Dark Night Skies	➢ The NPS NSNSD has not visited GARI. A visit is needed to provide accurate, on-the-ground data. Currently, the only data that exist for GARI are the result of GIS modeling.
Surficial Geologic Features	➢ Little is known about the surficial geologic features of GARI and an inventory and monitoring effort is needed for the park to determine any effects that rock climbing or recreational activities may be having on park resources. ➢ A survey of cliffs for rare organisms, including non-vascular plants, lichens, and invertebrates is needed. ➢ Scientific knowledge of algific slopes is limited to site-specific inventories in the upper Midwest. ➢ The soils and geology of algific talus slopes in West Virginia have not been studied. ➢ No official documentation of mass movement events in GARI have taken place. An inventory of areas where mass movements have occurred and identification of susceptible areas is needed.

Several of the park's data needs involve the continuation or expansion of monitoring programs to accumulate enough data for identification of trends over time (e.g., upland forest communities, riparian vegetation communities, birds). However, many of the identified data gaps for GARI center on the need for the establishment of an annual (or at least standardized) monitoring or inventory effort (e.g., mammals, herpetofauna, air quality, dark night skies). Many of the existing data sets for these resources are outdated, while components such as dark night skies and air quality do not have data specific to GARI; the data used in those assessments relied on either regional projections and trends or the best professional judgement of experts. Many components in the park are in need of

expanded data sets in order to have an accurate assessment of current condition that is based more on data and less on professional judgement.

5.2. Component Condition Designations

Table 76 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Table 77 and Table 78). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 76) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

For featured components with available data and fewer data gaps, assigned conditions varied. Two components were considered to be in good condition: upland forest communities and birds. Of those two components, however, only the birds component had enough data to assess a stable trend with high confidence. Three components (riparian vegetation communities, water quality, dark night skies) were of moderate concern; riparian vegetation communities and dark night skies lacked sufficient data to assign a current trend, while water quality had enough recent data to confidently assign a stable trend. Only the air quality component was determined to be of significant concern. The current trend of air quality in GARI was determined to be improving (a designation assigned with moderate confidence). Condition could not be determined for three components: mammals, herpetofauna, and aquatic wildlife communities. The surficial geologic features component was not treated as a condition assessment, and rather focused on describing the resource and highlighting its importance in the GARI area.

Table 76. Summary of current condition and condition trend for featured Natural Resource Condition Assessment components.

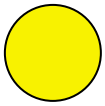
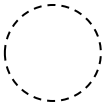
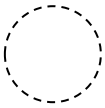
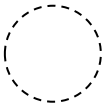
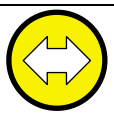
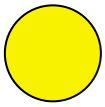
Component	WCS	Condition
Upland Forest Communities	0.33	
Riparian Vegetation Communities	0.53	
Birds	0.13	
Mammals	N/A	

Table 76 (continued). Summary of current condition and condition trend for featured Natural Resource Condition Assessment components.

Component	WCS	Condition
Herpetofauna	N/A	
Aquatic Wildlife Community	N/A	
Water Quality	0.35	
Air Quality	0.87	
Dark Night Skies	0.67	
Surface Water Hydrology	Not assigned[A]	Not assigned[A]

[A] The Surficial Geologic Features component was treated atypically and not assigned a condition, it was rather summarized and highlighted in text.

Table 77. Description of symbology used for individual component assessments.

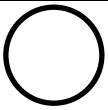
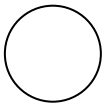
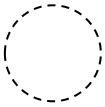
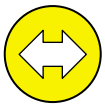
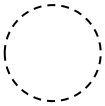
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 78. Example indicator symbols and descriptions of how to interpret them.

Symbol Example	Verbal Description
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment (explanation is required if a trend symbol or a medium/high confidence band is shown).

5.3. Park-wide Condition Observations

Despite the variety of habitats at GARI, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park, critical communities). The park protects over 40 km (25 mi) of the free-flowing Gauley River, nearly 10 km (6 mi) of the Meadow River, and large tracts of undeveloped and continuous forests on streamside habitats. The threats/stressors, data needs, and priority habitats of GARI are critical to park managers in order to fully understand the many ecosystems present in the park.

5.3.1. Vegetation Communities

The condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Perles et al. 2010). The native vegetation communities of GARI are vital resources for the park, providing habitat for wildlife and performing critical ecological functions. The vast majority of the park (over 86%) is covered in upland forests and woodlands that are dominated by eastern hemlock, maples, oaks, tuliptrees, and other hardwood species (Vanderhorst et al. 2010). These forests can be divided into 12 unique community types which provide habitats for the over 400 taxa that have been documented in GARI (Appendix B).

The park's riparian communities support high plant diversity and are primarily wooded, with species such as eastern hemlock and American sycamore, but also include some open areas with herbaceous vegetation, particularly where flooding disturbance is frequent. In addition to common and widespread riparian specices, a number of rare species, including the federally-threatened Virginia spiraea and the globally-rare Monongahela Barbara's button, are found in the park (Vanderhorst et al. 2010).

The current condition of the park's vegetation communities varied. The upland forests in the park were determined to be in good condition, although data relating to reference condition and pertaining to several metrics (rare plant EOs, tree mortality, and recruitment) were lacking. These data gaps somewhat reduced the overall confidence in the condition designation, and prevented the designation of a current trend. The upland areas in GARI cover the majority of the park's total area, and there is no indication that this extent is declining. The species richness estimates for GARI indicate that the upland forests are home to a diversity of species, although there is some concern that the number of invasive exotic species in the park may be slowly increasing. That being said, the proportion of total cover of exotic/invasive species in GARI was much lower than all nearby ERMN parks. While unable to be assigned a current *Condition Level*, the recruitment and tree mortality measures for upland forest communities both indicated some concern for the brief period where data were available (2011-2014). From 2011-2014, the mean annual tree mortality rate in GARI upland forest monitoring plots was 1.8% (Perles et al. 2016), which was slightly higher than reported rates for other eastern forests, which ranged from 0.3-1.6%/year (Perles et al. 2016). However, some of the observed mortality during this period may have been due to several severe storms that struck the area in 2012. Tree recruitment for GARI between 2011 and 2014 was 1.2%/year, with several species showing no recruitment at all (e.g., scarlet, white, black, and chestnut oak) (Perles et al. 2016).

Riparian communities in GARI were identified as a resource of moderate concern. Similar to the upland forest communities component, there were no available data in regards to reference conditions and rare plant EOs, and because of this no trend was assigned to the community. Over 470 plant species have been documented in GARI's riparian communities, which is nearly as many species as have been documented in upland forest communities, which cover over 200 times more area. There is no current evidence that the extent of the riparian areas is declining in GARI; however, these areas are especially vulnerable to natural and anthropogenic changes and must be monitored in the future. The river shrub prairies of the park are critically important areas that comprise just a small portion of the total landscape (16.1 ha [39.8 ac]). Fifty different river shrub prairies have been documented in the park, but these areas lack historical data which prevents comparisons and trend identification. Because these critical and rare areas are so small and isolated, they have an increased vulnerability to habitat loss and elimination.

Exotic and invasive plants continue to be a problem in GARI, and exotic species plant cover in the riparian communities has ranged from 0-10.8% (Vanderhorst et al. 2010). Invasive plant cover has been documented as high as 9.8% in some areas. During ERMN (2017) monitoring of river shrub prairies in the park, exotic species cover ranged from 0-8.2%, and averaged 2.6% across all sites. Additionally, woody plant species continue to encroach upon the park's rare endemic river shrub prairies. Perles (2016) found that woody plant cover was generally lower in GARI river shrub prairies when compared to nearby NERI sites, but cover at all GARI sites exceeded 10%. Coverage at seven of the 10 sites monitored by Perles (2016) exceeded 20%, with a maximum of 38.2%.

5.3.2. Wildlife

Animals featured as NRCA components included birds, mammals, amphibians and reptiles (under the herpetofauna component), and the broad group of organisms that inhabit the aquatic areas of

GARI (under the aquatic wildlife community component). The birds component was determined to be in good condition. The number of species and individuals associated with intact forests remained high throughout the period of record, indicating that the critical forest community remains healthy and is supporting many birds. Confidence in this assessment is high, and the current trend for this resource appears to be stable at present. GARI is home to large expanses of continuous, dense forests, free from fragmentation that is exhibited elsewhere in the Appalachian Mountains. These stretches of forest provide vital habitats for forest interior species such as the red-eyed vireo and hooded warblers, both of which were among the most frequently detected species in the park during annual monitoring. The species richness estimates of forest dwelling bird species remained high throughout the duration of all surveys in GARI, indicating that the forest community in GARI is in good condition. In fact, the most common and frequently detected species during the NPS PCS efforts were nearly universally forest-dwelling species. Overall, BCI scores in GARI were high from 2007-2012, with average values falling into either the "highest" or "high" ecological integrity categories for all sites. The BCI values for GARI were among some of the highest values obtained ERMN-wide by Marshall et al. (2013), indicating very high ecological integrity at GARI.

The dense forests, cliffs, and riparian areas of GARI provide critical habitat for the mammal species in the park. However, contemporary data are absent for half of the selected measures of mammal health (bat species richness, Allegheny woodrat presence/absence) and a current condition could not be assigned. The mammals of GARI include two bat species that are federally listed as either threatened (northern myotis) or endangered (Indiana bat), and several species of state conservation concern. The overall species richness values observed in GARI were about what was expected given the location of the park. Forty-three mammal species have been confirmed as present at GARI, along with one unconfirmed bat species. The number of mammals confirmed in GARI represents 65% of all mammal species known to occur in the state of West Virginia, and only three of the confirmed species are considered non-native. Additional research is needed in GARI in order to more accurately assess the current condition of the bat community, as the most recent bat survey is over 10 years old and WNS is known to have impacted bat species in other areas of the state. Another area in need of expanded research is the park's Allegheny woodrat population; this species of concern has not been trapped/surveyed in GARI since 2014.

The remaining two wildlife components, herpetofauna and aquatic wildlife communities, were not assigned a current condition due to data gaps. The forests and aquatic habitats of GARI support many species of herpetofauna, as was confirmed during intensive surveys in the park from 1999-2004. However, no systematic surveys have occurred since to determine if herpetofauna species richness has changed over time. Reptiles and amphibians are often understudied in protected areas, despite recently becoming a focal topic as protecting biodiversity has become a critical goal in NPS units (Scott and Seigel 1992). This trend has largely remained true in GARI, as the only inventory of herpetofauna in the park occurred over 15 years ago.

The aquatic wildlife community component was created to assess the other wildlife groups that utilize the park's rivers and streams (e.g., fish and aquatic macroinvertebrates). These species were not represented in other components, and park managers felt their inclusion was critical as fish and

aquatic macroinvertebrates are excellent bioindicators of stream and river health (Marshall et al. 2006, Faulk 2015, Tzilkowski et al. 2015). Unfortunately, contemporary data relating to many wildlife communities in GARI are lacking and a current condition or trend could not be assigned. GARI has relatively low native fish species richness values (Welsh et al. 2004), although low numbers of species alone are not necessarily indicative of poor condition. Rather, changes in species richness may indicate a cause for concern or need for further investigation. Overall species richness in GARI waters remained similar over the Welsh et al. (2004) study period, but species composition shifted somewhat. According to Welsh et al. (2004), nine fish species that had been present historically (1965-1980) were not found in 2003, and five species not previously observed were documented in 2003. Similarly, the percent of native fish species at GARI appears to have declined over time. According to historic records, 88% of species documented were native, while 79% of species observed in 2003 were native (Welsh et al. 2004). No more recent information is available to determine whether these trends have continued or shifted.

Information regarding aquatic macroinvertebrate species richness within GARI streams was somewhat limited, and a comprehensive macroinvertebrate survey has not been conducted. The only data currently available were from ERMN BMI sampling which showed no clear trends in total or EPT taxa richness. Two tributaries of the Gauley River (Meadow and Laurel Creeks) were sampled consistently from 2009-2012, while two additional tributaries (Horseshoe and Peters Creeks) were sampled three times during those years. Laurel Creek, at the western (downstream) end of GARI, showed the lowest average BMI taxa richness. The lowest average EPT taxa richness was from Peters Creek, a watershed with historic and current coal mining activity. Horseshoe Creek exhibited the highest average taxa richness and the highest average EPT taxa richness (NPS unpublished data). The average MIBI scores for two of the reaches sampled within GARI fell in the fair condition range (Laurel and Peters Creeks) and two reaches fell in the good condition range (Horseshoe and Meadow Creeks) (Tzilkowski et al. 2015).

5.3.3. Environmental Quality

Environmental quality is important in maintaining healthy, functioning ecosystems. The health of terrestrial and aquatic organisms can be substantially affected by the condition of air and water quality. The water quality of the many streams and rivers in GARI was determined to be of moderate concern. The confidence in the assessment of current condition was high, as sampling efforts have occurred on an annual basis since the 1990s and provide baselines for comparison. Conditions of the individual metrics in the water quality component were split between being of no concern (temperature, pH, DO), and being of moderate concern (specific conductance, turbidity, fecal coliform bacteria). Although water temperatures, pH, and DO were well within state standards and currently of no concern, the remaining measures have shown levels of concern during recent park monitoring (2012-2016). SpC and turbidity observations on both Peters Creek and the Meadow River have exceeded informal reference conditions on occasion, and sporadic elevated fecal coliform bacteria levels on these water bodies may pose a threat to human health. As there is no clear or consistent decline or improvement in the selected measures, a stable/unchanging trend was assigned.

Air quality was determined to be of significant concern in GARI, largely due to high levels of nitrogen and sulfur deposition, as well as poor visibility in the area. Although the most recent 5-year sulfur deposition estimate for GARI fell within the Moderate Concern range, the NPS ARD elevated the rating to Significant Concern, due to very high ecosystem sensitivity. Nitrogen deposition in GARI fell into the NPS ARD's Significant Concern range. While GARI is considered to be at very low risk of nutrient enrichment from nitrogen deposition, it is at high risk of acidification from acidic (nitrogen and sulfur) deposition, partially due to very high levels of ecosystem sensitivity (Sullivan et al. 2011a, 2011c). Similarly, the most recent estimated visibility average for mid-range days for GARI fell in the NPS ARD's Significant Concern range.

Despite not having any on-the-ground dark night skies data from within GARI's boundaries, NPS managers felt strongly about including dark night skies as a priority resource for this NRCA. The NPS NSNSD was able to use modeled ALR data for GARI and the surrounding regions to estimate the current night sky conditions. Using that modeled data, it was determined that the night skies around GARI are currently of moderate concern. However, GARI lies on the edge of perhaps the darkest areas in the entire region (Figure 76). While current night sky conditions in the park are by no means ideal, when compared to the overall night sky conditions in the region, the GARI night skies appear to be in a much better state. No current trend could be identified for this component, as all the data available were the result of modeling and not on-the-ground surveys. A visit to the park by the NPS NSNSD is needed to accurately measure the current condition of night skies in the park, and to elevate the confidence in condition designation (currently condition designation is of medium confidence).

5.3.4. Park-wide Threats and Stressors

The various priority natural resources highlighted in this NRCA are all subject to their own unique threats and stressors. However, several universal threats and stressors stood out in multiple components in this document. These common park-wide threats and stressors (climate change, exotic species, recreational use, and water quality degradation) are discussed below and emphasize how, despite each community being unique, they are all linked in many ways.

Climate Change

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). As a result of global climate change, temperatures are projected to increase across the eastern United States over the next century (Horton et al. 2014). Additionally, warming temperatures will likely alter the habitat suitability of certain areas for some plant species (Fisichelli et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014).

Climate change may alter the frequency and intensity of extreme weather events that already threaten GARI's forests, such as tornadoes/wind storms, ice storms, and droughts (Dale et al. 2001, Rentch 2006). Evidence suggests that the storm conditions contributing to tornado formation have increased with warming temperatures and will continue to do so under projected future climate changes (Dale et al. 2001). Higher temperatures also increase evaporation and transpiration (by plants), causing less

water to be available for plants and increasing moisture stress (Dale et al. 2001), particularly for species adapted to wet environments.

Wildlife communities are likely to be impacted by climate change in a variety of ways. As global temperatures change, some bird species in the U.S. have adapted by moving their home ranges north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring. These shifts could result in migratory periods becoming out of sync with food availability, which may result in lower fitness and reproductive success for the species. Mammalian species are likely to be impacted by climate change by experiencing heat and/or water stress, altered habitats, reduced food availability, and altered seasonal cues that some mammals need to trigger certain behaviors (e.g., reproduction, hibernation). GARI is home to several mammalian species that are particularly vulnerable to climate change-related impacts, such as the Allegheny woodrat, northern myotis, and the Indiana bat, which are species of concern in West Virginia.

With many of GARI's herpetofauna species dependent on aquatic habitat at some stage in their life cycles, drought is a major threat to these populations. Climate change has been implicated in widespread drought events, which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and occasional flooding that damage riparian areas and other important aquatic habitats, as well as degrading water quality (Bates et al. 2008). Riparian flooding during the summer may destroy vegetative cover utilized by young herpetofauna and could wash away larval amphibians and/or turtle nests (Purvis 2002). An overall increase in global temperatures associated with climate change, which contributes to extended periods of drought, will have a combined effect on biota by causing temperature and water stress (Bates et al. 2008). In West Virginia, amphibians have been identified as one of the taxonomic groups most vulnerable to climate change (Byers and Norris 2011), with some species already being negatively impacted within the state (Pauley 2006).

Climate affects the spread of invasive plant species and pathogens as well, which also threaten communities in GARI (Fisichelli et al. 2014). The warmer temperatures associated with climate change are likely to increase the survival, reproduction, and dispersal/distribution of some forest pests and pathogens (Dale et al. 2001). An increase in drought frequency and/or intensity as a result of climate change would likely make forests more vulnerable to these pests and pathogens (Dale et al. 2001).

Exotic Species

Exotic invasive plants are among the greatest threats to forests worldwide, including those in GARI. Of particular concern is the ability of these plants to outcompete native plants and disrupt ecosystem processes, such as nutrient cycling and disturbance regimes (Mooney et al. 2005, Perles et al. 2014b). Invasive cover averages 3.2% across GARI's upland forest (ERMN 2017), although invasive cover has exceeded 30% in one of the park's successional forest types (Vanderhorst et al. 2010). In 2016, exotic species comprised between 0% and 8.2% (mean 2.6%) of the total plant cover at surveyed GARI river shrub prairie sites. The Gauley River and the extensive recreational use of the floodplain

and shorelines during the rafting season may serve as pathways for the invasion and spread of these exotic species (Richardson et al. 2007, Perles et al. 2014b).

Exotic insect, fungal, and bacterial pests pose a serious threat to many communities in GARI. Plant pests are capable of altering entire vegetation communities by changing the species composition and structure of large areas; they can also be responsible for reductions in overall species diversity (Keefer 2009). The HWA has resulted in hemlock stands with declining crown vigor and increasing tree mortality in GARI. While the insect infestation is being treated in the park, it remains an intensive (labor and cost) process and is only a temporary solution. Another plant pest, the EAB, attacks only ash trees and is always fatal for the affected trees. The EAB has the potential to dramatically impact several globally rare vegetation and riparian areas in GARI; the pest has resulted in heavy mortality of white and green ash trees in the park since it was first detected in 2007. Oak trees are the primary host species of the gypsy moth, an insect pest that has been present in low numbers in GARI since the early 1990s (Weese 1992). While gypsy moths have not been responsible for major instances of defoliation or mortality in GARI, the species defoliated approximately 40,450 ha (100,000 ac) of forests across West Virgina in 2015 (USFS and WVDA 2016).

Exotic pathogens are also threatening many communities and species in GARI. The butternut canker is a fungal disease that has been decimating butternut trees throught the U.S. The effects of this disease have been so severe that the butternut has been extirpated from several areas in the south and has been listed as a species of federal concern by the USFWS (Schlarbaum et al. 1998). Butternut canker is not the only fungal pathogen affecting communities in West Virginia, as WNS has been decimating bat populations across the U.S. In West Virginia, WNS was first detected in Pendleton County in 2009 (WVDNR 2015). By 2012, the disease had spread across the karst regions of the state, affecting multiple bat species. Based on 2015 data, little brown bats experienced a 97% population decline and Indiana bats an 85% decline (WVDNR 2015). It is not known if WNS has impacted bat populations in the GARI area, but it is highly likely, given the large declines in neighboring counties (Paul, written communication, May 2018).

Recreational use of GARI and the surrounding area has contributed greatly to the presence of exotic species in the aquatic communities of the park. Exotic game fish such as bass and trout species have been intentionally introduced to improve angling and recreational opportunities; the WVDNR has been stocking trout at the Summersville Dam tailwaters for many years. Non-native species have also been introduced through bait-bucket releases (Cincotta and Chambers 1999). Although it has not been documented, it is likely that these non-native fish are having a negative impact on native species and may even out-compete some of the local endemics (Messinger and Chambers 2001, Purvis 2002). Bait-bucket releases are not only responsible for fish introductions but are also thought to be the source for non-native crayfish in the New River system (Purvis 2002, Swecker 2012). Boating traffic has contributed to the overall number of exotic species, as boats that were not cleaned properly when moved between bodies of water have transported exotic species such as mussels, aquatic vegetation, and other invertebrates. These exotic species change the structure of the aquatic communities of GARI, and may outcompete or prey upon native species.

