National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

New River Gorge National River

Natural Resource Report NPS/NERI/NRR—2018/1622

ON THE COVER

Red trillium (Trillium erectum) and Pink Lady Slipper (Cypridedium acaule) blooming at Kate's Branch wetland, May 2017 (left, top right, ©LAYNE STRICKLER). Water Stargrass (Heteranthera dubia) blooming, the New River at Stonecliff, August 2017 (©BRIANA CAIRCO AND KELLY BROWN). These species represent the plant diversity present within the forests and waters of the New River Gorge National River.

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

This report received informal peer review, which was provided by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. The level and extent of peer review was based on the importance of report content or its potentially controversial or precedent-setting nature.

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Executive Summary

New River Gorge National River (NERI) is located in south-central West Virginia along an 85-km stretch of the New River within the Appalachian Mountain chain. NERI conserves the outstanding natural, scenic, and historic values of the landscape immediately surrounding, and including, the New River Gorge. This conservation extends to the New River itself—a free-flowing river that supports small-mouth bass, freshwater mussels, native fish, and rare riparian plants. The landscape surrounding the New River main stem is a mosaic of mature and maturing forests, tributary streams, floodplains, and dramatic sandstone cliffs. This landscape has been shaped by a history of human occupation and resource extraction (e.g. mining, timbering, flood control).

Natural resources presented in this Natural Resource Condition Assessment (NRCA) can be divided into five general areas: air resources, geologic resources, water-related resources, plant resources, and terrestrial wildlife. Within each of these general areas, specific natural resources were assessed as follows:

- Air resources– acoustic environment, night sky, visibility, ozone, sulfur and nitrogen deposition, mercury/toxics, climate change, scenic vistas
- Geologic resources—mass movements, cliff communities
- Water-related resources—water quality (main stem and tributaries), fish, aquatic invertebrates, salamanders
- Plant resources—xeric plants (e.g. rimrock pine), mixed mesophytic forest, eastern hemlock, Appalachian flatrock/riverscour prairies, rare and medicinal plants
- Terrestrial wildlife --- Allegheny woodrat, bat communities, birds, game species.

The approach of this NRCA was to use existing data to evaluate the condition of natural resources at NERI. Thresholds for condition (good, moderate concern, and significant concern) were obtained from a variety of resources such as federal and state regulations (e.g. water quality criteria), peer-reviewed literature, research reports, and, in some cases, best professional judgment. If possible, trends in the condition (improving, deteriorating, or unchanging) were also evaluated. Finally, an estimate of the confidence in the assessment was provided based on the quality and quantity of available information (high, medium, low confidence). The assessment of condition used standardized symbology provided by NRCA guidelines.

This NRCA complements the park's General Management Plan (NPS 2011), Resource Stewardship Strategy (Mahan and Darden 2004) and the initial, comprehensive Natural Resource Assessment completed in 2004 (Mahan 2004). Therefore, this NRCA is a form of re-assessment that permits a better understanding of the trends in resource conditions at the park. A detailed comparison of the assessments is presented in the Discussion section but, in general, the overall score for natural resource condition at the park has declined in the past 13 years from 58 (on a 100-pt scale) based on 19 resource indicators in 2004 to 42 (on a 100-pt scale) based on 24 resource indicators in 2017. A composite resource condition score of 42 indicates moderate concern. This lower score is due, in part, to a better understanding of all natural resources at the park thanks to research and inventory and monitoring efforts. In addition, over the past 13 years, some natural resources at NERI have been negatively affected by non-native pests and pathogens that originated outside the park. For example, white-nose syndrome has decimated the bat population and Emerald ash borer has caused wide-spread mortality of both white and green ash trees. Furthermore, poor water quality issues persist within park tributaries and the New River main stem—especially after rain events. Most of these threats to water quality (fecal coliforms, acidity) also originate outside of park borders.

Despite these challenges, NERI continues to support a magnificent expanse of diverse, un-fragmented forest and globally-significant cliff, riverscour, and bird communities. In addition, the park provides outstanding recreational opportunities that include hiking, rock-climbing, rafting, fishing, and hunting. Continued natural resource stewardship, planning, and protection, both within and outside of the park boundaries, will ensure that NERI remains an important natural area within the Appalachian Mountains.

Acknowledgments

This Natural Resource Condition Assessment (NRCA) for New River Gorge National River (NERI) could not have been completed without the help of many people. In particular, the current natural resource staff at NERI provided their data, oversight, review, comment, and support throughout the project. These staff include John Perez, Layne Strickler, Lenza Paul, Lisa Wilson, Andy Steel, Kathy Oney, and Claire Rozdilski. Past NERI staff provided the information and framework upon which this condition assessment was built. These include Deborah Darden, Clif Bobinski, Mark Graham, Matt Varner, and Jesse Purvis. Lizzie Watts, NERI Superintendent, provided her comment and review of an earlier version of this document.

Other National Park Service (NPS) staff also provided valuable data, support, and insight. These include Matt Marshall, Caleb Tzilkowski, Stephanie Perles, Andy Weber, and Doug Manning of the Eastern Rivers and Mountains Inventory and Monitoring Network; Holly Salazar and Lochen Wood of the Air Resources Division, and Pete Sharpe from the Northeast Region. Christine Arnott, biologist and NRCA coordinator for the NPS Northeast Region, provided funding, contract management, project review, and kept the condition assessment 'on task.'

Lisa Emili (Penn State Altoona) reviewed, edited, and formatted this document prior to its final submission to the National Park Service. Her assistance and persistence were greatly appreciated.

In addition to those listed above, a preliminary draft of this document was peer-reviewed by Sheila Colwell (NPS Northeast Region), Li-We Hung (NPS Natural Sounds and Night Skies Division [NSNSD]), and Emma Brown (NSNSD). Any errors found in this final document are our own.

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

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[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 a 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.

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[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. History and Enabling Legislation

The following description is excerpted from the General Management Plan New River Gorge National River. 2011. (U.S.D.I., NPS, Glen Jean, WV).

“New River Gorge National River (NERI) was established in 1978 as a unit of the national park [service] (NPS) following a 20-year grassroots effort organized by local community leaders (NPS Organic Act 16 USC 1 -4). The earliest discussion regarding creation of a park to protect the New River and its gorge began in the late 1950s. Some residents of communities near the park believed that a national park designation for the area was needed to protect its resources and at the same time would enhance the area’s tourism appeal with potentially significant economic benefits to southern West Virginia (WV). While at that time there was growing local support of a new national park in the region, the real effort to protect the New River began in 1962 as a result of a major conservation effort upstream of the gorge in Virginia and North Carolina. The controversy focused on a series of proposed pump storage dams on the river. Many West Virginians were strongly opposed to the proposed dams because they would have significantly altered river flows downstream. Many also feared the upstream dams would set a precedent supporting future proposals for similar dams in the Kanawha Valley in West Virginia. These concerns led to the formation of the West Virginia Chapter of the National Coalition to Save the New River and to creation of the New River Gorge National Park Committee in 1974. These groups were subsequently instrumental in promoting public support for the 1976 addition of the New River in North Carolina to the National Wild and Scenic River System. This designation brought an end to the proposals for energy development projects on the river upstream of West Virginia. The conservation effort then turned to the West Virginia section of the New River. A number of key community leaders emerged from the existing river conservation groups. Working together for another two years they built the support needed for the park in the local communities along the river leading ultimately to creation of New River Gorge National River. President Jimmy Carter signed legislation establishing New River Gorge National River on November 10, 1978 (Public Law 95-625). As stated in the legislation the park was established as a unit of the national park system: “for the purpose of conserving and interpreting outstanding natural, scenic, and historic values and objects in and around the New River Gorge and preserving as a free-flowing stream an important segment of the New River in West Virginia for the benefit and enjoyment of present and future generations.”

Ten years later the West Virginia National Interest River Conservation Act of 1987 included a number of additional findings pertaining to New River Gorge National River. The purpose of the act was: to provide for protection and enhancement of the natural, scenic, cultural, and recreational values on certain free-flowing segments of the New, Gauley, Meadow, and Bluestone Rivers in the state of West Virginia for the benefit and enjoyment of present and future generations.”

As a NPS unit, NERI is subject to all NPS management policies. Additionally, there are several federal and state special park designations associated with NERI identified in the park’s General

Management Plan (NPS 2011). These include: 1) Outstanding Remarkable Values (NPS 2011) for wildlife, culture (New River Bridge), recreation (whitewater recreation), and geology (one of the oldest rivers in North America), 2) Nationally Significant and Unique Wildlife Ecosystem for wildlife values that provide 'substantial benefits to the public over a wide geographical area,' 3) Resource Category 1 habitat for habitat of high value for 'evaluation species and is unique and irreplaceable on a national basis', 4) High Quality Streams for the presence of streams with 'native or stocked populations of trout and native warm water streams five or more miles in length with desirable fish populations that are utilized by the public', 5) Protected Streams for management for the 'use and enjoyment of the citizens of West Virginia', 6) American Heritage River to support 'community-based efforts to preserve, protect, and restore designated rivers and their communities', and 7) Aquatic Resource of National Importance allows individual permits for discharge to be eligible for higher levels of environmental review.

2.1.2. Geographic Setting

The New River Gorge National River (NERI) is located in south-central West Virginia and covers over 28,000 hectares (70,000 acres) in the counties of Fayette, Summers, and Raleigh, and encompasses 85 linear kilometers (53 miles) of the New River (Figure 1). The park abuts Babcock State Park to the northwest, and is within close proximity to the Gauley River National Recreation Area (GARI), Bluestone Lake (BLUE), Bluestone and Pipestem State Parks, and Bluestone and Buery Mountain State Wildlife Management Areas. NERI also abuts the Boy Scout's Summit Bechtel Reserve, site of the National Boy Scout Jamboree. The nearest city is Beckley, WV, eight km (five miles) to the southwest of the park boundary. Other nearby towns include Mount Hope, Oak Hill, and Fayetteville, WV, all occurring along the State Highway 19 corridor to the west of the park.

Elevations at NERI range from a low of 248 meters (814 feet), to a high of 1,004 meters (3,294 feet), with a range of 756 meters (2,480 feet). As a river gorge, much of the park is steeply sloped with 73% of the park area in slopes greater than 20% (> 11 degree slope). The park lies completely within the Central Appalachians/Forested Hills and Mountains Ecoregion. Braun (1950) classified the area as part of the "mixed mesophytic forest region, Cumberland and Allegheny plateaus, rugged eastern area". Land cover at NERI is 89% forested, 3.8% developed, and 1.4% agriculture, with the remaining in open water, barren, grassland/herbaceous, or wetland land cover types (Vanderhorst et al. 2007).

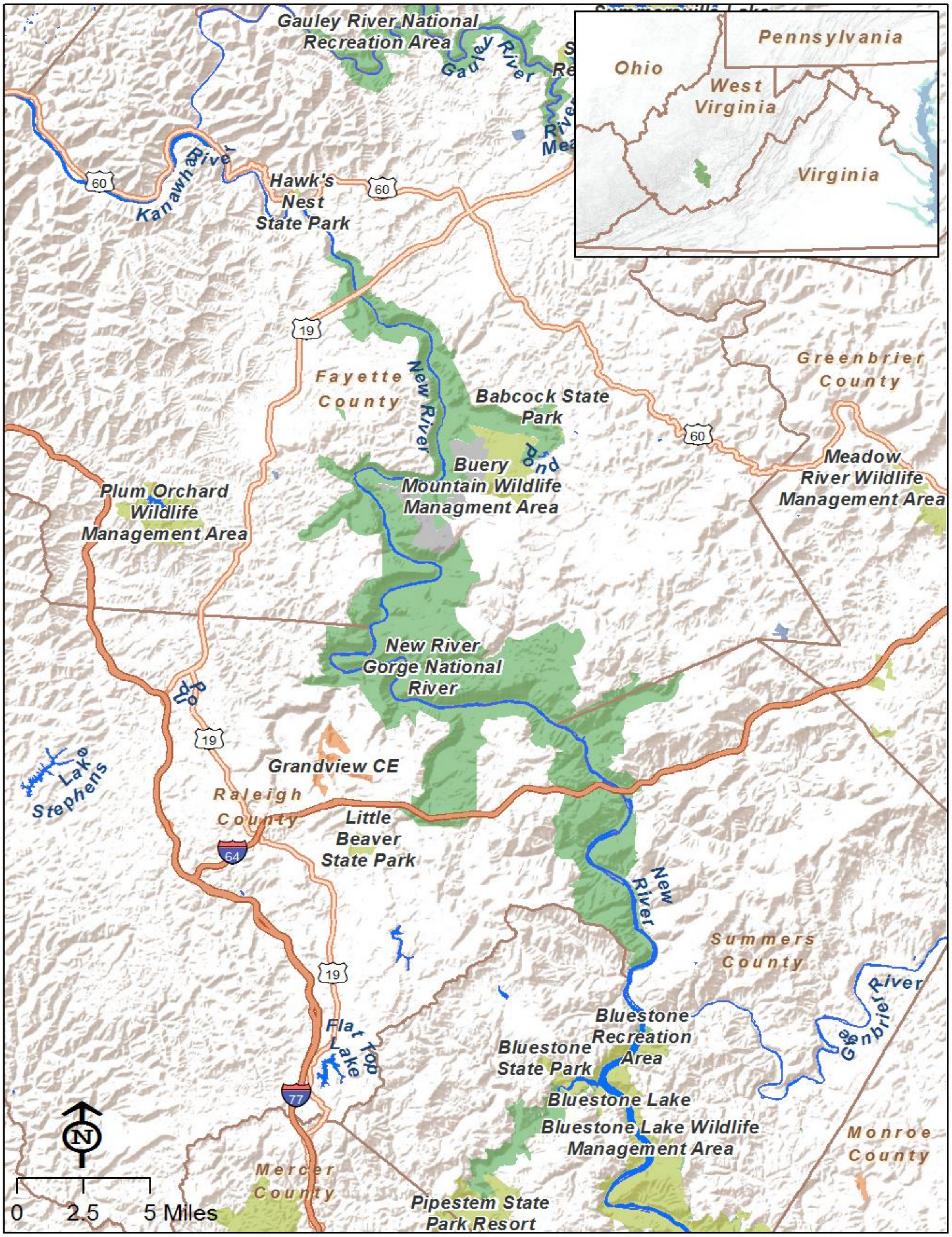


Figure 1. Setting of New River Gorge National River (NERI) in relation to rivers and other public lands.

2.1.3. Watershed

The New River is part of Ohio River watershed and flows north from North Carolina, through Virginia, and into West Virginia where it flows through NERI. The New River joins with the Gauley River downstream (to the north) of NERI to form the Kanawha River (Figure 1) which empties into the Ohio River. Locally, NERI is drained by several creeks that flow through the park and into the New River. The USGS Watershed Boundary Dataset categorizes watershed boundaries into a hierarchy of “hydrologic units”, identified by nested “hydrologic unit codes (HUC)”. At the “Watershed” or HUC 10 level, NERI is drained by three major creeks, Piney Creek, Glade Creek, and Manns Creek (Figure 2). At the HUC 12 or “Sub-basin” scale, there are 17 defined hydrologic units; three subdivisions of Piney Creek (Beaver Creek, headwaters Beaver Creek, and outlet Beaver Creek), eight subdivisions of Glade Creek (Madam Creek, Mudlick Branch – Laurel Creek, Lick Creek, Meadow Creek, headwaters Glade Creek, outlet Glade Creek, Chestnut Knob Fork – Laurel Creek, and Farleys Creek), and six subdivisions of Manns Creek (Dunloup Creek, Manns Creek, Arbuckle Creek, Wolf Creek, Mill Creek, and Laurel Creek) (Figure 3).

The West Virginia Division of Natural Resources modified a national HUC 12 watershed biodiversity ranking for state implementation, and assigned one creek (Farleys Creek) a ranking of B1, of “outstanding global biodiversity significance”, and five watersheds (Wolfs Creek, Arbuckle Creek, Dunloup Creek, outlet Glade Creek, and Madam Creek) were given a ranking of B2, of “high global significance.” Three watersheds (Chestnut Knob Fork-Laurel Creek, Meadow Creek, outlet Piney Creek) were given a ranking of B4, of “outstanding State biodiversity significance.”

2.1.4. Geologic Setting

The geologic structure of the New River Gorge forms the basis of the dramatic scenery, recreational climbing, and economic history of the park. The New River, through time, has down-cut through mostly horizontally deposited sedimentary geologic formations, forming the gorge. The gorge itself is largely a result of sandstone layers of the New River Formations (Nuttall and Raleigh Sandstones) that resisted the down-cutting erosion of the river and now form the upper walls and cliffs of the gorge popular for rock climbing. The Sewell coal seam of the New River Formation and the Pocahontas coal seam of the Pocahontas Formation were mined in the early-mid 1900s at numerous sites throughout the park. The remains of the former town of Kaymoor give testament to coal mining activities in the park.

The New River is often thought of as one of the oldest rivers in North America, however, the exact age is difficult to determine. Since the river down-cuts through rocks that were deposited 320 million years ago, it is no older than these rocks although, it could have formed in as little as 3 million years if the erosion rates of the down-cutting force were similar to the Grand Canyon (Lessing 1986). However, it is more generally thought that the river preceded the uplift of the Appalachian Mountains 225 million years ago or was formed during a second period of uplifting 60 million years ago (Lessing 1986).

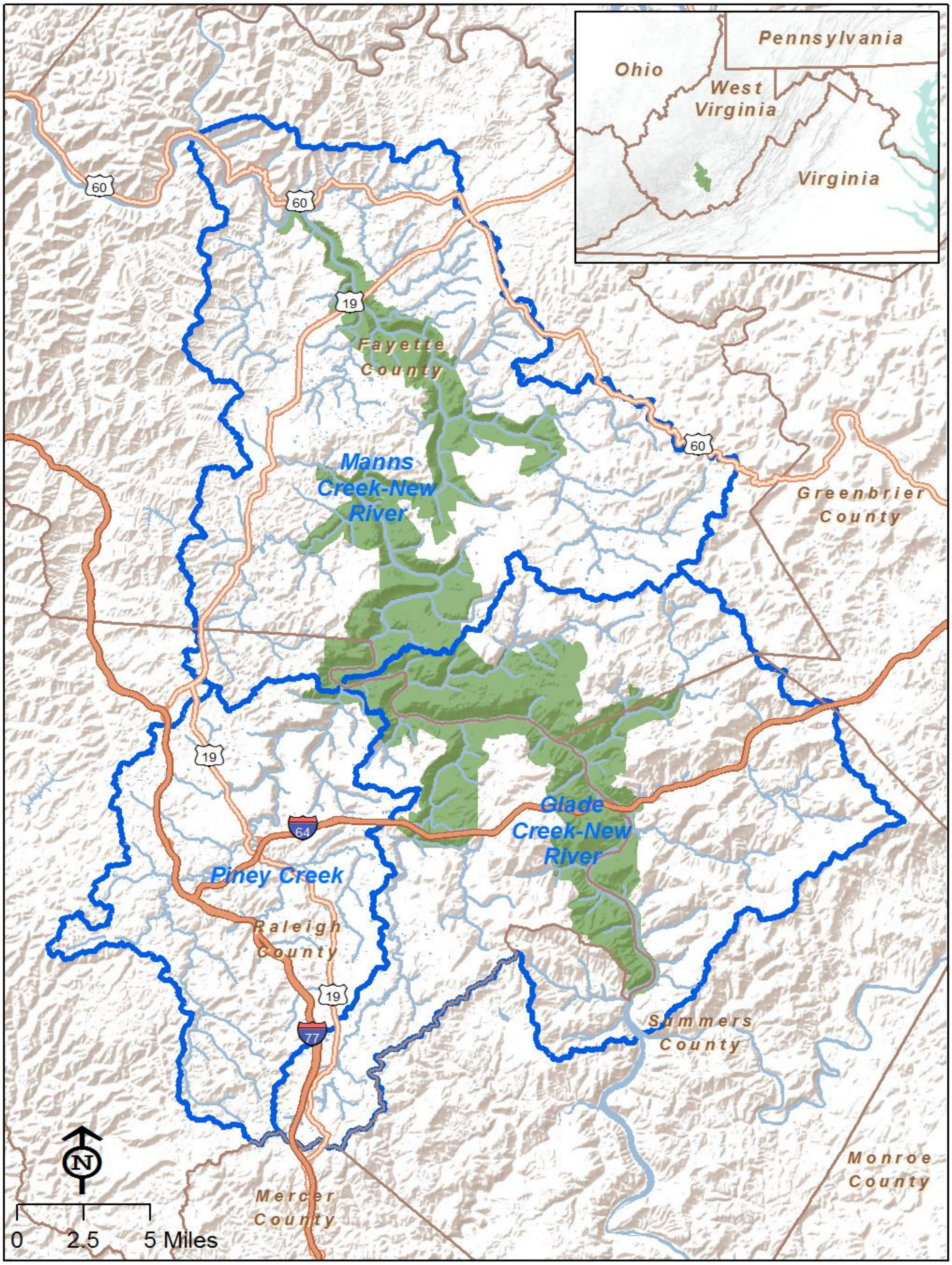


Figure 2. Watersheds (USGS 10-Digit Hydrologic Units) encompassing New River Gorge National River (NERI).

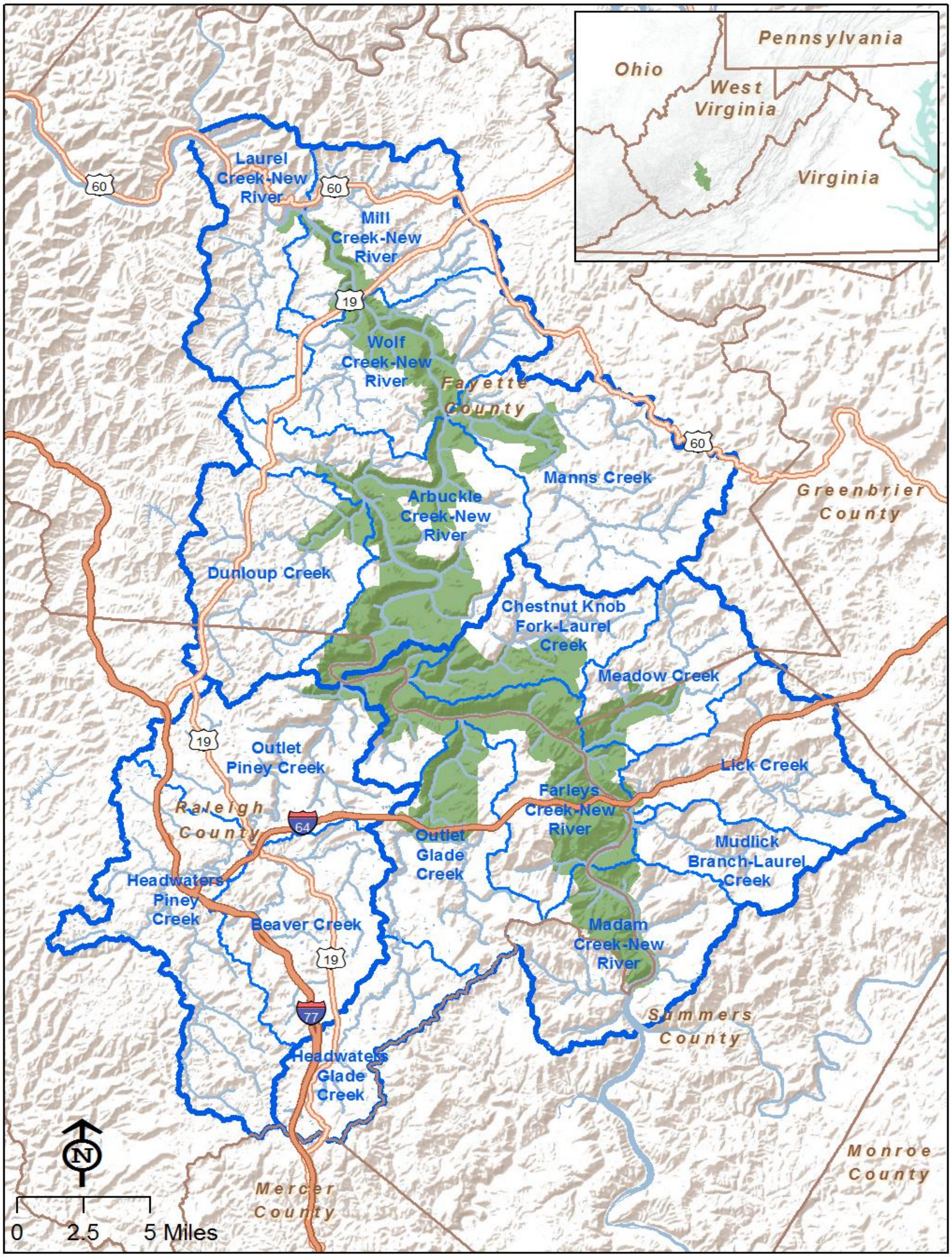


Figure 3. Sub-basins (USGS 12-Digit Hydrologic Units) encompassing New River Gorge National River (NERI).

2.1.5. Climate

The climate of NERI is classified as humid continental (Köppen climate classification), hot/warm summer subtype or mild/cool summer subtype. This climate type is characterized by warm to hot summers, and cold winters. The average high July temperature of Beckley, WV, for example, is over 25° C (78° F) while the average winter minimum temperature is below -7° C (19° F) [source: usclimatedata.com]. Precipitation is distributed relatively evenly throughout the year with the maximum average rainfall occurring in July (13.2 cm, 5.2 in), but with all months receiving on average over 5.1 cm (2.0 in) of rain and total annual rainfall of close to 101.6 cm (40.0 in).

A changing climate potentially poses threats to NERI including changing temperature and precipitation patterns, changing vegetation communities and habitats, and increased risk of severe storms and fire (NPS 2010). Although habitats at NERI may be somewhat resilient to changing climate, natural and human-made barriers may restrict the ability of wildlife and plants to migrate or expand their ranges to areas more climatically suitable (Byers and Norris 2014). Although many NPS units will be vulnerable to changing climate, particular landscape configurations and setting may make some parks more vulnerable to climate change than others (Monahan and Fisichelli 2014). However, many, if not most NPS units are already experiencing climates much warmer than their 1901-2012 historical average (Monahan and Fisichelli 2014), and NERI is no exception. In future climate change scenarios, NERI is predicted to experience significant increases in both precipitation (5.1-8.5%) and average temperature (1.9-6.8 °C, 35.4-44.2 °F) based on scenarios bracketed by least and most potential change (Fisichelli et al. 2014). These changes will result in decreasing habitats for some tree species (yellow birch [*Betula alleghaniensis*], sweet birch [*Betula lenta*], American basswood [*Tilia Americana*] and increasing habitat for others (eastern red cedar [*Juniperus virginiana*], sweetgum [*Liquidambar styraciflua*], shortleaf pine [*Pinus echinata*], southern red oak [*Quercus falcata*], and will likely increase the occurrence of nuisance tree pests (Fisichelli et al. 2014).

2.1.6. Visitation

Visitation to NERI primarily occurs in the summer months, peaking in July, but also attracting visitors in Spring (May) and during the Fall foliage season (October) with the fewest visitors in January (NPS 2011). Visitation increased steadily between 1984 (231,295 visitors) to 2007 (1,180,411 visitors), with visitations peaking in 1996 at 1,225,345 visitors, and then declining slightly to over 1,100,000 visitors in subsequent years (NPS 2011). It was estimated that close to 75% of visitors tabulated in 2007 were non-local residents either staying overnight or passing through (NPS 2011). The largest group of visitors during the period 1998-2007 journeyed to the park for trail use, followed by those visiting the park for river paddling, and these two visitor use types remained the highest for the entire period tabulated for the Parks' General Management Plan in 2011. A large increase in visitors (+239%) traveling to the park for rock climbing was noted between 1998-2007, with declines in tent and recreational vehicle (RV) campers (-39%) and bus visitors (-39%) (NERI GMP 2009). A 2011 study of economic benefits of National Parks found that NERI experienced 1,071,088 visitors to the park that year, resulting in over $46 M in visitor spending and directly influencing close to 600 local jobs (Cui et al. 2013).