Recreational Use

Recreational use of the Gauley River and the surrounding areas of the park often disrupts and disturbs various ecological communities. Examples of these recreational activities include ORV use, rock climbing, camping/river access along the Gauley River, rafting and boating, and fishing. While illegal in the park, ORV use does occur within the park's boundaries. Damage from extensive ORV use has been observed within GARI's forests. This is of concern due to the fact that ORVs cause soil compaction on trails, significantly more so than hiking or horseback riding (Sack and da Luz 2003). Soil compaction reduces water infiltration and increases surface runoff on the trails. ORV trails also show significant sediment flux (i.e., shifting of soils), as the tires disturb and kick up sediment that settles on the land adjacent to the trail (Sack and da Luz 2003). Such disturbances negatively impact surrounding vegetation and can contribute to dramatic soil erosion. These disturbed areas and the ORV traffic provide opportunities for the dispersal and establishment of invasive plant species (Perles et al. 2014b). Further, frequent ORV use can cause disturbances that change the behavior of wildlife (e.g., mammals, birds) which may result in increases in energy expenditure or abandonment of priority habitats (Knight and Cole 1995).

Rock climbing in central West Virginia has become a very popular recreational activity, and the park attracts climbers of all skill levels. Rock climbing remains a legal activity in GARI, and several maintained climbing areas have been established within the park. However, studies of rock climbing in a variety of locations have found impacts to the surrounding environment, including damage to mature trees (from climbing equipment), decreases in shrub and herbaceous cover, and increased soil erosion and compaction (Sutter et al. 1994, McMillan and Larson 2002, Wood 2006). Additionally, quiet, non-consumptive human recreational activities such as rock climbing have been shown to negatively impact mammalian carnivore species (Reed and Merenlender 2008). Rock climbing in non-designated areas carries the potential to harm species associated with rock and cliff habitats, such as nesting avian species and the Allegheny woodrat.

Rafting and boating on the Gauley River are major recreational activities, especially during the rafting season each fall. The most suitable access and camping sites for river rafting excursions are often in some of the park's rarest vegetation communities (e.g., river shrub prairies, riparian forests), and are home to several rare species of plants and animals. In a study on the nearby New River, Cole and Marion (1988) found that the disturbance caused by outfitter-led rafting parties was much greater than that caused by smaller fishing parties. Outfitter sites were larger overall than fishing party camp sites, with nearly four times the devegetated area and three times the disturbed shoreline length (Cole and Marion 1988). Bennett and McDonald (2006) observed varying degrees of disturbance at several riverbank campsites and river access points within the park, primarily to the herbaceous vegetation layer, during their 2006 riparian zone evaluation.

Activities related to fishing can affect GARI's natural resources in many ways. In addition to the threat posed by the annual stocking of non-native gamefish (as discussed previously), some salamanders, such as the black-bellied salamander, are collected for use as bait (Purvis 2002). Many amphibian species face competition or predation from non-native bait species (e.g., fish, crayfish) that are released, accidentally or intentionally, into aquatic habitats by visiting anglers. When bait

species are introduced to smaller water bodies where they previously were not present, amphibians and their eggs are often exposed to a novel predation source that they are not adapted to (Kats and Ferrer 2003, WVDNR 2015). Introduced bait species that are not predators may still compete with native herpetofauna for habitat and food resources and may spread pathogens (WVDNR 2015). Fishing activities can also be responsible for the introduction of non-native plant and invertebrate species, especially when anglers fail to clean baits/lines or do not clean their boat when they move between water bodies.

Degradation to GARI's Water Quality

Degradation of GARI's water quality is due to a variety of sources and impacts the majority of the natural resources in the park. Surrounding land use of protected areas where the majority of the watershed lies outside park boundaries, especially in areas like GARI, can have a significant impact on the surface water quality (Marshall and Piekielek 2007a). Agricultural land uses surrounding the park can contribute pollutants (e.g., chemicals, nutrients), bacteria, and excess sediment to streams (Purvis 2002). Active logging near and within park boundaries, as well as the associated logging roads, increases soil exposure and erosion, which in turn increases the sedimentation of streams in GARI (Hebner 1991, Purvis 2002). Additionally, the increase in residential and recreational development in the GARI area has resulted in an increase in impervious surface area (e.g., roads, parking lots) and a reduction in precipitation infiltration; this can increase runoff and contribute sediment to surface waters. De-icing solutions (e.g., salts) used on roads associated with developments may pollute park waters as well, particularly with chloride (Webber 2012).

There area still many active coal mines in the watersheds that flow into GARI, primarily in the Peters Creek watershed just north of the park. Similar to logging and residential developments in the area, mining activity contributes sediment to stream ecosystems. In addition to increased sedimentation, mining also increases certain mineral concentrations (e.g., sulfate, calcium, magnesium) and overall SpC, effects which can linger for decades even after mining ceases (Bernhardt et al. 2012). Coal is typically transported by rail, and a set of railroad tracks used for transporting coal runs parallel to a portion of the Gauley River downstream of Peters Creek. Coal may give off "fugitive dust" during transport if not covered properly (Lazo and McClain 1996), which could run off into nearby surface waters during precipitation events.

There are currently four active gas wells and four unmaintained wells within GARI boundaries, an additional 25 active wells within 1 km (0.6 mi) of park boundaries, and 11 abandoned wells nearby (WVDEP 2016b). The closest waste injection well to the park is just over 16 km (10 mi) to the northwest. During drilling and extraction, there is a risk that drilling fluids, gas, or waste fluids may spill or leak, potentially contaminating nearby waters (Purvis 2002, NPS 2009). Trucks, pipelines, and pumping stations required for the transportation of gas and waste products may spill or leak as well. Given that the park lies on the southeastern edge of the Marcellus Shale, a major gas-bearing rock formation, there is a potential for new gas exploration and development near the park, which could further threaten GARI's water quality in the park (NPS 2009).

The release of water from the Summersville Lake Reservoir through the Summersville Dam may also be impacting water quality in the park. Water released from the dam comes from the bottom of the

lake and is typically colder than water in the rest of the Gauley River and its tributaries (WVDNR 2015). Coldwater releases from reservoirs have been shown to alter downstream thermal regimes of rivers (Troxler and Thackston 1977, as cited by Caissie 2006). Shifts in thermal regime of a water body, specifically related to coldwater releases from the Summersville Dam, are likely to influence various aquatic organisms. Thermal regime influences the distribution and growth rates of aquatic organisms, as well as the overall health of aquatic ecosystems (Robinson and Childs 2001, Caissie 2006). Water temperatures are also important in the timing of fish reproduction and movements (Albanese et al. 2004, Caissie 2006).Also, Summersville Lake is a popular destination for recreational boating and fishing. The bilge and other waste products from these boats may contaminate the lake's waters (Milliken and Lee 1990).

As discussed previously, climate change is predicted to alter the frequency and intensity of extreme weather events such as droughts (Dale et al. 2001, Rentch 2006). Droughts reduce habitat availability; smaller streams may shrink to isolated pools or dry up completely, stranding any fish and aquatic invertebrates living there (Messinger and Chambers 2001, Boulton and Lake 2008). As water levels drop and pools become isolated, water quality often declines (e.g., higher water temperatures, lower dissolved oxygen, pH (Boulton and Lake 2008). Previous research in West Virginia streams found that BMI density declined significantly during droughts (Kaller 2001). This decline could impact other wildlife that rely on BMI as a food source, such as wading birds, waterfowl, and fish.

A major water quality-related concern in the GARI area, specifically the Meadow River and Peters Creek regions, is fecal coliform bacteria. These two regions were included on the 303d impaired waters listing due to high levels of fecal coliform bacteria. While some bacteria may originate from livestock and wildlife, it is likely that the primary contributor is inadequately treated sewage (i.e., human waste) (Purvis and Wilson 2007). Many communities and households in the region around the park lack adequate septic or sewage systems for the proper treatment of human and other domestic wastes (Purvis 2002, 2009). This is largely due to the longstanding poverty in the area and the high cost of building sewer lines in rocky, densely forested terrain (Purvis 2002).

Degradation of the park's water quality has a multitude of effects on the ecological communities in GARI. Elevated mineral concentrations and conductivities can negatively impact aquatic wildlife communities. Chambers and Messinger (2001) found that BMI communities in streams with recent mining activity showed impairment, and impairment increased as mining intensity increased. EPT taxa richness, in particular, decreased with increases in specific conductance and decreases in median streambed-particle size, an indicator of excess sedimentation (Chambers and Messinger 2001).

Water quality impairment due to human activities often impacts aquatic herpetofauna. These impairments include contaminants (e.g., pesticides, mining waste, endocrine disrupting chemicals) and siltation/sedimentation (WVDNR 2015). Contaminants have been shown to significantly affect herpetofauna development, growth, reproduction, and immune system functions (Gibbons et al. 2000, Hayes et al. 2006). Pesticides and other chemicals may be ingested by herpetofauna if their prey species are contaminated (e.g., insects, other invertebrates) and can be absorbed directly through the skin of some amphibians (Smith et al. 2007, WVDNR 2015).

5.3.5. Overall Conclusions

GARI is a diverse park with a variety of rare and unique resources, from dense stands of continuous upland forest to the raging rapids of the Gauley River. Continued monitoring of the park's priority resources, combined with management efforts directed at minimizing disturbance potential, will aid many of these natural communities and ensure their continued presence in the park. Additional monitoring in regards to the many shared threats and stressors in the area, particularly climate change and water quality, will strengthen park managers' overall understanding of the interrelated nature of the ecosystems and communities within the park. GARI possesses tremendous opportunity for scientific study, and continuing advancements in the scientific understanding of GARI's resources will not only benefit the park, but also other locales in the Appalachian Mountains with shared resources.

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Appendix A. Exotic invasive plant species documented within Gauley River National Recreation Area

Table A-1. Exotic invasive plant species documented within Gauley River National Recreation Area (NPS 2016) with West Virginia invasiveness ranks (WV NHP 2009).

Scientific Name	Common Name	Invasiveness Rank
Agrostis capillaris	colonial bentgrass	3
Agrostis gigantea	redtop, water bentgrass	3
Ailanthus altissima	tree of heaven	1
Albizia julibrissin	silktree	3
Alliaria petiolata	garlic mustard	1
Anthoxanthum odoratum ssp. *odoratum*	sweet vernalgrass	3
Artemisia vulgaris var. *vulgaris*	common wormwood	3
Barbarea vulgaris	garden yellowrocket	2
Cerastium fontanum ssp. *vulgare*	big chickweed	3
Cerastium glomeratum	sticky chickweed	3
Commelina communis	Asiatic dayflower	3
Securigera (Coronilla) varia	purple crownvetch	1
Dactylis glomerata ssp. *glomerata*	orchardgrass	3
Daucus carota	Queen Anne's lace	2
Dianthus armeria	Deptford pink	3
Duchesnea indica	Indian strawberry	2
Elaeagnus umbellata var. *parvifolia*	autumn olive	1
Glechoma hederacea	ground ivy	2
Hemerocallis fulva	orange daylily	3
Hieracium caespitosum	meadow hawkweed	2
Holcus lanatus	common velvetgrass	2
Hypericum perforatum	common St Johnswort	2
Iris pseudacorus	paleyellow iris	1
Kummerowia stipulacea	Korean clover	3
Kummerowia striata	Japanese clover	3
Lactuca saligna	willowleaf lettuce	3
Lamium purpureum var. *purpureum*	purple deadnettle	3
Lapsana communis	common nipplewort	3
Lespedeza cuneata	sericea lespedeza	1
Leucanthemum vulgare	oxeye daisy	2

Scientific Name	Common Name	Invasiveness Rank
Schedonorus pratensis	meadow fescue	1
Lonicera japonica	Japanese honeysuckle	1
Lonicera morrowii	Morrow's honeysuckle	1
Lonicera tatarica	Tatarian honeysuckle	1
Lysimachia nummularia	creeping jenny	2
Microstegium vimineum	Japanese stiltgrass	1
Paulownia tomentosa	princess tree	2
Phleum pratense	timothy	3
Poa compressa	Canada bluegrass	2
Poa pratensis ssp. *pratensis*	Kentucky bluegrass	2
Polygonum aviculare	prostrate knotweed	3
Persicaria longiseta	oriental ladysthumb	2
Polygonum convolvulus var. *convolvulus (Fallopia convolvulus)*	black bindweed	3
Polygonum cuspidatum (Fallopia japonica var. *japonica)*	Japanese knotweed	1
Polygonum persicaria (Persicaria maculosa)	spotted ladysthumb	3
Prunella vulgaris	common selfheal	3
Rosa multiflora	multiflora rose	1
Rubus phoenicolasius	wine raspberry	1
Rumex crispus	curly dock	3
Salix alba	white willow	3
Stellaria media	common chickweed	2
Stellaria pallida	common chickweed	2
Trifolium campestre	field clover	3
Trifolium pratense	red clover	3
Tussilago farfara	coltsfoot	3
Verbascum thapsus	common mullein	2
Veronica arvensis	corn speedwell	3
Veronica chamaedrys	germander speedwell	3
Veronica officinalis var. *officinalis*	common gypsyweed	3
Veronica serpyllifolia	thymeleaf speedwell	3
Vinca minor	common periwinkle	1

Appendix B. Plant species identified in Gauley River National Recreation Area's upland forest communities

Table B-1. Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Acalypha gracilens	slender threeseed mercury	–	–	–	X
Acalypha virginica	Virginia threeseed mercury	–	–	X	X
Acer negundo var. *negundo*	boxelder	–	–	X	X
Acer nigrum	black maple	–	–	X	X
Acer pensylvanicum	striped maple	–	X	X	X
Acer rubrum	red maple	N	X	X	X
Acer saccharum var. *saccharum*	sugar maple	N	–	X	X
Acer spicatum	mountain maple	G	–	X	–
Achillea millefolium[B]	common yarrow	–	–	X	–
Actaea pachypoda	white baneberry	–	–	–	X
Actaea racemosa	black baneberry	–	–	X	X
Adiantum pedatum	maidenhair fern	–	–	X	X
Adlumia fungosa	Allegheny vine	G	–	X	X
Aesculus flava	yellow buckeye	–	–	X	X
Ageratina altissima var. *altissima*	white snakeroot	–	–	X	X
Agrimonia pubescens	soft agrimony	–	–	–	X
Agrimonia rostellata	beaked agrimony	–	–	X	X
Agrimonia striata	roadside agrimony	–	–	X	–
Agrostis gigantea[B]	redtop	–	–	–	X
Agrostis perennans	upland bentgrass	–	–	X	X
Ailanthus altissima[B]	tree of heaven	–	–	X	X
Ambrosia artemisiifolia	annual ragweed	–	–	X	–
Amelanchier arborea	common serviceberry	–	–	X	X
Amphicarpaea bracteata	American hogpeanut	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Andropogon virginicus	broomsedge bluestem	–	–	–	X
Anemone acutiloba	sharplobe hepatica	–	–	X	–
Anemone lancifolia	mountain thimbleweed	–	–	X	X
Anemone quinquefolia var. *quinquefolia*	nightcaps	–	–	X	X
Anemone virginiana	tall thimbleweed	–	–	–	X
Anomodon attenuatus[C]	anomodon moss	–	–	X	–
Antennaria plantaginifolia	plantainleaf pussytoes	–	–	X	X
Antennaria solitaria	singlehead pussytoes	–	–	X	–
Anthoxanthum odoratum[B]	sweet vernalgrass	–	–	–	X
Aplectrum hyemale	Adam and Eve	–	–	X	X
Aralia racemosa ssp. *racemosa*	American spikenard	–	–	X	X
Aralia spinosa	devil's walkingstick	–	–	X	X
Arisaema triphyllum	Jack-in-the-pulpit	N	–	X	X
Aristolochia macrophylla	pipevine	–	–	X	X
Aristolochia serpentaria	Virginia snakeroot	–	–	X	X
Arnoglossum atriplicifolium	pale Indian plaintain	–	–	X	–
Asarum canadense	Canadian wild ginger	–	–	X	X
Asclepias quadrifolia	fourleaf milkweed	–	–	X	–
Asclepias tuberosa	butterfly milkweed	–	–	X	X
Asimina triloba	pawpaw	–	–	X	X
Asplenium montanum	mountain spleenwort	N	–	X	–
Asplenium pinnatifidum	lobed spleenwort	N	–	–	–
Asplenium platyneuron	ebony spleenwort	–	–	X	X
Asplenium rhizophyllum	walking fern	–	–	X	X
Athyrium filix-femina var. *angustum*	subarctic ladyfern	–	–	X	X
Athyrium filix-femina var. *asplenioides*	asplenium ladyfern	–	–	–	X

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[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Atrichum undulatum[C]	undulate atrichum moss	–	–	X	–
Aulacomnium heterostichum[C]	aulacomnium moss	–	–	X	–
Aureolaria flava	smooth yellow false foxglove	–	–	X	X
Aureolaria pedicularia	fernleaf yellow false foxglove	–	–	–	X
Aureolaria virginica	downy yellow false foxglove	–	–	X	–
Bazzania trilobata	threelobed bazzania	–	–	X	–
Betula alleghaniensis	yellow birch	G	X	X	X
Betula lenta	sweet birch	–	–	X	X
Betula nigra	river birch	–	–	–	X
Bidens sp.	beggarticks	–	–	–	X
Boechera (*Arabis*) *canadensis*	sicklepod	–	–	X	X
Boechera (*Arabis*) *laevigata*	smooth rockcress	–	–	X	X
Boehmeria cylindrica	smallspike false nettle	–	–	–	X
Botrychium dissectum	cutleaf grapefern	–	–	X	X
Botrychium oneidense	bluntlobe grapefern	–	–	–	X
Botrychium virginianum	rattlesnake fern	–	–	X	X
Brachyelytrum aristosum	northern shorthusk	–	–	X	–
Brachyelytrum erectum	bearded shorthusk	–	–	X	X
Brachythecium oxycladon[C]	brachythecium moss	–	–	X	–
Brachythecium plumosum[C]	brachythecium moss	–	–	X	–
Brachythecium rutabulum[C]	brachythecium moss	–	–	X	–
Brachythecium salebrosum[C]	brachythecium moss	–	–	X	–
Bromus ciliatus	fringed brome	–	–	–	X
Bromus pubescens	hairy woodland brome	–	–	X	–
Brotherella recurvans[C]	recurved brotherella moss	–	–	X	–

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Bryoandersonia illecebra[C]	bryoandersonia moss	–	–	X	–
Campanula americana	American bellflower	–	–	X	X
Campanula divaricata	small bonny bellflower	–	–	–	X
Campsis radicans	trumpet creeper	–	–	X	–
Cardamine concatenata	cutleaf toothwort	–	–	X	–
Cardamine diphylla	crinkleroot	–	–	X	–
Cardamine hirsuta	hairy bittercress	–	–	X	–
Cardamine parviflora	sand bittercress	–	–	X	–
Carex aestivalis	summer sedge	–	–	X	–
Carex albursina	white bear sedge	–	–	X	X
Carex amphibola	eastern narrowleaf sedge	–	–	X	–
Carex blanda	eastern woodland sedge	–	–	X	X
Carex communis var. *communis*	fibrousroot sedge	–	–	X	–
Carex cumberlandensis	Cumberland sedge	–	–	X	–
Carex debilis var. *rudgei*	white edge sedge	–	–	X	X
Carex digitalis var. *digitalis*	slender woodland sedge	–	–	X	X
Carex gracilescens	slender looseflower sedge	–	–	X	–
Carex gracillima	graceful sedge	–	–	X	–
Carex hirsutella	fuzzy wuzzy sedge	–	–	X	X
Carex jamesii	James' sedge	–	–	X	–
Carex laxiculmis var. *laxiculmus*	spreading sedge	–	–	X	X
Carex laxiflora	broad looseflower sedge	–	–	X	X
Carex leavenworthii	Leavenworth's sedge	–	–	–	X
Carex lurida	shallow sedge	–	–	–	X
Carex oligocarpa	richwoods sedge	–	–	–	X
Carex pensylvanica	Pennsylvania sedge	–	–	X	–
Carex plantaginea	plantainleaf sedge	–	–	X	–

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Carex platyphylla	broadleaf sedge	–	–	X	X
Carex radiata	eastern star sedge	–	–	X	X
Carex retroflexa	reflexed sedge	–	–	–	X
Carex rosea	rosy sedge	–	–	X	X
Carex swanii	Swan's sedge	–	–	X	X
Carex virescens	ribbed sedge	–	–	X	X
Carex vulpinoidea	fox sedge	–	–	–	X
Carex willdenowii	Willdenow's sedge	–	–	X	X
Carpinus caroliniana ssp. *virginiana*	American hornbeam	–	–	X	X
Carya cordiformis	bitternut hickory	–	–	X	X
Carya glabra	pignut hickory	–	–	X	X
Carya ovata	shagbark hickory	–	–	X	X
Carya tomentosa (*C. alba*)	mockernut hickory	–	–	X	X
Castanea dentata	American chestnut	–	X	X	X
Castanea pumila	chinkapin	–	–	–	X
Catalpa speciosa	northern catalpa	–	–	–	X
Caulophyllum thalictroides	blue cohosh	–	–	X	X
Celastrus orbiculatus[B]	Oriental bittersweet	–	–	–	X
Celtis occidentalis	common hackberry	–	–	–	X
Cercis canadensis var. *canadensis*	eastern redbud	–	–	X	X
Chelone glabra	white turtlehead	–	–	X	–
Chimaphila maculata	striped prince's pine	–	–	X	X
Cinna arundinacea	sweet woodreed	–	–	X	–
Circaea alpina ssp. *alpina*	small enchanter's nightshade	G	–	–	X
Circaea canadensis ssp. *canadensis*	broadleaf enchanter's nightshade	–	–	X	–

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Circaea lutetiana	broadleaf enchanter's nightshade	–	–	–	X
Cirsium altissimum	tall thistle	–	–	–	X
Cirsium sp.	thistle	–	–	X	–
Clematis virginiana	devil's darning needles	–	–	X	X
Clethra acuminata	mountain sweetpepperbush	G	–	X	X
Clethra alnifolia	coastal sweetpepperbush	–	–	–	X
Climacium americanum[C]	American climacium moss	–	–	X	–
Clinopodium vulgare	wild basil	–	–	–	X
Coleataenia anceps	beaked panicgrass	–	–	–	X
Collinsonia canadensis	richweed	–	X	X	X
Commelina virginica	Virginia dayflower	–	–	–	X
Conopholis americana	American cancer-root	–	X	X	X
Convolvulus sp.	bindweed	–	–	–	X
Coreopsis major	greater tickseed	–	–	X	X
Cornus alternifolia	alternateleaf dogwood	–	X	X	–
Cornus florida	flowering dogwood	N	–	X	X
Corylus americana	American hazelnut	–	X	X	X
Crataegus sp.	hawthorn	–	–	X	X
Crepis pulchra[B]	smallflower hawksbeard	–	–	X	–
Cryptotaenia canadensis	Canadian honewort	–	–	X	X
Cunila origanoides	common dittany	–	–	X	X
Cuscuta sp.	dodder	–	–	–	X
Cymophyllus fraserianus	Fraser's cymophyllus	G	–	X	X
Cynoglossum virginianum var. *virginianum*	wild comfrey	–	–	X	–
Cypripedium acaule	moccasin flower	–	X	X	X
Cystopteris fragilis	brittle bladderfern	–	–	–	X
Cystopteris protrusa	lowland bladderfern	–	–	–	X

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[B] Exotic species

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Dactylis glomerata[B]	orchardgrass	–	–	–	X
Danthonia compressa	flattened oatgrass	–	–	X	X
Danthonia sericea	downy danthonia	–	–	X	–
Danthonia spicata	poverty oatgrass	–	–	X	X
Delphinium tricorne	dwarf larkspur	–	–	X	–
Dennstaedtia punctilobula	eastern hayscented fern	–	–	X	X
Deparia acrostichoides	silver false spleenwort	–	–	X	X
Desmodium glutinosum	pointedleaf ticktrefoil	–	–	X	X
Desmodium nudiflorum	nakedflower ticktrefoil	–	–	X	X
Desmodium paniculatum var. *paniculatum*	panicledleaf ticktrefoil	–	–	X	X
Desmodium rotundifolium	prostrate ticktrefoil	–	–	X	X
Diarrhena americana	American beakgrain	–	–	X	X
Diarrhena obovata	obovate beakgrain	–	–	–	X
Dicentra canadensis	squirrel corn	–	–	X	–
Dichanthelium acuminatum var. *fasciculatum*	western panicgrass	–	–	–	X
Dichanthelium acuminatum var. *lindheimeri*	Lindheimer panicgrass	–	–	–	X
Dichanthelium boscii	Bosc's panicgrass	–	–	X	X
Dichanthelium clandestinum	deertongue	–	–	X	X
Dichanthelium commutatum	variable panicgrass	–	–	X	X
Dichanthelium dichotomum var. *dichotomum*	cypress panicgrass	–	–	X	X
Dichanthelium latifolium	broadleaf rosette grass	–	–	X	X
Dichanthelium laxiflorum	openflower rosette grass	–	–	X	X
Dichanthelium linearifolium	slimleaf panicgrass	–	–	X	X
Dichanthelium polyanthes	roundseed panicgrass	–	–	X	–
Dichanthelium portricense	N/A	–	–	X	–
Dicranella heteromalla[C]	dicranella moss	–	–	X	–

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Dicranum condensatum[C]	condensed dicranum moss	–	–	X	–
Dicranum flagellare[C]	dicranum moss	–	–	X	–
Dicranum fulvum[C]	dicranum moss	–	–	X	–
Dicranum fuscescens[C]	dicranum moss	–	–	X	–
Dicranum scoparium[C]	dicranum moss	–	–	X	–
Dicranum spurium[C]	dicranum moss	–	–	X	–
Dioscorea quaternata	fourleaf yam	–	–	X	–
Dioscorea villosa	wild yam	–	–	–	X
Diplazium pycnocarpon	glade fern	–	–	X	X
Doellingeria infirma	cornel-leaf whitetop	–	–	–	X
Dryopteris carthusiana	spinulose woodfern	–	–	–	X
Dryopteris goldiana	Goldie's woodfern	–	–	X	–
Dryopteris intermedia	intermediate woodfern	–	X	X	X
Dryopteris marginalis	marginal woodfern	–	X	X	X
Duchesnea indica[B]	Indian strawberry	–	–	X	X
Elaeagnus umbellata var. *parvifolia*[B]	autumn olive	–	–	X	X
Elymus hystrix var. *hystrix*	eastern bottlebrush grass	–	–	X	X
Epifagus virginiana	beechdrops	–	–	X	X
Epigaea repens	trailing arbutus	–	–	X	X
Erechtites hieraciifolius	American burnweed	–	–	–	X
Erigeron annuus	eastern daisy fleabane	–	–	–	X
Erigeron philadelphicus var. *philadelphicus*	Philadelphia fleabane	–	–	X	–
Erigeron pulchellus	robin's plantain	–	–	–	X
Euonymus americana	strawberry bush; bursting-heart	–	–	X	X
Eupatorium album	white thoroughwort	–	–	–	X
Eupatorium godfreyanum	Godfrey's thoroughwort	–	–	X	–

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Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Eupatorium rotundifolium var. *ovatum*	roundleaf thoroughwort	–	–	–	X
Eupatorium serotinum	lateflowering thoroughwort	–	–	–	X
Eupatorium sessilifolium	upland boneset	–	–	–	X
Eurybia divaricata	white wood aster	–	–	X	X
Eurhynchium hians[C]	eurhynchium moss	–	–	X	–
Euthamia graminifolia	flat-top goldentop	–	–	–	X
Eutrochium purpureum var. *purpureum*	sweetscented joepyeweed	–	–	X	X
Fagus grandifolia	American beech	N	X	X	X
Fallopia (*Polygonum*) *convolvulus*[B]	black bindweed	–	–	X	–
Fallopia (*Polygonum*) *scandens*	climbing false buckwheat	–	–	X	X
Festuca subverticillata	nodding fescue	–	–	X	X
Fissidens dubius[C]	fissidens moss	–	–	X	–
Fragaria vesca	woodland strawberry	–	–	–	X
Fraxinus americana	white ash	–	–	X	X
Fraxinus pennsylvanica	green ash	–	X	–	–
Frullania tamarisci var. *asagrayana*[C]	liverwort	–	–	X	–
Galearis spectabilis	showy orchid	–	–	–	X
Galium aparine	stickywilly	–	–	X	X
Galium circaezans	licorice bedstraw	–	–	X	X
Galium circaezans var. *hypomalacum*	licorice bedstraw	–	–	X	–
Galium lanceolatum	lanceleaf wild licorice	–	–	X	X
Galium obtusum	bluntleaf bedstraw	–	–	–	X
Galium triflorum	fragrant bedstraw	–	–	X	X
Gaultheria procumbens	eastern teaberry	–	–	X	X

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Gaylussacia baccata	black huckleberry	–	–	X	X
Geranium maculatum	spotted geranium	N	–	X	X
Geum canadense	white avens	–	–	X	X
Geum laciniatum	rough avens	–	–	–	X
Geum vernum	spring avens	–	–	–	X
Geum virginianum	cream avens	–	–	X	–
Gillenia trifoliata	Bowman's root	–	–	X	–
Glechoma hederacea[B]	ground ivy	–	–	X	–
-Glyceria striata	fowl mannagrass	–	–	–	X
Goodyera pubescens	downy rattlesnake-plantain	–	–	X	X
Grimmia pilifera[C]	grimmia dry rock moss	–	–	X	–
Hackelia virginiana	beggars-lice	–	–	–	X
Hamamelis virginiana	American witchhazel	N	X	X	X
Hedwigia ciliata[C]	ciliate hedwigia moss	–	–	X	–
Helianthus divaricatus	woodland sunflower	–	–	X	X
Helianthus strumosus	paleleaf woodland sunflower	–	–	–	X
Heuchera americana var. *americana*	American alumroot	–	–	X	X
Heuchera villosa var. *villosa*	hairy alumroot	–	–	X	–
Hexastylis heterophylla	variableleaf heartleaf	N	–	–	X
Hexastylis virginica	Virginia heartleaf	–	X	X	X
Hieracium caespitosum[B]	meadow hawkweed	–	–	X	–
Hieracium paniculatum	Allegheny hawkweed	–	–	X	X
Hieracium scabrum	rough hawkweed	–	–	–	X
Hieracium venosum	rattlesnakeweed	–	–	X	X
Houstonia longifolia	longleaf summer bluet	–	–	X	X
Hybanthus concolor	eastern greenviolet	–	–	X	–
Hydrangea arborescens	wild hydrangea	–	–	X	X

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Hydrastis canadensis	goldenseal	–	–	–	X
Hydrophyllum canadense	bluntleaf waterleaf	–	–	X	X
Hypericum hypericoides ssp. *multicaule*	St. Andrew's cross	–	–	X	X
Hypericum punctatum	spotted St. Johnswort	–	–	X	X
Hypnum imponens[C]	hypnum moss	–	–	X	–
Hypopitys monotropa	pinesap	–	–	X	X
Hypoxis hirsuta	common goldstar	–	–	X	X
Ilex montana	mountain holly	–	–	X	X
Ilex opaca var. *opaca*	American holly	G	X	X	X
Ilex verticillata	common winterberry	–	–	–	X
Impatiens capensis	jewelweed	–	–	–	X
Impatiens pallida	pale touch-me-not	–	–	X	–
Isotria verticillata	large whorled pogonia	–	–	–	X
Juglans cinerea	butternut	–	–	X	X
Juglans nigra	black walnut	–	–	X	X
Juncus effusus	common rush	–	–	–	X
Juncus tenuis	poverty rush	–	–	X	X
Juniperus virginiana var. *virginiana*	eastern redcedar	–	–	X	X
Kalmia latifolia	mountain laurel	–	–	X	X
Lactuca canadensis	Canada lettuce	–	–	X	X
Lamium purpureum var. *purpureum*[B]	purple deadnettle	–	–	X	X
Laportea canadensis	Canada woodnettle	–	–	X	X
Leersia virginica	whitegrass	–	–	–	X
Lespedeza cuneata[B]	Chinese lespedeza	–	–	X	X
Lespedeza frutescens	shrubby lespedeza	–	–	X	–
Lespedeza procumbens	trailing lespedeza	–	–	X	–
Leucobryum albidum[C]	leucobryum moss	–	–	X	–

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Leucobryum glaucum[C]	leucobryum moss	–	–	X	–
Lilium canadense	Canada lily	–	–	X	X
Lindera benzoin	northern spicebush	–	–	X	X
Liquidambar styraciflua	sweetgum	–	–	X	X
Liriodendron tulipifera	tuliptree	N	X	X	X
Lobelia inflata	Indian-tobacco	–	–	X	X
Loeskeobryum brevirostre[C]	loeskeobryum moss	–	–	X	–
Lolium perenne[B]	perennial ryegrass	–	–	–	X
Lonicera japonica[B]	Japanese honeysuckle	–	–	X	X
Lonicera morrowii[B]	Morrow's honeysuckle	–	–	–	X
Lophocolea heterophylla[C]	liverwort	–	–	X	–
Luzula echinata	hedgehog woodrush	–	–	X	–
Luzula multiflora ssp. *multiflora*	common woodrush	–	–	X	X
Lycopodium digitatum[C]	fan clubmoss	–	–	X	X
Lycopodium tristachyum[C]	deeproot clubmoss	–	–	X	–
Lycopus uniflorus var. *uniflorus*	northern bugleweed	–	–	X	X
Lysimachia quadrifolia	whorled yellow loosestrife	–	–	X	X
Magnolia acuminata	cucumber-tree	–	–	X	X
Magnolia fraseri	mountain magnolia	G	X	X	X
Magnolia tripetala	umbrella-tree	–	–	X	X
Maianthemum canadense	Canada mayflower	–	–	X	–
Maianthemum racemosum ssp. racemosum	feathery false lily of the valley	–	–	X	X
Medeola virginiana	Indian cucumber	–	–	X	X
Meehania cordata	Meehan's mint	–	–	X	–
Menispermum canadense	common moonseed	–	–	X	X
Micranthes (*Saxifraga*) *virginiensis*	early saxifrage	–	–	–	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Microstegium vimineum[B]	Japanese stiltgrass	–	–	X	X
Mitchella repens	partridgeberry	–	X	X	X
Mitella diphylla	twoleaf miterwort	–	–	X	–
Mnium hornum[C]	horn calcareous moss	–	–	X	–
Monarda clinopodia	white bergamot	–	–	X	X
Monarda fistulosa	wild bergamot	–	–	–	X
Monotropa uniflora	Indianpipe	–	X	X	X
Morus alba[B]	white mulberry	–	–	–	X
Morus rubra	red mulberry	–	–	X	–
Muhlenbergia sp.	muhly grass	–	–	X	X
Muhlenbergia sylvatica	woodland muhly	–	–	–	X
Nowellia curvifolia[C]	liverwort	–	–	X	–
Nyssa sylvatica	blackgum	–	X	X	X
Oclemena acuminata	whorled wood aster	–	–	–	X
Oenothera sp.	evening-primrose	–	–	–	X
Onoclea sensibilis	sensitive fern	–	–	–	X
Osmorhiza claytonii	Clayton's sweetroot	–	–	X	X
Osmorhiza longistylis	longstyle sweetroot	–	–	–	X
Osmunda cinnamomea	cinnamon fern	–	–	–	X
Osmunda claytoniana	interrupted fern	–	–	X	–
Ostrya virginiana	hophornbeam	–	–	X	X
Oxalis grandis	great yellow woodsorrel	–	–	X	X
Oxalis stricta	common yellow oxalis	–	–	–	X
Oxalis violacea	violet woodsorrel	–	–	X	–
Oxydendrum arboreum	sourwood	–	X	X	X
Packera aurea	golden ragwort	N	–	X	X
Packera obovata	roundleaf ragwort	N	–	X	X
Panax quinquefolius	American ginseng	–	–	X	X
Paronychia canadensis	smooth forked nailwort	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Parthenocissus quinquefolia	Virginia creeper	–	–	X	X
Passiflora lutea	yellow passionflower	–	–	X	X
Paulownia tomentosa[B]	princess tree	–	–	–	X
Pedicularis canadensis	Canadian lousewort	–	–	X	–
Persicaria longiseta[B] (*Polygonum caespitosum* var. *longisetum*)	oriental ladysthumb	–	–	X	–
Persicaria maculosa[B] (*Polygonum persicaria*)	spotted ladysthumb	–	–	–	X
Persicaria posumbu[B] (*Polygonum caespitosum*)	oriental ladysthumb	–	–	–	X
Persicaria (*Polygonum*) *sagittata*	arrowleaf tearthumb	–	–	–	X
Persicaria (*Polygonum*) *virginiana*	jumpseed	–	–	X	X
Phegopteris hexagonoptera	broad beechfern	–	–	X	X
Phryma leptostachya	American lopseed	–	–	X	X
Phytolacca americana var. *americana*	American pokeweed	–	–	X	X
Pilea pumila	Canadian clearweed	–	–	X	X
Pinus resinosa	red pine	–	–	–	X
Pinus rigida	pitch pine	–	–	X	X
Pinus strobus	eastern white pine	–	–	X	X
Pinus virginiana	Virginia pine	N	X	X	X
Plagiomnium ciliare[C]	plagiomnium moss	–	–	X	–
Plagiomnium cuspidatum[C]	toothed plagiomnium moss	–	–	X	–
Plagiomnium ellipticum[C]	elliptic plagiomnium moss	–	–	X	–
Plantago rugelii	blackseed plantain	–	–	–	X
Platanthera sp.	fringed orchid	–	–	X	–
Platanus occidentalis	American sycamore	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Poa alsodes	grove bluegrass	–	–	X	–
Poa compressa[B]	Canada bluegrass	–	–	X	–
Poa cuspidata	early bluegrass	–	–	X	X
Poa pratensis[B]	Kentucky bluegrass	–	–	–	X
Poa sylvestris	woodland bluegrass	–	–	X	X
Podophyllum peltatum	mayapple	–	–	X	X
Polygonatum biflorum	smooth Solomon's seal	–	–	X	X
Polygonatum pubescens	hairy Solomon's seal	–	–	X	X
Polymnia canadensis	whiteflower leafcup	–	–	X	X
Polypodium virginianum	rock polypody	–	X	X	X
Polystichum acrostichoides	Christmas fern	N	X	X	X
Polytrichum commune[C]	polytrichum moss	–	–	X	–
Polytrichum juniperinum[C]	juniper polytrichum moss	–	–	X	–
Polytrichum ohioense[C]	Ohio polytrichum moss	–	–	X	–
Polytrichum pallidisetum[C]	polytrichum moss	–	–	X	–
Populus grandidentata	bigtooth aspen	–	–	X	–
Potentilla canadensis	dwarf cinquefoil	–	–	X	X
Potentilla simplex	common cinquefoil	–	–	X	X
Prenanthes sp.	rattlesnakeroot	–	–	X	X
Prenanthes trifoliolata	gall of the earth	–	–	–	X
Prosartes lanuginosa	yellow fairybells	–	–	X	X
Prunella vulgaris	common selfheal	–	–	–	X
Prunus pensylvanica	pin cherry	–	–	X	X
Prunus serotina var. *serotina*	black cherry	–	X	X	X
Pteridium aquilinum	western brackenfern	–	–	X	–
Pterospora andromedea	woodland pinedrops	–	–	–	X
Pylaisiadelpha tenuirostris[C]	pylaisiadelpha moss	–	–	X	–
Pyrularia pubera	buffalo nut	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Quercus alba	white oak	N	X	X	X
Quercus coccinea	scarlet oak	N	–	X	X
Quercus montana (*Q. prinus*)	chestnut oak	N	X	X	X
Quercus muehlenbergii	chinkapin oak	–	–	X	X
Quercus rubra	northern red oak	N	X	X	X
Quercus velutina	black oak	N	X	X	X
Ranunculus abortivus	littleleaf buttercup	–	–	X	X
Ranunculus allegheniensis	Allegheny Mountain buttercup	–	–	X	–
Ranunculus recurvatus var. *recurvatus*	blisterwort	–	–	X	X
Rhodobryum ontariense[C]	Ontario rhodobryum moss	–	–	X	–
Rhododendron calendulaceum	flame azalea	–	–	X	X
Rhododendron catawbiense	Catawba rosebay	G	–	X	–
Rhododendron maximum	great laurel	N	–	X	X
Rhus copallinum	flameleaf sumac	–	–	X	X
Rhus glabra	smooth sumac	–	–	–	X
Rhus typhina	staghorn sumac	–	–	–	X
Ribes cynosbati	eastern prickly gooseberry	–	–	X	–
Ribes sp.	currant	–	–	–	X
Robinia pseudoacacia	black locust	–	–	X	X
Rosa carolina var. *carolina*	Carolina rose	–	–	X	X
Rosa multiflora[B]	multiflora rose	–	–	X	X
Rubus allegheniensis	Allegheny blackberry	–	–	X	X
Rubus flagellaris	northern dewberry	–	–	–	X
Rubus hispidus	bristly dewberry	–	–	–	X
Rubus occidentalis	black raspberry	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Rubus odoratus var. *odoratus*	purpleflowering raspberry	–	–	X	X
Rubus phoenicolasius[B]	wine raspberry, wineberry	–	–	X	X
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	–	–	X	–
Rumex sp.	dock	–	–	–	X
Salvia lyrata	lyreleaf sage	–	–	X	–
Sambucus nigra ssp. *canadensis*	common elderberry	–	–	X	X
Sambucus racemosa var. *racemosa*	red elderberry	G	–	X	–
Sanguinaria canadensis	bloodroot	–	–	X	X
Sanicula canadensis	Canadian blacksnakeroot	–	–	X	X
Sanicula canadensis var. *canadensis*	Canadian blacksnakeroot	–	–	X	–
Sanicula canadensis var. *grandis*	Canadian blacksnakeroot	–	–	X	–
Sanicula marilandica	Maryland sanicle	–	–	X	X
Sanicula odorata	clustered blacksnakeroot	–	–	–	X
Sanicula trifoliata	largefruit blacksnakeroot	–	–	X	X
Sassafras albidum	sassafras	N	–	X	X
Schedonorus pratensis[B]	meadow fescue	–	–	X	X
Schizachyrium scoparium	little bluestem	–	–	X	–
Scirpus atrovirens	green bulrush	–	–	–	X
Scirpus cyperinus	woolgrass	–	–	–	X
Scleria triglomerata	whip nutrush	–	–	–	X
Scutellaria elliptica var. *hirsuta*	hairy skullcap	–	–	X	X
Scutellaria nervosa	veiny skullcap	–	–	–	X
Scutellaria ovata	heartleaf skullcap	–	–	–	X
Sedum ternatum	woodland stonecrop	N	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Sericocarpus asteroides	toothed whitetop aster	–	–	X	–
Silene stellata	widowsfrill, whorled catchfly	–	–	X	X
Sisyrinchium angustifolium	narrowleaf blue-eyed grass	–	–	–	X
Smallanthus uvedalia	hairy leafcup	–	–	–	X
Smilax ecirrhata	upright carrionflower	–	–	X	X
Smilax glauca	cat greenbrier	–	–	X	X
Smilax herbacea	smooth carrionflower	–	–	X	X
Smilax rotundifolia	roundleaf greenbrier	–	–	X	X
Smilax tamnoides	bristly greenbrier	–	–	X	X
Solanum sp.	nightshade	–	–	–	X
Solidago arguta	Atlantic goldenrod	–	–	X	–
Solidago bicolor	white goldenrod	–	–	X	X
Solidago caesia	wreath goldenrod	–	X	X	X
Solidago curtisii	mountain decumbent goldenrod	–	–	X	X
Solidago erecta	showy goldenrod	–	–	–	X
Solidago flexicaulis	zigzag goldenrod	–	–	X	X
Solidago gigantea	giant goldenrod	–	–	–	X
Solidago hispida var. *hispida*	hairy goldenrod	–	–	X	–
Solidago juncea	early goldenrod	–	–	–	X
Solidago nemoralis	gray goldenrod	–	–	–	X
Solidago roanensis	Roan Mountain goldenrod	–	–	X	–
Solidago rugosa	wrinkleleaf goldenrod	–	–	X	X
Solidago simplex var. *racemosa*	Rand's goldenrod	–	–	X	–
Sphagnum capillifolium var. *capillifolium*[C]	sphagnum moss	–	–	X	–
Sphenopholis nitida	shiny wedgescale	–	–	X	–