2.2. Natural Resource Descriptions and Ecological Units

The central Appalachian ecoregion, in which NERI resides, is a high biodiversity area within North America, and is a center of endemism for a number of plants, invertebrates, salamanders, and small mammals due to relative climatic and habitat stability over very long time periods, and high physical habitat diversity due to variations in elevation, landforms, and geology. The physical habitat template can be assessed using geographic information systems to quantify the unique combinations of landform type, elevation range, and geologic units, and this type of analysis has been conducted by the Nature Conservancy, the state of West Virginia, and by NERI as a guide to ecosystem assessment and habitat suitability for a range of species. In NERI, park staff identified 146 unique combinations of elevation, geology, and 14 landform types. Landform types at NERI (by descending order of park area) include steep slopes, side slopes, cliffs, upper slopes, coves, slope crests, flat summits, moist flats, wet flats, slope bottoms, and dry flats. These mapped "ecological land units" or ELUs have been used successfully by park staff to model the distribution of rare and at risk plants, including American ginseng [*Panax quinquefolia* Panacis is] (A. Steele, NPS-NERI, personal communication).

2.2.1. Physical Resources

In 2017, a Geologic Resources Inventory report was completed for Bluestone National Scenic River, Gauley National Recreation Area, and New River Gorge National River (Thornberry-Ehrlich 2017). This report describes the geologic history, explores the geologic resources map for the park, and details geologic issues facing park resource managers. Major geologic issues identified echo those presented in the earlier natural resource assessments (Mahan 2004, Mahan and Darden 2014) and include a needed understanding of: hazards due to slope movements, paleontological resources (and interpretation), coal and other resource extraction effects on natural resources, stream channel morphology and flow dynamics, karst features, shrink-and-swell clays, geologic faults and folds, seismic activity levels, and a thorough wetland inventory. The geology and resulting soil profiles (see Soil Resource Inventory, irma.nps.gov/DataStore/Reference/Profile/2170705) of the NERI shaped the current ecological communities. Other geologic conditions (river gorges, exposed coal seams, limestone cliff exposure) influenced the long-history of human presence and use of the area. Native Americans' use of the New River as a transportation route dates back at least 12,000 years and industrial settlement of the area by Europeans (beginning in the 1850s) was influenced by the presence of natural resources including timber, coal, and, more recently, natural gas (Thornberry-Ehrlich 2017). More recently, swift water flows at the base of a deep river gorge, exposed limestone cliffs, and expansive forests, make NERI a recreation destination. Natural processes and human modification of the landscape continue to shape the geology of NERI through the effects of river damming on stream flow, past mining and resources extraction on soil movement and hazards, and recreational effects on cliffs, boulders, and flatrock vegetation communities (Mahan 2004, Mahan and Darden 2014, Mahan 2016).

2.2.2. Water Resources

Although the central feature of NERI is the New River and the water-based recreation it affords, water quality issues pose significant management challenges, many of which are beyond the control of the NPS. The predominant water quality issues are water quality impairments, specifically from fecal coliform bacterial pollution, low pH, metals (aluminum, iron), and or biological impairment. A number of the tributaries to the New River flowing through the park, as well as the main stem of the New River have been designated as impaired for some or all of these pollutants by the EPA (Figure 4) and placed on the EPA's 303(d) list. Most impaired waters have already been assessed for total maximum daily load (TMDL) designation and TMDL's have been developed by the State of West Virginia, Department of Environmental Protection (WV DEP) in cooperation with the Environmental Protection Agency (EPA). A TMDL is, "a determination of the amount of pollutant from point, non-point, and natural background sources, including a Margin of Safety (MOS), which may be discharged to a water quality limited body" (EPA 2014). TMDLs include consideration of environmental conditions, including impacts of high rainfall runoff and stream flow events on non-point source pollution, and impacts of low flow events on pollutant loading from point sources (EPA 2014).

Sources for impairment are varied; sources for pH and metals include point sources such as permitted mining discharges and construction sites, and non-point sources such as abandoned mine lands (EPA 2014). For fecal coliform bacteria, sources include permitted point discharges such as waste water treatment plants, and non-permitted point sources including failing septic systems and straight pipes into streams (EPA 2014). Non-point sources of fecal coliform include storm water runoff, agriculture, and "natural background" sources such as wildlife (EPA 2014). The primary identified sources of fecal coliform, however, are inadequately treated sewage and runoff from pasture land (EPA 2014). Review and enforcement of TMDLs are intended to remove untreated sewage sources and reduce agricultural runoff, which should also improve streams suffering from biological impairment (EPA 2014). Likewise, enforcement of TMDLs for metal pollution due to mine drainage may also help reduce biological impairment. Indeed, the TMDLs developed for the New River do not include separate TMDLs for biological impairment, but instead assume that enforcement of the developed TMDL will serve as surrogates for improving biological condition.

2.2.3. Ecosystem Integrity, Focal Species, Resource Issues

As outlined in previous natural resource management documents (Mahan 2004, NPS 2011, Mahan and Darden 2014), the fundamental ecosystems and species at NERI include outstanding features related to the presence of the New River and the surrounding New River Gorge. The cliffs of the gorge extend for a distance of 32.2 km (20.0 mi) and are primarily composed of perpendicular rock that, at its deepest point, extends 393.8 m (1,292 ft.) to the valley below (Mahan 2016). This gorge is a nationally significant geologic feature and is only rivaled in the eastern United States by the Niagara cliffs in New York (Brooks 1911). Waters of the New River and associated tributaries support a rich diversity of fish, amphibians, invertebrates, and outstanding recreational activities (e.g. fishing, rafting). The forests and plant communities of the surrounding gorge support rare plant species, diverse breeding bird communities, a rich assemblage of mammals, and popular recreational activities (e.g. rock climbing, hiking). Focal species of interest to, and representative of, these aquatic and terrestrial ecosystems include a variety of cliff-dwelling lichens (e.g. *Umbilicaria* spp.), Oak (*Quercus* spp.), Ash (*Fraxinus* spp.), Virginia Pine [*Pinus virginiana*[, Eastern Hemlock [*Tsuga Canadensis*], American ginseng, Small-mouth bass [*Micropterus dolomieu*], Big mouth chub [*Nocomis platyrhynchus*], Black-belly salamander [*Desmognathus quadramaculatus*], Cerulean Warbler [*Setophaga cerulean*] Louisiana Waterthrush [*Parkesia motacilla*], Allegheny Woodrat

[*Neotoma magister*], Myotis bats (*Myotis* spp.), and the Appalachian Flatrock vegetation community type.

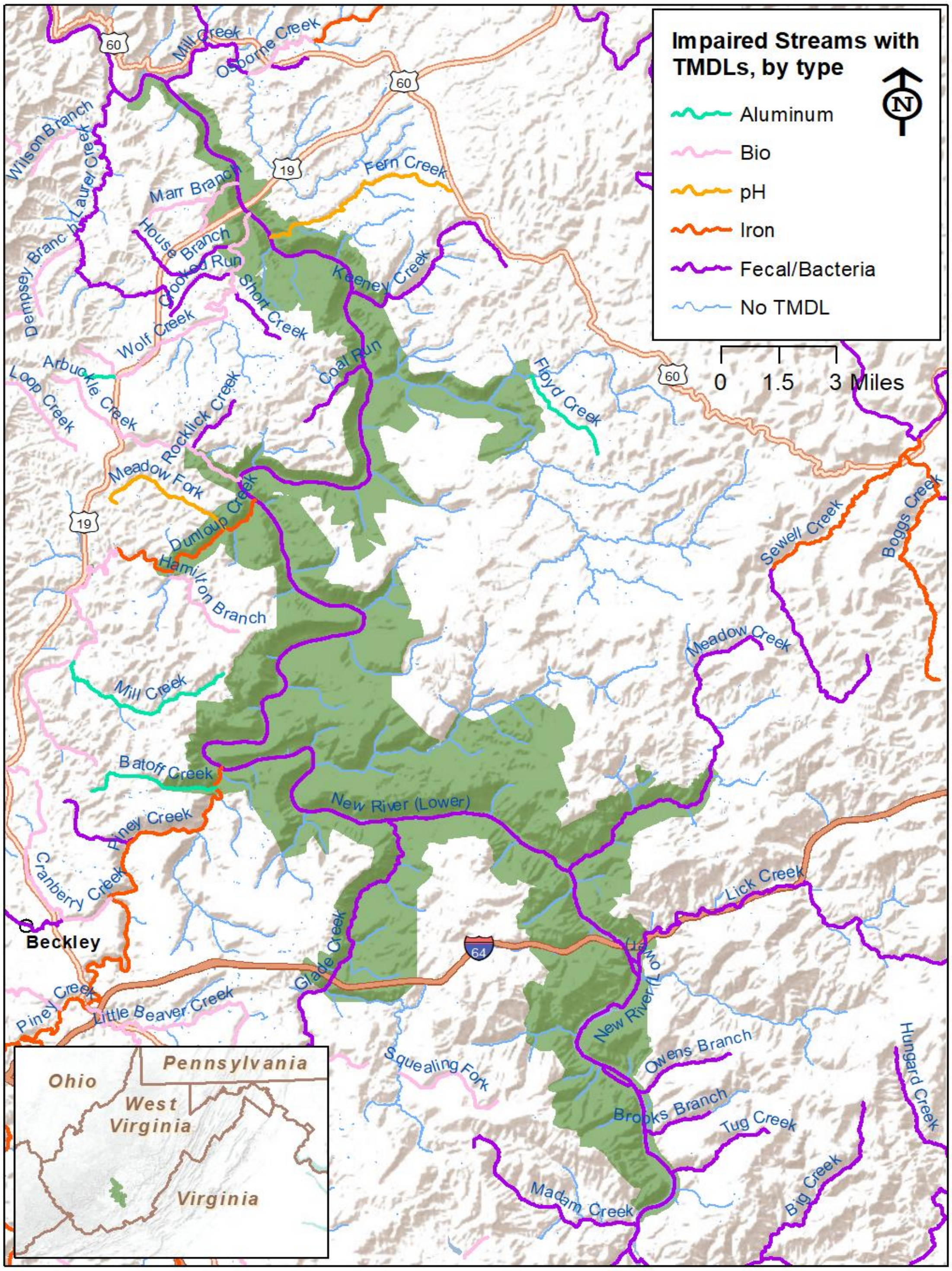


Figure 4. EPA and West Virginia 303(d) impaired streams and cause of impairment, for major streams flowing into New River Gorge National River (NERI) only. Note: many streams have multiple impairments that are not depicted on this map [Source: http://dep.wv.gov/WWE/watershed/IR/Pages/303d_305b.aspx].

Today, the major issues facing NERI and its natural resources include stream pollution, non-native species, mining and other development outside the park, recreational disturbances, and altered river flow regimes. Many of these activities fragment and degrade natural resources at NERI but their effects can be lessened with proper planning and management, resource protection, and improved infrastructure development within (e.g. proper trail placement) and outside the park (e.g. sewage treatment improvements; Mahan and Darden 2014).

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In 2011, a General Management Plan (GMP) was completed for NERI. The 1978 National Parks and Recreation Act requires the NPS to complete a GMP for each unit of the National Park System. A GMP recommends a course for the management of a national park for the next 15–20 years and any proposed management actions must follow the requirements of the National Environmental Policy Act of 1969 (NEPA). Therefore, the NPS is required to prepare an Environmental Impact Statement (EIS) to meet the requirements of NEPA. The EIS describes the existing environment of the national park prior to taking any action, proposes several alternatives for taking action, and analyzes the potential environmental impacts of implementing each alternative.

The GMP/EIS for NERI provides a park overview, summarizes the Foundation for Planning (Foundation Plan), describes the planning and consultation processes, and focuses on a comprehensive description of the preferred alternative that was selected for implementation (NPS 2011). The Foundation Plan describes the park purpose and significance, and identifies the fundamental and other important resources and values. The park purpose and significant statements convey the reasons for which the park was set aside and why, within a national, regional, and system-wide context, the park's resources and values are important enough to warrant national park designation. The purposes of NERI are to:

1. preserve an important free-flowing segment of the New River,
2. preserve, protect, and conserve outstanding resources and values in and around the New River Gorge, including geologic and hydrologic features, terrestrial and aquatic ecosystems, historic and archeological resources, cultural heritage, and scenic character,
3. provide opportunities for public understanding, appreciation, and enjoyment of the park's natural, cultural, scenic, and recreational resources and values.

The significance of NERI is conveyed in the following six statements:

1. Flowing water is the definitive creative force shaping the geologic features of the New River Gorge. The New River, one of the oldest rivers in the world, continues to sculpt the longest and deepest river gorge in the Appalachian Mountains.
2. The waters of the New River system contain a mosaic of hydrologic features and aquatic habitats, support a unique aquatic ecosystem, and nourish a riparian zone that supports rare plants, animals, and communities.

3. New River Gorge National River lies at the core of a globally significant forest, contains the most diverse flora of any river gorge in central and southern Appalachia, and provides essential habitat for endangered mammals and rare birds and amphibians.
4. New River Gorge National River contains a large, outstanding and representative group of historic places that testify to the experiences of those diverse people who settled and developed this part of Appalachia between the 19th and mid-20th centuries.
5. New River Gorge National River has diverse and extraordinary scenic resources and views accessible to visitors from the river, rocky overlooks, trails, and rural roads throughout the park
6. New River Gorge National River provides visitors with exceptional opportunities for exploration, adventure, discovery, solitude, and community.

Additional fundamental and other important resources and values were most recently identified and described within NERI's Foundation Plan and include resources and values related to: flowing water, the deep river gorge, rare aquatic habitats (including plants, animals, and ecological communities), globally significant forest cover that contains habitat for rare plants and animals, culturally significant settlements that 'testify to the experiences of those diverse people who settled and developed this part of Appalachia between the 19th and mid-20th centuries', scenic vistas and views, recreational opportunities for exploration, adventure, solitude, and community.

2.3.2. Status of Supporting Science

In preparation for NERI's General Management Plan (2011), a natural resource assessment for the park was prepared in 2004 that summarized all available science for the park to date (Mahan 2004). Since that initial assessment and the final GMP, additional studies have been conducted within the park by resource managers and cooperating partners. These studies are the focus of this natural resource condition assessment (NRCA). Recent scientific studies of significance include the completion of a Resource Stewardship Strategy (Mahan and Darden 2014), research on cliff geology and ecology (Mahan 2016), forest and plant community types (e.g. Vanderhorst et al. 2007), amphibians, breeding birds (e.g. Varner and Biasiolli 2008), bats (e.g. Paul 2014), and the Allegheny woodrat (e.g. Wood 2001). In addition, monitoring of streams for water quality, macroinvertebrates, and fish is on-going by the state and park staff (e.g. Long-term environmental monitoring program [LTEMS]). Finally, the establishment of the Eastern Rivers and Mountain Inventory and Monitoring Network (ERMN) within the NPS has produced a variety of findings focused on six selected vital signs: 1) Vegetation and Soil (e.g. Perles et al. 2016), 2) Invasive species (e.g. Manning 2016), 3) River Water Quality, 4) Rare riparian plant communities (e.g. Perles 2016), 5) Stream benthic invertebrates (e.g. Tzilkowski et al. 2015), and 6) Streamside birds (e.g. Marshall et al. 2013).

3. Study Scoping and Design

3.1. Preliminary Scoping and NPS Involvement

An initial kick-off meeting for the NRCA was conducted on 20 October 2015 at NERI. Meeting attendees included staff from NERI: M. Graham, J. Perez, J. Purvis, L. Strickler, A. Steel, L. Paul, the Northeast Region: C. Arnott (NER), and the ERMN: M. Marshall, C. Tzilkowski. At this meeting, the general approach and framework for the Natural Resource Condition Assessment was presented and discussions were held about natural resource research conducted since completion of the last Natural Resource Assessment in 2004 (Mahan 2004). In addition, available data, projects, and products (published and unpublished) related to NERI and housed at the ERMN were discussed and listed. Availability of digital GIS datasets was also shared. Finally, park staff provided information about projects that are in-progress and explained the availability of data for these projects. Throughout the compilation of this document the authors communicated with NERI, ERMN, and Regional staff for additional information and data regarding park resources. A meeting that summarized the initial findings and conclusions of the NRCA was held with park and Northeast region staff in May 2017.

3.2. Assessment Framework and General Approach and Methods

This Natural Resource Condition Assessment report was organized by Physical and Biological Natural Resource Components of specific interest to the park. In particular, fundamental and important natural resources as identified in the NPS (2011) were prioritized for assessment and are presented in the **Natural Resource Conditions** section (below). In addition, research and data that was collected and/or conducted since the completion of the last Natural Resource Assessment (Mahan 2004) were the focus of this report. No new data were collected in the preparation of this report. However, where appropriate, new analyses of existing data sets were performed. These analyses were primarily performed with landscape data sets although summaries of species and related data sets were also conducted.

Within each natural resource component, a description of the resource including (if known) its current condition, reference condition, thresholds, trends, and threats/stressors was provided. Within this description, summaries of data and reports available since 2004 were included along with appropriate references. The NRCA does not attempt to replicate the information found within other reports but, rather, synthesizes and contextualizes those data and findings to better describe the current condition of a particular natural resource component. Whenever possible established NPS metrics and benchmarks (e.g. NPS vital sign parameters, ERMN forest condition summaries, NPS air quality assessment) or metrics from established monitoring programs (e.g. WV water quality monitoring) were used to estimate the condition of the park's natural resources. In cases where metrics and/or benchmarks were not available, condition was based on the most recent, quantitative, and reliable data for the park or on best professional judgment. For each natural resource component, a section on data gaps, needs, and, in some cases, potential management strategies are presented. These strategies were extracted from natural resource documents, adapted from NERI's Resource Stewardship Strategy (Mahan and Darden 2014), or recommended by natural resource managers at, or familiar with, the park.

For each natural resource component a graphic summary of the status of the resource (good, moderate concern, significant concern, Table 1) based on historic, recent research, and/or monitoring efforts and a statement of current condition status and trend was presented and interpreted (Table 2 for example). The NPS shared guidelines for combining conditions for various metrics in order to develop an overall assessment of resource condition (Table 3, NPS 2013). To determine the overall trend the total number of down arrows was subtracted from the total number of up arrows. If the result was -3 or lower, the overall trend was down. If the result is between 2 and - 2, the overall trend was unchanging (NPS 2013). These graphic summaries are presented for all natural resource components in the **Discussion** section (below). These graphics are followed by a synthesis of suggested management, research, and inventory/monitoring strategies to maintain or improve condition of key natural resources.

Table 1. Symbol key legend used to report natural resource condition, trend, and confidence in data used for the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	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
	Condition Status Unknown; Consequently, Trend is also Unknown and Confidence is Low				

Table 2. Example of interpretation of natural resource condition symbols.

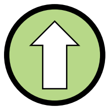
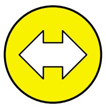
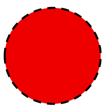
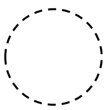
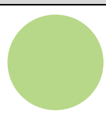
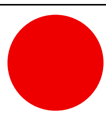
Symbol	Interpretation of condition or trend
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; 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.

Table 3. Range of values from Natural Resource Condition Assessment guidelines when averaging multiple metrics estimate natural resource condition.

Condition		Point value	Average for multiple metrics
	Good	100	67 to 100 points (Good)
	Moderate Concern	50	34 to 66 points (Moderate Concern)
	Significant Concern	0	0 to 33 points (Significant Concern)

4. Natural Resource Conditions

4.1. Acoustic Environment/Soundscapes*

*Modified from: Lochen Wood, NPS, Natural Sounds and Night Sky Division (NSNSD), 2016.

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

The acoustic environment is a resource with intrinsic value. It is a critical component of wilderness character and plays an important role in wildlife communication, behavior, and other ecological processes. Multiple surveys of the American public indicate that hearing the sounds of nature is an important reason for visiting national parks (e.g. Haas and Wakefield 1998). Despite this desire for quiet environments, anthropogenic noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011, Buxton et al. 2017). Sound also plays a critical role in intra-species communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats (Shannon et al. 2016). While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (USDA 1992, Anderssen et al. 1993, NPS 1994). Therefore, the value of acoustic environments and soundscapes is related to an array of park resources and has broad implications for park management. At NERI, noise could be generated from a variety of human-based sources including: park facilities and operations, nearby development, transportation, aircraft, visitor vehicles, music, shouting, and electronics.

For management and planning purposes, it is important to distinguish and define certain key terms. As defined by the National Park Service (NPS), a*coustic resources* are physical sound sources, including both natural sounds (wind, water, wildlife, vegetation movement) and cultural (e.g. noises associated with Native American settlement) and historic (e.g. the noises of battle) sounds. The *acoustic environment* is the combination of all the acoustic resources within a given area - natural sounds and human-caused sounds – as modified by the environment. The acoustic environment includes sound vibrations made by geological processes, biological activity, and even sounds that are inaudible to most humans, such as bat echolocation calls. *Soundscape*, however, is that component of the acoustic environment that can be perceived and comprehended by humans. The character and quality of the soundscape influence the human perceptions of an area, providing a sense of place that differentiates it from other regions. *Noise* refers to sound which is unwanted, either because of its effects on humans and wildlife, or its interference with the perception or detection of other sounds.

Reference condition for ambient sound refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustic environment. The influence of anthropogenic noise on the acoustic environment is generally reported in terms of sound pressure level (SPL) across the full range of human hearing (12.5-20,000 Hz).

Various characteristics of sound can contribute to how noise may affect the acoustic environment. These characteristics may include rate of occurrence, duration, amplitude, pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustic environment is assessed using a number of different metrics including: 1) existing ambient and natural ambient sound level (measured in decibels), 2) percent time human-caused noise is audible, and 3) noise-free interval. The use of all these metrics can make selecting one reference condition difficult. Ideally, reference conditions would be based on measurements collected in the park, but this is not always logistically feasible.

Thresholds for assessing the effects of sound on disturbance can come from a variety sources. For example, Haralabidis et al. (2008) have found that a sound level of 35 dBA (A-weighted decibel) can have adverse effects on humans by causing sleep interruption. The World Health Organization sets a “human sleeping threshold” of 45 dBA (Berglund et al. 1999). Other sound thresholds related to the ability to hear human speech. The EPA sets a threshold of 52 dBA for speaking in a raised voice to an audience at 10 meters. This threshold addresses the effects of noise on interpretive programs in parks. Another threshold set by the EPA is 60 dBA which provides a basis for estimating impacts on normal voice communications at 1 meter.

In cases where ability to collect acoustic data on site is limited, NPS Natural Sounds and Night Sky Division (NSNSD) developed a geospatial sound model which predicts natural (Figure 5) and existing (Figure 6) sound levels with 270-m resolution (Mennitt et al. 2013). In addition to predicting these two ambient sound levels, the model also calculates the difference between the two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources (Figure 7). The resulting metric (L50 dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location.

At NERI, the mean impact is predicted to be 1.3 dBA (ranging from 0 dBA in the least impacted areas to 8.9 dBA in the most impacted areas (Figure 7). That is, the average existing sound level (with the influence of human-caused sounds) is predicted to be 1.3 dBA above natural conditions. A one decibel change is not readily perceivable by the human ear, but any addition to this difference could begin to impact listening ability. An increase of 1.3 dBA would reduce the listening area for wildlife and visitors by 26%. For example, if a predator can hear a potential prey animal in an area of 9.3 m^2 (100 square feet) in a setting with natural ambient sounds, that animal’s ability to hear would be reduced to 6.9 m^2 (74 square feet) if the sound levels were increased by 1.3 dBA. Similar reduction would occur for visitors and their ability to hear natural sounds or interpretive programs. Compared to parks throughout the national park system, this is a low number and shows a prominence of natural sounds that should be preserved and protected.

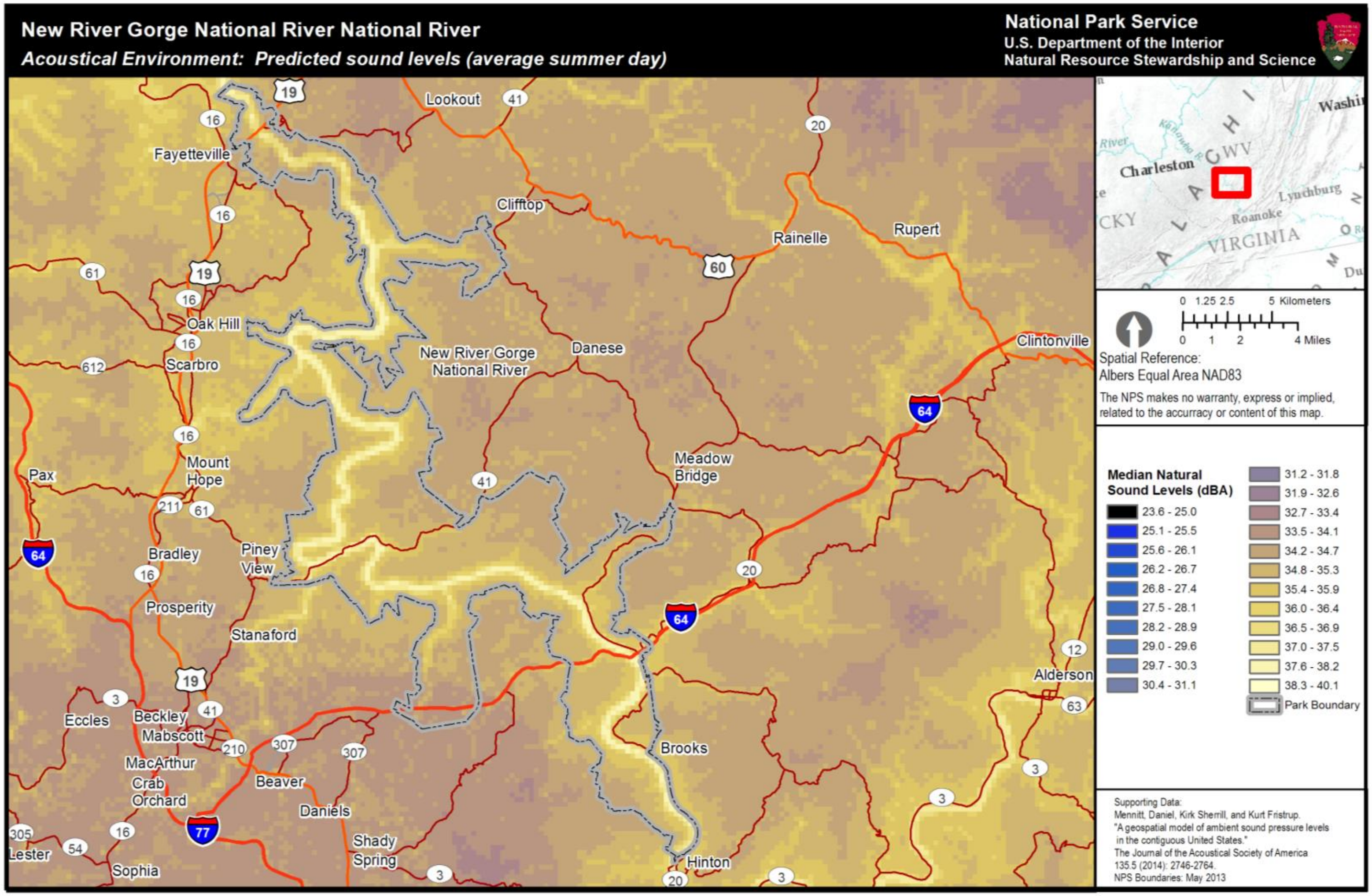


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Figure 5. Median natural sound pressure levels for New River Gorge National River (NERI). The color scale indicates the decibel level that is predicted in the park based only on natural sound sources. Sound level is measured in A-weighted decibels, or dBA, with 270 meter resolution. Black and dark blue colors indicate low decibel impact levels while yellow or white colors indicate higher decibel impact levels. Note that due to the national scale of the model inputs, this graphic may not reflect recent localized changes such as new access roads or development (NPS, Natural Sound and Night Skies Division, 2016).