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Staphylea trifolia	American bladdernut	–	–	X	X
Steerecleus serrulatus[C]	steerecleus moss	–	–	X	–
Stellaria media[B]	common chickweed	–	–	–	X
Stellaria pallida[B]	common chickweed	–	–	X	–
Stellaria pubera	star chickweed	N	–	X	X
Streptopus lanceolatus	twistedstalk	–	–	X	–
Stylophorum diphyllum	celandine poppy	–	–	X	–
Symphyotrichum cordifolium	common blue wood aster	–	–	–	X
Symphyotrichum lateriflorum	calico aster	–	–	X	–
Symphyotrichum patens var. *patens*	late purple aster	–	–	X	X
Symphyotrichum puniceum var. *puniceum*	purplestem aster	–	–	X	–
Symphyotrichum undulatum	wavyleaf aster	–	–	X	X
Taenidia integerrima	yellow pimpernel	–	–	X	X
Taraxacum officinale ssp. *officinale*[B]	common dandelion	–	–	X	–
Thalictrum thalictroides	rue anemone	–	–	X	X
Thelypteris noveboracensis	New York fern	N	X	X	X
Thuidium delicatulum[C]	delicate thuidium moss	–	–	X	–
Tiarella cordifolia	heartleaf foamflower	N	–	X	X
Tilia americana	American basswood	–	–	X	X
Tipularia discolor	crippled cranefly	–	–	–	X
Toxicodendron radicans	eastern poison ivy	–	–	X	X
Trichocolea tomentella[C]	liverwort	–	–	X	–
Trillium erectum	red trillium	N	–	X	X
Trillium grandiflorum	white trillium	–	–	–	X
Tsuga canadensis	eastern hemlock	N	X	X	X
Tussilago farfara[B]	coltsfoot	–	–	–	X
Ulmus americana	American elm	–	–	–	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Ulmus rubra	slippery elm	–	–	X	X
Ulota hutchinsiae[C]	Hutchins' ulota moss	–	–	X	–
Uvularia perfoliata	perfoliate bellwort	–	–	–	X
Uvularia puberula	mountain bellwort	–	–	–	X
Vaccinium angustifolium	lowbush blueberry	–	–	–	X
Vaccinium pallidum	Blue Ridge blueberry	–	–	X	X
Vaccinium stamineum	deerberry	–	–	X	X
Verbena urticifolia	white vervain	–	–	X	–
Verbesina alternifolia	wingstem	–	–	X	X
Verbesina occidentalis	yellow crownbeard	–	–	X	X
Veronica chamaedrys[B]	germander speedwell	–	–	X	–
Veronica officinalis[B]	common gypsyweed	–	–	–	X
Viburnum acerifolium	mapleleaf viburnum	–	–	X	X
Viburnum prunifolium	blackhaw	–	–	X	X
Viola blanda	sweet white violet	–	–	X	X
Viola canadensis	Canadian white violet	–	–	X	X
Viola cucullata	marsh blue violet	–	–	X	X
Viola hastata	halberdleaf yellow violet	–	–	X	X
Viola hirsutula	southern woodland violet	–	–	X	X
Viola palmata	early blue violet	–	–	X	X
Viola primulifolia	primrose leaf violet	–	–	–	X
Viola pubescens	downy yellow violet	–	–	X	X
Viola rostrata	longspur violet	–	–	X	–
Viola rotundifolia	roundleaf yellow violet	–	X	X	X
Viola sagittata	arrowleaf violet	–	–	X	–
Viola sororia	common blue violet	–	–	X	X
Viola striata	striped cream violet	–	–	X	X
Vitis aestivalis	summer grape	–	–	X	X

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species identified in Gauley River National Recreation Area's upland forest communities.

Scientific Name	Common Name	Norris 1992/Grafton 1993[A]	Fortney et al. 1995	Vanderhorst et al. 2010	ERMN 2007-2016
Vitis aestivalis var. *bicolor*	summer grape	–	–	–	X
Xanthorhiza simplicissima	yellowroot	G	–	X	–
	Total	–	–	403	380

[A] In this column, an "N" represents species documented by Norris (1992) in a study focusing on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Appendix C. Lichen species documented in Gauley River National Recreation Area

Table C-1. Lichen species documented in Gauley River National Recreation Area by Vanderhorst et al. (2010).

Scientific Name	Common Name	Uplands	Riparian
Abrothallus cladoniae	lichen	–	X
Cladonia sp.	cup lichen	–	X
Cladonia caroliniana	Carolina cup lichen	X	–
Cladonia cristatella	British soldier lichen	X	–
Cladonia cylindrica	cylinder cup lichen	X	–
Cladonia fimbriata	cup lichen	X	–
Cladonia furcata	cup lichen	X	–
Cladonia pyxidata	cup lichen	X	–
Cladonia rangiferina	reindeer lichen	X	–
Cladonia squamosa	cup lichen	X	–
Cladonia subtenuis	reindeer lichen	X	–
Cladonia uncialis	cup lichen	X	–
Coccocarpia palmicola	coccocarpia lichen	–	X
Dermatocarpon luridum	silverskin lichen	–	X
Flavoparmelia baltimorensis	Baltimore flavoparmelia lichen	X	–
Flavoparmelia caperata	common greenshield lichen	X	–
Lasallia papulosa	blistered naval lichen	X	–
Lasallia pensylvanica	Pensylvania blistered naval lichen	X	X
Myelochroa aurulenta	myelochroa lichen	X	–
Parmelia sp.	foliose lichen	–	X
Parmotrema hypotropum	parmotrema lichen	–	X
Phaeocalicium polyporaeum	phaeocalicium lichen	–	X
Punctelia rudecta	punctelia lichen	X	–
Tuckermannopsis ciliaris	tuckermannopsis lichen	X	–
Umbilicaria mammulata	navel lichen	X	–
Xanthoparmelia conspersa	xanthoparmelia lichen	X	X
Xanthoparmelia plittii	Plitt's xanthoparmelia lichen	X	X

Appendix D. Plant species documented within Gauley River National Recreation Area riparian vegetation communities

Table D–1. Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Acalypha rhomboidea	Virginia threeseed mercury	–	X	X	–
Acer pensylvanicum	striped maple	–	X	X	–
Acer rubrum	red maple	–	X	X	X
Acer saccharum var. *saccharum*	sugar maple	–	X	X	–
Achillea millefolium[B]	common yarrow	–	X	X	–
Aesculus flava	yellow buckeye	–	–	X	–
Ageratina altissima var. *altissima*	white snakeroot	–	X	X	–
Agrostis gigantea[B] (*A. alba*)	redtop	–	X	X	–
Agrostis perennans	upland bentgrass	–	–	X	–
Ailanthus altissima[B]	tree of heaven	–	–	–	X
Alisma subcordatum	American water plantain	–	–	X	–
Alnus serrulata	hazel alder	N	X	X	X
Ambrosia artemisiifolia	annual ragweed	–	X	X	X
Ambrosia trifida	giant ragweed	–	X	X	X
Amelanchier arborea	common serviceberry	–	X	X	–
Amelanchier spicata	running serviceberry	–	–	X	–
Amphicarpaea bracteata	American hogpeanut	–	–	X	–
Andropogon gerardii	big bluestem	N	X	X	X
Angelica triquinata	filmy angelica	–	–	X	–
Anemone quinquefolia	nightcaps	–	–	X	–
Anomodon attenuatus[C]	anomodon moss	–	–	X	–
Anthoxanthum odoratum ssp. *odoratum*[B]	sweet vernalgrass	–	–	X	–

[A] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at GARI. Neither source provided a comprehensive species list for the park.

[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table D–1 (continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Apios americana	groundnut	–	–	X	–
Apocynum cannabinum	Indian hemp	–	X	X	X
Aralia spinosa	devil's walkingstick	–	X	X	–
Arisaema triphyllum	Jack–in–the–pulpit	–	–	X	–
Aristolochia macrophylla	pipevine	–	X	X	–
Arnoglossum atriplicifolium	pale Indian plaintain	–	–	X	X
Artemisia vulgaris[B]	common wormwood	–	–	–	X
Asclepias incarnata ssp. *pulchra*	swamp milkweed	–	X	X	–
Asimina triloba	pawpaw	–	–	X	–
Athyrium filix–femina	subarctic ladyfern	–	X	X	–
Athyrium filix–femina var. *asplenioides*	asplenium ladyfern	–	X	–	–
Atrichum angustatum[C]	atrichum moss	–	–	X	–
Atrichum undulatum[C]	undulate atrichum moss	–	–	X	–
Aulacomnium palustre[C]	aulacomnium moss	–	–	X	–
Avenella flexuosa	wavy hairgrass	–	X	X	X
Baptisia tinctoria	horseflyweed	N	X	X	X
Bazzania trilobata	threelobed bazzania	–	–	X	–
Betula alleghaniensis	yellow birch	G	X	X	–
Betula lenta	sweet birch	–	X	X	X
Betula nigra	river birch	N	X	X	X
Bidens frondosa	devil's beggartick	–	–	X	–
Bidens trichosperma	crowned beggarticks	–	X	X	–
Bidens vulgata	big devils beggartick	–	–	X	X
Boehmeria cylindrica	smallspike false nettle	–	X	X	–
Botrychium virginianum	rattlesnake fern	–	–	X	–
Boykinia aconitifolia	Allegheny brookfoam	–	–	X	–
Brachyelytrum erectum	bearded shorthusk	–	X	X	–

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[B] Exotic species

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Table D–1 (continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Brachythecium rutabulum[C]	brachythecium moss	–	–	X	–
Bryoandersonia illecebra[C]	bryoandersonia moss	–	–	X	–
Bryum pseudotriquetrum[C]	common green bryum moss	–	–	X	–
Calystegia sepium	hedge false bindweed	–	–	–	X
Campsis radicans	trumpet creeper	–	X	X	X
Campylium sp.[C]	campylium moss	–	–	X	–
Campylopus tallulensis[C]	Tallul campylopus moss	–	–	X	–
Cardamine concatenata	cutleaf toothwort	–	–	X	–
Cardamine diphylla	crinkleroot	–	–	X	–
Carex amphibola	eastern narrowleaf sedge	–	–	X	–
Carex atlantica ssp. *atlantica*	prickly bog sedge	–	–	X	–
Carex baileyi	Bailey's sedge	–	–	X	–
Carex blanda	eastern woodland sedge	–	–	X	–
Carex caroliniana	Carolina sedge	–	–	X	–
Carex communis var. *communis*	fibrousroot sedge	–	–	X	–
Carex crinita var. *crinita*	fringed sedge	–	–	X	–
Carex debilis var. *rudgei*	white edge sedge	–	–	X	–
Carex digitalis var. *digitalis*	slender woodland sedge	–	–	X	–
Carex emoryi	Emory's sedge	–	–	–	X
Carex festucacea	fescue sedge	–	–	X	–
Carex gracillima	graceful sedge	–	X	X	–
Carex intumescens	greater bladder sedge	–	–	X	–
Carex laxiculmis var. *laxiculmis*	spreading sedge	–	–	X	–
Carex laxiflora	broad looseflower sedge	–	–	X	–
Carex leptalea	bristlystalked sedge	–	–	X	–

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Table D–1 (continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

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Carex lurida	shallow sedge	–	–	X	–
Carex pensylvanica	Pennsylvania sedge	–	X	X	–
Carex plantaginea	plantainleaf sedge	–	–	X	–
Carex prasina	drooping sedge	–	–	X	–
Carex radiata	eastern star sedge	–	–	X	–
Carex scabrata	eastern rough sedge	–	–	X	–
Carex seorsa	weak stellate sedge	–	–	X	–
Carex swanii	Swan's sedge	–	–	X	–
Carex torta	twisted sedge	–	X	X	–
Carpinus caroliniana ssp. *virginiana*	American hornbeam	–	X	X	X
Carya cordiformis	bitternut hickory	–	–	X	–
Carya glabra	pignut hickory	–	X	X	–
Carya tomentosa (*C. alba*)	mockernut hickory	–	–	X	–
Castanea dentata	American chestnut	–	–	X	–
Catalpa bignonioides	southern catalpa	–	X	X	–
Cephalanthus occidentalis	common buttonbush	N	X	X	X
Chasmanthium latifolium	Indian woodoats	–	–	X	–
Chelone glabra	white turtlehead	–	X	X	–
Chimaphila maculata	striped prince's pine	–	X	X	–
Chionanthus virginicus	white fringetree	–	X	X	X
Chrysopsis mariana	Maryland goldenaster	G	X	X	X
Cicuta maculata var. *maculata*	spotted water hemlock	–	–	X	–
Cinna arundinacea	sweet woodreed	–	–	X	–
Circaea canadensis ssp. *canadensis*	broadleaf enchanter's nightshade	–	–	X	–
Clematis virginiana	devil's darning needles	–	X	X	X

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Table D–1 (continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

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Clethra acuminata	mountain sweetpepperbush	G	–	X	–
Climacium americanum[C]	American climacium moss	–	–	X	–
Collinsonia canadensis	richweed	–	–	X	–
Conoclinium coelestinum	blue mistflower	–	–	–	X
Coreopsis major	greater tickseed	–	X	X	X
Coreopsis pubescens	star tickseed	–	–	X	–
Coreopsis tripteris	tall tickseed	–	X	X	–
Cornus amomum	silky dogwood	N	X	X	X
Cornus florida	flowering dogwood	–	X	X	–
Corylus americana	American hazelnut	–	–	X	–
Crataegus sp.	hawthorn	–	–	X	–
Cuscuta pentagona	fiveangled dodder	–	–	X	–
Cryptotaenia canadensis	Canadian honewort	–	–	X	–
Cyperus sp.	flatsedge	–	–	–	X
Cyperus strigosus	stawcolored flatsedge	–	–	X	–
Danthonia compressa	flattened oatgrass	–	–	X	–
Daucus carota[B]	Queen Anne's lace	–	–	X	–
Dennstaedtia punctilobula	eastern hayscented fern	–	–	X	–
Deparia acrostichoides	silver false spleenwort	–	–	X	–
Desmodium pauciflorum	fewflower ticktrefoil	–	X	X	–
Diarrhena americana	American beakgrain	–	–	X	–
Dichanthelium acuminatum var. *acuminatum*	tapered rosette grass	–	X	X	–
Dichanthelium acuminatum var. *fasciculatum*	western panicgrass	–	–	X	–
Dichanthelium boscii	Bosc's panicgrass	–	–	X	–
Dichanthelium clandestinum	deertongue	–	–	X	X

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Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Dichanthelium commutatum	variable panicgrass	–	–	X	–
Dichanthelium dichotomum	cypress panicgrass	–	X	X	–
Dichanthelium dichotomum var. *ramulosum*	cypress panicgrass	–	–	X	X
Dichanthelium dichotomum ssp. *yadkinense*	cypress panicgrass	–	–	X	–
Dichanthelium latifolium	broadleaf rosette grass	–	–	–	X
Dichanthelium laxiflorum	openflower rosette grass	–	–	X	X
Dichanthelium polyanthes	roundseed panicgrass	–	X	X	X
Dicranella sp.[C]	dicranella moss	–	–	X	–
Dicranum scoparium[C]	dicranum moss	–	–	X	–
Dioscorea quaternata	fourleaf yam	–	–	X	–
Diospyros virginiana	common persimmon	–	X	X	X
Doellingeria umbellata var. *umbellata* (*Aster umbellatus*)	parasol whitetop	–	X	X	–
Dryopteris intermedia	intermediate woodfern	–	–	X	–
Dryopteris marginalis	marginal woodfern	–	–	X	–
Duchesnea indica[B]	Indian strawberry	–	–	–	X
Elaeagnus umbellata var. *parvifolia*[B]	autumn olive	–	X	X	X
Eleocharis sp.	spikerush	–	–	–	X
Eleocharis acicularis	needle spikerush	–	–	X	–
Eleocharis obtusa	blunt spikerush	–	–	X	–
Eleocharis tenuis	slender spikerush	–	–	X	–
Elephantopus carolinianus	Carolina elephantsfoot	–	–	X	–
Elymus canadensis	Canada wildrye	–	–	X	–
Elymus riparius	riverbank wildrye	–	X	X	–
Entodon seductrix[C]	seductive entodon moss	–	–	X	–

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Epifagus virginiana	beechdrops	–	–	X	–
Equisetum arvense	field horsetail	–	X	X	–
Erigeron pulchellus	robin's plantain	–	X	X	X
Erigeron pulchellus var. *brauniae*	Braun's erigeron	–	–	X	X
Euonymus sp.	burningbush	–	–	–	X
Euonymus americana	strawberry bush	–	X	X	–
Eupatorium album	white thoroughwort	–	X	X	–
Eupatorium perfoliatum	common boneset	–	–	X	–
Eupatorium rotundifolium var. ovatum	roundleaf thoroughwort	–	X	X	–
Euphorbia corollata	flowering spurge	N	X	X	X
Eurybia divaricata (*Aster divaricatus*)	white wood aster	–	X	X	–
Eurybia schreberi	Schreber's aster	–		X	X
Euthamia graminifolia	flat–top goldentop	–	X	X	–
Eutrochium (*Eupatorium*) *fistulosum*	trumpetweed	–	X	X	X
Eutrochium purpureum var. *purpureum*	sweetscented joepyeweed	–	–	X	–
Fagus grandifolia	American beech	–	X	X	–
Fallopia japonica[B] (*Polygonum cuspidatum*)	Japanese knotweed	–	X	X	X
Festuca subverticillata	nodding fescue	–	–	X	–
Fissidens osmundioides[C]	osmund fissidens moss	–	–	X	–
Fraxinus americana	white ash	–	X	X	–
Fraxinus pennsylvanica	green ash	–	X	X	X
Galax urceolata	beetleweed	–	–	X	–
Galium sp.	bedstraw	–	X	–	–
Galium lanceolatum	lanceleaf wild licorice	–	–	X	–

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Galium tinctorium	stiff marsh bedstraw	–	–	X	–
Galium triflorum	fragrant bedstraw	–	–	X	–
Gaultheria procumbens	eastern teaberry	–	X	X	–
Gaylussacia baccata	black huckleberry	–	X	X	X
Geranium maculatum	spotted geranium	–	–	X	–
Geum canadense	white avens	–	–	X	–
Glechoma hederacea[B]	ground ivy	–	X	X	X
Glyceria striata	fowl mannagrass	–	–	X	–
Goodyera pubescens	downy rattlesnake–plantain	–	X	X	–
Grimmia pilifera[C]	grimmia dry rock moss	–	–	X	–
Grimmia laevigata[C]	grimmia dry rock moss	–	–	X	–
Gymnadeniopsis clavellata	small green wood orchid	–	–	X	–
Hamamelis virginiana	American witchhazel	–	X	X	X
Hedwigia ciliata[C]	ciliate hedwigia moss	–	–	X	–
Helenium autumnale	common sneezeweed	–	X	X	X
Helianthus decapetalus	thinleaf sunflower	–	X	X	–
Helianthus giganteus	giant sunflower	–	X	X	–
Helianthus strumosus	paleleaf woodland sunflower	–	X	X	–
Heliopsis helianthoides	smooth oxeye	–	–	X	–
Hemerocallis fulva[B]	orange daylily	–	–	X	–
Hexastylis virginica	Virginia heartleaf	–	–	X	–
Hieracium paniculatum	Allegheny hawkweed	–	–	X	–
Houstonia caerulea	azure bluet	–	X	X	X
Houstonia serpyllifolia	thymeleaf bluet	–	–	X	X
Hydrangea arborescens	wild hydrangea	–	–	X	–
Hydrophyllum canadense	bluntleaf waterleaf	–	–	X	–
Hygrohypnum eugyrium[C]	hygrohypnum moss	–	–	X	–

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Hypericum densiflorum	bushy St. Johnswort	–	–	X	–
Hypericum ellipticum	pale St. Johnswort	–	X	X	–
Hypericum hypericoides ssp. *multicaule*	St. Andrew's cross	–	X	X	X
Hypericum mutilum	dwarf St. Johnswort	–	X	X	X
Hypericum perforatum[B]	common St. John's wort	–	X	X	–
Hypericum prolificum	shrubby St. Johnswort	–	X	X	X
Hypericum punctatum	spotted St. Johnswort	–	X	X	–
Hypnum curvifolium[C]	curveleaf hypnum moss	–	–	X	–
Hypnum imponens[C]	hypnum moss	–	–	X	–
Hypoxis hirsuta	common goldstar	N	–	X	X
Ilex montana	mountain holly	–	–	X	–
Ilex opaca var. *opaca*	American holly	G	X	X	X
Ilex verticillata	common winterberry	N	X	X	X
Impatiens capensis	jewelweed	–	–	X	–
Ionactis linariifolia	flaxleaf whitetop aster	–	X	X	X
Ipomoea pandurata	man of the earth	N	X	X	X
Iris sp.	iris	–	X	–	–
Iris cristata	dwarf crested iris	G	–	X	X
Iris virginica	Virginia iris	–	–	–	X
Isoetes engelmannii	Appalachian quillwort	–	–	X	–
Juncus sp.	rush	N	X	–	–
Juncus acuminatus	tapertip rush	–	–	X	–
Juncus dudleyi	Dudley's rush	–	–	X	–
Juncus effusus	common rush	–	–	X	–
Juncus marginatus	grassleaf rush	–	–	X	–
Juncus tenuis	poverty rush	–	–	X	–
Juniperus virginiana var. *virginiana*	eastern redcedar	N	X	X	X

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Justicia americana	American water–willow	N	X	X	X
Kalmia latifolia	mountain laurel	–	X	X	X
Krigia biflora	twoflower dwarfdandelion	–	–	X	X
Laportea canadensis	Canada woodnettle	–	–	X	–
Leersia oryzoides	rice cutgrass	–	–	X	–
Leersia virginica	whitegrass	–	X	X	X
Lespedeza cuneata[B]	sericea lespedeza	–	X	X	X
Lespedeza repens	creeping lespedeza	–	X	X	–
Leucanthemum vulgare[B]	oxeye daisy	–	–	X	–
Leucobryum albidum[C]	leucobryum moss	–	–	X	–
Leucobryum glaucum[C]	leucobryum moss	–	–	X	–
Leucolejeunea clypeata[C]	liverwort	–	–	X	–
Liatris scariosa var. *scariosa*	devil's bite	N	X	X	X
Ligustrum vulgare[B]	European privet	–	–	–	X
Lilium canadense	Canada lily	–	–	X	–
Lilium superbum	turk's–cap lily	–	X	–	–
Lindera benzoin	northern spicebush	–	X	X	–
Lindernia dubia	yellowseed false pimpernel	–	–	X	–
Linum striatum	ridged yellow flax	–	X	X	X
Linum virginianum	woodland flax	–	X	X	–
Liquidambar styraciflua	sweetgum	–	X	X	X
Liriodendron tulipifera	tuliptree	–	X	X	X
Lobelia cardinalis	cardinalflower	–	X	X	–
Lobelia inflata	Indian–tobacco	–	–	X	–
Lonicera japonica[B]	Japanese honeysuckle	–	–	X	X
Lonicera morrowii[B]	Morrow's honeysuckle	–	–	X	X
Ludwigia palustris	marsh seedbox	–	–	X	–

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Luzula acuminata	hairy woodrush	–	–	X	–
Luzula echinata	hedgehog woodrush	–	–	X	–
Lycopodium digitatum[C]	fan clubmoss	–	–	X	–
Lycopus sp.	water horehound	–	X	–	–
Lycopus uniflorus var. *uniflorus*	northern bugleweed	–	–	–	–
Lycopus virginicus	Virginia water horehound	–	–	X	–
Lyonia ligustrina var. *ligustrina*	maleberry	–	X	–	–
Lysimachia ciliata	fringed loosestrife	–	X	X	X
Lysimachia lanceolata	lanceleaf loosestrife	–	X	X	X
Lysimachia nummularia[B]	creeping jenny	–	X	X	X
Lysimachia quadrifolia	whorled yellow loosestrife	–	X	X	–
Magnolia acuminata	cucumber–tree	–	–	X	–
Magnolia fraseri	mountain magnolia	G	–	X	–
Magnolia tripetala	umbrella–tree	–	–	X	–
Maianthemum canadense	Canada mayflower	–	X	X	–
Maianthemum racemosum ssp. *racemosum*	feathery false lily of the valley	–	X	X	–
Marshallia grandiflora	Monongahela Barbara's buttons	N	X	X	X
Medeola virginiana	Indian cucumber	–	–	X	–
Menispermum canadense	common moonseed	–	–	X	–
Microstegium vimineum[B]	Japanese stiltgrass, Nepalese browntop	G	–	X	X
Mimulus alatus	sharpwing monkeyflower	–	–	X	–
Mimulus ringens var. *ringens*	Allegheny monkeyflower	–	–	X	–
Mitchella repens	partridgeberry	–	X	X	–
Monotropa uniflora	Indianpipe	–	–	X	–

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Muhlenbergia frondosa	wirestem muhly	–	–	X	–
Muhlenbergia schreberi	nimblewill	–	X	X	–
Muhlenbergia sylvatica	woodland muhly	–	–	X	–
Muhlenbergia tenuiflora	slender muhly	–	X	X	–
Nyssa sylvatica	blackgum	–	X	X	X
Oenothera sp.	evening–primrose	–	X	X	–
Onoclea sensibilis	sensitive fern	–	–	X	–
Osmorhiza claytonii	Clayton's sweetroot	–	–	X	–
Osmunda cinnamomea	cinnamon fern	–	–	X	–
Osmunda claytoniana	interrupted fern	–	–	X	X
Osmunda regalis var. *spectabilis*	royal fern	N	X	X	X
Oxalis sp.	woodsorrel	–	X	–	–
Oxalis dillenii	slender yellow woodsorrel	–	–	X	X
Oxalis stricta	common yellow oxalis	–	–	X	–
Oxalis violacea	violet woodsorrel	–	–	X	–
Oxydendrum arboreum	sourwood	–	X	X	–
Oxypolis rigidior	stiff cowbane	–	X	X	–
Packera (*Senecio*) *aurea*	golden ragwort	–	X	X	X
Packera obovata	roundleaf ragwort	–	X	X	–
Packera paupercula	balsam groundsel	N	X	X	X
Panax quinquefolius	American ginseng	–	–	X	–
Panicum dichotomiflorum ssp. *dichotomiflorum*	fall panicgrass	–	–	X	–
Panicum virgatum	switchgrass	–	X	X	X
Parthenocissus quinquefolia	Virginia creeper	–	X	X	–
Paulownia tomentosa[B]	princess tree	–	–	X	–
Pedicularis canadensis	Canadian lousewort	–	X	X	–

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[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Pellia epiphylla[C]	liverwort	–	–	X	–
Penthorum sedoides	ditch stonecrop	–	X	X	–
Persicaria hydropiperoides	swamp smartweed	–	–	X	–
Persicaria longiseta[B]	oriental ladysthumb	–	–	X	X
Persicaria posumbu[B] (*Polygonum caespitosum*)	oriental lady's thumb	–	X	–	X
Persicaria (*Polygonum*) *virginiana*	jumpseed	–	X	X	–
Phegopteris hexagonoptera	broad beechfern	–	–	X	–
Phlox maculata	wild sweetwilliam	N	X	X	X
Phlox maculata ssp. *pyramidalis*	wild sweetwilliam	–	–	X	–
Phlox paniculata	fall phlox	–	X	X	–
Physocarpus opulifolius	common ninebark	N	X	X	X
Physostegia virginiana	obedient plant	N	X	X	X
Pilea pumila	Canadian clearweed	–	–	X	X
Pinus rigida	pitch pine	–	X	X	X
Pinus virginiana	Virginia pine	N	X	X	X
Plagiomnium ciliare[C]	plagiomnium moss	–	–	X	–
Plantago rugelii var. *rugelii*	blackseed plantain	–	–	X	–
Platanthera sp.	fringed orchid	–	–	X	–
Platanus occidentalis	American sycamore	N	X	X	X
Poa alsodes	grove bluegrass	–	–	X	–
Poa cuspidata	early bluegrass	–	–	X	–
Podophyllum peltatum	mayapple	–	–	X	–
Polygala polygama	racemed milkwort	–	–	X	–
Polygala senega	Seneca snakeroot	–	X	X	–
Polygonatum biflorum	smooth Solomon's seal	–	X	X	–

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[B] Exotic species

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Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Polygonatum pubescens	hairy Solomon's seal	–	–	X	–
Polypodium virginianum	rock polypody	–	–	X	–
Polystichum acrostichoides	Christmas fern	–	X	X	X
Polytrichum juniperinum[C]	juniper polytrichum moss	–	–	X	–
Porella pinnata[C]	liverwort	–	–	X	–
Potentilla canadensis	dwarf cinquefoil	–	X	X	–
Potentilla simplex	common cinquefoil	–	–	X	X
Prenanthes alba	white rattlesnakeroot	–	–	X	–
Prunella vulgaris	common selfheal	–	X	X	–
Prunus pumila var. *depressa*	eastern sandcherry	N	–	–	–
Prunus pumila var. *susquehanae*	Sesquehana sandcherry	–	X	X	–
Prunus serotina var. *serotina*	black cherry	–	X	X	–
Pteridium aquilinum	western brackenfern	–	X	X	–
Pteridium aquilinum var. *latiusculum*	western brackenfern	–	–	X	–
Pylaisiadelpha tenuirostris[C]	pylaisiadelpha moss	–	–	X	–
Pyrularia pubera	buffalo nut	–	–	X	–
Quercus alba	white oak	–	X	X	–
Quercus montana (*Q. prinus*)	chestnut oak	–	X	X	X
Quercus palustris	pin oak	–	X	X	–
Quercus rubra	northern red oak	–	–	X	–
Quercus velutina	black oak	–	X	X	–
Racomitrium aciculare[C]	racomitrium moss	–	–	X	–
Ranunculus hispidus var. *hispidus*	bristly buttercup	–	X	X	–

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[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Ranunculus hispidus var. *nitidus*	bristly buttercup	–	X	X	–
Rhododendron arborescens	smooth azalea	N	X	X	X
Rhododendron calendulaceum	flame azalea	–	–	X	–
Rhododendron maximum	great laurel	–	X	X	–
Rhododendron periclymenoides	pink azalea	–	–	X	–
Rhynchospora capitellata	brownish beaksedge	–	X	X	X
Rhynchospora recognita	globe beaksedge	N	–	–	–
Rhus copallinum	flameleaf sumac	–	–	X	–
Robinia pseudoacacia	black locust	–	X	X	–
Rorippa palustris ssp. *palustris*[B]	bog yellowcress	–	–	X	–
Rosa blanda	smooth rose	–	–	–	X
Rosa carolina var. *carolina*	Carolina rose	–	X	X	X
Rosa multiflora[B]	multiflora rose	–	X	X	X
Rosa palustris	swamp rose	–	X	–	–
Rubus sp.	blackberry	–	X	–	–
Rubus flagellaris	northern dewberry	–	–	X	X
Rubus phoenicolasius[B]	wine raspberry, wineberry	–	–	X	
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	–	X	X	X
Rumex crispus[B]	curly dock	–	–	X	–
Sagittaria latifolia	broadleaf arrowhead	–	–	X	–
Salix alba[B]	white willow	–	X	X	–
Salix caroliniana	coastal plain willow	–	X	X	X
Salix fragilis[B]	crack willow	–	X	X	–
Salix nigra	black willow	–	X	X	X

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Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Salix sericea	silky willow	–	X	X	X
Salvia lyrata	lyreleaf sage	–	–	X	–
Sambucus nigra ssp. *canadensis*	common elderberry	–	–	X	–
Sanguinaria canadensis	bloodroot	–	–	X	–
Sanicula sp.	blacksnakeroot	–	–	X	–
Sassafras albidum	sassafras	–	–	X	–
Scapania nemorea[C]	liverwort	–	–	X	–
Schedonorus (*Lolium*) *arundinaceus*[B]	tall fescue	–	X	X	–
Schedonorus pratensis[B]	meadow fescue	–	–	X	X
Schistidium apocarpum[C]	schistidium moss	–	–	X	–
Schizachyrium scoparium	little bluestem	–	X	X	X
Schoenoplectus tabernaemontani	softstem bulrush	–	X	X	–
Scirpus atrovirens	green bulrush	–	–	X	–
Scirpus cyperinus	woolgrass	–	–	X	–
Scirpus polyphyllus	leafy bulrush	–	–	X	–
Scutellaria elliptica var. *hirsuta*	hairy skullcap	–	–	X	–
Scutellaria lateriflora var. *lateriflora*	blue skullcap	–	–	X	–
Sedum ternatum	woodland stonecrop	–	X	X	–
Sematophyllum demissum[C]	sematophyllum moss	–	–	X	–
Sericocarpus asteroides (*Aster paternus*)	toothed whitetop aster	–	X	X	–
Silene stellata	widowsfrill, whorled catchfly	–	–	X	–
Sisyrinchium sp.	blue–eyed grass	–	–	–	X

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[B] Exotic species

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Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Sisyrinchium angustifolium	narrowleaf blue–eyed grass	–	X	X	–
Smilax ecirrhata	upright carrionflower	–	–	X	–
Smilax glauca	cat greenbrier	–	X	X	X
Smilax herbacea	smooth carrionflower	–	X	X	–
Smilax rotundifolia	roundleaf greenbrier	–	X	X	X
Smilax tamnoides	bristly greenbrier	–	–	X	–
Solanum carolinense	Carolina horsenettle	–	–	X	–
Solidago bicolor	white goldenrod		X	X	–
Solidago caesia	wreath goldenrod	–	–	X	–
Solidago curtisii	mountain decumbent goldenrod	–	–	X	–
Solidago flexicaulis	zigzag goldenrod	–	X	X	–
Solidago gigantea	giant goldenrod	–	X	X	X
Solidago juncea	early goldenrod	–	–	X	–
Solidago rugosa	wrinkleleaf goldenrod	–	X	X	–
Solidago simplex var. *racemosa*	Rand's goldenrod	N	X	X	X
Sorghastrum nutans	Indiangrass	–	X	X	–
Sparganium emersum	European bur–reed	–	–	X	–
Sphagnum lescurii	Lescur's sphagnum	–	–	X	–
Sphagnum palustre	prairie sphagnum	–	–	X	–
Spiraea alba var. *alba*	white meadowsweet	–	–	X	–
Spiraea virginiana	Virginia spiraea	N	X	X	–
Stellaria pubera	star chickweed	–	–	X	–
Streptopus lanceolatus var. *roseus*	twistedstalk	–	–	X	–
Symphyotrichum boreale	northern bog aster	–	–	X	–

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[B] Exotic species

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Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Symphyotrichum cordifolium	common blue wood aster	–	–	X	–
Symphyotrichum dumosum var. *dumosum*	rice button aster	–	X	X	–
Symphyotrichum laeve	smooth blue aster	–	X	X	X
Symphyotrichum laeve var. *concinnum*	smooth blue aster	–	–	X	–
Symphyotrichum lanceolatum (*Aster simplex*)	white panicle aster	–	X	X	X
Symphyotrichum lateriflorum	calico aster	–	X	X	X
Symphyotrichum patens var. *patens*	late purple aster	–	–	X	–
Symphyotrichum pilosum	hairy white oldfield aster	–	–	X	–
Symphyotrichum praealtum	willowleaf aster	–	–	X	–
Symphyotrichum prenanthoides	crookedstem aster	–	X	X	X
Symphyotrichum puniceum var. *puniceum*	purplestem aster	–	X	X	–
Symphyotrichum racemosum	smooth white oldfield aster	–	–	X	–
Tephrosia virginiana	Virginia tephrosia	N	X	X	X
Tetraphis pellucida[C]	tetraphis moss	–	–	X	–
Thalictrum sp.	meadow–rue	–	X	–	X
Thalictrum clavatum	mountain meadow–rue	N	–	X	–
Thalictrum pubescens	king of the meadow	–	–	X	–
Thalictrum revolutum	waxyleaf meadow–rue	–	–	X	–
Thalictrum thalictroides	rue anemone	–	–	X	–
Thelypteris noveboracensis	New York fern	–	X	X	–

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[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Thuidium delicatulum[C]	delicate thuidium moss	–	–	X	–
Tiarella cordifolia	heartleaf foamflower	–	–	X	–
Tilia americana	American basswood	–	X	X	–
Toxicodendron radicans	eastern poison ivy	–	X	X	X
Trautvetteria caroliniensis	Carolina bugbane	N	X	X	X
Triadenum sp.	marsh St. Johnswort	–	–	X	–
Trifolium sp.[B]	clover	–	X	–	–
Trifolium pratense[B]	red clover	–	–	X	–
Trillium erectum	red trillium	–	–	X	–
Tsuga canadensis	eastern hemlock	–	X	X	X
Tussilago farfara[B]	coltsfoot	–	–	X	–
Ulmus americana	American elm	–	X	X	–
Ulmus rubra	slippery elm	–	–	X	–
Uvularia grandiflora	largeflower bellwort	–	–	X	–
Uvularia perfoliata	perfoliate bellwort	–	–	X	–
Uvularia puberula	mountain bellwort	–	X	X	–
Uvularia sessilifolia	sessileleaf bellwort	–	X	X	–
Vaccinium corymbosum	highbush blueberry	N	X	X	X
Vaccinium pallidum	Blue Ridge blueberry	–	X	X	–
Vaccinium stamineum	deerberry	–	–	X	–
Verbesina alternifolia	wingstem	–	X	X	–
Verbesina occidentalis	yellow crownbeard	–	–	X	–
Vernonia gigantea	giant ironweed	–	X	X	–
Viburnum acerifolium	mapleleaf viburnum	–	X	X	–
Viburnum lentago	nannyberry	–	X	–	–
Viburnum nudum var. *cassinoides*	possumhaw	–	X	X	X
Viburnum prunifolium	blackhaw	–	–	–	X

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[B] Exotic species

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Table D–1 (Continued). Plant species documented within Gauley River National Recreation Area riparian vegetation communities. Some species names have been updated to match accepted names in ITIS (Integrated Taxonomic Information System – https://www.itis.gov/).