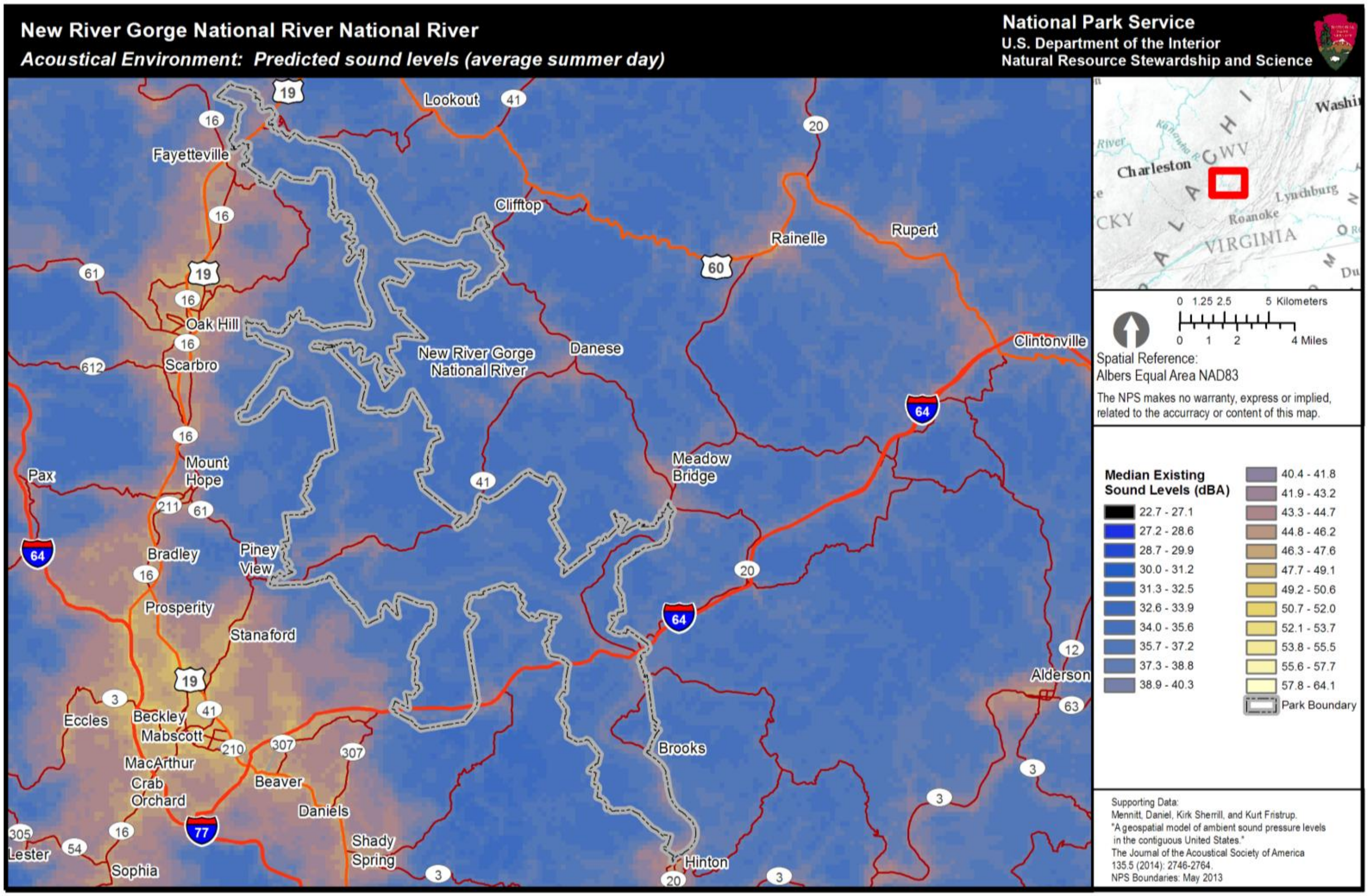

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Figure 6. Median existing sound pressure levels for New River Gorge National River (NERI). The color scale indicates the decibel level that is predicted in the park based only on both human-caused and natural sound sources. Sound level is measured in A-weighted decibels, or dBA, with 270 meter resolution. Black and dark blue colors indicate low existing decibel levels while yellow or white colors indicate higher existing decibel levels. Sound levels in national parks can vary greatly, depending on location, topography, vegetation, biological activity, weather conditions and other factors. Note that due to the national scale of the model inputs, this graphic may not reflect recent localized changes such as new access roads or development (NPS, Natural Sound and Night Skies Division, 2016).

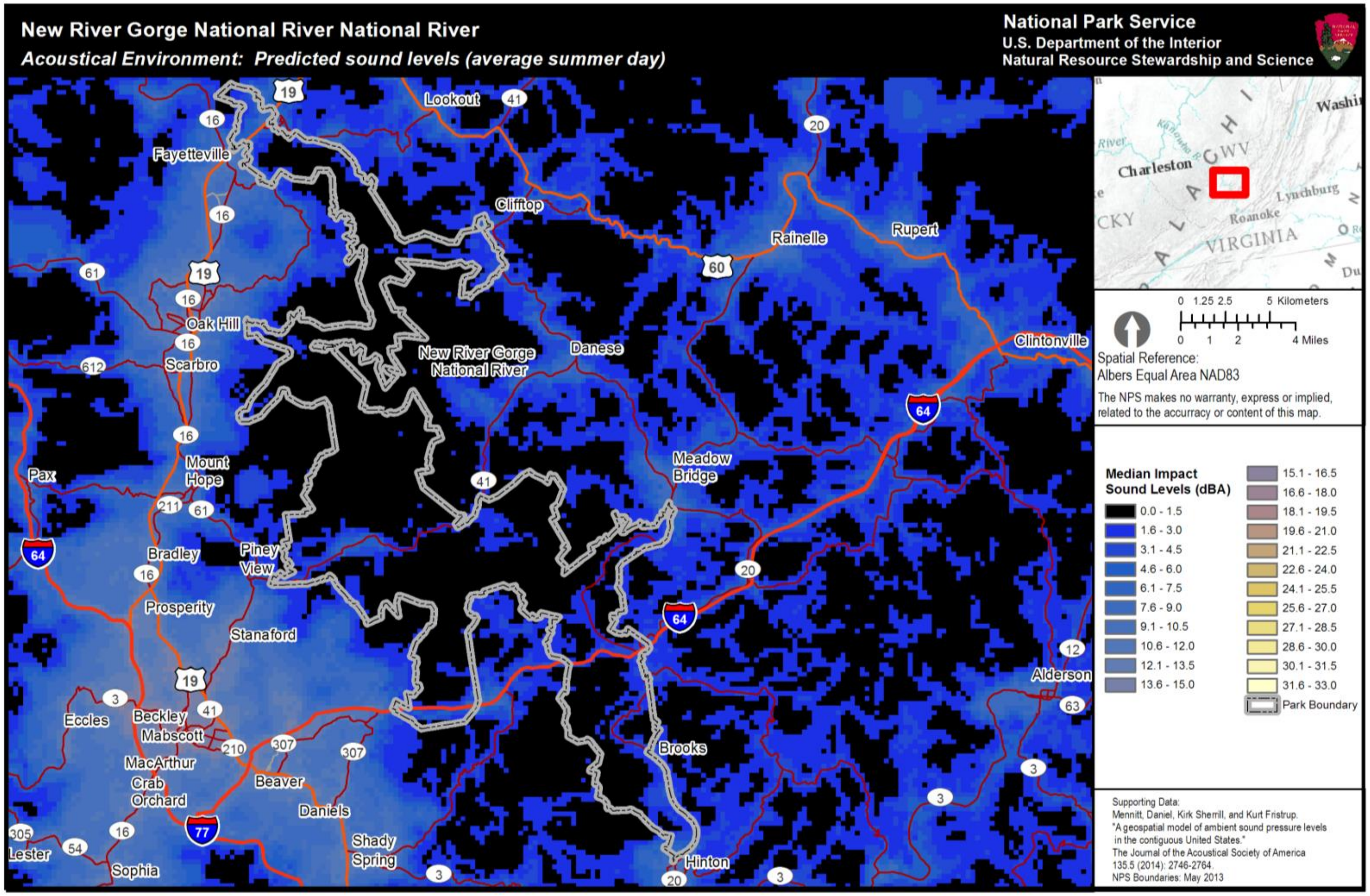

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Figure 7. Median sound level impact map for New River Gorge National River (NERI). The color scale indicates how much human-caused noise raises the existing sound pressure levels in a given location (measured in A-weighted decibels, or dBA), with 270 meter resolution. Black and dark blue colors indicate low impacts while yellow or white colors indicate greater impacts. Note that due to the national scale of the model inputs, this graphic may not reflect recent localized changes such as new access roads or development. (NPS, Natural Sound and Night Skies Division, 2016).

At NERI, the mean existing sound level (natural and human-caused sounds) is estimated to be 36.7 dBA (ranging from 33.8 to 45.7 dBA; Figure 6). At this sound level, campers would begin to be interrupted during sleep but personal and interpretive speech could be heard by a listener. Since 36.7 dBA is a mean, there may be periods and locations where noise exceeds the listening thresholds described above. The mean existing sound levels at the park are lower than the sound levels in nearby developed areas. This condition demonstrates that sounds intrinsic to the park could be an important resource to protect in the park environment.

4.1.1. Data Gaps, Needs, and Management Strategies

Baseline acoustic ambient data collection within the park will clarify existing conditions and provide greater confidence in resource condition trends. In addition to providing site-specific information, this information can also strengthen the national noise model. With respect to the effects of noise, there is compelling evidence that wildlife can suffer adverse behavioral and physiological changes from noise and other human disturbances, but the ability to translate that evidence into quantitative estimates of impacts is presently limited. Several recommendations have been made for human exposure to noise, but no guidelines exist for wildlife and the habitats we share. The majority of research on wildlife has focused on acute noise events, so further research needs to be dedicated to chronic noise exposure (Barber et al. 2011). In a review of the literature addressing the effects of noise on wildlife published between 1990 and 2013, wildlife responses to noise were observed beginning at about 40 dBA, and further, 20% of papers showed impacts to terrestrial wildlife at or below noise levels of 50 dBA (Shannon et al. 2016). Wildlife response to noise was found to be highly variable between taxonomic groups. Furthermore, response to noise varied with behavior type e.g. singing versus foraging (Shannon et al. 2016). In addition to wildlife, standards have not been developed yet for assessing the quality of physical sound resources (the acoustic environment), separate from human or wildlife perception.

Park managers at NERI could study ways to reduce noise from park operations (e.g. time activities to preserve quiet times, purchase quieter equipment, consider the use of quiet pavement, include noise mitigations as specification in contracting actions, where appropriate, etc.). In addition, outreach and communication to visitors about reducing noise from sources such as electronics and idling vehicles and the benefits of noise reduction to park experience and wildlife health may be helpful. Finally, park managers could seek ways to collaborate with partners and neighbors to manage noise sources that could affect park resources.

4.2. Dark Night Skies*

*Modified from: Lochen Wood, NPS, Natural Sounds and Night Sky Division, 2016.

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

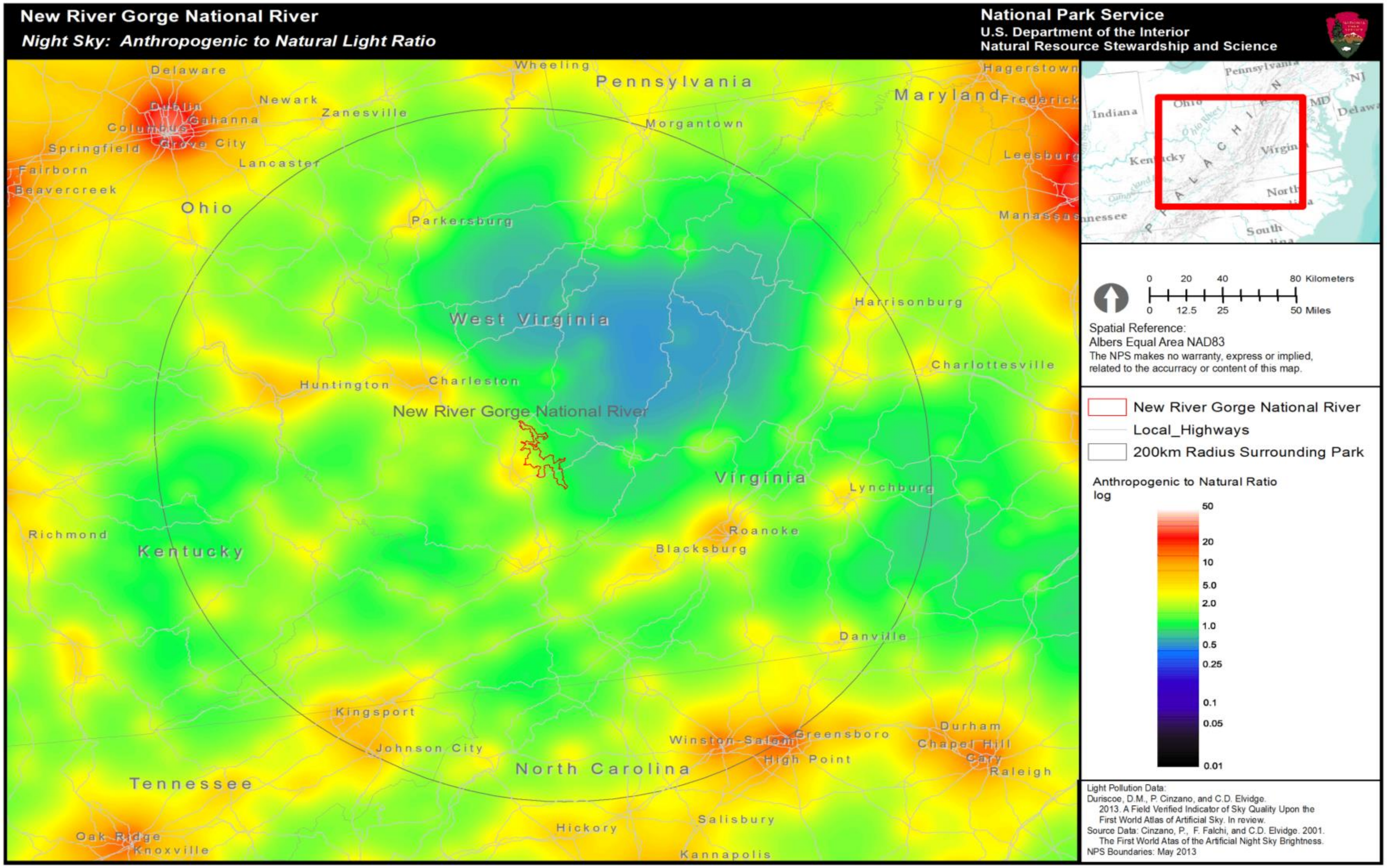
The 2006 NPS management policies document the importance of a natural photic environment to ecosystem function and the importance of the natural lightscape for aesthetics. Natural lighting conditions are also important to wilderness character and have been identified under the Clean Air Act (CAA) Amendments as an air quality related value. Therefore, the importance of lightscapes and photic environments is related to an array of park resources and values at NERI including nocturnal wildlife such as migratory birds, owls, bats and other small mammals, riparian invertebrates, and visitor experiences (including night-time interpretive programming and camping).

One way the NSNSD scientists measure the quality of the photic environment is by measuring total sky brightness averaged across the entire sky and comparing that value to natural nighttime light levels (reference condition). This measure, called the Anthropogenic Light Ratio (ALR), can be directly measured or modeled when observational data are unavailable. Lower ALR levels reflect higher quality night sky conditions. At NERI, the modeled median ALR value is 1.80 (Figure 8). An ALR of 0.0 would indicate pristine natural conditions. At an ALR of 1.8, the Milky Way is visible but has typically lost some of its detail and is not visible as a complete band. Zodiacal light (or “false dawn” which is faint glow at the horizon just before dawn or just after dusk) is rarely seen. Anthropogenic light likely dominates light from natural celestial features and shadows from distant lights may be seen. The ARL at NERI is comparable to that found at the Wright Brothers National Memorial on North Carolina’s Outer Banks (1.2) and much lower than the ARL at the Kennesaw Mountain National Battlefield Park (19.3) located just outside of Atlanta, Georgia (NPS 2013, NPS 2016).

Although the park night sky quality is partially degraded due to the proximity to multiple population centers, NERI provides important habitat for nocturnal wildlife and a unique opportunity for visitors to enjoy night sky resources. By providing overnight camping and conducting night time programming, the park has demonstrated that it is dedicated to protecting night sky resources.

4.2.1. Data Gaps, Needs, and Management Strategies

Data on background night-time light levels collected in the park are important to better assess threats to the dark night-time skies at NERI. Threats to the dark night sky at NERI include artificial light from park facilities and operations, artificial light from nearby development, light domes from nearby bright towns/cities, and artificial light from visitors. The park could address some of these issues by developing and implementing a park lighting plan (e.g. develop night sky goals, indicators, and standards) and/or pursuing an International Dark Sky Park status. In the short-term, the park could retrofit light sources to reduce glare, reduce overall light output, direct lights downward, and install warmer color lamps.



Created by NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group on 20150316

Figure 8. Regional view of anthropogenic light near New River Gorge National River (NERI). White and red represents more environmental influence from artificial lights while blues and black represent less artificial light (NPS, Natural Sound and Night Skies Division, 2016).

4.3. Air Quality (includes Visibility, Ozone, Sulfur and Nitrogen Deposition, Mercury Deposition, and Climate Change)*

*Modified from: Holly Salazer, NPS, Air Resources Division, 2016.

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

The 2006 NPS management policies clarify that the Service will seek to “perpetuate the best possible air quality in parks”. This means establishing benchmark conditions for air quality that are consistent with the CAA and other policy goals. The NPS Air Resources Division (ARD) focuses on air quality indicators and associated benchmarks to evaluate air quality conditions in national parks: visibility, ozone, sulfur and nitrogen deposition, and mercury/toxics deposition.

4.3.1. Visibility

Vistas at NERI are often obscured by pollution-caused haze. Currently, the visibility condition at the park warrants significant concern and does not meet the NPS-ARD recommended benchmark for good condition. Visibility is a measure of how far and how well we can see a distant and varied scene. Pollutant particles in the atmosphere – from both natural and human-caused sources (e.g. power plants, dust) – scatter and absorb light, creating a haze that impairs scenic views. The deciview (dv) metric measures visibility changes as perceived by the human eye (analogous to the decibel scale), and is used by the air regulatory community to track visibility conditions and trends. The CAA established a national goal to return visibility to “natural conditions” in Class I areas and the NPS-ARD recommends a visibility benchmark condition for all NPS units, regardless of Class designation, consistent with the CAA goal. Natural visibility conditions (reference conditions) are those estimated to exist in a given area in the absence of human caused visibility impairment (EPA-454/B-03-005). The NPS-ARD recommends that average visibility days should be < 2 dv above natural conditions as a benchmark for good visibility condition (NPS-ARD 2015). Based on 2008-2015 estimated visibility data, average visibility in NERI was 8.4 dv—above estimated natural conditions, and falls within the significant concern category. Data from the nearby Natural Bridge, Virginia visibility IMPROVE (Interagency Monitoring of Protected Visual Environments) monitoring site indicates that during the 2003-2012 decade, the trend in visibility improved on both the 20% clearest days and 20% haziest days, resulting in an overall improving visibility trend. The degree of confidence in the visibility condition and trend at NERI is high because of the nearby visibility monitor (IMPROVE Site ID: JARI1, VA; NPS-ARD 2015). The major pollution sources that impact scenic resources are power plants, oil and gas development, industrial facilities, agriculture, vehicle exhaust, and urban developments.

As reported in Mahan (2004), a detailed visibility analysis of 35-mm slide data collected at NERI from 1995 to 2000 support the seasonal pattern described by the IMPROVE data collected at the surrogate monitoring site. The vista in each 35-mm slide was reviewed for visible haze events and haze events were judged to be “slight”, “moderate”, or “considerable”, depending on the appearance of selected targets. Summer exhibited the poorest visibility, with slight, moderate, and considerable haze intensities occurring 43%, 20%, and 17% of the time, respectively (the remaining 20% was made up of weather concealed views or unusable slides). The best visibility was shown to be in winter, with slight, moderate, and considerable haze intensities occurring 64%, 4%, and 1% of the time, respectively.

4.3.2. Ozone

Ground-level ozone at NERI warrants moderate concern for human health and vegetation health in accordance with NPS-ARD benchmarks. Ground-level ozone is formed when nitrogen oxides from vehicles, power plants, and other combustion sources combine with volatile organic compounds from gasoline, solvents, and vegetation in the presence of sunlight. The National Ambient Air Quality Standard (NAAQS) for ozone is set by the EPA, and is based on human health effects. NERI is located in Fayette, Raleigh, and Summers counties in West Virginia that meet the NAAQS ozone standard of an 8-hour average concentration of 75 parts per billion (ppb). For this reason, these counties are EPA designated “attainment” areas for ozone. The NPS-ARD recommends a benchmark for good ozone condition of 60 ppb or less, which is 80% of the human health-based NAAQS. The moderate concern for NERI ozone levels is based on NPS-ARD benchmarks and the 2008–2015 estimated ozone concentration (4th highest 8-hour average) of 64.5 ppb. The degree of confidence in the ozone condition is medium because estimates are based on interpolated data from more distant ozone monitors (NPS-ARD 2015).

In addition to being a concern to the health of park staff and visitors, long-term exposures to ozone can cause injury to ozone-sensitive plants. The W126 metric, developed by the EPA in 2006, relates plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the human health standard. The W126 metric measures cumulative ozone exposure over the growing season in “parts per million-hours” (ppm-hrs). The NPS-ARD recommends a W126 of < 7 ppm-hrs to protect sensitive vegetation. At NERI, the W126 metric during 2008-2012 was 7.4 ppm-hrs, and, therefore, warrants moderate concern. The degree of confidence in the condition of ozone risk to vegetation is medium because estimates are based on interpolated data from more distant ozone monitors (NPS-ARD 2015). A risk assessment that considered ozone exposure, soil moisture, and sensitive plant species concluded that plants in NERI were at moderate risk of foliar ozone injury (Kohut 2007). The park has at least 20 ozone-sensitive plants including American Sycamore [*Platanus occidentalis*], Yellow Poplar [*Liriodendron tulipera*], Cut-leaf Coneflower [*Rudbeckia laciniata*], and Spreading Dogbane [*Apocynum androsaemifolium*] (NPSpecies 2015).

4.3.3. Sulfur and Nitrogen Deposition

Both sulfur and nitrogen deposition warrant significant concern at NERI in accordance with NPS-ARD benchmarks. Lichen and forest vegetation may be at risk for harmful effects from nitrogen deposition. Airborne pollutants are deposited to the earth through a process called atmospheric deposition. Pollutants that come down with rain, snow, or other precipitation are wet deposition; and pollutants that come down as dust, particles, or gas are dry deposition. Total deposition includes both wet and dry deposition. Sulfur and nitrogen compounds in air pollution (e.g. industry, agriculture, oil and gas development) can be deposited into ecosystems and cause acidification, excess fertilization (eutrophication), and changes in soil and water chemistry that can affect community composition and alter biodiversity. Sulfur, together with nitrogen, contribute to acid deposition and can result in changes in community structure, biodiversity, reproduction, and decomposition.

In and around NERI, coal-fired power plants and mobile sources such as vehicles are believed to be major contributors to air pollution regionally in the eastern United States. Due to ozone and fine particulate air quality standards, emissions from coal fired power plants and mobile sources have declined significantly in the past decade. These emission reductions should also improve air quality conditions at NERI. For example, sulfur dioxide emissions from power plants in West Virginia and Virginia were reduced by 85% between 2000 and 2014; over the same time period nitrogen oxide emissions from electric utilities in these states were reduced by 74%. Neighboring states have accomplished similar reductions and additional emission reductions from electric utilities are required before 2018. The EPA requires cleaner engines and cleaner fuels for vehicles and non-road engines so nitrogen oxide emissions from mobiles sources have also been reduced.

Increasing oil and gas development also poses a threat to park air quality. New drilling technologies such as horizontal drilling and hydraulic fracturing, and shale gas development has increased exponentially within the region, including within West Virginia (EIA 2014). Equipment associated with oil and gas development such as drill rigs, fracturing engines, valves, seals, compressors, etc. all emit air pollutants, and in regions of extensive development, can contribute to air quality impacts. There are a significant number of active wells west of the park boundaries (WV DEP 2017).

Ecosystems at NERI were rated as having very high sensitivity to potential effects of acid deposition relative to all other parks within the Eastern Rivers and Mountains (ERMN) NPS monitoring network. This rating was based on conditions such as steep slope, high elevation, and the abundance of vegetative types expected to be most sensitive to acidification. Plants sensitive to the effects of acidification in the park include sugar maple trees [*Acer saccharum*] and may be most vulnerable in areas that contain soils with low acid-neutralizing capability (Sullivan et al. 2011). Most NERI streams are well-buffered (pH 7.5-8.5), indicating some resistance to the effects of acid deposition (Purvis et al. 2002).

The NPS-ARD recommends sulfur wet deposition of less than 1 kilogram per hectare per year (kg/ha/yr) to protect sensitive ecosystems. Wet sulfur deposition at the park warrants moderate concern based on NPS-ARD benchmarks and the 2008–2015 estimated wet sulfur deposition of 2.9 kg/ha/yr. The degree of confidence in the wet sulfur deposition condition is high because estimates are based on interpolated data from on-site or nearby monitors (NPS-ARD 2015).

Although nitrogen is an essential plant nutrient, surplus levels of atmospheric nitrogen deposition can stress ecosystems by contributing to acid deposition. In addition, excess nitrogen can cause weedy, non-native plant species to grow faster and out-compete native vegetation adapted to low nitrogen conditions, decreasing biodiversity and contributing to loss of ecosystem health and function (Blett & Eckert 2013; Bobbink et al. 2010). Atmospheric nitrogen deposition may cause cumulative impacts to ecosystems when coupled with terrestrial sources from fertilizers. The NPS-ARD recommends nitrogen wet deposition of less than 1 kg/ha/yr to protect sensitive ecosystems. Wet nitrogen deposition at the park warrants significant concern based on NPS-ARD benchmarks and the 2008–2015 estimated wet nitrogen deposition of 3.7 kg/ha/yr. The degree of confidence in the wet nitrogen deposition condition is high because estimates are based on interpolated data from on-site or nearby monitors (NPS-ARD 2015).