Scientific Name	Common Name	Norris (1992)/Grafton (1993)[A]	Walton & Anderson (1997)	Vanderhorst et al. (2010)	ERMN (2016)
Viburnum recognitum	southern arrow–wood	–	X	X	–
Viola appalachiensis	Appalachian violet	N	–	–	X
Viola blanda	sweet white violet	–	–	X	–
Viola cucullata	marsh blue violet	–	–	X	X
Viola hastata	halberdleaf yellow violet	–	–	X	–
Viola pedata	birdfoot violet	N	X	X	X
Viola primulifolia	primrose leaf violet	–	–	X	X
Viola pubescens	downy yellow violet	–	–	X	–
Viola rotundifolia	roundleaf yellow violet	–	–	X	–
Viola sororia	common blue violet	–	–	X	–
Viola striata	striped cream violet	–	–	X	–
Vitis sp.	grape	–	–	–	X
Vitis aestivalis var. *bicolor*	summer grape	–	–	X	–
Vitis riparia	riverbank grape	–	X	X	–
Xanthium strumarium	rough cocklebur	–	–	X	–
Xanthorhiza simplicissima	yellowroot	N	X	X	X
Zizia aptera	meadow zizia	–	–	X	X
Zizia trifoliata	meadow alexanders	–	–	X	–
	Total	–	207	457	131

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[B] Exotic species

[C] Non-vascular (e.g., mosses, liverworts)

Appendix E. Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts

Table E-1. Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Empidonax virescens	Acadian flycatcher	X	X	X	X	X
Anas rubripes	American black duck	X	–	–	–	–
Fulica americana	American coot	X	–	–	–	–
Corvus brachyrhynchos	American crow	X	X	X	X	X
Spinus tristis	American goldfinch	X	X	X	X	X
Falco sparverius	American kestrel	X	–	X	–	–
Setophaga ruticilla	American redstart	X	X	X	X	X
Turdus migratorius	American robin	X	–	X	X	X
Haliaeetus leucocephalus	bald eagle	X	–	–	–	X
Icterus galbula	Baltimore oriole	X	–	X	–	–
Hirundo rustica	barn swallow	X	–	X	–	–
Strix varia	barred owl	X	–	X	X	X
Setophaga castanea	bay-breasted warbler	X	–	X	–	–
Megaceryle alcyon	belted kingfisher	X	X	X	X	X
Coragyps atratus	black vulture	X	–	X	–	–
Mniotilta varia	black-and-white warbler	X	X	X	X	X
Coccyzus erythropthalmus	black-billed cuckoo	X	–	X	–	–
Setophaga fusca	blackburnian warbler	X	–	X	–	–
Poecile atricapillus	black-capped chickadee	X	X	X	X	X
Nycticorax nycticorax	black-crowned night-heron	X	–	X	–	–
Setophaga striata	blackpoll warbler	X	–	–	–	X
Setophaga caerulescens	black-throated blue warbler	X	–	X	X	X
Setophaga virens	black-throated green warbler	X	X	X	X	X
Cyanocitta cristata	blue jay	X	X	X	X	X

Table E-1 (continued). Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Polioptila caerulea	blue-gray gnatctcher	X	–	X	X	X
Vireo solitarius	blue-headed vireo	X	X	X	X	X
Vermivora cyanoptera	blue-winged warbler	X	X	X	X	–
Buteo platypterus	broad-winged hawk	X	–	X	–	–
Certhia americana	brown creeper	X	X	X	X	X
Toxostoma rufum	brown thrasher	X	–	X	–	–
Molothrus ater	brown-headed cowbird	X	–	X	X	X
Bucephala albeola	bufflehead	X	–	–	–	–
Branta canadensis	Canada goose	X	X	X	X	–
Cardellina canadensis	Canada warbler	X	X	–	X	–
Poecile carolinensis	Carolina chickadee	X	X	X	X	X
Thryothorus ludovicianus	Carolina wren	X	X	X	X	X
Bombycilla cedrorum	cedar waxwing	X	X	X	X	X
Setophaga cerulea	cerulean warbler	X	–	X	X	X
Setophaga pensylvanica	chestnut-sided warbler	X	–	X	X	–
Chaetura pelagica	chimney swift	X	–	X	X	–
Spizella passerina	chipping sparrow	X	X	X	X	X
Petrochelidon pyrrhonota	cliff swallow	X	–	X	–	–
Quiscalus quiscula	common grackle	X	–	X	–	X
Gavia immer	common loon	X	–	–	–	–
Corvus corax	common raven	X	–	X	X	X
Geothlypis trichas	common yellowthroat	X	–	X	X	X
Accipiter cooperii	Cooper's hawk	X	–	X	–	X
Junco hyemalis	dark-eyed junco	X	X	X	X	–
Picoides pubescens	downy woodpecker	X	X	X	X	X
Sialia sialis	eastern bluebird	X	–	X	X	–
Tyrannus tyrannus	eastern kingbird	U	–	–	–	–
Sturnella magna	eastern meadowlark	X	–	X	X	–
Sayornis phoebe	eastern phoebe	X	X	X	X	X
Megascops asio	eastern screech-owl	X	–	X	X	–
Pipilo erythrophthalmus	eastern towhee	X	X	X	X	X

Table E-1 (continued). Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Contopus virens	eastern wood-pewee	X	–	X	X	X
Sturnus vulgaris	European starling	X	–	X	–	–
Spizella pusilla	field sparrow	X	–	X	X	–
Anas strepera	gadwall	X	–	–	–	–
Regulus satrapa	golden-crowned kinglet	X	–	X	X	–
Vermivora chrysoptera	golden-winged warbler	X	–	X	–	–
Ammodramus savannarum	grasshopper sparrow	X	–	X	–	–
Dumetella carolinensis	gray catbird	X	–	X	X	X
Ardea herodias	great blue heron	X	–	X	–	–
Myiarchus crinitus	great crested flycatcher	X	X	X	X	X
Ardea alba	great egret	X	–	X	–	–
Bubo virginianus	great horned owl	X	–	X	–	–
Aythya marila	greater scaup	X	–	–	–	–
Butorides virescens	green heron	X	–	X	–	–
Picoides villosus	hairy woodpecker	X	X	X	X	X
Catharus guttatus	hermit thrush	X	–	X	–	–
Lophodytes cucullatus	hooded merganser	X	–	–	–	–
Setophaga citrina	hooded warbler	X	X	X	X	X
Carpodacus mexicanus	house finch	X	–	X	–	–
Passer domesticus	house sparrow	X	–	X	–	–
Troglodytes aedon	house wren	X	–	X	–	–
Passerina cyanea	indigo bunting	X	X	X	X	X
Geothlypis formosa	Kentucky warbler	X	X	X	X	–
Charadrius vociferus	killdeer	X	–	X	–	–
Empidonax minimus	least flycatcher	X	–	X	–	–
Aythya affinis	lesser scaup	X	–	–	–	–
Melospiza lincolnii	Lincoln's sparrow	X	–	X	–	–
Parkesia motacilla	Louisiana waterthrush	X	X	X	X	X
Setophaga magnolia	magnolia warbler	X	–	X	–	–
Anas platyrhynchos	mallard	X	–	X	X	–

Table E-1 (continued). Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Zenaida macroura	mourning dove	X	–	X	X	X
Cardinalis cardinalis	northern cardinal	X	X	X	X	X
Colaptes auratus	northern flicker	X	X	X	X	X
Circus cyaneus	northern harrier	X	–	–	–	–
Mimus polyglottos	northern mockingbird	X	–	X	–	X
Setophaga americana	northern parula	X	X	X	X	X
Stelgidopteryx serripennis	northern rough-winged swallow	X	X	X	–	X
Parkesia noveboracensis	northern waterthrush	X	–	X	–	–
Oreothlypis celata	orange-crowned warbler	X	–	–	–	X
Icterus spurius	orchard oriole	X	–	X	–	–
Pandion haliaetus	osprey	X	–	X	–	–
Seiurus aurocapilla	ovenbird	X	X	X	X	X
Setophaga palmarum	palm warbler	X	–	X	–	–
Falco peregrinus	peregrine falcon	X	–	–	–	–
Podilymbus podiceps	pied-billed grebe	X	–	X	–	–
Dryocopus pileatus	pileated woodpecker	X	X	X	X	X
Setophaga pinus	pine warbler	X	–	X	X	X
Melanerpes carolinus	red-bellied woodpecker	X	–	X	X	X
Sitta canadensis	red-breasted nuthatch	X	–	X	X	–
Vireo olivaceus	red-eyed vireo	X	X	X	X	X
Aythya americana	redhead	X	–	–	–	–
Melanerpes erythrocephalus	red-headed woodpecker	X	–	X	–	–
Podiceps grisegena	red-necked grebe	X	–	–	–	–
Buteo lineatus	red-shouldered hawk	X	X	X	X	X
Buteo jamaicensis	red-tailed hawk	X	X	X	X	–
Agelaius phoeniceus	red-winged blackbird	X	–	X	X	–
Larus delawarensis	ring-billed gull	X	–	X	–	–
Aythya collaris	ring-necked duck	X	–	–	–	–
Columba livia	rock pigeon	X	–	X	–	–
Pheucticus ludovicianus	rose-breasted grosbeak	X	–	X	X	X

Table E-1 (continued). Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Regulus calendula	ruby-crowned kinglet	X	–	X	–	–
Archilochus colubris	ruby-throated hummingbird	X	–	X	X	X
Bonasa umbellus	ruffed grouse	X	–	X	–	–
Piranga olivacea	scarlet tanager	X	X	X	X	X
Accipiter striatus	sharp-shinned hawk	X	–	X	X	X
Melospiza melodia	song sparrow	X	–	X	X	X
Actitis macularius	spotted sandpiper	X	–	X	–	–
Piranga rubra	summer tanager	–	–	–	X	–
Catharus ustulatus	Swainson's thrush	X	–	X	–	–
Limnothlypis swainsonii	Swainson's warbler	X	X	–	X	X
Melospiza georgiana	swamp sparrow	X	–	X	–	–
Oreothlypis peregrina	Tennessee warbler	X	–	X	–	–
Tachycineta bicolor	tree swallow	X	–	X	–	–
Baeolophus bicolor	tufted titmouse	X	X	X	X	X
Cathartes aura	turkey vulture	X	X	X	X	X
Bartramia longicauda	upland sandpiper	X	–	X	–	–
Catharus fuscescens	veery	X	–	X	X	–
Pooecetes gramineus	vesper sparrow	X	–	X	–	–
Vireo gilvus	warbling vireo	X	–	X	–	–
Antrostomus vociferus	whip-poor-will	X	–	X	–	–
Sitta carolinensis	white-breasted nuthatch	X	–	X	X	X
Zonotrichia leucophrys	white-crowned sparrow	X	–	X	–	–
Vireo griseus	white-eyed vireo	X	–	X	–	–
Zonotrichia albicollis	white-throated sparrow	X	–	X	–	–
Meleagris gallopavo	wild turkey	X	–	X	–	–
Troglodytes hiemalis	winter wren	X	X	X	X	X
Aix sponsa	wood duck	X	–	X	–	–
Hylocichla mustelina	wood thrush	X	X	X	X	X
Helmitheros vermivorum	worm-eating warbler	X	X	X	X	X
Setophaga petechia	yellow warbler	X	–	X	–	–

Table E-1 (continued). Bird species observed in Gauley River National Recreation Area during the various avian inventory and monitoring efforts. X indicates a confirmed species and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	NPS Point Counts	Pauley et al. (2005)	Wood et al. (2009)	Marshall et al. (2013)
Sphyrapicus varius	yellow-bellied sapsucker	X	–	X	–	–
Coccyzus americanus	yellow-billed cuckoo	X	X	X	X	X
Setophaga coronata	yellow-rumped warbler	X	–	–	–	X
Vireo flavifrons	yellow-throated vireo	X	–	X	X	X
Setophaga dominica	yellow-throated warbler	X	–	X	X	X
Confirmed species	–	**148**	**45**	**129**	**76**	**66**
Unconfirmed species	–	**1**	**0**	**0**	**0**	**0**

Appendix F. Avian species detected with unlimited radius on 36 point counts from 1999-2008 at Gauley River National Recreation Area and NERI

Table F-1. Avian species detected with unlimited radius on 36 point counts from 1999-2008 at Gauley River National Recreation Area and NERI (reproduced from Wood et al. 2009).

Scientific Name	Common Name	Avg. annual # of Detections			
		Mean	SE	Min	Max
Seiurus aurocapillus	ovenbird	52.1	2.18	43	62
Vireo olivaceus	red-eyed vireo	48.6	4.68	34	81
Hylocichla mustelina	wood thrush	47.0	2.95	32	69
Wilsonia citrina	hooded warbler	45.8	2.33	34	56
Piranga olivacea	scarlet tanager	37.4	1.89	29	47
Corvus brachyrhynchos	American crow	29.3	2.56	16	41
Vireo solitarius	blue-headed vireo	23.8	1.76	14	32
Setophaga virens	black-throated green warbler	20.8	2.36	13	32
Cyanocitta cristata	blue jay	20.7	1.37	16	31
Empidonax virescens	acadian flycatcher	20.5	3.10	12	44
Baeolophus bicolor	eastern tufted titmouse	19.6	2.20	9	30
Parula americana	northern parula	12.4	1.29	7	18
Limnothlypis swainsonii	Swainson's warbler	12.1	0.99	8	18
Thryothorus ludovicianus	Carolina wren	11.1	1.60	2	18
Cardinalis cardinalis	northern cardinal	11.1	1.35	6	18
Poecile carolinensis	Carolina chickadee	10.8	2.56	3	25
Dryocopus pileatus	pileated woodpecker	10.6	1.02	7	16
Mniotilta varia	black-and-white warbler	10.4	1.12	4	16
Sitta carolinensis	white-breasted nuthatch	9.3	1.41	3	16
Pipilo erythrophthalmus	eastern towhee	6.5	1.04	3	14
Helmitheros vermivorus	worm-eating warbler	5.9	1.39	0	15
Turdus migratorius	American robin	5.6	0.60	3	9
Contopus virens	eastern wood pewee	4.7	1.22	1	11
Picoides villosus	hairy woodpecker	4.7	1.23	1	13
Carduelis tristis	American goldfinch	3.5	1.40	0	14
Sayornis phoebe	eastern phoebe	3.4	0.85	0	8
Melanerpes carolinus	red-bellied woodpecker	3.4	0.79	1	9

Table F-1 (continued). Avian species detected with unlimited radius on 36 point counts from 1999-2008 at Gauley River National Recreation Area and NERI (reproduced from Wood et al. 2009).

Scientific Name	Common Name	Avg. annual # of Detections			
		Mean	SE	Min	Max
Colaptes auratus	northern flicker	3.1	0.92	0	9
Picoides pubescens	downy woodpecker	3.0	0.77	0	7
Passerina cyanea	indigo bunting	2.5	0.34	1	4
Seiurus motacilla	Louisiana waterthrush	2.4	0.72	0	6
Coccyzus americanus	yellow-billed cuckoo	2.4	0.60	1	7
Myiarchus crinitus	great crested flycatcher	2.2	0.49	0	5
Melospiza melodia	song sparrow	2.2	0.33	0	3
Setophaga caerulescens	black-throated blue warbler	2.0	0.63	0	6
Poecile atricapillus	black-capped chickadee	1.8	1.15	0	12
Zenaida macroura	mourning dove	1.8	0.47	0	5
Buteo lineatus	red-shouldered hawk	1.7	0.40	0	4
Molothrus ater	brown-headed cowbird	1.6	0.56	0	5
Corvus corax	common raven	1.5	0.52	0	5
Geothlypis trichas	common yellowthroat	1.5	0.40	0	4
Vireo flavifrons	yellow-throated vireo	1.4	0.60	0	6
Setophaga dominica	yellow-throated warbler	1.4	0.48	0	4
Setophaga ruticilla	American redstart	0.9	0.53	0	5
Strix varia	barred owl	0.9	0.31	0	3
Junco hyemalis	dark-eyed junco	0.8	0.42	0	4
Oporornis formosus	Kentucky warbler	0.8	0.33	0	3
Troglodytes troglodytes	winter wren	0.8	0.33	0	3
Setophaga cerulea	cerulean warbler	0.7	0.52	0	5
Spizella passerina	chipping sparrow	0.6	0.27	0	2
Spizella pusilla	field sparrow	0.6	0.22	0	2
Branta canadensis	Canada goose	0.4	0.27	0	2
Pheucticus ludovicianus	rose-breasted grosbeak	0.4	0.16	0	1
Verminora pinus	blue-winged warbler	0.3	0.15	0	1
Bombycilla cedrorum	cedar waxwing	0.3	0.21	0	2
Chaetura pelagica	chimney swift	0.3	0.15	0	1
Setophaga pinus	pine warbler	0.3	0.15	0	1
Archilochus colubris	ruby-throated hummingbird	0.3	0.15	0	1

Table F-1 (continued). Avian species detected with unlimited radius on 36 point counts from 1999-2008 at Gauley River National Recreation Area and NERI (reproduced from Wood et al. 2009).

Scientific Name	Common Name	Avg. annual # of Detections			
		Mean	SE	Min	Max
Piranga rubra	summer tanager	0.3	0.15	0	1
Cardellina canadensis	Canada warbler	0.2	0.20	0	2
Setophaga pensylvanica	chestnut-sided warbler	0.2	0.13	0	1
Cathartes aura	turkey vulture	0.2	0.20	0	2
Catharus fuscescens	veery	0.2	0.13	0	1
Ceryle alcyon	belted kingfisher	0.1	0.10	0	1
Polioptila caerulea	blue-gray gnatcatcher	0.1	0.10	0	1
Certhia americana	brown creeper	0.1	0.10	0	1
Sialia sialis	eastern bluebird	0.1	0.10	0	1
Sturnella magna	eastern meadowlark	0.1	0.10	0	1
Otus asio	eastern screech owl	0.1	0.10	0	1
Regulus satrapa	golden-crowned kinglet	0.1	0.10	0	1
Dumetella carolinensis	gray catbird	0.1	0.10	0	1
Anas platyrhynchos	mallard	0.1	0.10	0	1
Sitta canadensis	red-breasted nuthatch	0.1	0.10	0	1
Buteo jamaicensis	red-tailed hawk	0.1	0.10	0	1
Agelaius phoeniceus	red-winged blackbird	0.1	0.10	0	1
Accipiter striatus	sharp-shinned hawk	0.1	0.10	0	1

Appendix G. Bird species detected and the total number of detections in Gauley River National Recreation Area

Table G-1. Bird species detected and the total number of detections in Gauley River National Recreation Area from 2007-2012. Appendix modified from Marshall et al. (2013). Species of continental and/or regional conservation importance have table notes and are in bold.

Scientific Name	Common Name	# of Ind.
Setophaga citrina	**hooded warbler[B]**	**296**
Vireo olivaceus	red-eyed vireo	191
Empidonax virescens	**Acadian flycatcher[B,C]**	**174**
Seiurus aurocapilla	ovenbird	158
Parkesia motacilla	**Louisiana waterthrush[B,C]**	**157**
Piranga olivacea	scarlet tanager	125
Parula americana	northern parula	104
Limnothlypis swainsonii	**Swainson's warbler[A,B]**	**104**
Hylocichla mustelina	**wood thrush[A,B,C]**	**104**
Setophaga virens	black-throated green warbler	97
Corvus brachyrhynchos	American crow	96
Baeolophus bicolor	tufted titmouse	81
Mniotilta varia	**black-and-white warbler[C]**	**68**
Vireo solitarius	blue-headed vireo	63
Cyanocitta cristata	blue jay	60
Poecile carolinensis	Carolina chickadee	56
Cardinalis cardinalis	northern cardinal	56
Sayornis phoebe	eastern phoebe	54
–	unknown bird	52
Setophaga ruticilla	American redstart	51
Thryothorus ludovicianus	**Carolina wren[B]**	**50**
Dryocopus pileatus	pileated woodpecker	49
Passerina cyanea	**indigo bunting[B]**	**30**
Pipilo erythrophthalmus	**eastern towhee[B,C]**	**28**
Setophaga dominica	**yellow-throated warbler[B]**	**28**

[A] Partners in Flight (PIF) Species of Continental Conservation Importance Watchlist Species (multiple reasons for conservation concern across its range)

[B] PIF Stewardship Species (proportionately high percentage of their world population within the Eastern Avifaunal Biome)

[C] PIF Regional Concern Species (Appalachian Mountains Bird Conservation Region [BCR 28])

Table G-1 (continued). Bird species detected and the total number of detections in Gauley River National Recreation Area from 2007-2012. Appendix modified from Marshall et al. (2013). Species of continental and/or regional conservation importance have table notes and are in bold.

Scientific Name	Common Name	# of Ind.
Turdus migratorius	American robin	23
Picoides pubescens	downy woodpecker	23
Contopus virens	**eastern wood-pewee[C]**	**18**
Colaptes auratus	**northern flicker[C]**	**16**
Spinus tristis	American goldfinch	15
Bombycilla cedrorum	cedar waxwing	15
Troglodytes hiemalis	winter wren	13
Polioptila caerulea	blue-gray gnatcatcher	11
Myiarchus crinitus	great crested flycatcher	11
Sitta carolinensis	white-breasted nuthatch	11
Picoides villosus	hairy woodpecker	10
Vireo flavifrons	**yellow-throated vireo[B,C]**	**10**
Setophaga caerulescens	black-throated blue warbler	9
Molothrus ater	brown-headed cowbird	9
Melospiza melodia	song sparrow	9
Melanerpes carolinus	**red-bellied woodpecker[B]**	**8**
Archilochus colubris	ruby-throated hummingbird	7
Coccyzus americanus	yellow-billed cuckoo	7
Setophaga cerulea	**cerulean warbler[A,B,C]**	**6**
Spizella passerina	chipping sparrow	6
Zenaida macroura	mourning dove	6
–	unknown woodpecker	6
Buteo lineatus	**red-shouldered hawk[B]**	**5**
Helmitheros vermivorum	**worm-eating warbler[A,B,C]**	**4**
Strix varia	barred owl	3
Corvus corax	common raven	3
Dumetella carolinensis	gray catbird	3
Geothlypis trichas	common yellowthroat	2

[A] Partners in Flight (PIF) Species of Continental Conservation Importance Watchlist Species (multiple reasons for conservation concern across its range)

[B] PIF Stewardship Species (proportionately high percentage of their world population within the Eastern Avifaunal Biome)

[C] PIF Regional Concern Species (Appalachian Mountains Bird Conservation Region [BCR 28])

Table G-1 (continued). Bird species detected and the total number of detections in Gauley River National Recreation Area from 2007-2012. Appendix modified from Marshall et al. (2013). Species of continental and/or regional conservation importance have table notes and are in bold.