Ecosystems at NERI are not typical of nutrient polluting, nitrogen-sensitive systems and were rated as having very low sensitivity to nutrient-enrichment effects relative to all other ERMN parks (NPS-ARD 2015). However, park wetlands may be vulnerable to excess nitrogen deposition, which can alter plant communities and reduce biodiversity. (Sullivan et al. 2011).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of nitrogen deposition impacts (i.e., nutrient enrichment) to park resources. A critical load is defined as a level of deposition below which harmful effects to the ecosystem are not expected. Pardo et al. (2011) suggested following critical load ranges for total nitrogen deposition in the Eastern Temperate Forests ecoregion: 1) 3.0–8.0 kg/ha/yr to protect forest vegetation, 2) 4.0–8.0 kg/ha/yr to protect lichen, and 3) 17.5–17.5 kg/ha/yr to protect herbaceous vegetation. To maintain the highest level of protection in the park, the minimum of the critical load ranges (3.0 kg/ha/yr) is an appropriate management goal. The estimated maximum 2010–2012 average for total nitrogen deposition was 9.0 kg/ha/yr in the Eastern Temperate Forests ecoregion (NADP-TDEP 2014) of NERI. Therefore, the total nitrogen deposition level in the park is above the minimum ecosystem critical loads for some park vegetation communities, suggesting that lichen and forest vegetation types are at risk for harmful effects. In addition, higher nitrogen concentrations in some plants have been shown to increase susceptibility to certain insect pests. Pontius et al. (2006), for example, found that nitrogen concentration in Eastern Hemlock stands correlated with infestation of Hemlock Woolly Adelgid [*Adelges tsugae*], and increased severe dieback symptoms.

4.3.4. Mercury and Toxics Deposition

Mercury and toxics deposition is rated by the NPS-ARD as a significant concern at NERI. Mercury and other toxic pollutants accumulate in the food chain and can affect both wildlife and human health. Potential sources of atmospheric mercury at NERI include by-products of coal-fire combustion, municipal and medical incineration, and mining operations. Mercury also may enter the environment from historically contaminated soils, effluent from waste water treatment facilities, current local industrial practices, and regional and global air transport. Wet and dry deposition can lead to mercury loadings in water bodies, where mercury may be converted to a bioavailable toxic form of mercury, methylmercury, and bio-accumulate through the food chain. Wetlands, especially those rich in organic matter, are important sites for methylmercury production.

Exposure to high levels of mercury in humans by consuming contaminated fish may cause damage to the brain, kidneys, and a developing fetus. High mercury concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success. Other toxic air contaminants of concern include pesticides (e.g. DDT), industrial by-products like PCBs and PFCs, and emerging chemicals such as flame retardants for fabrics (PBDEs). Some of these contaminants are carcinogenic. There is a West Virginia statewide fish advisory that includes consumption guidelines due to mercury and polychlorinated biphenyls (PCBs) for fish caught in the New River within the park (WVDHHR 2015). Recommended meal frequency and size is determined by fish species and body weight, to keep the amount of chemicals consumed at a safe level. Women of childbearing age, children, and people who regularly eat fish are particularly susceptible to contaminants that build up over time (EPA-NLFA 2015; WVDHHR 2015). NERI receives a high level of mercury deposition at the park, relative to other areas of the United States (NADP-MDN 2014). The predicted concentration of methylmercury in park surface waters is low as compared to other NPS units (USGS 2015). Overall, mercury and toxics deposition is rated as a moderate concern at NERI, given the moderate mercury deposition, low predicted concentration of methylmercury in park surface waters, and West Virginia statewide fish consumption advisory for mercury and PCBs. The degree of confidence in the condition is low because there are no park-specific studies examining mercury and toxics levels in park ecosystems. Nearby, Shenandoah National Park (SHEN) is assessing mercury levels in water, sediment, and dragonfly larvae samples via a citizen science project (Eagles-Smith et al. 2013); however, results are not yet available.

4.3.5. Climate Change

Air pollution, and specifically the emission of greenhouse gases, is the primary cause of human caused climate change. Air pollution also directly impacts park resources, further decreasing resilience to the effects of climate change. Findings of a recent climate change investigation for NERI include: 1) recent climatic conditions are already shifting beyond the historical range of variability, 2) on-going and future climate change will likely affect all aspects of park management, including natural and cultural resource protection as well as park operations and visitor experience, 3) effective planning and management must be grounded in comprehension of past dynamics, present conditions, and projected future change, and 4) climate change will manifest itself not only as changes in average conditions, but also as changes in particular climate events (e.g. more intense storms, floods, or drought; Monahan and Fisichelli 2014). Extreme climate events can cause widespread and fundamental shifts in conditions of park resources including increased challenges to attain ozone reductions, increased flooding risk, and changes in species distributions, and increased frequency of pathogenic infections (e.g. Nemeth et al. 2017).

At NERI, Gonzalez (2016) indicates that average annual temperature has increased 0.4 °C/century (0.7 °F/century) and annual precipitation has increased 9%/century based on data from 1950-2010. With current highest greenhouse gas emission scenarios, projections indicate that NERI may experience 9-15 more days per year with temperatures > 35 °C (95 °F, Gonzalez 2016).

Sneddon and Galbraith (2015) developed a climate change vulnerability assessment for the Appalachian landscape. Their assessment utilized the NatureServe GIS-based Climate Change Vulnerability Index (CCVI) tool and examined the vulnerability of species, terrestrial habitats, and aquatic ecosystems to climate change. A particular resource's vulnerability depends, in part, on its ability to disperse, its level of exposure to climate change, and its ability to adapt to climatic changes. For the region of West Virginia, in which NERI is located, the CCVI is approximately 0.5 on a 0-1 scale. A score that approaches zero indicates a high probability of climate change effects and departure from current conditions (Sneddon and Galbraith 2015). The effects of climate change in and around NERI are partially tempered by the availability of north - south dispersal corridors, a relatively unfragmented landscape, and phenological adaptations in species of the region.

4.3.6. Data Gaps, Needs, and Management Strategies

While the majority of air pollutants are emitted from sources outside of the parks, air pollution is also emitted directly inside parks. With respect to air pollution and climate change, there are several strategies NERI can undertake: 1) continue Climate Friendly Parks Action Plan with an operational Environmental Management System (EMS, NPS Director's Order 13A.http://www.nps.gov/policy/DOrders/DO-13A.htm) for park environmental leadership and emission reduction activities (e.g., vehicle fleet and energy efficiencies), 2) identify ecosystems and plant communities most vulnerable to climate change and air quality impacts, and devise management strategies accordingly, 3) reduce ecosystem vulnerability to climate change by mitigating air pollution stressors and increasing ecosystem resilience, 4) use interpretive and educational tools to communicate the connections between climate change, air pollution, scenic views, night sky, sensitive park resources, visitor experience, human health, and other associated resources, and 5) work cooperatively with federal, state, tribal, local agencies, industry, and public interest groups, to develop strategies to reduce air quality impacts in the park from sources of air pollution. There are some opportunities through federal air quality programs (e.g. regional haze program) for the NPS to work cooperatively with these stakeholders.

Park managers could use the CCVI tool locally (versus regionally) to assess the effects of species conservation status on climate change adaptation. This type of assessment may facilitate conservation planning. In particular, protecting large core habitat areas, increasing habitat connectivity, improving local habitat conditions, and employing monitoring to adaptively manage resources will help species and ecosystems respond to climate change.

There is an on-going need to study air pollution impacts on sensitive park ecosystems, including the potential impact of mercury and other pollutants to lichens, bryophytes, vascular plants, and fish. For example, NERI may wish to participate in the Eastern Fish Mercury Study - an NPS/USGS cooperative assessment of mercury in fish from eastern national parks. NERI is one of approximately 20 NPS units involved. These types of programs may increase the confidence in determining threats to air quality in the park. Sometimes, park management activities can contribute to air quality decline. For example, park managers could consult with appropriate state and federal environmental agencies prior to prescribed fire implementation to meet smoke management and air quality requirements. Finally, incentives for park staff to take the "Air Resources in National Parks" 2-hour training course could be provided.

4.4. Scenic Resources*

*Modified from: Holly Salazer, NPS, Air Resources Division, 2016.

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Visitors often come to parks to take in spectacular views and marvel at the unique scenery of diverse areas. However, the views are sometimes obscured by air pollutants or spoiled by unsightly development. Scenery is composed of visual resources which are the visible physical features such as topography and landform, vegetation, water, structures, and other features that combine to create the visual landscape. Visual resources are key to the purpose and significance of many NPS units. Scenery is both valued for its present-day characteristics and as an important means of enhancing visitor connections to cultural resources associated with historic or even prehistoric landscapes.

At NERI, the landscape characteristics of the southern Appalachian Mountains retains unique scenic qualities that makes it a great place to get away from the fast pace of city life and enjoy boating, fishing, whitewater rafting, picnicking or just relaxing on the shores of the river. The importance of scenic resources is included in the park's significance statements and fundamental values. Vistas at NERI include natural forests and bluffs as well as wetland and river habitat. Though some views have been affected by development outside the park many views from the river are in relatively good condition. Continued development and changes in land use could affect scenic views in the future.

The two primary components to consider in the management of visual resources are the resources within the park boundaries and those that extend beyond the boundaries. Within park boundaries the visual landscape can be maintained through careful NPS management. The vistas that encompass visual resources beyond park boundaries can be more challenging, but just as important, to maintain unimpaired scenic resources for future generations. While the park is surrounded mostly by small towns and rural areas, future development such as residential and commercial areas could continue to diminish the quality of views that are an important part of the visitor experience. Other threats to visual resources come from activities and pollutants that degrade visibility (NPS-ARD 2015). In some areas, human activities that disturb vegetation and soil surfaces may trigger dust emissions that degrade visibility and the expansive scenic views from within the park.

4.4.1. Data Gaps, Needs, and Management Strategies

Addressing visual resources through internal planning provides the NPS with information necessary to protect a park's scenic resources. It allows parks to ensure internal vistas are protected, and may enhance NPS success in protecting visual resources beyond park boundaries. When development is proposed within shared viewsheds, there are opportunities for the NPS to engage in local, regional, and national regulatory and planning processes. Information about existing visual resources, most visited park view points, and the potential sensitivity of visitors to changes in the visual setting can inform external planning and development proposals and protect park scenic vistas.

Park planning team members could consider the following items when evaluating the current status of scenic views at the park: 1) the extent to which scenic resources at the park are adequately evaluated or inventoried and appropriately addressed in current park planning documents, 2) the relative level of importance of the park's visual setting to the visitor experience and the general quality of the park's scenic views, including impacts from development outside the park boundaries, and 3) the potential for change in scenic quality from development outside the park and the relative extent to which the park is engaged with stakeholders, land managers, and other stakeholders to protect scenic views.

Due to the potential for nearby land management activities, the park could continue to participate in opportunities to provide input on the scale and location of potential development and other human activities through coordination with land management agencies and land owners. NERI could consider developing a scenic resource inventory from sensitive park vista points that include views extending beyond NPS boundaries. For each of these vista points it could be beneficial to assess the existing and desired future conditions of the visual setting and to prepare a visibility analysis that includes a photo documentation and a description of the view, surrounding land use (existing and planned), the general level of visitor use, and the importance of the view to the visitor experience.

4.5. Geologic Features

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

As identified by Mahan (2004) and by the park's General Management Plan (NPS 2011), the geologic features at NERI are internationally and nationally significant. In particular, extensive (> 30 km, 18.6 mi) linear sandstone cliffs that rise 250 m (155 ft) above the gorge sustain distinct ecological communities while supporting multi-million dollar recreational rock climbing opportunities at NERI (NPS 2011). Over the past six years, the cliffs at NERI have been the subject of intensive study and monitoring (Olcott 2011, Clark 2012, Smaldone and McKenney 2013, Mahan 2016).

In NERI, there are two geologic sandstone formations exposed by the gorge: 1) the Pocahontas Formation and 2) the New River Formation. Both formations are in the Pottsville bedrock group of the Pennsylvanian Period –making this rock approximately 300 million years old (Lessing 1986). The walls of New River gorge are dominated by the New River Formation. The Nuttall Sandstone is the uppermost member of the New River Formation and its exposure dominates the northwest portion of the gorge (Figure 9). Other lower geologic members of the New River Formation include the Guyandot, Raleigh, and Pineville Sandstones which contain fine rock layers (< 1 cm, 0.4 in thick) that lie at an angle to the main bedding layers (Olcott 2011).

Due, in part, to its geologic features, the Nuttall Sandstone is preferred by rock climbers over other cliff-forming sandstones present in NERI and contains nearly all documented climbing areas in the gorge (Olcott 2011). For example, the lower Nuttall Sandstone forms 15 to 35 m (49.2 to 114.8 ft) high cliffs along the gorge walls, containing more than 1500 documented climbing routes. Olcott (2011) conducted outcrop investigations on climbed routes and demonstrated that the lower Nuttall Sandstone's competence, level of surface features, jointing, and bedding are controlling variables acting on climbing desirability. The Nuttall Sandstone contains weathered (erodible) rock units called "huecos" by climbers. These huecos (or hollows) are spherical depressions in rock which are used as foot or hand holds by climbers. In addition, the Nuttall Sandstone at NERI contains widely spaced vertical tectonic joints (e.g. rock fractures; Remo 1999). Over geologic time, differential erosion and tectonic jointing lead to large blocks of lower Nuttall Sandstone failing in a predictable pattern, creating planar cliff faces and opening joints that provide additional climbing appeal (e.g. create holds for feet, hands, and gear). These planar cliff faces provide a relatively fresh, unweathered surface of rock available to climb (Olcott 2011, Mahan 2016).

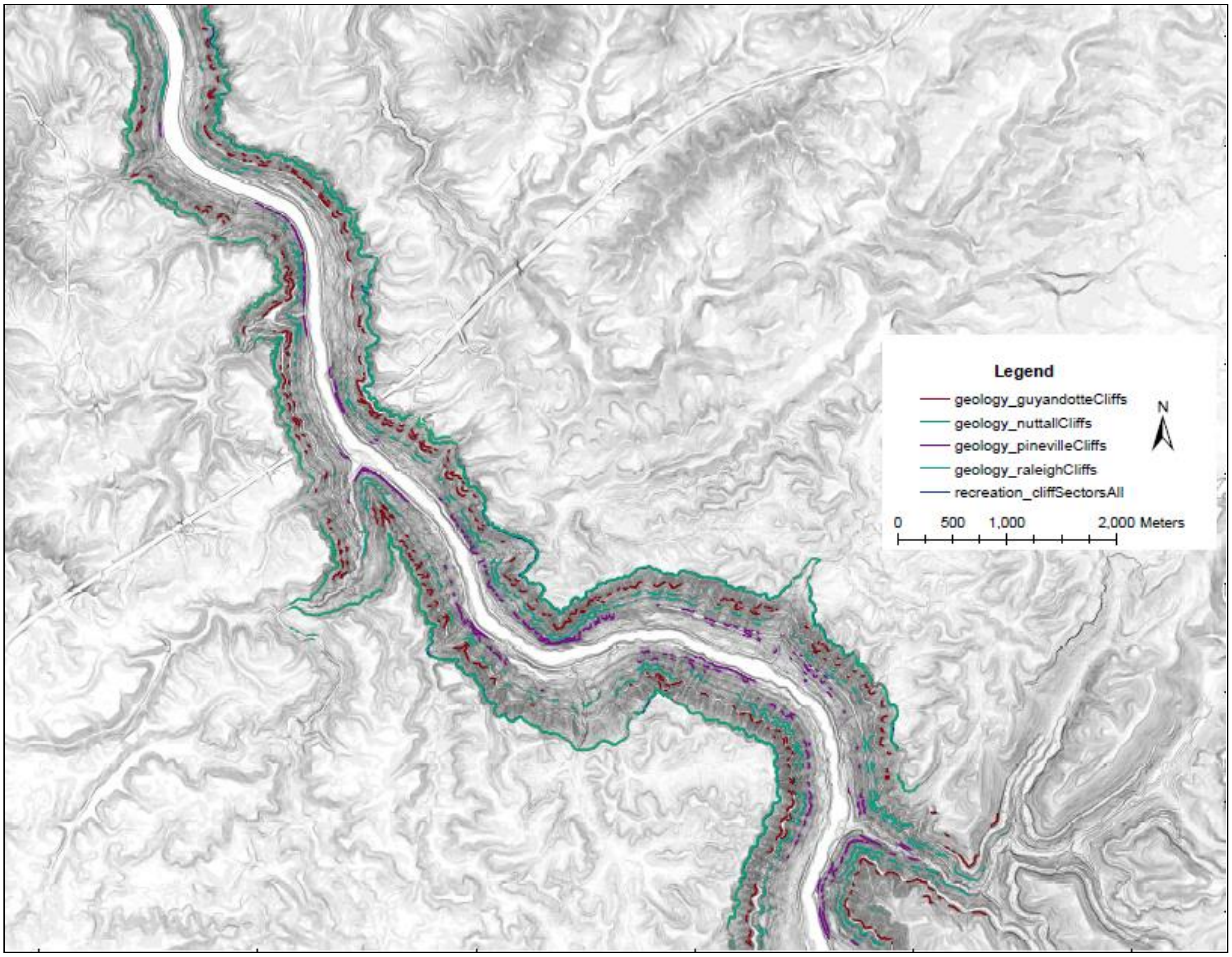


Figure 9. Location, extent, and type of sandstone cliffs within the lower New River Gorge at New River Gorge National River (NERI), West Virginia (from Mahan, 2015).

In addition to these cliff features, NERI contains other geologic features of note including plant fossils [*Mariopteris muricata* and *Neuropteris pochontas*] that are used in aging the exposed Pennsylvania and Mississippian coal seams in the gorge. NERI also contains geologic formations called "rock cities" (large boulders creating interconnected passages) that have been developed for visitor use and interpretation (NPS 2011). The geology of the New River Gorge also influences river flow regimes including the mainstem rapids and channels that contribute to the park's recreational appeal to rafters, anglers, and the ecological diversity of the riparian habitat.

The geology of the gorge also shaped the settlement and industrialization of the area. In the process of forming the gorge, the New River sliced through coal-bearing Carboniferous period sediments thus creating coal-seam exposure which lie between the sandstone formations (Mahan 2016). This exposure not only alerted people to the presence of coal in the area but also permitted its relatively easy removal and led to industrialization of the gorge and surrounding areas (Mahan 2004, NPS 2011).

The reference condition of the New River Gorge is difficult to determine, in part, due to the 200+ year history of industrial use within and around the gorge. However, reference conditions would certainly include the geology and associated ecology present prior to coal extraction and recreational rock climbing. Based upon recent work by Clark (2012) we know that unclimbed portions of the New River Gorge contain non-vascular plant communities that differ from those remaining at climbed routes. In addition, most climbing areas contain associated social trails (i.e. informal trails created by repeated human trampling), tree damage, and cliff-top erosion that are not found in unclimbed and rarely visited areas in the gorge. Unclimbed cliffs with undisturbed vegetation may serve as remaining indicators of pre-settlement, reference conditions.

Resource extraction—including coal mining--influenced the geology of the New River Gorge via the secondary effects of deforestation and construction on local erosion, sedimentation, and mass movements in and around the park. For example, construction of haul roads and mine sites may have exacerbated mass-movement soil erosion events on steep slopes—especially during flood events (Mahan 2004, Johnson et al. 2000). In addition, coal refuse and spoil-piles are still scattered throughout the New River Gorge. These features are often unstable and associated failures contribute to increased erosion rates within the gorge (e.g. Remo 1999). Coal and timber extraction in and around the gorge was in decline by the 1930s although surface coal mining continued in the vicinity of New River Gorge until the late 1990s.

The baseline mass-movement rate for the gorge is unknown. However, Remo (1999) found that mass movement events associated with past land-use history reflect regional rates of mass movements and do not exceed them. Remo (1999) concluded that mass movements have occurred for millennia on the steep slopes of New River gorge and are part of the natural disturbance regime in the park. However, the composition of the eroded soils and rock may contain increased contaminants due to the land-use and mining history. For example, heavy metals, nutrients, and organic molecules associated with mining and human settlement are primarily transported as adsorbed contaminants on sediment rather than in solution.

In June 2016, extreme flooding associated with storms events in and around the New River gorge caused wide-spread mass-movements within the gorge. This storm event was a 1- in- 1000-year event with a total of 20.3- 25.4 cm (8-10 inches) of rainfall recorded in a 24-hour period in surrounding counties (NOAA 2016). Flooding and associated movements washed out Keeney's Creek road, Fayette State Road, the Hellm's Beach access point and walk-in campsites at Grandview Sandbar and Glade Creek. These mass-movements events may have been exacerbated by legacy landuse conditions that may have increased susceptibility to extreme events.

Clark (2012) conducted inventories of vascular and non-vascular plants at climbing areas in NERI that differed in use intensity (low, medium, high, extreme, unclimbed) and represented a variety of geologic conditions in the park (Figure 10). Clark (2012) compared species richness and abundance of plants among climbing areas and geological structures (e.g., cliff slope, height, microtopography). In particular, lichens were especially sensitive to the effects of rock climbing with a significantly higher species richness and abundance on unclimbed sites than climbed sites (see Mahan 2016 for synthesis). Specifically, growth form and reproductive method of a species plays a critical role in how bryophytes and lichens respond to disturbances caused by recreational rock climbing (Mahan 2016). In particular, fruticose and umbilicate lichens (e.g. Frosted Rock Tripe [*Umbilicaria americana*], Rock Ramalins (*Ramalina spp*.), Horny Beard Lichens [*Usnea subscabrosa*] were absent from cliff faces that experience high to extreme recreational use. Rare populations of some lichens (e.g. Scattered Flack Lichen, Horny Beard Lichen and Frosted Rock Tripe) were only found on cliff faces where no rock climbing had yet occurred. Most rare and specialized bryophytes and lichens were found on cliff faces (versus cliff tops and bottoms) with high frequency of microtopographic features (Mahan 2016). Notable cliff habitats in the park that contain the highest concentration of rare or sensitive species are: South Nuttall, Upper Endless Wall, and Upper Kaymoor. These sites are either remote (e.g., South Nuttall), less accessible (e.g. Upper Endless Wall), or have cliff face conditions not as highly sought by rock climbers (e.g Kaymoor). In particular, the South Nuttall botanic sites correspond to an area of high overall species diversity at NERI and could be prioritized for conservation (Figure 11).

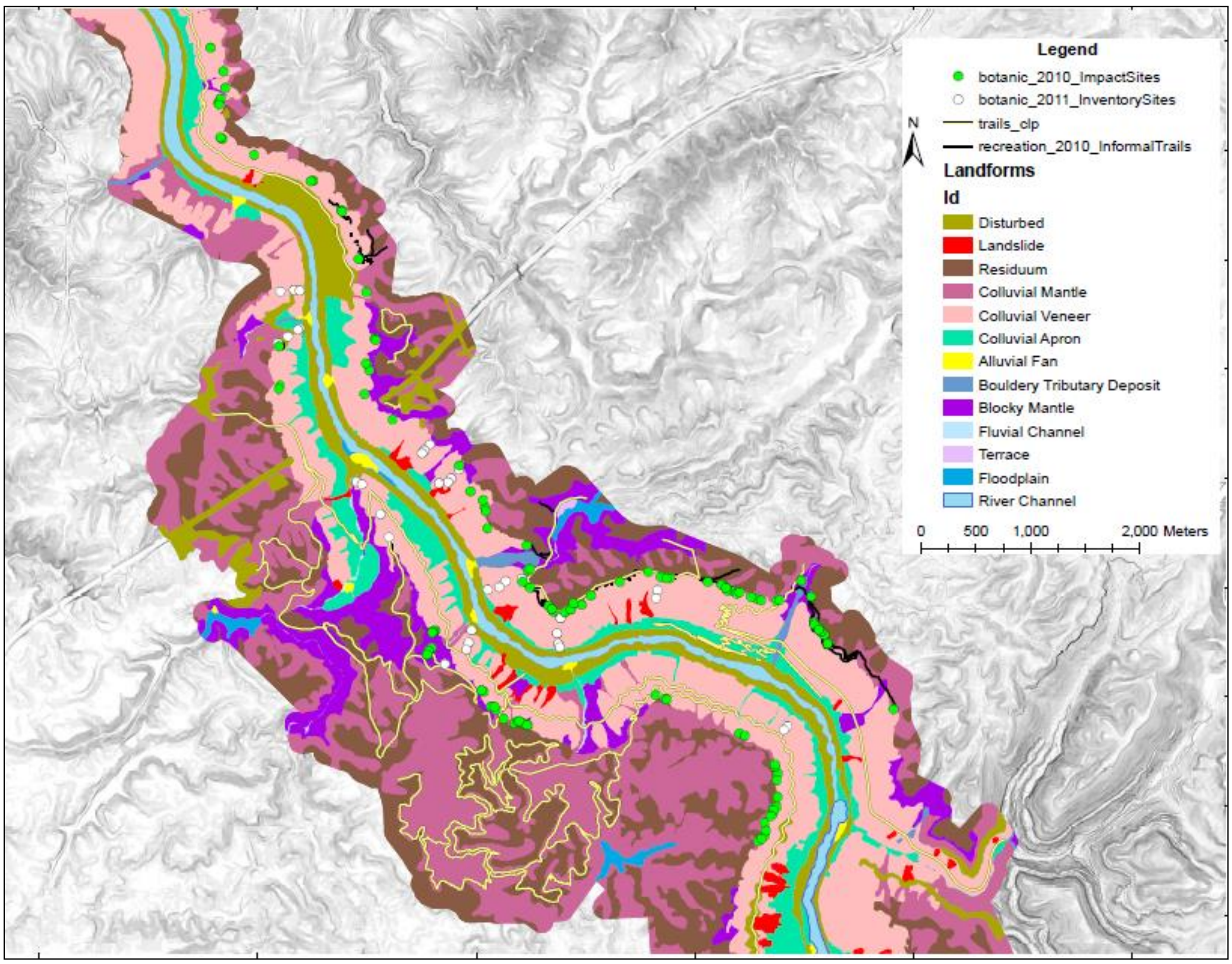


Figure 10. Geologic landforms at New River Gorge National River (NERI). Formal and social tails and botanic (vegetative) inventory sites established in 2010 are marked (from Mahan 2015).

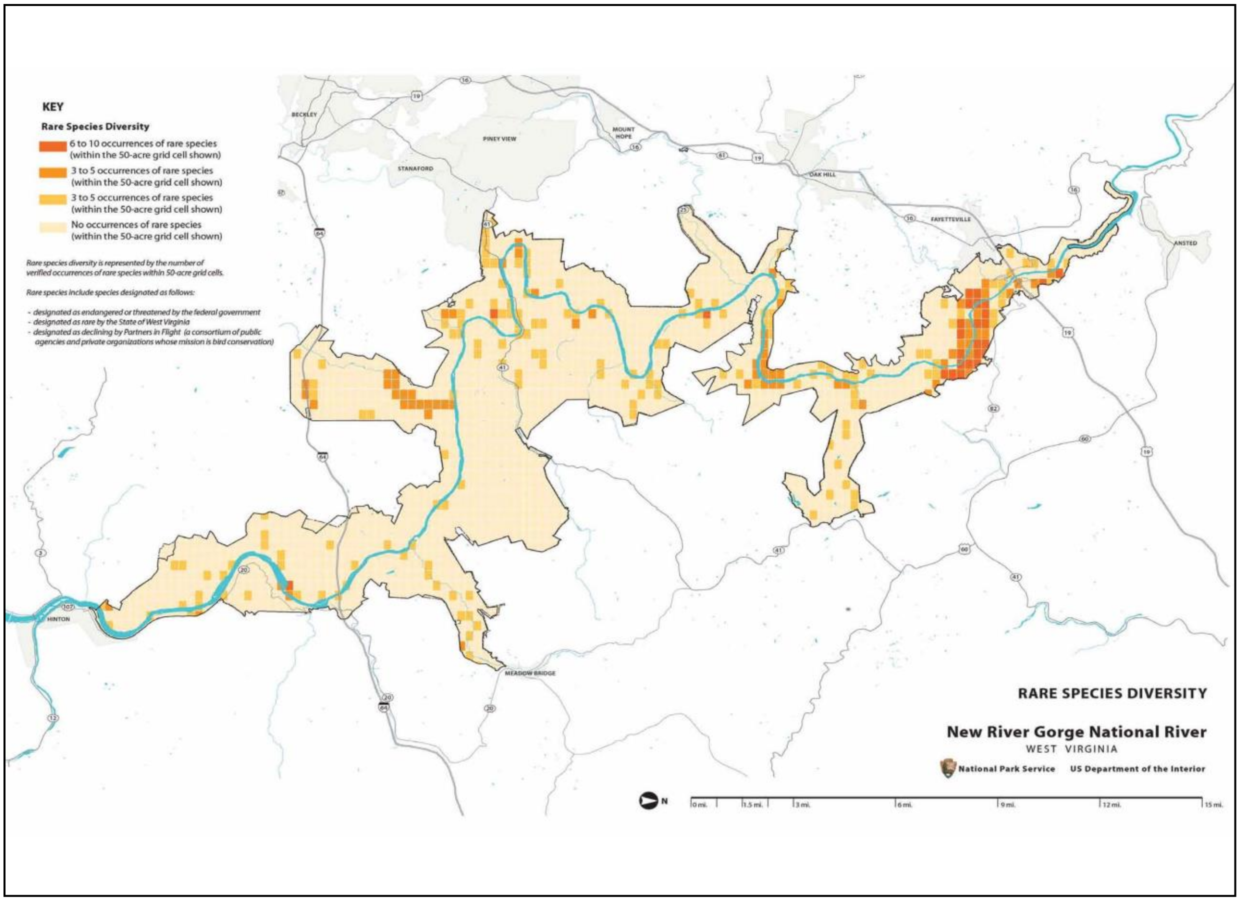


Figure 11. Areas of high species diversity at New River Gorge National River (NERI). The area around South Nuttall in the northern portion of the park is notable from its known diversity (from GMP, NPS 2011).

In 2011, Olcott conducted a study on the recreational use of cliffs at NERI. Recreational uses included traditional climbing, sport climbing, top-rope climbing, rappelling, and day hikers (Olcott 2011, Mahan 2016). Olcott (2011) identified behavior patterns of recreational users that could detrimentally affect natural resources at the cliffs. Detrimental behaviors observed comprised tree anchoring, top-out climbing, non-official trail use, vegetation trampling, off-trail hiking, and tree damage. A subset of cliff users were surveyed by Smaldone and McKenney (2013) to assess visitor attitudes and perceptions of natural resources associated with cliffs and their management.

At NERI, top-rope climbers and rappellers caused the most [obvious] damage to natural resources at cliff sites by anchoring to trees and creating and using non-official trails. Top-rope climbers would use trees as anchors even when fixed anchors were nearby or would use fixed anchors and trees anchors simultaneously (Olcott 2011, Mahan 2016). Smaldone and McKenney (2013) found that cliff use was divided equally among day-hikers and climbers. However, climbers spent more time at cliffs, visited cliffs more often during the year, and felt a greater connection to, and responsibility for, the condition of natural resources at cliffs. Despite these attitudes, 60% of climbers felt it was acceptable to remove vegetation from cliff faces to create climbing routes and 40% agreed it was acceptable to secure top ropes to trees. A third of hikers surveyed felt it was acceptable to create and use unofficial trails at cliff locations in NERI. A majority of rock climbers and day hikers (~60%) agreed that there should be regulations to protect the natural resources associated with cliffs. In particular, rock climbers seemed accepting of regulations regarding the placement of fixed anchors, bolts, and climbing guide certification. However, enforcement of park regulations is problematic—only 1% of hikers and climbers reported encountering a NPS ranger or employee while visiting the park.

4.5.1. Data Gaps, Needs, and Management Strategies

A mass-movement hazard assessment could be conducted in conjunction with events associated with the 2016 floods. Mass-movement and landslide locations could be mapped into GIS and correlated with known coal spoils and mine piles. Such a mapping exercise could be used to model other locations in the gorge susceptible to flood-induced mass movements and to stabilize such locations.

Sediment sampling associated with mass movements could be conducted to determine if hazardous levels of heavy metals, organics, or other pollutants are found in sediments. If found, further systematic sampling could be conducted to find source areas and appropriate mitigation should follow.

Mahan (2016) identified extensive research, monitoring, and education data gaps and needs to protect cliff resources in the face of recreation in NERI. At a minimum, continued monitoring of sensitive lichen and bryophyte species and locations every 3 years could help resource managers evaluate resource trends and determine if increased regulation and enforcement is necessary at selected sites. Recolonization rates by bryophytes and lichens of disturbed sites are unknown and experimental studies could determine how likely an area could be restored if warranted. The effects of climbing chalk and resulting pH effects on vegetation is unknown as well. Finally, as mentioned previously, the South Nuttall cliff area harbors a high diversity of species and could be prioritized for conservation via careful management and increased park ranger patrols.

4.6. New River Mainstem and Tributaries

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

NERI contains an 85-km free-flowing stretch of the New River that forms one of the longest and deepest river gorges in the Appalachian Mountains. The New River has shaped the landscape in and around NERI since the time of the extinct Teays River system (440-550 million years ago), making it one of the oldest rivers in the world (Mahan 2004, NPS 2011). The New River mainstem supports outstanding biological communities as well as popular recreational activities for visitors. For example, the stretch of river from Hinton to Sandstone Falls is one of the most popular fishing areas in West Virginia and white-water rafting on the river supports a $30 million/year industry (Mahan 2004, Versel 2006). The New River flow and flooding regimes shapes in-stream fish, invertebrate, and plant communities while also influencing riparian communities including the globally-rare Appalachian flatrock and riverscour prairie vegetation types.

The reference condition for the New River is the pre-dam condition—of which little is known. Currently, NERI is located between two impounded lakes—the Bluestone Lake (upstream) and Hawks Nest Lake (downstream). The Bluestone dam is managed by the U.S. Army Corps of Engineers in a "run of river" approach (e.g. as much water is let out of the dam as flows into Bluestone Lake). Since its construction in the 1940s, the Bluestone dam has reduced peak flow regimes by 50% and associated changes in river flow and flooding intervals affects in-stream conditions. Research conducted by Flug (1987) indicates that prior to dam construction, mean winter and summer flows were lower and higher, respectively within the main stem of the New River than they are today. The Bluestone dam and associated changes in flow regime has also changed the location and composition of in-river gravel bars and reduced the extent of the riverscour plant communities (Mahan 2004).

Pre-industrial water quality also differed from current conditions (e.g. Webber 2012). Human development and associated sewage-treatment failures have caused dramatic increases in fecal coliform contamination in the main stem and tributaries of the New River. In addition, trace metals associated with a past history of mining (e.g. antimony, cadmium, lead, mercury, and thallium) and trace chemical elements (e.g. arsenic, beryllium, chromium, copper, cyanide, fluoride, nickel, silver, sulfate, and zinc) and acid mine runoff all create a water quality profile that differs from the reference condition (Mahan 2004, Purvis et al. 2002, Table 4). A number of the tributaries to the New River flowing through the park, as well as the main stem of the New River have been designated as impaired for some or all of these pollutants by the EPA (Table 4) and placed on the EPA's 303(d) list. Most impaired waters have already been assessed for total maximum daily load (TMDL) designation and TMDL's have been developed by the WV DEP in cooperation with the EPA (EPA 2014). A TMDL is, "a determination of the amount of pollutant from point, non-point, and natural background sources, including a Margin of Safety (MOS), which may be discharged to a water quality limited body" (EPA 2014). TMDLs include consideration of environmental conditions, including impacts of high rainfall runoff and stream flow events on non-point source pollution, and impacts of low flow events on pollutant loading from point sources (EPA 2014).

Water quality sampling and benthic macroinvertebrate monitoring has been conducted along the main stem and park tributaries of the New River from 2009-2016 by park managers. Currently, these data are the subject of analysis and synthesis to provide a means of assessing data completeness and quality. This analysis will help park resource managers develop a robust and defendable water quality monitoring program (P. J. Kinder, Jr., Natural Resource Analysis Center, Davis College of Agriculture, Natural Resources and Design West Virginia University, Morgantown, WV, proposed Scope of Work, 2017).

Table 4. Designated uses and status of wadeable stream monitoring reaches at New River Gorge National River (Tzilkowski et al. 2015).

Reach Name	Designated Use[1]	Status[2]
Arbuckle Creek	A&W, B-2, C, I, PWS	Impaired (Benthic Macroinvertebrates, Fecal Coliform, Iron)
Batoff Creek	A&W, B-2, C, I, PWS	Impaired (Metals [other than Mercury], pH/Acidity/Caustic Conditions)
Big Branch	A&W, B-1, C, I, PWS	Not Assessed
Bucklick Branch	A&W, B-1, C, I, PWS	Not Assessed
Buffalo Creek	A&W, B-2, C, I, PWS, Tier 3	Supporting
Camp Branch	A&W, B-1, C, I, PWS	Not Assessed
Davis Branch	A&W, B-1, C, I, PWS, Tier 3	Supporting
Dowdy Creek	A&W, B-1, C, I, PWS	Supporting
Ephraim Creek	A&W, B-1, C, I, PWS, Tier 3	Supporting
Fall Branch	A&W, B-2, C, I, PWS, Tier 3	Supporting
Fire Creek	A&W, B-1, C, I, PWS	Not Assessed
Glade Creek	A&W, B-2, C, I, PWS	Impaired (Fecal Coliform)
Keeney's Creek	A&W, B-2, C, I, PWS	Impaired (Fecal Coliform)
Laurel Creek	A&W, B-2, C, I, PWS, Tier 3	Supporting
Little Laurel Creek	A&W, B-1, C, I, PWS	Not Assessed
Meadow Creek	A&W, B-2, C, I, PWS Tier 3	Impaired (Fecal Coliform)
Mill Creek	A&W, B-2, C, I, PWS	Supporting
Piney Creek	A&W, B-2, C, I, PWS	Impaired (Fecal Coliform, Iron)
Richlick Branch	A&W, B-1, C, I, PWS	Not Assessed
Slater Creek	A&W, B-1, C, I, PWS, Tier 3	Supporting
UNT, Buffalo Creek	Not designated	Not Assessed
UNT, Laurel Creek	Not designated	Not Assessed
UNT, Meadow Creek	Not designated	Not Assessed
Wolf Creek	B-2, PWS	Impaired (Benthic Macroinvertebrates, Fecal Coliform, Iron)

[1] All designated uses of streams in New River Gorge NR are determined by the West Virginia Department of Environmental Protection (W. Va. C.S.R.§47-2):

Tier 3 = Outstanding Natural Resource Water

B-1 = Warm Water Fishery

B-2 = Trout Waters

A&W = Agriculture and Wildlife

C = Water Contact Recreation

I = Industrial PWS = Public Water Supply

[2] Assessment status determined from http://www.epa.gov/waters/ir/index.html; August 2013

In addition to water quality monitoring conducted by park managers, the ERMN monitors water quality and benthic macroinvertebrate data at NERI as one of its vital signs. From 2008-2013, 22 wadeable stream reaches were monitored (Figure 12). Ten of the stream reaches in this study had never been assessed by the park or the state of WV. Consistent with park data, dissolved oxygen (DO ~11 mg/l) met or exceeded all designated use criteria set by the EPA and WV (Tzilkowski et al. 2015). However, pH readings that were below state criterion (< 6.0) were recorded on two previously unassessed streams (Little Laurel Creek and Richlick Branch) and Dowdy Creek. Although Dowdy Creek is not monitored by the park, WV monitoring program lists Dowdy Creek as unimpaired and supporting all designated uses (EPA 2017).

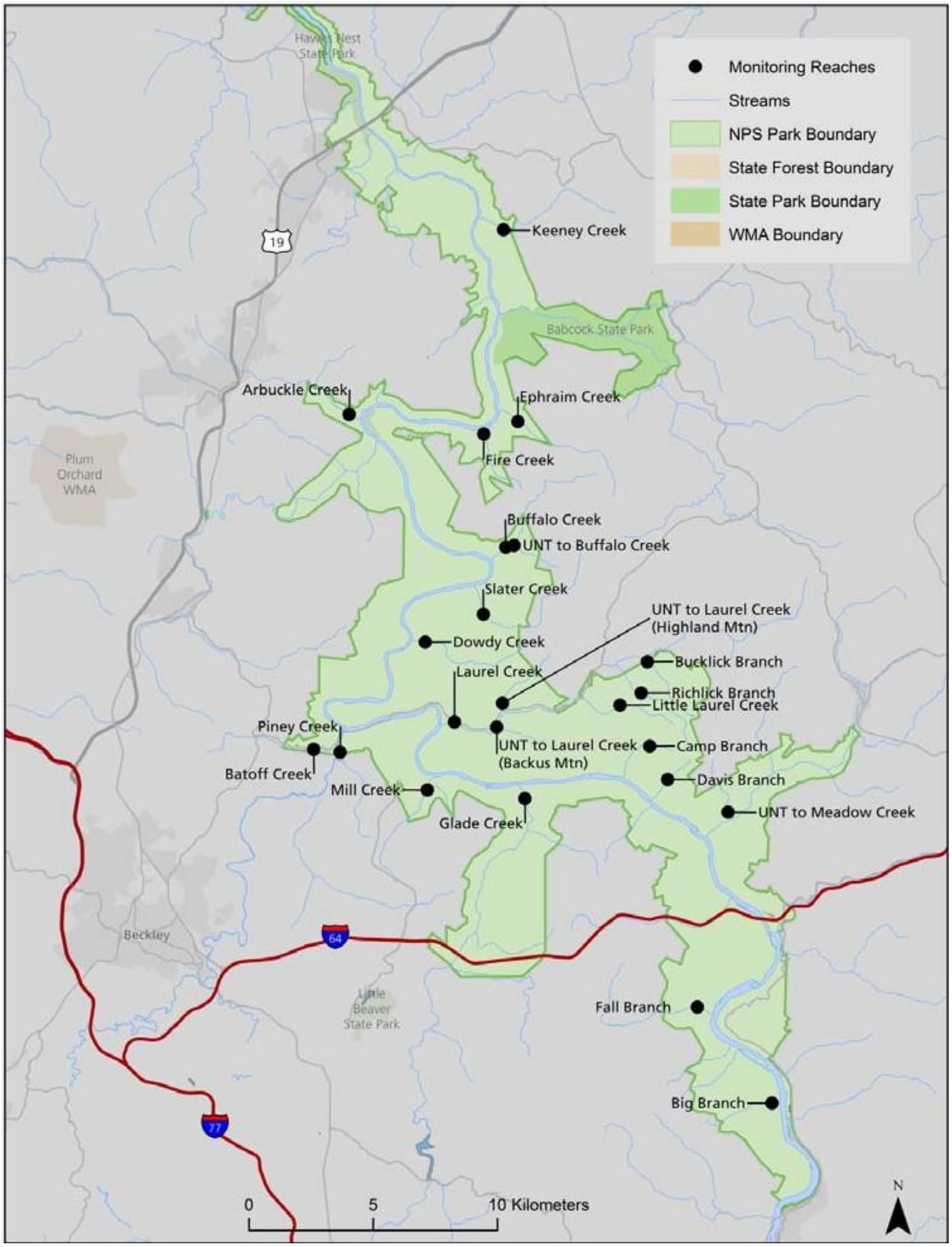


Figure 12. Wadeable stream reaches monitored by the NPS Eastern Rivers and Mountains Network for water quality and benthic macroinvertebrates from 2008-2013 (from Tzilkowski et al. 2015).

Benthic macroinvertebrates collected by ERMN researches in wadeable stream reaches were used to calculate a Multimetric Index of Biological Integrity (MIBI) for NERI. The average score based upon data from the 22 stream reaches was 50.5/100, a ranking of "fair" and departs from reference condition. Macroinvertebrate communities, in some cases, may be negatively affected by water quality conditions in the park (Tzilkowski et al. 2015). However, this score is close to the threshold value of 51 which indicates a ranking of "good." The most likely causes of degradation are fecal coliform pollution in some tributaries. In particular, MIBI scores were exceptionally low in Arbuckle Creek (15.9-22.8) and Piney Creek (29.9-32.8) where there is a long-history of fecal coliform pollution. Both of these streams also appear on the 303 (d) impaired streams list in WV due to fecal coliform bacteria (WV DEP 2016, Tzilkowski et al. 2015).

Mathes et al. (2007) examined the presumptive sources of fecal contamination in tributaries to the New River within NERI. These researchers examined presumptive sources on Arbuckle Creek, Dunloup Creek, Keeney Creek, and Wolf Creek. Their research using several indicators of fecal/sewage pollution (*Enterococus*, urine, *Bacteroidetes*, mitochondrial DNA), found that human sources were detected in all creeks. Livestock DNA markers (dog, pig, horse, and chicken) also were found in lower amounts in all sampled tributaries. These findings, coupled with the correlation of fecal coliform levels with stream flow, indicate that overflowing sewage treatment stations, straight-pipe discharges, leaking sewer lines, faulty septic systems, and farming practices all contribute to fecal coliform pollution in the park (Mathes et al. 2007).

Thresholds for fecal coliforms are set by the EPA in response to potential effects on human health (e.g. Wade at al. 2003) and the direct effects of fecal coliform on aquatic organisms are not well-understood. However, high fecal coliform levels may alter pH levels and reduce dissolved oxygen in surface waters (e.g. Clark and Norris 2000). Furthermore, high fecal coliform levels from human sources indicate pollution from sewage effluent—the primary source of estrogenic and other pharmaceutical compounds in surface water (Ebele et al. 2016). In addition, pathogenic infections may increase with fecal coliform levels and associated stresses to fish may increase their susceptibility to infection (Snieszko 1974).

4.6.1. Data Gaps, Needs, and Management Strategies

Since the Natural Resource Assessment was conducted in 2004, little additional knowledge has been gathered regarding sedimentation and deposition rates due to changes in historic hydrologic regimes within the main stem of the New River. Therefore, data gaps remain (Mahan 2004). Baseline data also do not exist to indicate what flow is needed to maintain aquatic and riverscour plant communities within and along the New River. These types of data are needed before considering the reestablishment of pre-dam flood regimes in the park. Furthermore, since flooding events are the primary geomorphological agent shaping the fluvial and riparian environment, these data will help park managers understand processes that are occurring in the park in their absence (Johnson et al. 2000).

NERI natural resource documents (e.g. Purvis et al. 2002, Mahan 2004, Mahan and Darden 2014, NPS 2011, Tzilkowski et al. 2015) have repeatedly stated the need to identify, map, and mitigate the sources of untreated sewage that is entering the New River tributaries and its main stem.

Identification of these sources is important so that local communities, working in conjunction with state and federal officials can contain and treat this sewage outfall. However, as of this writing, these sources have not been addressed—although further data collection and analysis by NERI staff continues.

At NERI, fecal coliforms are measured in the water column. However, sediment storage of fecal coliform bacteria can be high in freshwater systems (see Bai and Lung 2005). Fecal coliform and other contaminant (e.g. metals, arsenic, etc.) levels in sediments could be examined in conjunction with a sedimentation transport study to better understand the total effect of various pollutants to aquatic organisms, ecosystems, and human health in the park. Finally, NERI may wish to explore funding a NPS/USGS partnership to develop a program that models the effects of turbidity and water temperature on fecal coliform density in the surface waters of the park. Such an approach could model the 'BacteriALERT' program developed on the Chattahoochee River upstream from Atlanta, Georgia (Lawrence 2012). 'BacterALERT' is a modeling system that predicts *Esherichia coli* (a fecal coliform) density based upon turbidity, streamflow characteristics, and season in real time. These data are available online to river users so that they can make informed choices about engaging in recreation in the river or its tributaries.

4.7. Plants

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

4.7.1. Forest Mosaic

The mosaic of forest types that exist in and around NERI are globally significant and represent the largest remaining area of mid-latitude forest in the world (Riitters et al. 2000, Anderson et al. 2016). The major forest types present in NERI include: 1) Rimrock pine (Virginia Pine, Pitch Pine [*Pinus rigada*]) located in a narrow strips above cliffs in the park, 2) Eastern Hemlock forests located in ravines and on steeped-slope, shallow-soil sites in the park, 3) Oak-Hickory forests located in xeric sites throughout the park and, 4) Mixed Mesophytic forest located on mountain slopes, coves, and riparian areas. These forest types support a diversity of plant and animal communities and this feature, combined with the park's geology, and a long-history of botanical study indicates the New River Gorge contains the most floristically diverse river gorge documented in the central and southern Appalachians (Mahan 2004, Fortney et al. 1995). All forest types exist in the park but, since the last natural resource assessment, all have experienced additional threats and declines (Mahan 2004, Mahan and Darden 2014, NPS 2011, DeMaio and Perez 2010, Perles et al. 2016). The most recent vegetation analysis was completed in 2007 (Vanderhorst et al. 2007) and indicated that the "Sugar Maple – Yellow Buckeye [*Aesculus flava*] – American Basswood Forest" is the most abundant forest type by coverage in NERI (7,570 ha, 24.2%) followed by "Oak – Hickory Forest" (7,512 ha, 24.0%) and "Oak – Hickory [Carya] – Sugar Maple Forest" (6,001 ha, 19.2%). In the first Natural Resource Assessment for NERI (Mahan 2004), reference was made to vegetation mapping surveys by Vanderhorst et al. (2001). However, this work was a preliminary assessment that was superseded by the work of Vanderhorst et al. (2007). As stated in the Vanderhorst et al. (2007):

> Work on this project was started in 1998, and a report, plots database, and GIS map products for the northern and southern thirds of the park were released three years later (Vanderhorst 2001). Following this initial effort, standards of the U.S. Geological Survey / National Park Service Vegetation Mapping Program were adopted for the completion of a vegetation classification and map for the entire park.

Therefore, the area estimates for vegetation communities reported in Mahan (2004) may not necessarily be directly comparable in terms of vegetation community change.

Researchers at the NPS ERMN assessed the health of forests in NERI by measuring mortality, recruitment, and non-native species abundance at monitoring plots in both xeric and mesic habitats. Their research indicates that from 2007-2014, there was moderate tree growth, recruitment, and mortality at xeric sites in the park (Perles et al. 2016; Figure 13). Specifically, American beech [*Fagus grandifolia*], Shagbark hickory [*Carya ovata*], Serviceberry [*Amelanchier arborea*], Fraser magnolia [*Magnolia fraseri*], and Maple (*Acer* spp.) had recruitment that exceeded mortality. Oaks, Sassafras [*Sassafras albium*], Black cherry [*Prunus serotine*], Black locust, and particularly ash are declining (Figure 13). On mesic sites sourwood [*Oxydendrum arboreum*] and maples are the only native species that had recruitment that was greater than mortality. All other native species on these sites had mortality that outpaced recruitment---with the exception of eastern hemlock where mortality equaled recruitment (Figure 14).

The effects of a variety of forest stressors including non-native species, herbivory by white-tailed deer, and site conditions (e.g. calcium availability) are revealed by the data. For example, *Fraxinus* (green and white ash) had the highest mortality rate (average = 8%/year during the 7-year period) of any tree species in NERI and in any of the parks within the ERMN network. This mortality is due to infestation by the non-native emerald ash borer (EAB; *Agrilus planipennis*) that was first discovered in the park in 2009. Ash seedlings still persist in monitoring plots but will likely die as EAB infestation continues. At NERI, ash is found in high numbers along the New River main stem corridor and other mesic and riparian sites. Therefore, ash mortality may have a disproportionate effect in these areas of the park (DeMaio 2010). Ash species are also a component of upland mixed mesophytic forest types including the Sugar Maple-Yellow Buckeye-American Basswood forest type and the Oak-Hickory-Sugar Maple forest type (Vanderhorst et al. 2007). The park is actively treating ash trees with the insecticide, Emamectin benzoate, to protect them from EAB. This insecticide must be injected into the lower trunk of the infected tree; it will move systemically through the tree. From 2012-2016, park managers treated 876 ash trees in the park (L. Strickler, 2017, NPS, pers. comm.). Treatment of ash trees is focused within rare plant community types (e.g. Army Camp; DeMaio and Perez 2010) and culturally significant sites at NERI (e.g. Trump Lilly Farm).

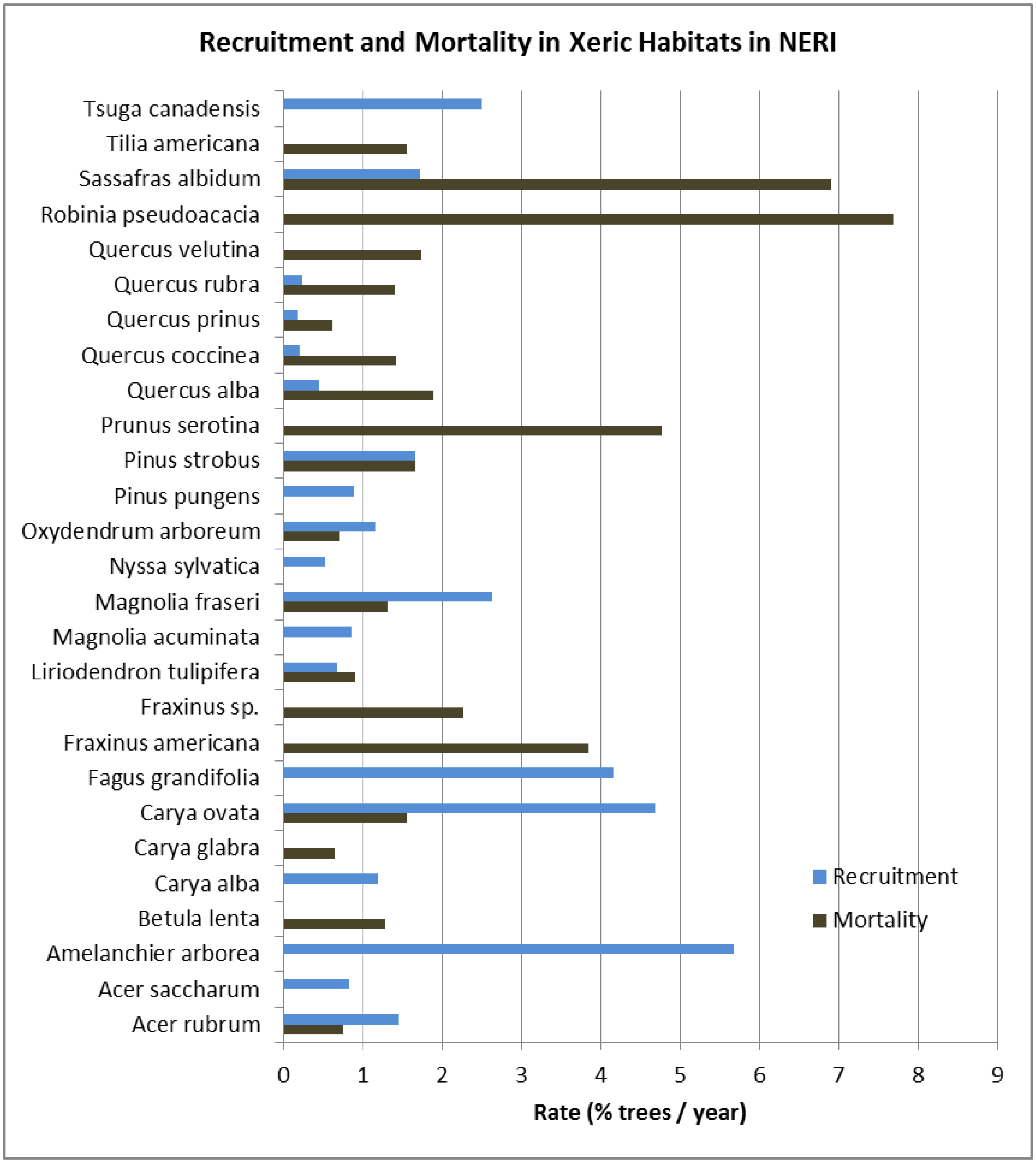


Figure 13. Tree species recruitment versus mortality in xeric forest health plots in New River Gorge National River (NERI), 2007-2014 (data and table from Perles et al. 2016).