Scientific Name	Common Name	# of Ind.
Stelgidopteryx serripennis	northern rough-winged swallow	2
Setophaga coronata	yellow-rumped warbler	2
Haliaeetus leucocephalus	bald eagle	1
Megaceryle alcyon	belted kingfisher	1
Poecile atricapillus	black-capped chickadee	1
Setophaga striata	blackpoll warbler	1
Certhia americana	brown creeper	1
Quiscalus quiscula	common grackle	1
Accipiter cooperii	cooper's hawk	1
Mimus polyglottos	northern mockingbird	1
Oreothlypis celata	orange-crowned warbler	1
Setophaga pinus	**pine warbler[B]**	**1**
Pheucticus ludovicianus	rose-breasted grosbeak	1
Accipiter striatus	sharp-shinned hawk	1
Cathartes aura	turkey vulture	1
Total		**2618**

[A] Partners in Flight (PIF) Species of Continental Conservation Importance Watchlist Species (multiple reasons for conservation concern across its range)

[B] PIF Stewardship Species (proportionately high percentage of their world population within the Eastern Avifaunal Biome)

[C] PIF Regional Concern Species (Appalachian Mountains Bird Conservation Region [BCR 28])

Appendix H. Mammal species occurring at Gauley River National Recreation Area

Table H-1. Mammal species occurring at Gauley River National Recreation Area according to NPSpecies (NPS 2016d) and species observed by Pauley et al. (2005) during 2000-2001 sampling.

Scientific Name	Common Name	Pauley et al. (2005)	
		2000	2001
Odocoileus virginianus	white-tailed deer	X	X
Canis latrans	coyote	–	X
Urocyon cinereoargenteus	gray fox	–	–
Vulpes vulpes	red fox	X	X
Felis catus[A]	domestic/feral cat	–	X
Lynx rufus	bobcat	X	X
Mephitis mephitis	striped skunk	–	X
Mustela frenata	long-tailed weasel	X	–
Neovison vison	American mink	–	X
Procyon lotor	raccoon	X	X
Ursus americanus	American black bear	X	X
Corynorhinus rafinesquii[B]	Rafinesque's big-eared bat	–	X
Eptesicus fuscus	big brown bat	–	X
Lasionycteris noctivagans	silver-haired bat	–	–
Lasiurus borealis	eastern red bat	–	X
Lasiurus cinereus	hoary bat	–	X
Myotis leibii	eastern small-footed myotis	X	X
Myotis lucifugus	little brown myotis/bat	X	X
Myotis septentrionalis	northern myotis	–	–
Myotis sodalis	Indiana myotis/bat	–	–
Perimyotis subflavus	tricolored bat (eastern pipistrelle)	X	X
Didelphis virginiana	Virginia opossum	X	X
Sylvilagus floridanus	eastern cottontail	X	X
Castor canadensis	American beaver	–	–
Myodes gapperi	southern red-backed vole	–	X
Neotoma magister	Allegheny woodrat	–	X
Peromyscus leucopus	white-footed deermouse	X	X
Peromyscus maniculatus	North American deermouse	–	–

[A] Non-native

[B] Considered "unconfirmed" by NPSpecies

Table H-1 (continued). Mammal species occurring at Gauley River National Recreation Area according to NPSpecies (NPS 2016d) and species observed by Pauley et al. (2005) during 2000-2001 sampling.

Scientific Name	Common Name	Pauley et al. (2005)	
		2000	2001
Napaeozapus insignis	woodland jumping mouse	X	X
Mus musculus[A]	house mouse	–	X
Rattus norvegicus[A]	Norway rat	–	X
Glaucomys volans	southern flying squirrel	–	X
Marmota monax	woodchuck, groundhog	–	X
Sciurus carolinensis	eastern gray squirrel	X	X
Sciurus niger	eastern fox squirrel	X	X
Tamias striatus	eastern chipmunk	X	X
Tamiasciurus hudsonicus	red squirrel	X	X
Blarina brevicauda	northern short-tailed shrew	X	X
Cryptotis parva	North American least shrew	–	X
Sorex cinereus	cinereus (masked) shrew	–	X
Sorex dispar	long-tailed shrew	–	X
Sorex fumeus	smoky shrew	–	X
Sorex hoyi	American pygmy shrew	–	X
Parascalops breweri	hairy-tailed mole	–	X

[A] Non-native

[B] Considered “unconfirmed” by NPSpecies

Appendix I. Herpetofauna species of Gauley River National Recreation Area

Table I-1. Herpetofauna species of Gauley River National Recreation Area (Pauley et al. 2005, NPS 2016d). Abundances are from NPSpecies (NPS 2016d) and state ranks are from the WVDNR (2015). Ranks are only given for species with a rank of S3 or higher.

Group	Scientific Name	Common Name	Abundance	State Rank[A]
Reptiles	*Carphophis amoenus amoenus*	eastern worm snake	Uncommon	S3
	Coluber constrictor constrictor	northern black racer	Uncommon	–
	Diadophis punctatus edwardsii	northern ringneck snake	Uncommon	–
	Lampropeltis triangulum triangulum	eastern milk snake	Uncommon	–
	Nerodia sipedon sipedon	common water snake	Uncommon	–
	Pantherophis (Elaphe) alleghaniensis	eastern ratsnake	Uncommon	–
	Regina septemvittata	queen snake	Uncommon	–
	Storeria dekayi dekayi	northern brown snake	Rare	–
	Storeria occipitomaculata occipitomaculata	northern redbelly snake	Rare	–
	Thamnophis sirtalis sirtalis	common garter snake	Common	–
	Agkistrodon contortrix mokasen	northern copperhead	Common	–
	Crotalus horridus	timber rattlesnake	Uncommon	S3
	Sceloporus undulatus	eastern fence lizard	Common	–
	Eumeces fasciatus	five-lined skink	Common	–
	Eumeces laticeps	broad-headed skink	–	S2
	Chelydra serpentina	common snapping turtle	Uncommon	–
	Graptemys geographica	northern map turtle	Uncommon	S1
	Terrapene carolina carolina	eastern box turtle	Common	–
	Apalone spinifera spinifera	eastern spiny softshell	Uncommon	–
Amphibians	*Anaxyrus americanus americanus*	eastern American toad	Common	–
	Anaxyrus fowleri	Fowler's toad	Uncommon	–
	Hyla chrysoscelis	Cope's gray treefrog	Common	–
	Pseudacris brachyphona	mountain chorus frog	Uncommon	–
	Pseudacris crucifer	northern spring peeper	Common	–
	Lithobates catesbeianus	American bullfrog	Uncommon	–

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation

Table I-1 (continued). Herpetofauna species of Gauley River National Recreation Area (Pauley et al. 2005, NPS 2016d). Abundances are from NPSpecies (NPS 2016d) and state ranks are from the WVDNR (2015). Ranks are only given for species with a rank of S3 or higher.

Group	Scientific Name	Common Name	Abundance	State Rank[A]
Amphibians (continued)	*Lithobates clamitans melanota*	northern green frog	Common	–
	Lithobates palustris	pickerel frog	Uncommon	–
	Lithobates sylvaticus	wood frog	Common	–
	Ambystoma jeffersonianum	Jefferson salamander	Uncommon	S2
	Ambystoma maculatum	spotted salamander	Common	–
	Aneides aeneus	green salamander	Common	S3
	Desmognathus fuscus	northern dusky salamander	Abundant	–
	Desmognathus monticola	seal salamander	Abundant	–
	Desmognathus ochrophaeus	Allegheny Mountain dusky salamander	Common	–
	Desmognathus quadramaculatus	black-bellied salamander	Uncommon	S3
	Eurycea bislineata	northern two-lined salamander	–	–
	Eurycea cirrigera	southern two-lined salamander	Common	–
	Eurycea longicauda	long-tailed salamander	Uncommon	–
	Gyrinophilus porphyriticus porphyriticus	northern spring salamander	Common	–
	Hemidactylium scutatum	four-toed salamander	Common	–
	Plethodon cinereus	eastern red-backed salamander	Abundant	–
	Plethodon electromorphus	northern ravine salamander	Uncommon	–
	Plethodon glutinosus	northern slimy salamander	Abundant	–
	Plethodon wehrlei	Wehrle's salamander	Rare	–
	Pseudotriton ruber ruber	northern red salamander	Uncommon	S3
	Notophthalmus viridescens viridescens	red-spotted newt	Common	–

[A] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation

Appendix J. Abundance of herpetofauna species at Gauley River National Recreation Area by terrestrial habitat type

Table J-1. Abundance of herpetofauna species at Gauley River National Recreation Area by terrestrial habitat type, as observed from 1999-2004 by Pauley et al. (2005). Column headings/habitat types are: DF – Deciduous forests, F/RW – Fields/Rights-of-way, ER/BF – Emergent rocks/Boulder Fields, RO – Rock outcrops, RP – Rock piles, RR – Railroads, RRT – Railroad tunnels, TRB – Trails/Roads and banks.

Group	Species	DF	F/RW	ER/BF	RO	RP	RR	RRT	TRB	Total
Reptiles[A]	northern copperhead	0	2	0	2	8	0	0	6	**18**
	eastern wormsnake	0	1	0	0	0	0	0	5	**6**
	northern black racer	0	4	0	1	0	3	0	6	**14**
	timber rattlesnake	2	0	0	1	1	2	0	0	**6**
	northern ringneck snake	2	4	0	1	1	0	0	1	**9**
	eastern ratsnake	1	0	0	0	0	0	0	3	**4**
	eastern milk snake	0	0	0	0	0	0	0	4	**4**
	common water snake	0	1	0	0	0	0	0	0	**1**
	northern redbelly snake	0	0	0	0	1	0	0	0	**1**
	common garter snake	2	0	0	0	3	0	0	13	**18**
	five-lined skink	3	0	0	0	0	37	0	4	**44**
	eastern fence lizard	6	10	2	2	4	1	0	3	**28**
	eastern box turtle	8	3	0	0	0	2	0	1	**14**
Amphibians	spotted salamander	0	0	0	0	0	0	0	2	**2**
	green salamander	2	0	5	24	0	0	0	0	**31**
	northern dusky salamander	0	0	0	0	0	0	1	4	**5**
	seal salamander	0	0	0	4	0	0	0	0	**4**
	northern two-lined salamander	9	1	0	0	1	0	0	0	**11**
	long-tailed salamander	2	0	1	1	0	0	0	0	**4**

[A] Pauley et al. (2005) also recorded one northern brown snake but did not report what habitat it was found in.

Table J-1 (continued). Abundance of herpetofauna species at Gauley River National Recreation Area by terrestrial habitat type, as observed from 1999-2004 by Pauley et al. (2005). Column headings/habitat types are: DF – Deciduous forests, F/RW – Fields/Rights-of-way, ER/BF – Emergent rocks/Boulder Fields, RO – Rock outcrops, RP – Rock piles, RR – Railroads, RRT – Railroad tunnels, TRB – Trails/Roads and banks.

Group	Species	DF	F/RW	ER/BF	RO	RP	RR	RRT	TRB	Total
Amphibians (continued)	northern spring salamander	0	0	0	0	0	0	2	0	**2**
	red-spotted newt	25	1	1	9	0	0	0	27	**63**
	eastern red-backed salamander	30	0	0	3	0	0	0	5	**38**
	northern slimy salamander	22	1	0	9	0	0	0	1	**33**
	northern ravine salamander	4	0	0	0	0	0	0	0	**4**
	Wehrle's salamander	2	0	0	0	0	0	0	0	**2**
	northern red salamander	3	0	0	1	0	0	0	1	**5**
	Cope's gray treefrog	1	2	0	1	0	0	0	1	**5**
	mountain chorus frog	0	1	0	0	0	0	0	4	**5**
	northern spring peeper	1	0	0	0	1	0	1	3	**6**
	northern green frog	0	1	1	0	0	0	0	2	**4**
	pickerel frog	0	0	0	2	0	0	0	2	**4**
	wood frog	0	1	0	0	0	0	2	2	**5**
	eastern American toad	1	2	0	3	0	0	1	17	**24**
	Fowler's toad	1	1	0	0	0	0	0	0	**2**
Totals	**–**	**127**	**36**	**10**	**64**	**20**	**45**	**7**	**117**	**426**

[A] Pauley et al. (2005) also recorded one northern brown snake but did not report what habitat it was found in.

Appendix K. Abundance of herpetofauna species at Gauley River National Recreation Area by aquatic habitat type

Table K-1. Abundance of herpetofauna species at Gauley River National Recreation Area by aquatic habitat type, as observed from 1999-2004 by Pauley et al. (2005). Column headings/habitat types are: EP – Ephemeral pools, PP – permanent pools, RP – Road-rut pools, S/S – Springs/Seeps, WRF – Wet rock faces, FOS – 1st order streams, SOS – 2nd order streams, TOS – 3rd order streams, RIV – Gauley and Meadow Rivers, FSD – Flood scar depressions, RF – Riparian floodplains

Group	Species	EP	PP	RP	S/S	WRF	FOS	SOS	TOS	RIV	FSD	RF	Totals
Reptiles	northern copperhead	0	0	0	0	1	0	0	0	0	0	0	**1**
	eastern wormsnake	0	0	5	0	0	0	0	0	0	0	0	**5**
	northern black racer	0	0	0	0	0	0	1	0	0	0	0	**1**
	northern ringneck snake	0	0	0	1	0	0	0	0	0	0	0	**1**
	eastern ratsnake	0	0	0	0	0	0	0	0	2	0	1	**3**
	common water snake	0	1	1	0	0	0	0	0	1	1	1	**5**
	queen snake	0	0	1	0	0	0	0	0	2	0	0	**3**
	common garter snake	0	0	1	0	0	0	0	0	0	0	0	**1**
	five-lined skink	0	0	3	0	1	0	1	0	0	0	0	**5**
	broad-headed skink	0	0	1	0	0	0	0	0	0	0	0	**1**
	eastern fence lizard	0	0	0	0	2	0	0	0	0	0	0	**2**
	eastern spiny softshell	0	0	0	0	0	0	0	0	2	0	0	**2**
	common snapping turtle	0	0	0	0	0	0	0	0	1	0	0	**1**
	northern map turtle	0	1	0	0	0	0	0	0	6	2	0	**9**
	eastern box turtle	0	0	4	0	0	2	0	0	0	0	2	**8**
Amphibians	Jefferson salamander	0	0	3	0	0	0	0	0	0	0	0	**3**
	spotted salamander	0	0	10	0	0	1	0	0	0	0	0	**11**
	green salamander	0	0	0	0	0	0	1	0	0	0	0	**1**
	northern dusky salamander	1	2	19	30	0	17	0	2	0	0	0	**71**

Table K-1 (continued). Abundance of herpetofauna species at Gauley River National Recreation Area by aquatic habitat type, as observed from 1999-2004 by Pauley et al. (2005). Column headings/habitat types are: EP – Ephemeral pools, PP – permanent pools, RP – Road-rut pools, S/S – Springs/Seeps, WRF – Wet rock faces, FOS – 1st order streams, SOS – 2nd order streams, TOS – 3rd order streams, RIV – Gauley and Meadow Rivers, FSD – Flood scar depressions, RF – Riparian floodplains

Group	Species	EP	PP	RP	S/S	WRF	FOS	SOS	TOS	RIV	FSD	RF	Totals
Amphibians (continued)	seal salamander	0	0	5	3	13	59	23	13	0	0	0	**116**
	Allegheny Mountain dusky salamander	0	0	4	3	0	1	0	0	0	0	0	**8**
	black-bellied salamander	0	0	4	3	0	1	0	2	0	0	4	**14**
	northern two-lined salamander	0	0	2	2	0	28	1	10	0	0	0	**43**
	long-tailed salamander	0	0	0	1	0	0	1	0	0	0	0	**2**
	northern spring salamander	0	0	3	3	1	0	1	0	0	0	0	**8**
	four-toed salamander	0	0	8	0	0	0	0	0	0	0	0	**8**
	red-spotted newt	3	0	38	0	0	5	1	0	0	3	0	**50**
	eastern red-backed salamander	0	0	6	0	0	3	0	0	0	0	0	**9**
	northern slimy salamander	0	0	2	0	0	0	1	0	0	0	1	**4**
	northern red salamander	0	0	2	1	1	0	0	1	0	0	0	**5**
	Cope's gray treefrog	2	0	62	0	0	0	0	0	0	0	0	**64**
	mountain chorus frog	0	0	11	0	0	0	0	0	0	0	0	**11**
	northern spring peeper	3	0	27	0	0	0	0	0	0	0	0	**30**
	American bullfrog	0	0	4	0	1	0	0	0	0	1	0	**6**
	northern green frog	3	0	16	1	0	3	1	0	0	3	0	**27**
	pickerel frog	0	0	6	0	0	1	0	0	1	0	0	**8**
	wood frog	0	0	28	0	0	0	0	0	0	0	1	**29**
	eastern American toad	1	0	7	0	0	0	0	0	0	0	0	**8**
	Fowler's toad	1	0	1	0	0	0	0	0	0	0	1	**3**
Totals	**–**	**14**	**4**	**284**	**48**	**20**	**121**	**32**	**28**	**15**	**10**	**11**	**587**

Appendix L. Number of habitat types where each herpetofauna species was observed within Gauley River National Recreation Area

Table L-1. Number of habitat types where each herpetofauna species was observed within Gauley River National Recreation Area by Pauley et al. (2005).

Group	Species	Total Habitat Types	Terrestrial Types	Aquatic Types
Reptiles	eastern fence lizard	8	7	1
	eastern box turtle	7	4	3
	five-lined skink	6	3	3
	northern ringneck snake	6	5	1
	common water snake	6	1	5
	northern copperhead	5	4	1
	northern black racer	5	4	1
	eastern ratsnake	4	2	2
	common garter snake	4	3	1
	timber rattlesnake	4	4	0
	eastern wormsnake	3	2	1
	northern map turtle	3	0	3
	queen snake	2	0	2
	eastern milk snake	1	1	0
	northern redbelly snake	1	1	0
	eastern spiny softshell	1	0	1
	common snapping turtle	1	0	1
	broad-headed skink	1	0	1
Amphibians	red-spotted newt	10	5	5
	northern green frog	9	3	6
	northern dusky salamander	8	2	6
	northern slimy salamander	7	4	3
	northern two-lined salamander	7	3	4
	northern red salamander	7	3	4
	eastern American toad	7	5	2
	seal salamander	7	1	6
	Cope's gray treefrog	6	4	2
	northern spring peeper	6	4	2
	long-tailed salamander	5	3	2

Table L-1 (continued). Number of habitat types where each herpetofauna species was observed within Gauley River National Recreation Area by Pauley et al. (2005).

Group	Species	Total Habitat Types	Terrestrial Types	Aquatic Types
Amphibians (continued)	eastern red-backed salamander	5	3	2
	wood frog	5	3	2
	pickerel frog	5	2	3
	Fowler's toad	5	2	3
	northern spring salamander	5	1	4
	black-bellied salamander	5	0	5
	green salamander	4	3	1
	mountain chorus frog	3	2	1
	spotted salamander	3	1	2
	Allegheny Mountain dusky salamander	3	0	3
	American bullfrog	3	0	3
	northern ravine salamander	1	1	0
	Wehrle's salamander	1	1	0
	four-toed salamander	1	0	1
	Jefferson salamander	1	0	1

Appendix M. Observation locations for herpetofauna species at Gauley River National Recreation Area

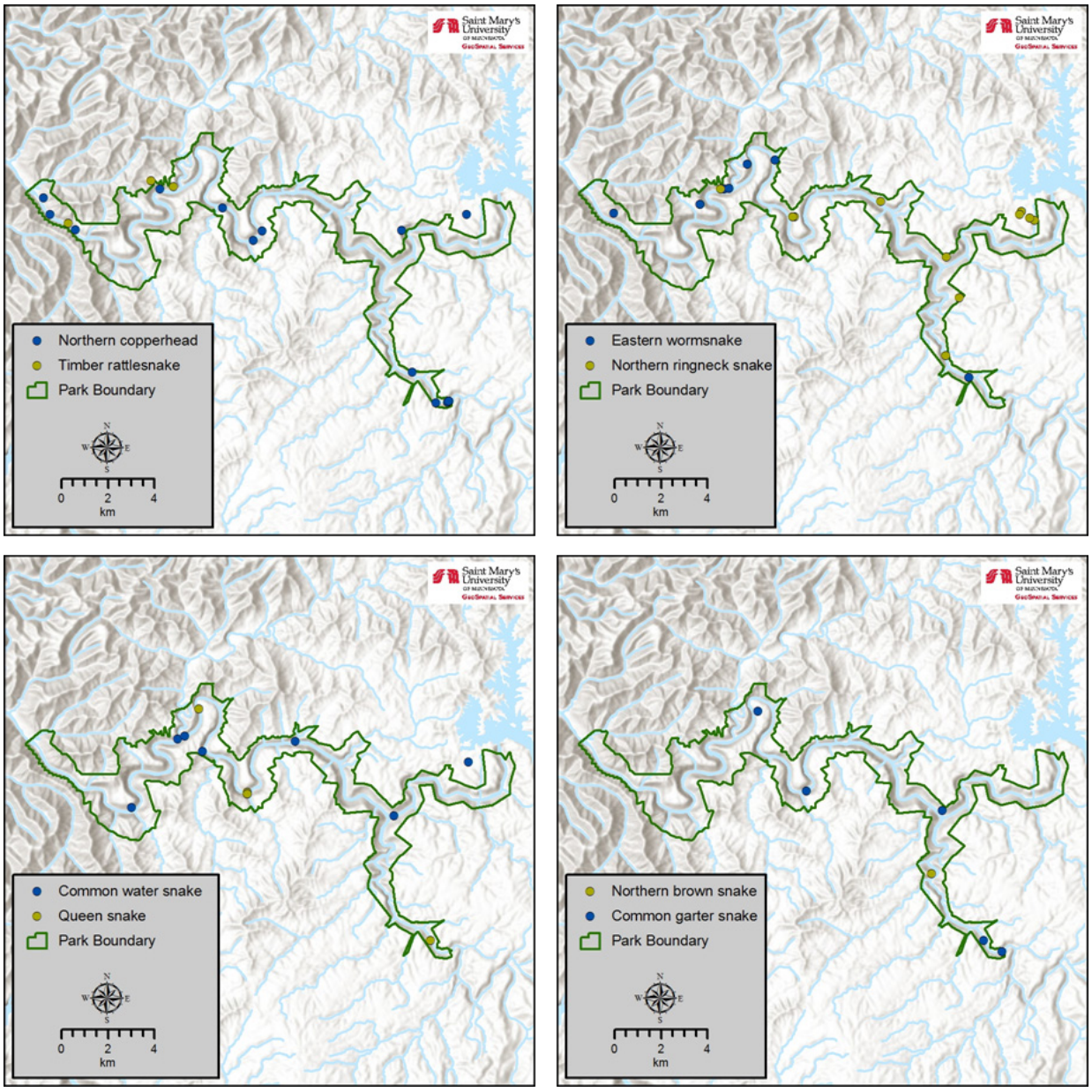


Figure M-1. Sampling locations where eight different snake species were observed within Gauley River National Recreation Area (Pauley et al. 2005).