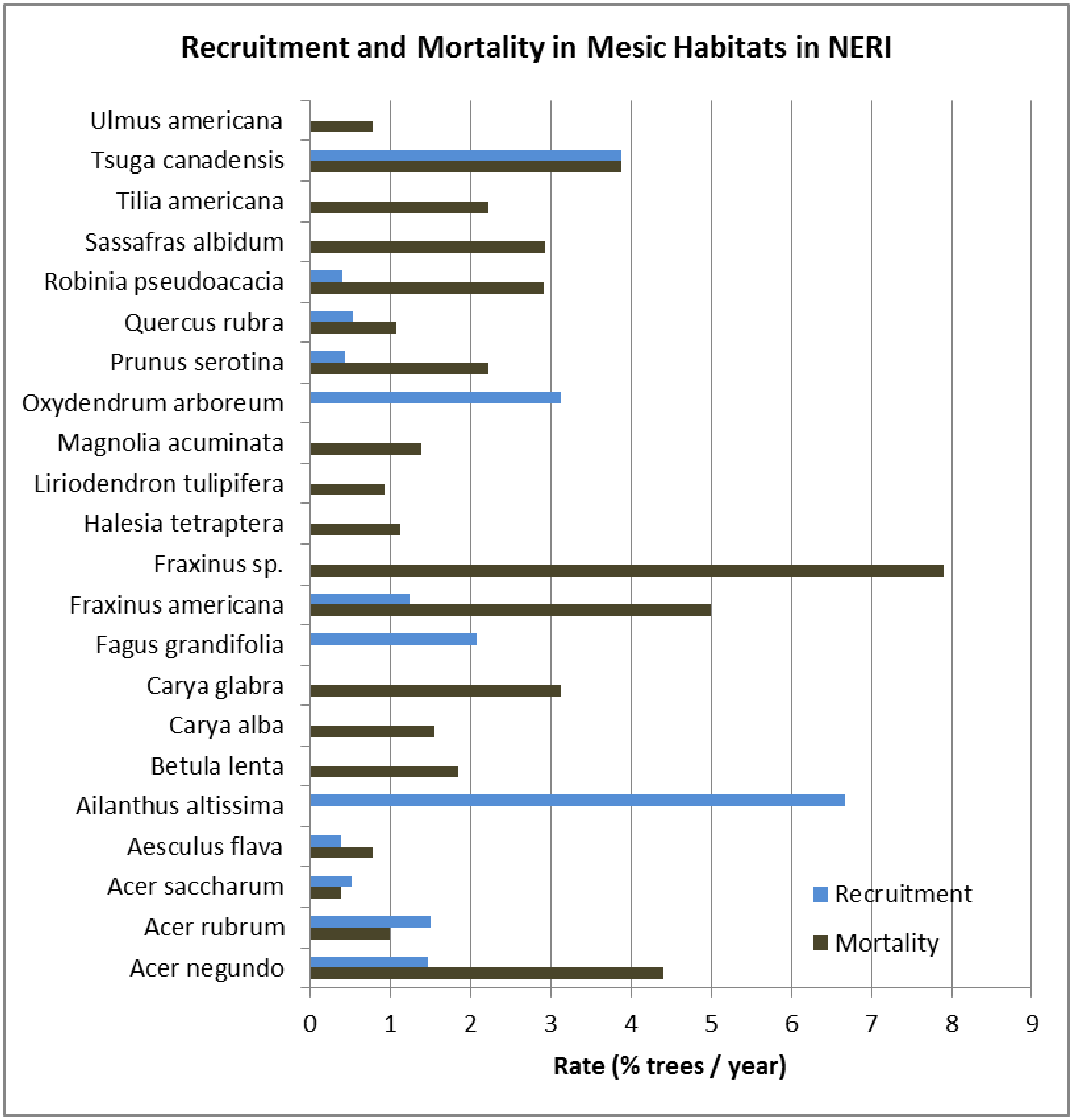


Figure 14. Tree species recruitment versus mortality in mesic forest health plots in New River Gorge National River (NERI), 2007-2014 (data and table from Perles et al. 2016).

Eastern Hemlock which have been infested with the hemlock woolly adelgid (HWA) in the park since 2004 also exhibited an elevated mortality rate (4%) at NERI from 2007-2014 (Perles et al. 2016). However, hemlock seedlings still occur at forest monitoring plots in NERI and recruitment into the canopy balances mortality (Perles et al. 2016). Research conducted by Wood et al. (2009) indicates that from 2004-2007, more than 20% of hemlock trees on mesic and xeric plots were infested by HWA, although infestation rate in hydric plots only reached 5% during this time period. Overall, 8% of hemlock trees monitored died over the three year period (Wood et al. 2009) but hemlock stem density did not decline statistically. However, by 2016, 80-90% of hemlock trees monitored were infested by HWA and crown vigor had declined by 50% at all monitoring sites (Strickler 2017).

Site condition quality, cold winters (e.g., Paradis et al. 2008) and the park-sponsored HWA control project (Strickler 2017) will all help determine whether hemlocks persist at NERI. HWA control includes predatory beetle releases and insecticide application and is concentrated in areas of high ecological value and at urban interfaces for safety concerns (L. Strickler, 2017, NPS, pers. comm.). To date, 22,956 HWA predatory beetles [*Laricobius nigrinus*] have been released at NERI and Gauley River National Recreation Area (GARI) to help control HWA. From 2006-2016, 19,574 hemlocks were treated with the insecticide Imidacloprid (NERI+GARI+BLUE), with 15,177 (265 ha) in NERI alone (HWA Management Summary, pers. comm., 2016).

All Imidacloprid applications have been conducted according to the pesticide label and restricted to the base of individual trees so that any impacts to non-target organisms could be minimized and localized. However, concern arises when dozens to a couple of hundred trees per acre are treated within biologically diverse floodplains. For example, the Fern Creek (21 ha, 53 acres) and Kates Branch (30 ha, 75 acres) hemlock conservation areas are located in biologically diverse riparian habitat containing many rare plant and animal species and several thousand hemlocks have received Imidacloprid treatments. Although previous studies (Cowles 2009, Dilling et al. 2009) showed that systemic Imidacloprid could impact non-target canopy arthropods, it remains unknown what the extent of the cumulative and long-term effects of repeated Imidacloprid treatments on soil ecology and macrofauna. An understanding of the effects of HWA insecticide treatments on soil macroinvertebrates, soil chemistry, and water quality will assist managers in making resource based decisions concerning the long-term viability of chemical treatments to protect the hemlock ecosystem. To this end, research was initiated at NERI in 2016 to assess the risk and potential impact of Imidacloprid on soil and aquatic macrofauna within the hemlock treatment areas (Park and Wood, West Virginia University, Effects of Imidacloprid on Soil Macrofauna within Riparian Hemlock Forests, Scope of Work, 2016).

Oak forest types that dominate the xeric sites at NERI, appear to be declining in the park as oak mortality exceeds recruitment (Figures 13, 14). This decline, however, is typical for a middle-aged forest transitioning to a mixed mesophytic forest type (Fei and Steiner 2009, Perles et al. 2016). Oak seedlings are under-represented but the growth rate of overstory trees is about 0.2 – 0. 3 cm/year. Reflecting conditions throughout the Appalachians, red maple [*Acer rubrum*] seedlings are dominating the understory in the park at both xeric and mesic sites instead of oak recruits (e.g. Fei and Steiner 2009, Perles et al. 2016; Figures 13, 14).

It is unclear whether this oak decline is a natural effect of a cessation of industrial activities in and around NERI or due to changes in natural disturbance regimes. Oak abundance in NERI may be more abundant today than it was prior to the industrialization in and around the park. For example, post-settlement activities including clearcutting, railroad and mine fires, and other canopy-level disturbance created conditions suitable for oak. As the landscape changed, the forest may naturally be reverting to its historic more-mesic forest types. However, modern day conditions of higher white-tailed deer populations and increased herbivory, and suppression of natural fires may also be contributing to the decline of oak and other more xeric-adapted species (including rimrock pine) in the park and throughout the Appalachians (Abrams 2003, McShea et al. 2007). To help elucidate the cause of oak decline, Perles and Forder (2015) and park managers have initiated a research study to examine the potential effects of fire suppression and deer herbivory on oak regeneration in NERI.

The mixed mesophytic forest type is dominated by a diverse group of trees and vegetation communities including tuliptree [Liriodendron], basswood, beech [Fagus], maples, and red oak. Based on forest health data, red maple and black cherry will likely increase in abundance in the overstory during the next 20 years. In addition, beech, serviceberry [Amelanchier], maples, and black gum [*Nyssa sylvatica*] have recruitment rates that are higher than mortality. Whether this increase is a naturally-occurring phenomenon due to reduced human industrialization in and around the park or due to other conditions is not well-understood at this time.

The most serious and urgent near-term ecological threat for many United States forests and urban and suburban trees is the recurrent introduction of insects and pathogens from other continents (Liebhold et al. 1995, Lovett et al. 2016, Moser et al. 2009). Invasive forests pests are an undesirable consequence of international trade and travel, and while these pests are not a new phenomenon, they inflict increasing ecological and economic damage and may be increasing at NERI (Aukema et al. 2011, 2011; Perles et al. 2016). Aside from forest pests already established in the last decade at NERI (gypsy moth, HWA, EAB) other potential pests include Asian Long-horned beetle [*Anoplophora glabripennis*], Sudden oak death [*Phytophthora ramorum*], Beech bark disease, Winter moth [*Operophtera brumata*], and White pine blister rust [*Cronartium ribicola*] (Lovett et al. 2016).

4.7.2. Appalachian Flatrock Vegetation and Riverscour Prairie

The Appalachian Flatrock vegetation community type is globally rare and is known from three sites in NERI: Camp Brookside, Sandstone Falls, and the mouth of Keeney’s Creek (Vanderhorst et al. 2007). This community type is found on sandstone ledges and is comprised of rare sedges (e.g. annual fimbry [*Fimbrylis annua*], eastern red cedar [*Juniperus virginiana*], and pines (e.g. Virginia pine) that are dependent upon scouring caused by occasional flooding for long-term persistence in the park. With the construction of the Bluestone Dam and subsequent reduction in river scour activity, invasive species and plant species non-characteristic of the Flatrock community began invading these sandstone ledges. These successional processes and nonnative species invasion continually threaten the rare species associated with this community type (e.g. Mahan 2004).

As part of its vital sign monitoring, ERMN researchers focus on another rare riparian community type—the Riverscour prairie. Riverscour prairies are found in association with certain riparian conditions along the New River. These conditions include a rocky substrate located adjacent to river rapids. The scouring action of the rapids maintain the Riverscour Prairies and create habitats that support rare, native herbaceous plants: big blue stem [*Andropogon gerardii*[, blue wild indigo [*Baptisia australis*], Indian hemp [*Apocynum cannabinum*], and switch grass [*Panicum virgatum*]. In addition, stunted flood-stressed trees such as river birch [*Betula nigra*], and sycamore [*Platanus occidentalis*] are found in this habitat type. Without regular flood-scour, the riverscour prairies, dominated by herbaceous vegetation, gradually changes into one dominated by woody vegetation. Recent research on these river scour prairies indicate that this succession is already happening. At

NERI, for example, 15-75% of the river scour prairies are now composed of woody vegetation (Perles et al. 2016).

4.7.3. Old growth Forest

One 4 ha (9.9 acre) patch of old growth forest has been documented in NERI. The stand is comprised of oak-hickory-sugar maple forest type and is located along the mainstem of the New River upstream from the confluence of Buffalo Run and the New River (A. Steel, NERI, pers. comm, 2016). Detailed age data and dendrochronology could be examined from this stand.

4.7.4. Rare and Medicinal Plants

Mahan (2004) provides a complete list of all state and globally-rare vascular plant species documented at NERI. Although not included in this list, medicinal plants such as bloodroot [*Sanguinaria canadensis*] and American ginseng may be declining throughout the Appalachians due to over-collecting (Farrington et al. 2009). It is illegal to collect medicinal plants at NERI, however, collecting may still continue in and around the park. American ginseng is a perennial herb that is harvested for the purported medicinal qualities of its root. Harvest and export of ginseng roots to Asia has long been a source of supplementary income for people living in the Appalachian Mountains, but recent increases in the market value of American ginseng roots have intensified legal (and illegal) harvest pressure. Concerns of possible over-harvest led to listing of American ginseng in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Under CITES, the U.S. Fish and Wildlife Service (USFWS), Division of Scientific Authority (DSA) must determine whether the export of American ginseng will be detrimental to the survival of the species, and whether wild-harvest is sustainable. American ginseng is also cultivated in woodlands, but it is unclear what effect this “wild-simulated” ginseng is having on native populations. American ginseng also is susceptible to herbivory by white-tailed deer and high deer populations may contribute to its decline (e.g. Farrington et al. 2009).

Scientists at the USGS Leetown Science Center have been studying the regional distribution of rare species in the mid-Atlantic region since 2003. Young et al. (2011) reported on a study of the regional distribution of American ginseng, bloodroot, goldenseal [*Hydrastis canadensis*], and black cohosh [*Actaea racemose*] from field surveys conducted in 2004-2005. As a guide to field investigations, GIS-based logistic regression models of habitat suitability for the four species were completed, and the model outputs included coverage of NERI. Suitable habitat for all four species was predicted at NERI, but subsequent field investigations found American ginseng at only 10% of sites surveyed during this study. Several sites surveyed also included black cohosh (7 sites) and bloodroot (5 sites). Although not detected during this study, goldenseal was noted at several locations within NERI by Vanderhorst et al. (2007).

4.7.5. Non-native Plants

In 2010, Perez and Akerson completed an implementation plan for managing invasive exotic vegetation at NERI. As part of the plan, they conducted a reconnaissance survey for invasive and non-native plants in the park. They documented 210 non-native plants, 38 of which (18%) were determined to be invasive and threats to the natural environment (Akerson et al. 2010); 13 species of non-native, invasive plants were found to cover 5% or more in these reconnaissance plots: Tree-ofheaven [*Ailanthus altissima*], Princess tree [*Paulownia tomentosa*], Japanese honeysuckle [*Lonicera japonica*], Privet [Ligustrum], Multiflora rose [*Rosa multiflora*], Japanese stiltgrass [*Microstegium vimineum*], Japanese knotweed [*Fallopia japonica*], Kudzu [Pueraria], Sericea Lespedeza [*Lespedeza cuneate*], Autumn olive [*Elaeagnus umbellate*], Wineberry [*Rubus phoenicolasius*], Ground ivy [*Glechoma hederacea*], and Stonecrop (*Sedum* spp). These species, therefore, became primary targets for control throughout the park. In addition, purple-loosestrife [*Lythrum salicaria*], Phragmites, and Wisteria vine were targeted for eradication at the Meadow Creek confluence, below McKendree Road, and below the New River Bridge, respectively. Park managers also prioritized local extirpation of all invasive plant species within the Appalachian Flatrock vegetation community sites at Camp Brookside, Sandstone Falls, and Keeney's Creek (Akerson et al. 2010). Non-native species were also found at all riverscour habitats monitored at NERI, with non-native species dominating the riverscour and flatrock sites at Keeney's and Glade Creek (Table 5). The following non-native species were found at nearly all nine sites monitored in NERI: Autumn Olive, Sericea Lespedeza, Creeping Jenny [*Lysimachia nummularia*], Purple-loosestrife, Japanese Stiltgrass, and Multiflora Rose. Despite these data, Perles et al. (2016) found that fewer than 5% (~3%) of forest health monitoring plots contained non-native vegetation—the lowest prevalence in the ERMN.

Table 5. Proportion of cover and species richness in non-native and native plant species in riverscour prairie sites National River Gorge National River (NERI), West Virginia, 2015 (from Perles et al. 2016).

Site	Non-native Species		Native Species	
	Proportion of Cover	Proportion of Species Richness	Proportion of Cover	Proportion of Species Richness
Camp Brookside	0.32%	3.15%	87.07%	75.37%
Dowdy Creek 1	0.65%	1.91%	92.35%	77.07%
Dowdy Creek 2	0.10%	1.67%	84.06%	72.81%
Glade Creek	0.89%	3.22%	79.59%	72.27%
Glade Creek Island	0.89%	8.17%	67.45%	58.09%
Keeney Creek	3.44%	6.22%	76.99%	71.76%
Manns Creek	1.60%	2.92%	88.34%	80.29%
Plateau	4.64%	5.60%	77.32%	71.19%
Terry	2.87%	4.74%	88.82%	72.63%

4.7.6. Data Gaps, Needs, and Management Strategies

The location and extent of oak and oak-hickory forest types within NERI prior to the European settlement and industrialization period is unknown. Therefore, the historic role of fire and other disturbances to maintaining an oak component is also unknown. A better understanding of the ecological significance of oak decline and concurrent mesophytic forest expansion at NERI is needed.

The associated ecological and recreational effects of ash decline in the park are unknown. DeMaio (2010) indicates that several bird, mammal, and associated arthropod species may be at risk due to their association with ash trees for breeding or feeding. In addition, ash trees contribute to nutrient cycling in eastern forests and, at NERI, grow in association with many recreational areas including campsites, parking lots, picnic areas, and raft take-outs (DeMaio 2010).

The amount and extent of legal and illegal harvesting of plants in NERI needs to be better understood. For example, the harvesting/collecting rate of mosses, ramps, and medicinal plants and the subsequent ecological effects are unknown.

Continual monitoring and removal is critical for minimizing the abundance and effects of nonnative species (plants, insects, and other pathogens) at NERI. For example, in 2012, the ERMN field crew working in a NERI riverscour prairie found the non-native plant, Sweet Autumn Virgin's Bower [*Clematis terniflora*] for the first time in the park. Park managers quickly responded by eliminating the plant from this rare community type (Perles et al. 2016, Perez and Akerson 2010). Removing invasive plants, insects, and pathogens when they first establish in an area (before they spread) is a cost-effective strategy for protecting natural areas (Perles et al. 2016, Perez and Akerson 2010).

In light of the continued visitation to the park and neighboring lands, protecting the park's forests from recreational impacts will be a challenge. Continued vigilance and outreach to park neighbors and user groups are equally important in preventing the introduction and spread of new invasive plant and pest species. Minimizing trail construction will also help protect forest communities from the dispersal of invasive exotic plants, pests, and diseases.

4.8. Fish

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

A variety of habitat types within the New River and its tributaries support a diversity of fish. These fish are reflective of a confined, warm-water (mean summer temperature $\geq$ 22 °C, 71.6 °F), medium-sized river in the mid-Atlantic Appalachian Mountains (see Sheldon et al. 2015). These fish represent native and non-native species that, in part, support a multi-million dollar sport fishing industry (Versel 2006). A variety of past and on-going research efforts at NERI provide data on the diversity, abundance, and changing community structure of fish in the park.

The native fish in the New River drainage represent a community with a high rate of endemism. For example, Big Mouth Chub, New River Shiner [*Notropis scabriceps*], Kanawha Minnow [*Phenacobius teretulus*], Find-scaled Saddle (candy) Darter [*Etheostoma osburni*], Bluestone Sculpin [Cottus sp. 1], Kanawha Darter [*Etheostoma kanawhae*], and Appalachian Darter [*Percina gymnocephala*] are endemic to the New River drainage. However, of these endemic species, only the Big Mouth Chub, a species of conservation concern, and the New River Shiner have been collected within park boundaries (Welsh and Wellman 2001, J. Purvis, NERI, pers. comm., 2009).

Approximately 50% of the fish species found within the park are non-native (Purvis 2009, Mahan 2004). However, most of these non-native species occur in low abundance in the park and vary in their distribution among the mainstem and tributaries (Faulk and Weber 2017). Most game fish found within the park are non-native and were deliberately introduced to provide recreational opportunities for anglers—complicating their management and removal. In particular, Smallmouth Bass, first introduced in WV in the late 1880s, supports an economically-important recreational fishery (Mahan 2004, Versel 2006). The native game fish found in the park are American Eel [*Anguilla rostrata*], Channel Catfish [*Ictalurus punctatus*], Flathead Catfish [*Pylodictis olivaris*], Green Sunfish [*Lepomis cyanellus*] and Brook Trout [*Salvelinus fontinalis*] (in some park tributaries) (Mahan 2004, Stauffer 2007).

Since 1991, park resource managers have conducted the long-term environmental monitoring system (LTEMS) to better understand the potential effects of black fly larva control (via *Bti* application) on the fish and benthic macroinvertebrates of the New River. Currently, these data are the subject of analysis and synthesis to provide a means of assessing data completeness and quality. This analysis will help park resource managers develop a robust and defendable LTEMS program (P.J.Kinder, Jr., Natural Resource Analysis Center, Davis College of Agriculture, Natural Resources and Design West Virginia University, Morgantown, WV, proposed Scope of Work, 2017). In an earlier analysis, Smith and Marini (1998) concluded that there have been no detectable detrimental effects of black fly larva control on fish biomass and community structure in the park.

In 2013, a pilot fish sampling project was initiated by the ERMN to monitor fish populations in streams (tributaries) to the New River within the park (Faulk and Weber 2017). These stream reaches corresponded to those sampled for both streamside birds and benthic macroinvertebrates (Marshall et al. 2013, Tzilkowski et al. 2015). Researchers encountered at total of 8,010 individual fish representing 21 species and five families at sampling sites (Faulk and Weber 2017). No fish were documented at 10 of the 34 stream reaches sampled. Fifteen of the stream reaches sampled only contained native fish while the remaining 9 reaches contained some non-native fish. Native fish comprised only 52% of the species encountered but represented 99% of the individuals encountered in the streams. The most common species were Blacknose Dace [*Rhinichthys atratulus*], Central Stoneroller [*Campostoma anomalum*], and Creek Chub [*Semotilus atromaculatus*]—all of which are native to the New River watershed. The most commonly encountered non-native species in the sampled streams were Rainbow Darter [*Etheostoma caeruleum*], Rock Bass [*Ambloplites rupestris*], and Variegated Darter [*Etheostoma variatum*] (see Faulk and Weber 2017 for complete species list).

4.8.1. Data Gaps, Needs, and Management Strategies

The fish community at NERI could be continually monitored to determine the abundance, distribution, and range expansion of all nonnative fish and to understand status and trends in the native fish community. Banning the use of live bait in the park could limit future and continued non-native fish introductions. The effects of pharmaceutical pollution also could be examined at NERI to determine if sewage pollution is having secondary impacts on the fish community.

4.9. Aquatic Invertebrates (mussels, crayfish)

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Molluscs, crayfish, and other macroinvertebrates are important components of aquatic environments at NERI---providing ecosystem services (food, filtration, substrate) within the park. Native mussels are declining throughout the Appalachians and are considered species of special conservation concern in West Virginia (Mahan 2004). Jirka and Neves (1987) identified eight species of native mussels from the New River within NERI. However, a subsequent mussel survey in 2002 only documented five species of native mussel. Mucket [*Actinonaias lieamentina*] never has been collected upstream of Roundbottom Creek (Pennington and Associates 2002). Pistolgrip mussel [*Tritogonia verrucosa*] and pocketbook mussel [*Lampsilis cardium*] have declined dramatically in the park or have been extirpated. Because mussels are dependent upon, and help maintain, good water quality, water pollution threatens mussel communities within the New River. In addition, silt loads associated with dam discharges, sedimentation, and competition from non-native molluscs (e.g. Asian clam [*Corbicula fluminea*]) also threaten remaining mussel populations in the park (Mahan 2004).

There are three native species of crayfish within NERI. Appalachian brook crayfish [*Cambarus bartonii*], rock crayfish [*C. carinirostris*], and Teays River crayfish [*C. sciotnensis*] have all been documented in the park (Purves et al. 2002). The New River crayfish [*C. chasmodactylus*] may be found within NERI but has not yet been documented. In addition, one individual of the Upland Burrowing Crayfish [*C. dubius*] was documented at Grandview (A. Weber, NPS, ERMN, personal communication, 2017). All species of native crayfish are declining dramatically in the Appalachian Mountains. The primary threat to their persistence is competition from non-native crayfish from the genus *Orconectes* (Taylor et al. 2011). These non-native crayfish are introduced to the watersheds by anglers as discarded or escaped bait (Purves et al. 2002). Today *Orconectes* crayfish (particularly, *O. virlis*) comprises over 90% of crayfish collected in the New River between Bluestone Dam and Sandstone Falls.

4.9.1. Data Gaps, Needs, and Management Strategies

To limit the continued introduction and range expansion of non-native crayfish and molluscs to NERI, programs aimed at educating the public about the dangers of moving crayfish from one water body to another are needed (e.g. Lieb et al. 2011). The establishment of signs along streams, particularly those subject to heavy recreational activity (e.g. fishing pressure), warning the public not to release crayfish into the water would also be beneficial. Banning the use of live bait in the park could limit future and continued non-native crayfish introductions—including the highly invasive rusty crayfish [*Orconectes rusticus*]. Urbanization and resulting habitat alterations and influx of toxic chemicals and sediment also represent a significant threat to NERI's aquatic resources (including the crayfish and mussel populations). Therefore, management strategies that improve water quality would also benefit these resources. Finally, including crayfish and mussels in the park's monitoring programs (ERMN, LTEMS) would help better manage these resources.

4.10. Amphibians

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

At NERI, forests, abandoned mine systems, and river/stream reaches provide habitat for a diverse, globally-significant assemblage of amphibians (37 species) that includes the diverse assemblage of salamanders endemic to the Appalachian Mountains (Mahan 2004). Of these 37 species, 4 are considered vulnerable (S3): Green salamander [*Aniedes aeneus*], Black-bellied salamander, Cave salamander [*Eurycea lucifuga*], and Northern red salamander [*Pseudotriton ruber ruber*]. An additional two species are considered imperiled (S2): Jefferson salamander [*Ambystoma jeffersonianum*] and Cumberland Plateau salamander [*Plethodon kentucki*]; and one species (Midland mud salamander [*Pseudotriton montanus diastictus*], is considered critically imperiled (S1). In WV and NERI, stream salamanders are susceptible to harvest by bait collectors, poor water quality and emerging infectious diseases (Mahan 2004, Miller et al. 2011).

In the past decade, the devastating effects of *Batrachochytrium dendrobatidis (Bd)*—an invasive fungal pathogen that causes the fatal infectious disease, Chytridiomycosis has become the basis of world-wide study (Skerratt et al. 2007). In 2007, 9 species of salamanders and 2 frog species were sampled for the presence of *Bd* at NERI (Paul 2014). Five of the 11 species sampled for *Bd* tested positive although prevalence in the populations was low (Figure 15). For example, only 23 of the 144 individuals (16%) tested were positive for *Bd*. Prevalence was highest in the northern dusky salamander (DeFu, *Desmognathus fuscus*) (26.1% of sample) followed by the black-bellied salamander (25% of sample; Figure 15). These rates were lower than overall prevalence rates in Connecticut (Richards-Hrdlicka et al. 2013) but reflective of other studies conducted in WV (e.g. Grant et al. 2008). The prevalence rate of *Bd* at NERI may also be reflective of the availability of headwater stream habitat which tends to have a low prevalence of Chytrid fungus (e.g. Hossack et al. 2010). None of the three *Plethodon* salamanders sampled were positive for *Bd*—which mimics findings by Muletz et al. (2014) who stated the *Bd* is an unlikely cause for *Plethodon* salamander declines. The presence of *Bd* and its physiological effects in black-bellied salamanders at NERI should be carefully monitored. More than any other salamander species in the park, black-bellied salamanders are collected by anglers for use as bait and *Bd* potentially could be an additive stressor on this population (see Mahan 2004).