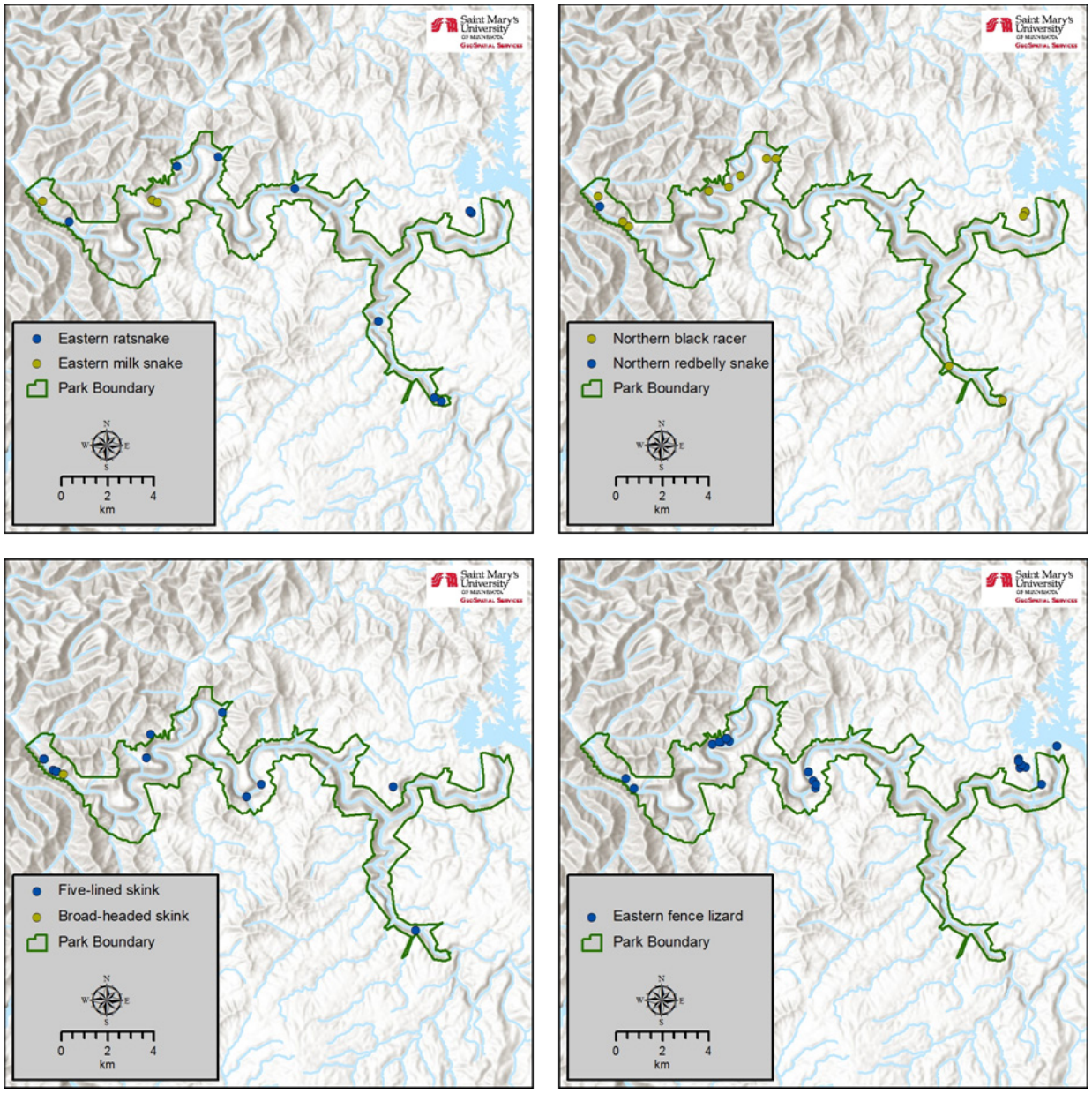


Figure M-2. Sampling locations where four snake species and three lizard species were observed within Gauley River National Recreation Area (Pauley et al. 2005).

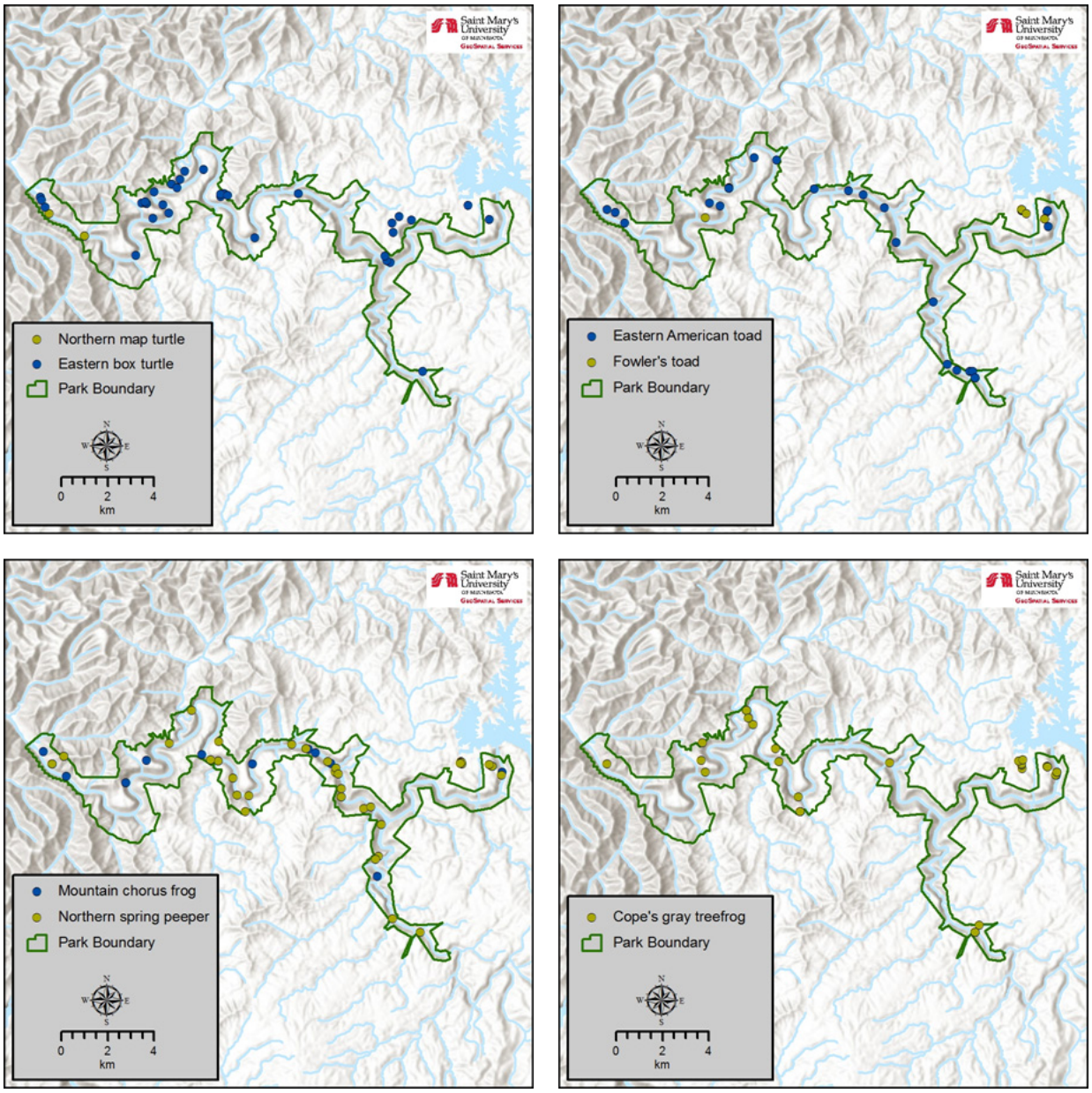


Figure M-3. Sampling locations where turtle (upper left), toad (upper right), and several frog species (bottom) were observed within Gauley River National Recreation Area (Pauley et al. 2005). Note that locations were not available for the other two turtle species documented (common snapping turtle [*Chelydra serpentina*] and eastern spiny softshell [*Apalone spinifera spinifera*].

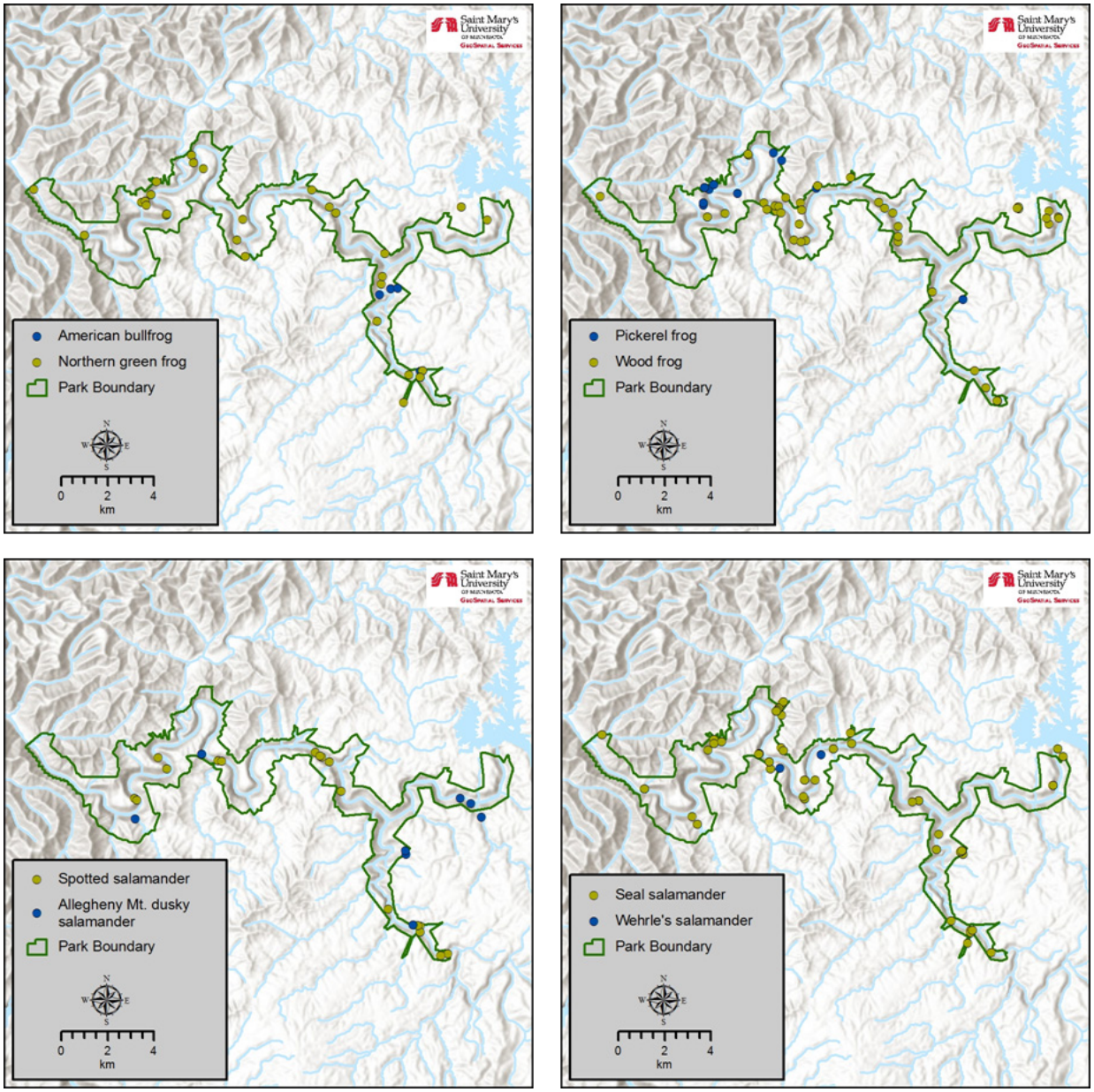


Figure M-4. Sampling locations where different frog (top) and salamander (bottom) species were observed within Gauley River National Recreation Area (Pauley et al. 2005).

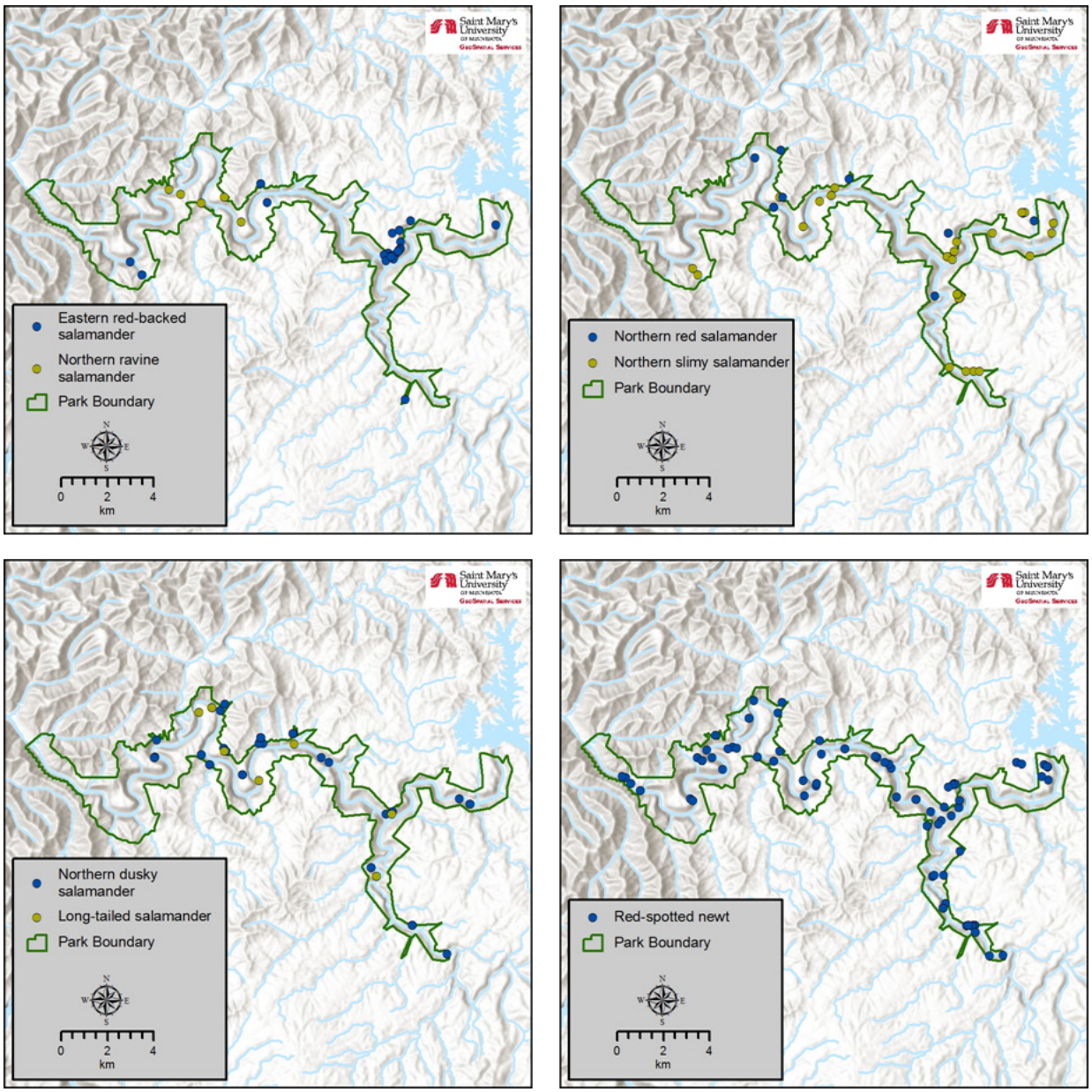


Figure M-5. Sampling locations where several salamander species were observed within Gauley River National Recreation Area (Pauley et al. 2005).

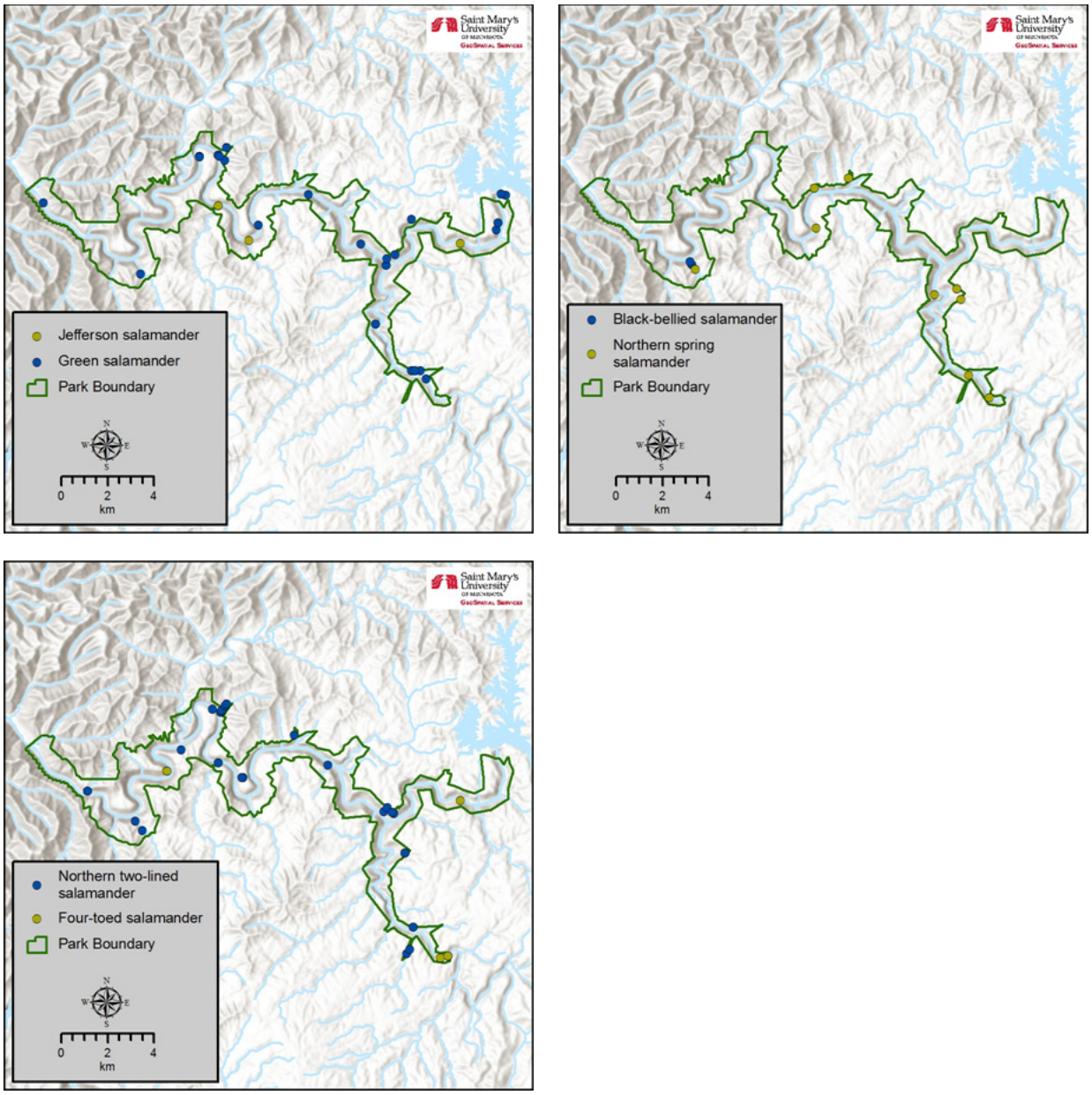


Figure M-6. Sampling locations where several salamander species were observed within Gauley River National Recreation Area (Pauley et al. 2005).

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