At NERI, ranaviruses also potentially threaten amphibian and reptile populations. The USGS National Wildlife Health Center has isolated amphibian ranaviruses from 16 species of frogs, one species of toad and six species of salamanders. Mortality events due to ranaviruses occur most commonly in the following groups: mole salamanders (*Ambystoma* spp.), true frogs (*Rana* spp.) and chorus frogs (*Pseudacris* spp.). Infrequent isolates have been obtained from adult newts [*Notophthalmus viridescens*] and adult tree frogs (*Hyla* spp.). Ranavirus infections in turtles occur mostly in captive colonies of eastern box turtles [*Terrapene carolina carolina*] but die-offs of free-ranging box turtles also have been observed. Because box turtles in the wild usually are solitary animals, it has been difficult to document die-offs of multiple box turtles from an area (USGS 2017).

4.10.1. Data Gaps, Needs, and Management Strategies

Although the park has sampled for *Bd*, ranavirus inventories could also be conducted in the park. In addition, the effect of bait collecting on salamander populations is not well-studied. Management strategies to improve water quality could also benefit stream salamanders at NERI. Prohibiting the use of live bait in the park may also protect the park's population of black-bellied salamanders. Finally, disinfection of field research equipment should be followed (e.g. Northeast Partners for Amphibian and Reptile Conservation 2017) to minimize the risk of spread of Chytridiomycosis and ranavirus.

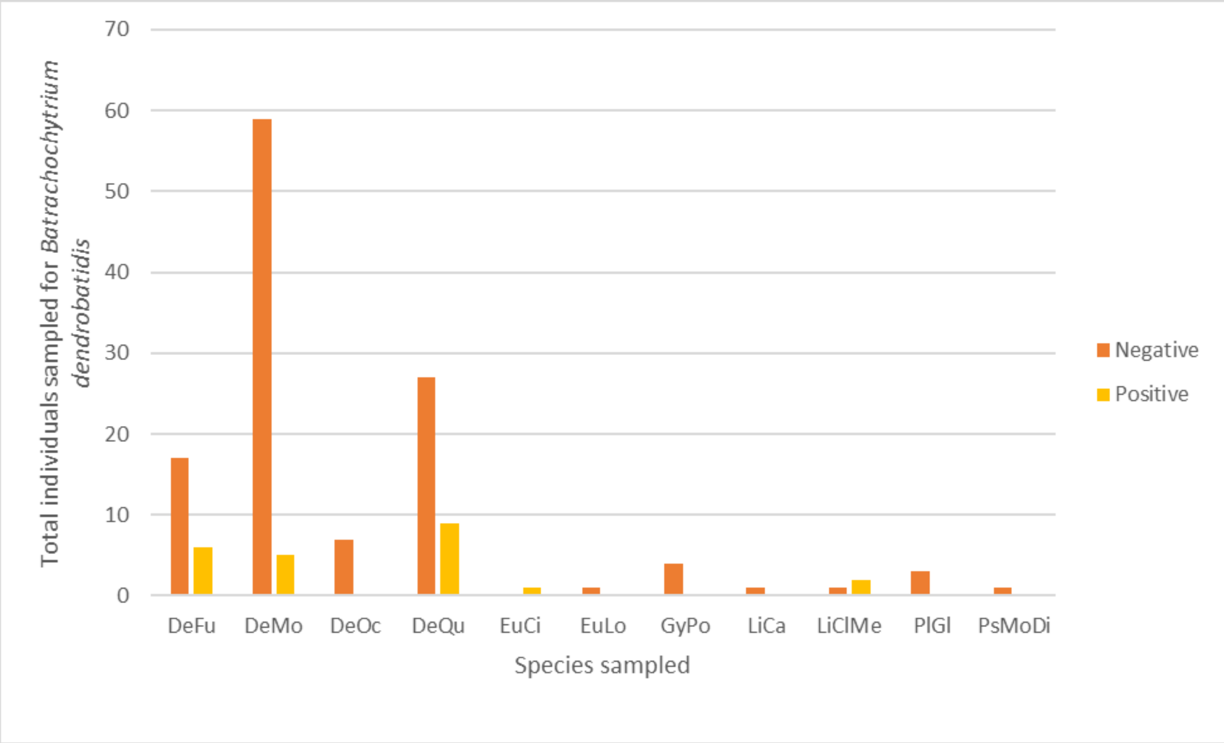


Figure 15. Salamander species sampled for *Batracheochytrium dendrobatidis* and resulting positive or negative findings in New River Gorge National River (NERI), 2007. Species: Dusky salamander (DeFu, *Desmognathus fuscus*), Seal salamander (DeMo, *Desmognathus monticola*), Allegheny Mountain dusky salamander (DeOc, *Desmognathus ochrophaeus*), Blackbelly salamander (DeQu, *Desmognathus quadramaculatus*), Southern two-lined salamander (EuCi, *Eurycea cirrigera*), Long-tailed salamander (EuLo, *Eurycea l. longicauda*), Northern spring salamander (GyPo, *Gyrinophilus p. porphyriticus*), American bullfrog (LiCa, *Lithobates catesbeianus*), Northern green frog (LiClMe, *Lithobates clamitans melanota*), Northern slimy salamander (PlGl, *Plethodon glutinosus*), Midland mud salamander (PsMoDi, *Pseudotriton montanus diastictus*).

4.11. Birds

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

To date, 233 species of birds have been documented in the park---93 of which breed at NERI (NPSpecies 2017). Furthermore, 74% of all bird species known to occur in WV and 42% of bird species of special concern in WV are found in NERI (see Mahan 2004). In particular, the mosaic of forested habitats at NERI support globally significant populations of neotropical migrants—especially the wood warblers (Mahan 2004). These interior-forest-dependent birds are the dominant breeding bird community at NERI (Mahan and Darden 2014). For example, the forests of NERI help form the core of the breeding range of the Cerulean warbler---a species of concern in the United States and a primary indicator of Appalachian forest condition (Appalachian Mountains Joint Venture 2016). Populations of Louisiana Waterthrush—another warbler species----breed along the streams of NERI and populations of black-throated green warblers [*Setophaga virens*] persist in the remaining hemlock ravines (Wood et al. 2009).

In the past decade, research on the breeding bird communities have provided valuable information for park managers. These research and monitoring studies include: point count breeding bird routes within the park (Daughtery 2016), the Monitoring Avian Productivity and Survivorship (MAPS) station at Sandstone falls (Varner and Biasiolli 2008), Streamside Bird Monitoring by the Eastern Rivers and Mountains Network (Marshall et al. 2013), and Bird Community monitoring at hemlock stands throughout the park (Wood et al. 2009).

At NERI, point count surveys (PCS) for monitoring breeding populations of forest birds have been conducted since 1977. However, since 1997, bird PCS have been standardized and now include 5 permanent annual monitoring routes in the park (Daughtery 2016). Eighty-nine species of resident and migratory birds were recorded during summer site visits along the five PCS routes. Of these species, 33 are considered residents and 56 are considered migratory. Data from PCS provides park managers information about bird species of concern that are declining in the Appalachian Mountains. In particular, abundance of Cerulean Warbler, Wood Thrush [*Hylocichla mustelina*], Worm-eating Warbler [*Helmitheros vermivorum*], Kentucky Warbler [*Geothlypis formosa*], and Canada Warbler [*Cardellina canadensis*] are examined within point count survey data due to their widespread decline (Daughtery 2016). PCS data indicates that Cerulean Warblers are declining in the park, although there is no statistically-significant trend in overall bird species richness at NERI since 1997.

Varner and Biasiolli (2008) summarized 12-years of breeding bird data collected from the MAPS research site at Sandstone Falls. Thirty species of breeding birds were captured and trends in their abundance (capture per mist-net hour) analyzed. General trends at this MAPS station reflect declines in early-successional bird species with a simultaneous increase in forest species. For example, five early-successional species (White-eyed Vireo [*Vireo griseus*], American Goldfinch [*Spinus tristis*], Yellow Warbler [*Setophaga petechia*], Gray Catbird [*Dumetella carolinensis*], and Yellow-breasted Chat [*Icteria virens*] declined significantly over the twelve-year period. Concurrently, five forest species (Wood Thrush, Eastern Towhee [*Pipilo erythrophthalmus*], Worm-eating Warbler, Louisiana Waterthrush, and Black-and-White Warbler [*Mniotilta varia*]) increased significantly in the same time period (Varner and Biasiolli 2008). Researchers believe that these trends reflect local changes in the vegetation community at the MAPS station which has undergone succession from pasture/shrubland to a young forest with increasing vertical structure (Varner and Biasiolli 2008). Observed local increases in Wood Thrush, Louisiana Waterthrush, and Worm-eating Warbler are promising for the conservation of these species which are included in the USFWS Partners-in-Flight watchlist. Other species included on this watchlist also were captured at this MAPS station. For example, Kentucky Warbler, Acadian Flycatcher [*Empidonax virescens*], Scarlet Tanager [*Piranga olivacea*], Black-and-White Warbler, Field Sparrow [*Spizella pusilla*], Yellow-breasted Chat, Eastern

Townhee, Indigo bunting [*Passerina cyanea*], and Willow Flycatcher *[Empidonax traillii*] were captured at least 6 times during the past 12 years.

Streamside birds were selected as a ‘vital signs’ resource for long-term monitoring in the national parks of the ERMN (Marshall et al. 2013). Birds have been monitored using this protocol at NERI since 2007. Birds are monitored using PCS along stream reaches that vary in length from 250-m to 1 km. In NERI, 25 reaches in forested watersheds were monitored using this protocol and 83 species of birds were detected (Marshall et al. 2013). Louisiana Waterthrush (LoWa) were used as a rough indicator of streamside condition— where “healthy” streams should have at least two territories per km (after Mulvihill et al. 2008). Approximately 50% of sites monitored supported at least 2 territories of LoWa. However, the relationship between LoWa and water quality and stream condition remains unclear. For example, Meadow Creek, Wolf Creek, Arbuckle Creek, Batoff Creek, and Keeney’s Creek are all impaired due to fecal coliform pollution yet support at least two LoWa territories (Tzilkowski et al. 2015, Marshall et al. 2013). A Bird Community Index of biotic integrity (BCI, O’Connell et al. 2000) was also applied to bird communities detected in NERI streamside counts. The mean BCI score (62) from these counts indicates “highest” or “excellent” biotic integrity for breeding birds— second only to Bluestone National Scenic River (BLUE) within all ERMN parks.

Research on tree health and breeding bird communities at five hemlock stands infested with HWA has been conducted at NERI from 1998-2008 (Wood et al. 2009). Both hemlock trees and hemlock-associated breeding birds declined during this time period. For example, both Acadian Flycatcher and Black-throated Green Warbler [*Dendroica virens*] declined in abundance at monitored stands during this 10-year period (Wood et al. 2009). These data reflect an overall declining trend in species richness and abundance of forest interior birds both within hemlock stands and regionally within the Appalachian Mountains (Wood et al. 2009).

Cerulean Warbler, a species of neotropical migrant that is in decline throughout the Appalachians and a candidate for federal listing, appears to have a concentrated distribution in and around NERI (Rosenberg et al. 2000, Wood et al. 2013). Therefore, this population may be a critical source population for the central Appalachian Mountains (Rosenberg et al. 2000). Within the park, Cerulean Warblers primarily occur in white oak-dominated forest stands on the upper, steep slopes of mountain ridges (Wood et al. 2013). Cerulean warblers appear to prefer forest stands that contain large (> 16 in dbh) diameter trees and small forest gaps in the canopy. These forest gaps permit sunlight to reach the forest floor and promote understory vegetation that provides foraging cover for nesting females and fledglings (Wood et al. 2013). Other neotropical migrants that co-occur in this forest condition at NERI include American Redstart [*Setophaga ruticilla*], Blue-grey Gnatcatcher [*Polioptila caerulea*], Eastern Towhee, Hooded Warbler [*Setophaga citrina*], Indigo Bunting, and Kentucky Warbler (which also is a species of USFWS Management Concern; Wood et al. 2013).

The forested landscape at NERI is affected, in part, by the history of industrial development. In particular the effects of mine lands on soil condition and subsequent reforestation may affect bird communities in the park. For example, Wood et al. (2005) and Weakland and Wood (2005) found that Cerulean Warbler abundance and territory density declined with forest fragmentation that occurred in ridge-top mine locations and within clearcuts themselves. Mizel (2011) found that reclaimed forests associated with compacted bench minelands within NERI contained a distinctive vegetation structure and forest bird community. Forests in these compacted bench minelands were dominated by mixed mesophytic forest tree species (e.g. Yellow Poplar, Red Maple, and Aspen [*Populus grandidentata*], had a lower canopy height than other forests of the same age, lower foliage density, and higher canopy vine density than unmined forest sites. These vegetation changes resulted in a forest bird community that was dominated by American Redstart, Rose-breasted Grosbeak [*Pheucticus ludovicianus*], and Worm-eating Warbler. Forests of the same age that occurred on unmined sites supported a distinct bird community characterized by Blue-headed Vireos and Ovenbirds (Mizel 2011).

4.11.1. Data Gaps, Needs, and Management Strategies

Compared to other terrestrial vertebrates, the birds of NERI are relatively well-studied. However, Mahan and Darden (2014) recommended continued study of the trend in neotropical warblers in the park. A better understanding of the breeding population, abundance, and productivity of wood warblers with a focus on Cerulean Warblers could help determine the contextual importance of NERI to this community of native birds. In addition, mining and resulting forest fragmentation and habitat disturbance around NERI may have persistent negative effects on particular assemblages of wood warblers—including Cerulean Warblers (Wood et al. 2005).

4.12. Bats

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

There are 10 species of bats known to occur in NERI (Wood et al. 2002, Gates and Johnson 2006, Castlebury et al. 2007, Varner, 2007, 2008, Figure 16). Of these species, all cave-hibernating species (n = 7) are threatened by white-nose syndrome. White-nose syndrome (WNS) is a fatal disease in bats caused by the fungus *Pseudogymnoascus destructans.* The disease was first discovered in New York in the winter of 2006. Since then, it has spread to more than half of the United States, killing millions of bats—up to 99% of some bat colonies (Foley et al. 2016). The effects of white-nosed syndrome, which was first recorded in the park in 2011, are dramatically evident in the live-trapping data collected at mine portals in NERI (Table 6). In 2005, a total of 2,346 individual bats representing 9 species were captured (Figure 17). Ten years later, 138 individual bats of 6 species were captured in the park.

The decline was most pronounced in *Myotis* species and the Tri-colored bat (all of which hibernate in the park; Figure 16). Research hypothesizes that the disease is selecting for individuals that choose colder locations for hibernation (temperatures below 10° C are less ideal for fungal growth) or for those who have a natural resistance to the fungal infection (Reynolds and Barton 2014, Lilley et al. 2016). Recent data analysis confirms a statistically significant decline in abundance of little brown bat [*Myotis lucifugus*], Northern long-eared bat [*M. septentrionalis*], Eastern small-footed bat [*M. leibii*], and tri-colored bat [*Perimyotis subfavus*] from 2005-2016 with a significant decline in weights of captured tri-colored bats during this period (Paul 2014). Since 2014, 29 abandoned mine portals used as hibernacula by bats have been gated to protect subterranean bat species susceptible to WNS.

4.12.1. Data Gaps, Needs, and Management Strategies

Any bats that still survive in the park may represent individuals that have physiological and/or behavioral resistance to WNS. It is, therefore, important to protect these individuals from mortality and disturbances at all known roosting and hibernation locations within the park. At NERI, abandoned mines represent important hibernacula and protection from all winter-time disturbances could beneficially continue.

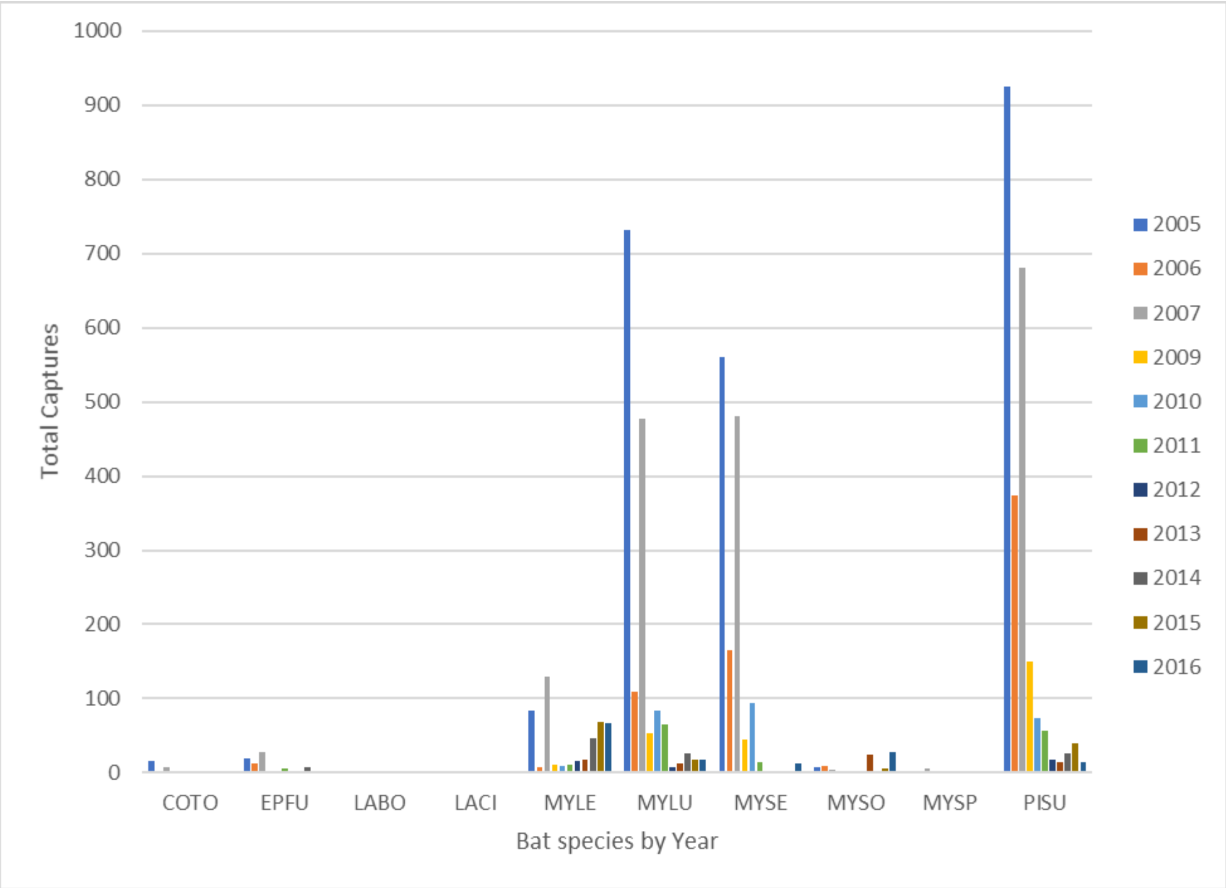


Figure 16. Total captures of Virginia big-eared bat (CoTo *Corynorhinus townsendii virginianus)*, Big brown bat (EpFu, *Eptesicus fuscus*), Eastern red bat (LaBo, *Lasiurus borealis*), Hoary bat (LaCi, *Lasiurus cinereus*), Little brown bat (MyLe, *Myotis lucifugus*), Northern long-eared bat (MySe, *Myotis septentrionalis*), Indiana bat (MySo, *Myotis sodalis*), Unidentified myotis (MySp, *Myotis* sp.), Eastern pipestrelle (PiSu, *Perimyotis subflavus*), 2005-2016, New River Gorge National River (NERI), West Virginia.

Table 6. Total bat captures by mine portal site, New River Gorge National River (NERI), West Virginia, 2005-2016.

Mine Portal Sites	2005	2006	2007	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
Ames C	n/a	142	n/a	93	n/a	n/a	n/a	n/a	n/a	n/a	n/a	235
Ames E	n/a	71	n/a	9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	80
Ames G	n/a	98	41	n/a	33	n/a	n/a	n/a	4	n/a	n/a	176
Beury A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	26	74	62	106	272
Brooklyn A	286	n/a	16	n/a	34	35	13	13	9	1	n/a	407
Brooklyn B	n/a	n/a	n/a	n/a	n/a	8	n/a	n/a	n/a	n/a	n/a	8
Buffalo Creek South A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	3
Cunard South	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	n/a	1
Dunloup North A	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	n/a	3
Dunloup North B	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	1
Fayette Station C	n/a	30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	30
Fayette Station F	n/a	25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	25
Fire Creek #2 D	213	n/a	272	n/a	44	7	2	1	n/a	n/a	n/a	539
Fire Creek #2 E	172	n/a	75	n/a	47	21	1	3	1	n/a	n/a	320
Fire Creek East A	45	n/a	3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	48
Fire Creek East B	10	n/a	4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	14
Fire Creek East C	18	n/a	9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	27
Gaymont C	n/a	n/a	7	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7
Gaymont D	n/a	n/a	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5
Gaymont E	n/a	n/a	75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	75
Grandview Bat Condo	n/a	n/a	20	n/a	34	n/a	n/a	n/a	n/a	n/a	n/a	54
Hawk's Nest 1	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
Hawk's Nest 2	n/a	n/a	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	10
Hawk's Nest 3	n/a	n/a	11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	11
Kaymoor D	n/a	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
Kaymoor H	n/a	71	3	33	n/a	13	1	2	n/a	n/a	n/a	123
Kaymoor L	n/a	92	7	18	n/a	17	6	2	1	n/a	n/a	143
Kaymoor M	n/a	152	9	19	n/a	11	n/a	3	n/a	n/a	n/a	194

Table 6 (continued). Total bat captures by mine portal site, New River Gorge National River (NERI), West Virginia, 2005-2016.

Mine Portal Sites	2005	2006	2007	2009	2010	2011	2012	2013	2014	2015	2016	Grand Total
Kaymoor Tunnel	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	n/a	2
Lower Arbuckle E		2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
Lower Rush Run F	91	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6	n/a	97
Lower Rush Run G	35	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	35
Mill Creek 4	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1
Mill Creek 5	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1
Mill Creek 6	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2
Mill Creek 7	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1
Nuttallburg B	254	n/a	164	n/a	69	n/a	n/a	n/a	n/a	28	2	517
Nuttallburg South D	268	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5	n/a	273
Red Ash B	13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	13
Red Ash E	62	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	62
Rush Run B	15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	15
Stone Cliff A	131	n/a	114	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	251
Stone Cliff B	24	n/a	45	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	71
Stone Cliff C	481	n/a	699	78	n/a	24	23	17	20	13	20	1375
Stone Cliff E	n/a	n/a	173	n/a	n/a	n/a	n/a	n/a	n/a	1	n/a	174
Stone Cliff F	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
West Nuttall B	56	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	56
West Nuttall G	71	n/a	30	n/a	n/a	n/a	n/a	n/a	n/a	21	10	132
West Nuttall M	101	n/a	19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	120
Whitney A	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	2
Whitney B	n/a	n/a	n/a	n/a	n/a	10	n/a	n/a	n/a	n/a	n/a	10
Grand Total	**2346**	**683**	**1818**	**260**	**261**	**152**	**47**	**73**	**112**	**137**	**138**	**6027**

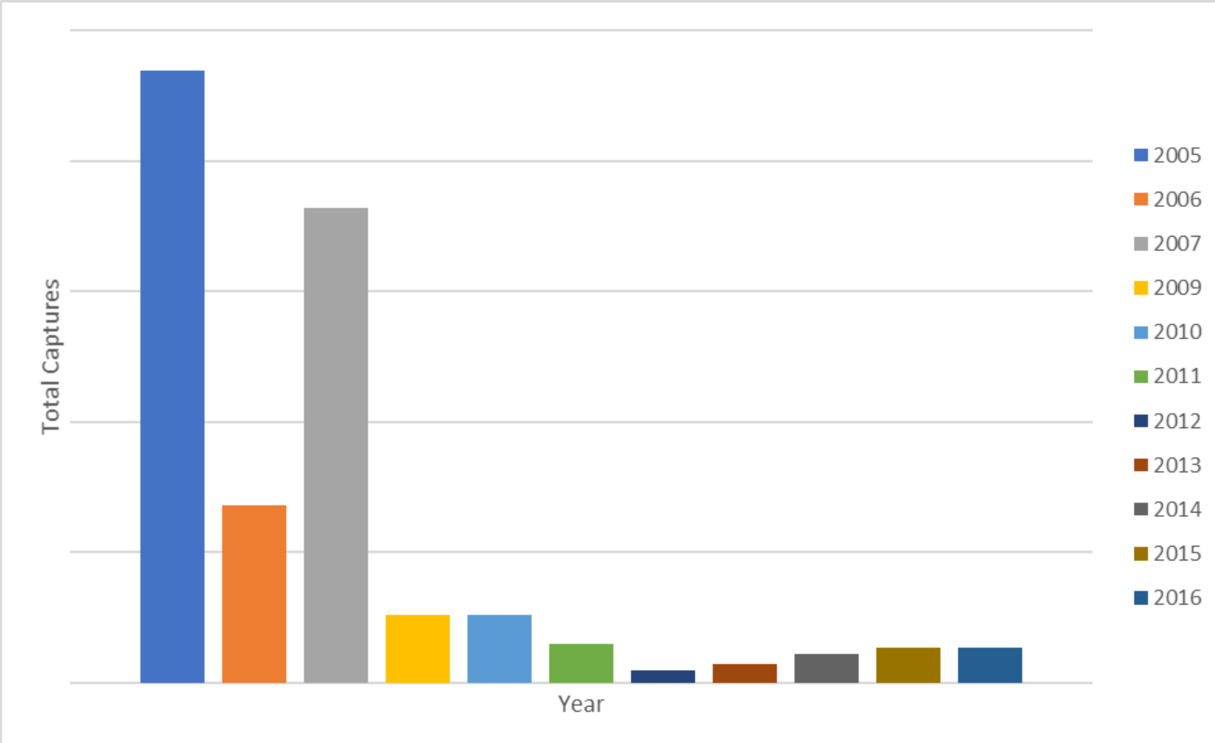


Figure 17. Total bat captures of all species New River Gorge National River (NERI), West Virginia, 2005-2016.

4.13. Allegheny Woodrat

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Since the late 1970s, the Allegheny woodrat, an Appalachian endemic species, has been declining throughout the species' range (Peles and Wright 2008). The Allegheny woodrat is a habitat specialist that inhabits rocky habitat (e.g. talus slopes) within in a forest dominated matrix. The rocky habitat provides nesting sites and protection from predators. Several possible causes of woodrat decline have been proposed and include: habitat loss and forest fragmentation, infection of roundworms [*Baylisascaris procyonis*] transmitted by raccoons, and loss of American chestnut [*Castanea dentata*] and resulting mast declines (Balcom and Yahner 1996, Smyser et al. 2012). Mahan (2004) identified the population of Allegheny woodrat as nationally significant at NERI due to its relatively robust population abundance in the park. At that time, the population in the park appeared to be stable and represented the core population for the species in the eastern United States (Wood 2001). Due to their conservation status and national importance, woodrat populations have been monitored via live-trapping at 33 sites in NERI since 1999. All live-trapping sites contain known or historic populations of woodrats or contain habitat that is suitable for this species. Woodrats have consistently been captured at four sites (Ames Mine, Elverton, Kaymoor, and Underwood) and seem to be persisting at these locations (Figure 18).

In 2012, the South Nuttall site was first surveyed for woodrats and fewer than 5 individuals were captured at all sites (Figure 18). Yearly variabilities in capture rates at individual locations are expected due to the distributional pattern of small, isolated woodrat populations that represent subpopulations within a larger metapopulation (Peles and Wright 2008). Despite these expected population variations, the overall abundance of woodrats in the park is declining at the park with numbers of unique woodrat captures and captures per mile of sampling declining from 1999-2011 at all but one sampling site (Underwood).

4.13.1. Data Gaps, Needs, and Management Strategies

Better and more specific management guidelines resulting in the protection of Allegheny woodrat habitats are needed throughout the species' range. In particular, attention needs to be given to maintaining dispersal corridors among isolated populations. Therefore, minimizing forest fragmentation and maintaining habitat connectivity among rocky habitats is critical. All areas that contain woodrats could be protected from excessive human traffic—so careful placement of new trails and re-routing of existing trails in the park may be necessary.

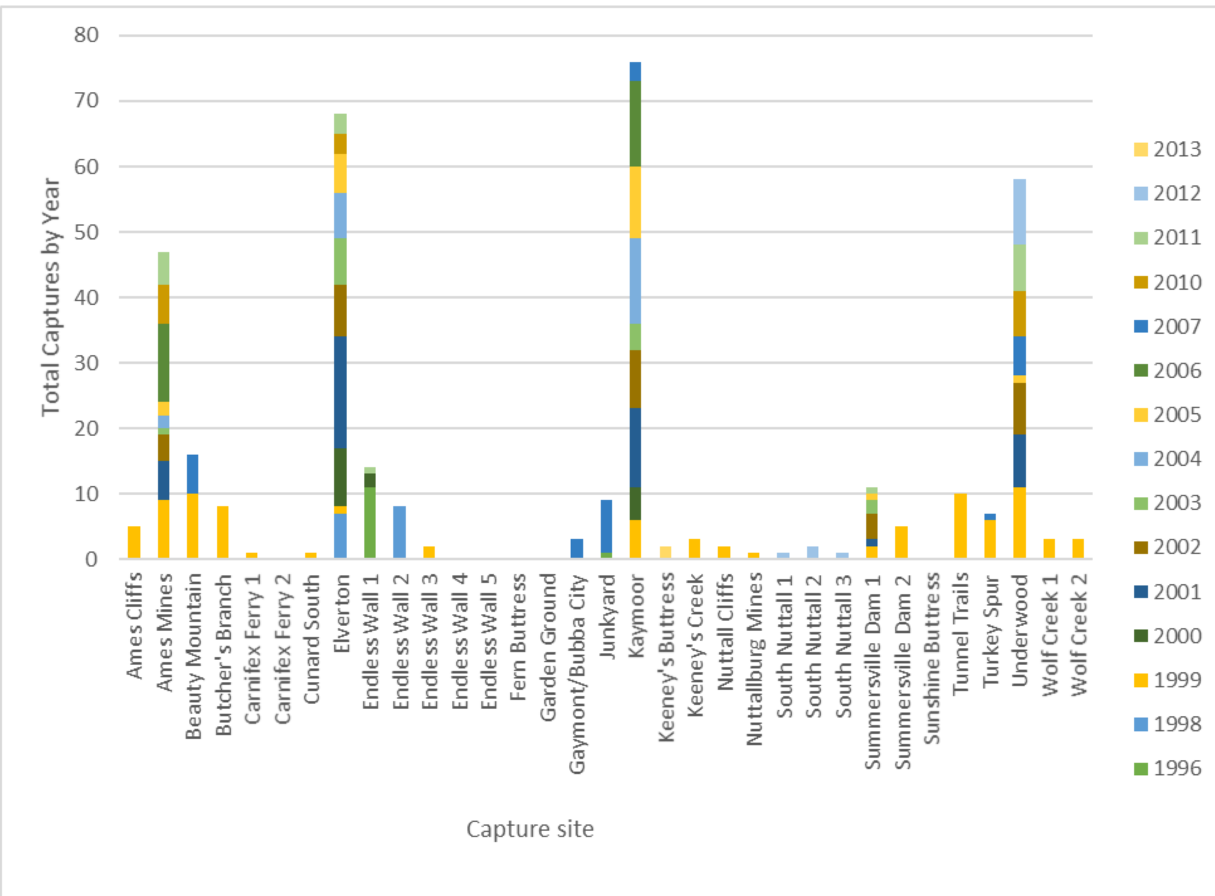


Figure 18. Total captures of Allegheny woodrats (*Neotoma magister*), New River Gorge National River (NERI), West Virginia, 1996-2013.

4.14. Game (Hunted) Species

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Hooper et al. (2006) identified 50 species of mammals and birds that are, or may be, hunted at NERI. However, their research indicates that only five game species (white-tailed deer, black bear, wild turkey, bobcat, and gray squirrel) were hunted with enough intensity to provide adequate data to demonstrate potential population impacts (Hooper at al. 2006). In fact, Hooper et al. (2006) found that even with legal, regulated hunting, white-tailed deer [*Odocoileus virginianus*], black bear *[Ursus americanus*], and wild turkey [*Meleagris gallopavo*] expanded in abundance both statewide and locally in the vicinity of NERI. These researchers determined that hunting provides a valuable wildlife management tool to control the non-native wild boar [*Sus scrofa*] population in West Virginia and to maintain white-tailed deer populations in balance with forest regeneration (Hooper at al. 2006).

An emerging infectious disease threatens white-tailed deer populations in North America. Chronic Wasting Disease (CWD) is a neurological disease found in deer and elk [*Cervus canadensis*] in North America. The disease belongs to a family of diseases knowns as transmissible spongiform encephalopathies (TSE) or prion diseases. The disease causes breakdown of brain tissue and is always fatal. Since the last Natural Resource Assessment for NERI (Mahan 2004), CWD has been documented in eastern WV since 2005 and now has spread to Virginia (2010), MD (2011), and Pennsylvania (2012). The only demonstrated method to reduce prevalence and spread of CWD is through extreme culling operations such as those carried out in Illinois since 2003 (Wasserberg et al. 2008, Manjerovic et al. 2014). CWD can be transmitted through blood, urine, and saliva of infected deer and the disease-causing prions can adhere to, and accumulate in, soils (Almberg et al. 2011). CWD has been detected in both Hampshire and Hardy counties, WV—about 200 miles northeast of NERI.

The rate of harvest of Ruffed Grouse [*Bonasa umbellus*], Northern Bobwhite [*Colinus virginianus*], American Woodcock [*Scolopax minor*], and waterfowl is not well-understood within NERI. However, populations of these game birds are closely monitored regionally and nationally and these data indicate annual fluctuations in abundance that must be examined prior to setting bag limits. Ruffed grouse, Northern bobwhite, and American woodcock continue to decline in the Appalachians and habitat quality management for these species may be the best way to compensate for any additive hunter mortality (e.g. Devers et al. 2007, Cox et al. 2004). American Woodcock is also a priority species for protection by the Appalachian Mountains Joint Venture (2016) and habitat restoration through active forest management of early successional forest patches is a critical goal of this conservation effort. Finally, emerging research indicates that Ruffed Grouse are susceptible to West Nile virus and this pathogen may be contributing to this game bird's decline throughout the Mid-Atlantic (Nemeth et al. 2017).

Hooper et al. (2006) identified potential secondary negative effects of hunting within NERI on other recreational users of the park. For example, recreationists who perceive that they are in danger from hunters may choose not to engage in outdoor recreation in a particular area or during a particular hunting season.

4.14.1. Data Gaps, Needs, and Management Strategies

The park can work with the WV DNR to test a proportion of deer harvested or killed (road-killed) in and around NER for CWD. In addition, signage that educates park visitors and hunters about the threat of CWD is needed—especially to limit the movement of harvested deer. Most importantly, the park could continue to permit and encourage harvesting of white-tailed deer to keep the population size in balance with local ecological conditions and reduce the spread of emerging infectious disease.

4.15. Landscape Development: Surrounding Land Use and Land Use Trends

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Landscape development near park boundaries can affect within park resources through flows of materials (water and air pollution, noise) through parks along drainage networks, or by increasing interactions and invasions through increased edge environments (Monahan and Gross 2012, Hansen et al. 2011, Hansen and DeFries 2007). Many national parks are becoming forested habitat islands in a surrounding developed landscape matrix, or are at increasing risk from extractive land uses such as oil and gas development or coal mining near, and sometimes this development is occurring in the park itself (Hansen et al. 2011, Davis and Hansen 2011, Lund 2017). Additionally, pre-existing or newly developed roads can fragment interior forest environments, reducing the sizes of core forests necessary for many bird and animal species, and increasing the amount of edge habitats (Heilmann et al. 2002, Trombulak and Frissell 2000). Assessment of these larger scale impacts are important for understanding the context of natural resource conditions in national parks, especially in river-focused parks since flows of materials generally occur in a downstream direction into the park environment (Monahan and Gross 2012, Lawrence et al. 2011).

The National Park Service's NPScape program was designed to assess the local and regional landscape dynamics of National Park units using standardized operating procedures (SOP) built on landscape ecology principles (Monahan et al. 2012). We employed the NPScape SOPs as well as other GIS-based analysis to assess the landscape conditions and land cover changes in areas around NERI.

The National Land Cover Database (NLCD) is a nationally consistent land cover mapping product created by a multi-agency consortium (Multi-Resolution Land Characteristics consortium, http:///www.mrlc.gov). Land cover is mapped into standardized land cover classes at a moderate spatial resolution (30-meter, 98.4 ft pixels) at roughly five year intervals since 2001 (e.g. 2001, 2006, 2011). Although the spatial resolution and classification system are too coarse for within park vegetation assessments, the national extent and consistency are ideal for regional scale analysis. Additionally, the temporal resolution allows for assessment of change between major land cover categories and time periods. We used land cover data from 2001 and 2011 to represent changes since the last Natural Resource Assessment in 2004 (Mahan 2004). While more current land cover data would have been preferable, the 2016 time period NLCD is neither complete nor available for download.

We summarized land cover data using the 2011 NLCD (Homer et al. 2015) for both assessing the landscape setting of the park, for landscape fragmentation and connectivity analysis (see below), and to assess changes in land cover in the ten-year period between 2001-2011. The NLCD includes a land cover change product that maps land cover changes between time periods and provides the “from” and “to” land cover transition classes between time periods. We used the NPScape land cover change SOP (NPS 2013) to assess and summarize land cover changes in a standardized “Area of Analysis” (AOA) or buffer zone around the park. For consideration of this and other landscape dynamics metrics we primarily assessed the landscape conditions in a 30 km (18.6 mi) AOA surrounding the NERI park boundary, but we also contrasted this regional landscape with a more local 3 km (1.9 mi) AOA and/or conditions within the park boundary itself.

While the NLCD tracks changes in land cover, it does not track changes in land use. For some land uses the transition in cover and of itself may be sufficient to infer change in land use (e.g. forest to agriculture), but for other transitions information on land use may be lacking. For instance, an area may have transitioned from forested to barren land cover, but the nature of the transition may not be well explained. Of particular interest in the surrounding landscape of NERI are land use changes associated with energy production, including oil and gas development and coal mining. In addition to the NLCD, we assess data for oil and gas, as well as coal permitting from permit databases maintained by the WV DEP (WV DEP 2017) within the 30 km AOA surrounding the park.

Developed lands surrounding NERI influence the area of impervious cover potentially affecting water resources of the park. Impervious surfaces are known to impact water quality and aquatic communities because rainfall runoff enters streams and rivers directly rather than slowly infiltrating through soil and bedrock, and can wash sediments and contaminants picked up from roads, parking lots, and roof tops into receiving waters. The NLCD also includes a separate percent imperviousness data layer created from satellite imagery, aerial photography, and other ancillary datasets (Xian et al. 2011). This data set records the percentage of each 30 m pixel covered by impervious land cover. We used an NPScape SOP (NPS 2013) to summarize 2011 NLCD impervious surface cover data in the 30 km AOA surrounding NERI.

The WV DEP maintains GIS data sets of oil and gas well permit locations, limits of underground coal mining operations, and areas of mining refuse structures (e.g. piles and slurry impoundments) as well as areas of valley fills formed from removal and dumping of overburden (WV DEP 2017). These maps represent the best available data source on the location and size of these features. We summarized the type, location, and areas of these features within the 30 km AOA surrounding NERI.

We also assessed the potential for future energy development (gas and coal) in the area surrounding the park using a recently completed project modeling energy build out potential that was conducted by the Nature Conservancy for the Appalachian Landscape Conservation Cooperative (Dunscomb et al. 2014). This spatial statistical model was created using geospatial predictors including geologic attributes (coal and shale formations, thickness), topographic attributes (surface roughness) and transportation attributes (distance to rail, ports, power plants). While at a coarse spatial scale (1 km pixels), this raster dataset estimates the probability of coal and natural gas development for the next 30 years for areas within the Appalachian LCC, which includes areas surrounding NERI. The Dunscombe et al. (2014) analysis also considers wind power generation potential, but we did not have enough locational data on existing wind power generation for comparison with future build out in the area surrounding NERI.

We do not have comparable land cover datasets for time periods prior to 2001 that can be reliably assessed against the 2011 NLCD data for a per-category land cover change assessment. Although the USGS conducted national land cover mapping in 1973 and 1992, these data were produced using either different image data sources or scales, or using different mapping methodologies. Therefore, our comparisons consider only the change in land cover since 2001 as a reference point.

However, the USGS LANDFIRE program (https://www.landfire.gov/) produces a "biophysical settings" land cover layer that attempts to predict vegetation conditions prior to European settlement based on the current biophysical setting and historical disturbance regime at a similar spatial scale to the NLCD (30 m pixels). Summarizing this data layer, the original land cover of the NERI 30 km AOA prior to European settlement was predicted to be 88.6% upland forest (87.1% hardwood, 0.7% mixed hardwood-conifer, and 0.8% conifer), and 9.4% riparian forest, with the remaining 2% in natural rock outcrops, glades, or open water, and no developed or human-influenced impervious land cover.

Multiple studies have examined the impact of (developed) impervious surfaces on stream communities, and various thresholds of impervious surface percentage have been suggested as indicators of stream health, with general agreement that watersheds with greater than 10% impervious cover become impacted and show signs of degradation (Schueler et al. 2009).

Coal extraction and oil and gas well drilling have been a feature of the West Virginia landscape and the region surrounding NERI for over 100 years. Similar to other land cover changes, the most appropriate reference condition for energy extraction activities is probably drawn from models of land cover conditions predicted to have been present prior to European settlement.

4.15.1. Landscape Trends

In 2011, the 30 km AOA surrounding NERI was 79.8% forested (74.6% deciduous forest, 0.9% mixed conifer-deciduous forest, and 4.3% conifer/evergreen) (Figure 19, Table 7). Other significant land cover categories in the surrounding landscape include 8.2% agriculture land cover (7.9% hay/pasture and 0.3% cultivated crops), and 6.8% developed land cover (4.2% developed open space, 1.8% developed low intensity, 0.7% developed medium intensity, and 0.1% developed high intensity. Approximately 1.2% of surrounding land cover was classified as barren land.

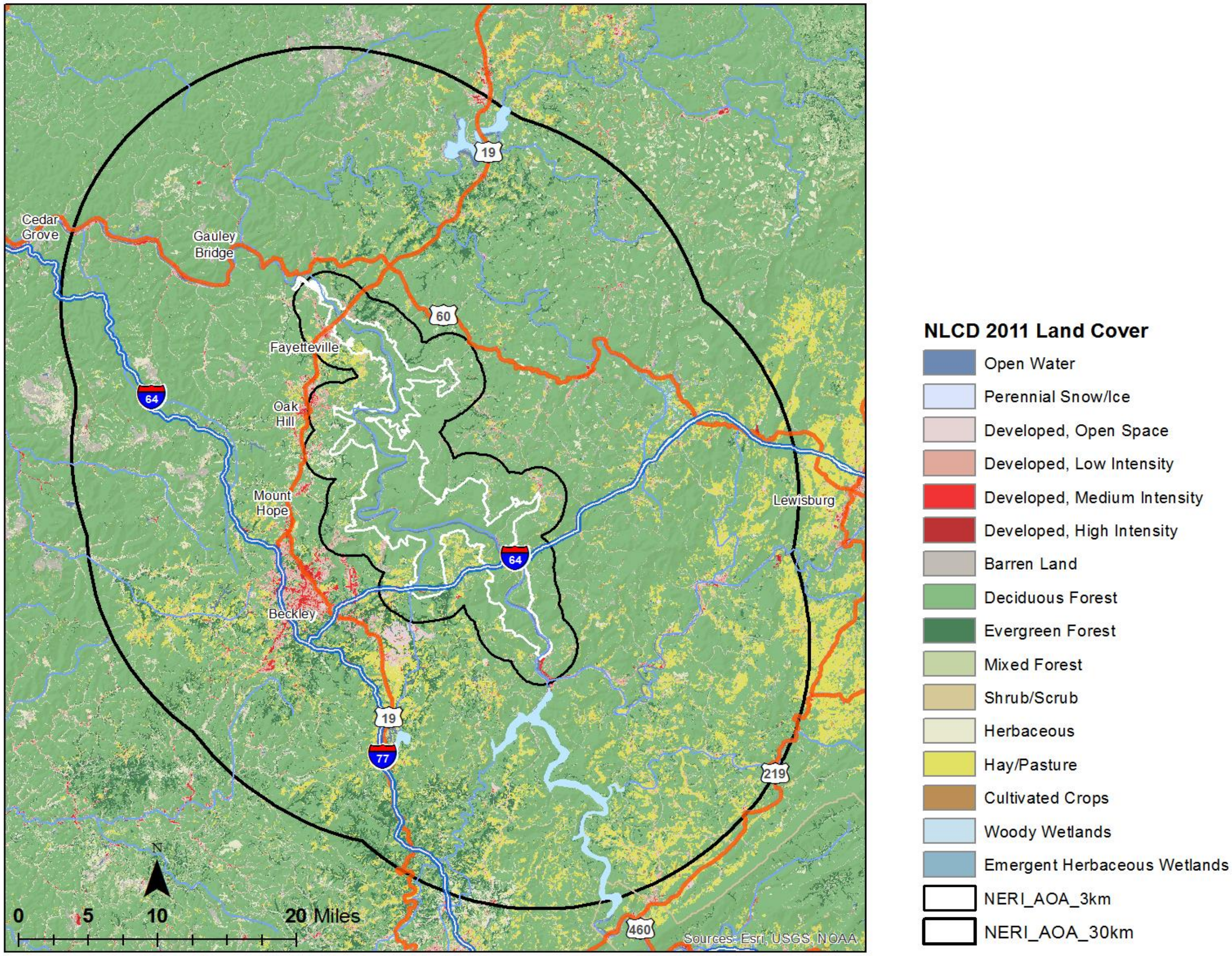


Figure 19. Land cover distribution in the 30Km area of analysis (AOA) surrounding New River Gorge National River (NERI) from the 2011 National Land Cover Database. Also shown for reference are a 3Km AOA and the park boundary (white). The 30 km and 3 km AOA are standard summary units used by the NPScape program (NPS 2013).

Table 7. Landcover area and percentage in the 30 km area of analysis (AOA) surrounding New River Gorge National River (NERI), summarized using the 2011 National Landcover Database.

Class Name	Area (km^2)	Area (%)
Open Water	65.56	1.0
Developed, Open Space	288.41	4.2
Developed, Low Intensity	125.65	1.8
Developed, Medium Intensity	50.90	0.7
Developed, High Intensity	9.34	0.1
Barren Land	80.80	1.2
Deciduous Forest	5111.68	74.6
Evergreen Forest	292.24	4.3
Mixed Forest	61.56	0.9
Shrub/Scrub	9.79	0.1
Herbaceous	182.95	2.7
Hay/Pasture	538.87	7.9
Cultivated Crops	18.19	0.3
Woody Wetlands	6.25	0.1
Emergent Herbaceous Wetlands	11.70	0.2

As of 2011, (developed) impervious surface cover exists primarily along the Highway 19, Beckley to Fayetteville corridor to the west of the park (Figure 20). Mapped impervious surfaces, for the most part, occur outside the NERI park boundary but do occur in the 3 km AOA near the park boundary. Although approximately 96% of the 30 km AOA surrounding NERI was under the suggested 10% impervious surface threshold (Table 8), many stream headwaters originating from the west drain areas of high percentage impervious surface cover.

From the period 2001 to 2011, the major transitions in land cover were from deciduous forest to grassland/herbaceous (58.7 km^2 [22.7 mi^2] 0.9% of the area), barren land (22.4 km^2, [8.8 mi^2], 0.3% of the area), or shrub/scrub (7.0 km^2 [3.0 mi^2], 0.1% of the area) (Table 9). A relatively minor amount of the 30 km AOA area (5.0 km^2 [1.9 mi^2], < 0.1%) transitioned to developed land cover types, and this was primarily from a less intensive developed land cover to more intensive development types (Table 9). A number of small (< 1 km^2 [0.4 mi^2]) land cover transitions were also reported, but are not listed.

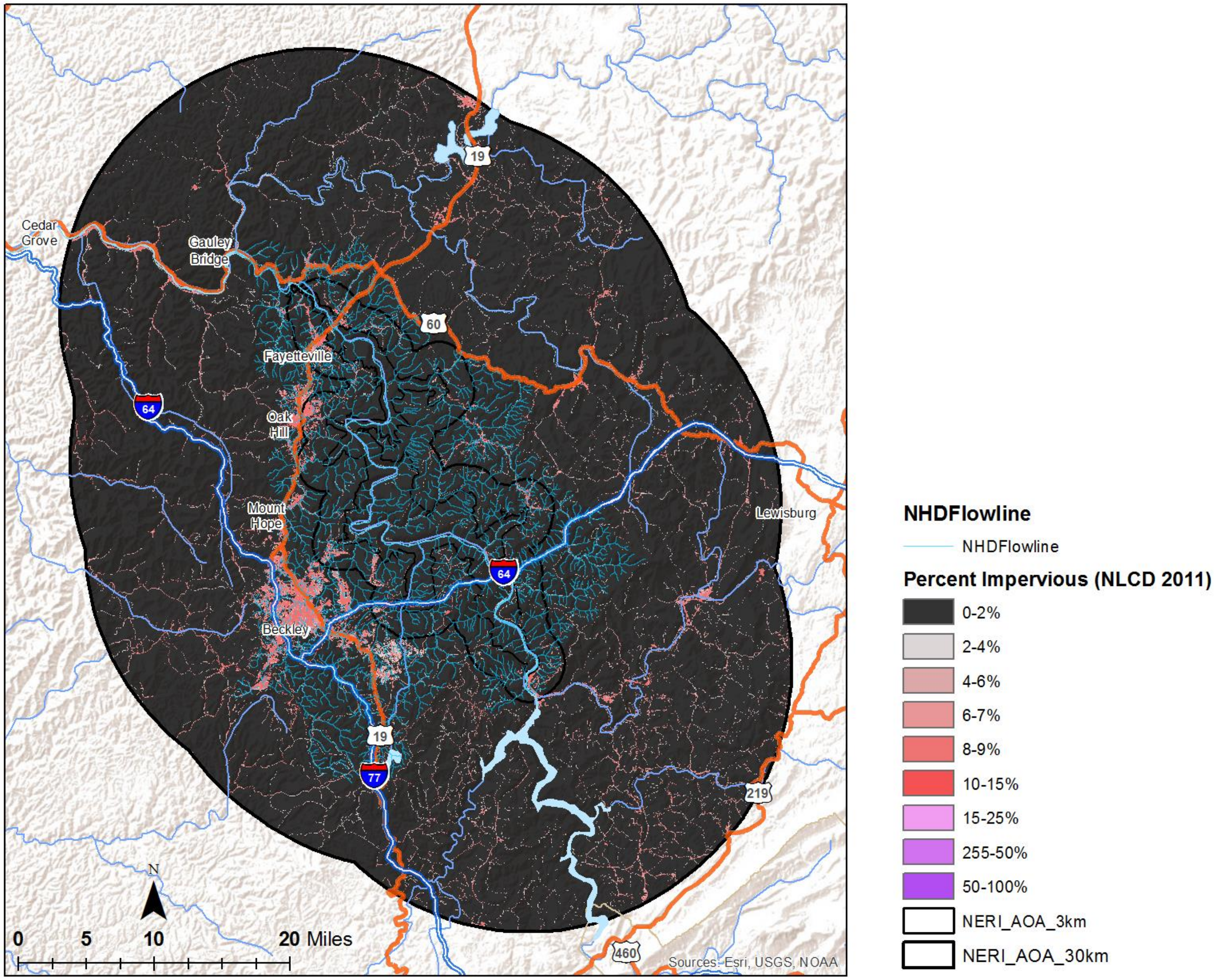


Figure 20. Impervious surface cover percentage in the 30 km AOA surrounding New River Gorge National River (NERI), derived from the 2011 NLCD impervious surface data layer (Xian et al. 2011). Also shown are streams (flowlines) that flow through NERI as mapped by the National Hydrological Database (NHD).

Table 8. Impervious surface percentage class categories for the 30 km AOA surrounding New River Gorge National River (NERI), as summarized by the NPScape land cover SOP (NPS 2013).

Class Name	Area (km^2)	Area (%)
0% - 2%	6422.42	93.7
2% - 4%	64.99	0.9
4% - 6%	48.32	0.7
6% - 8%	26.53	0.4
8% - 10%	23.59	0.3
10% - 15%	45.29	0.7
15% - 25%	63.52	0.9
25% - 50%	97.62	1.4
50% - 100%	61.63	0.9

Table 9. Major land cover transitions in the 30 km area of analysis (AOA) surrounding NERI from 2001-2011 as mapped in the National Land Cover Database.

Class Name	Area (km^2)	Area (%)
Deciduous Forest to Grassland/Herbaceous	58.68	0.9
Deciduous Forest to Barren Land	22.42	0.3
Deciduous Forest to Shrub/Scrub	7.01	0.1
Barren Land to Grassland/Herbaceous	4.71	0.1
Evergreen Forest to Grassland/Herbaceous	3.98	0.1
Grassland/Herbaceous to Barren Land	3.02	0.0
Developed, Open Space to Developed, Medium Intensity	2.38	0.0
Mixed Forest to Grassland/Herbaceous	1.38	0.0
Developed, Low Intensity to Developed, Medium Intensity	1.34	0.0
Developed, Open Space to Developed, Low Intensity	1.29	0.0

Transitions to barren land cover (deciduous forest to barren, and grassland/herbaceous to barren) may be capturing the conversion of these land cover types to energy development land uses. A large number of well drilling permits have been issued in the area surrounding NERI over the years, especially to the northwest and west of the park (Figure 21). An overall total of 5,457 well drilling permits have been issued in the 30 km AOA surrounding NERI (WV DEP 2017) (Table 10). Of all permits issued in the 30 km AOA, 2,896 (53%) are classified as currently active as of May, 2017 (Figure 22). Of the active wells, nearly all are vertical wells with most (1806, 62%) used for gas production, although a large number (983, 34%) are not classified with a use type. Only a small number of well permits (14) are classified as horizontal wells, although as of May 2017 none of these wells are active. Within the 3 km AOA, there are 43 reported active well permits (all vertical), 27 (62%) of which are classified as being used for gas production, with the remaining listed as unknown use. Since 2001, 384 new well permits have been issued in the 30 km AOA that are classified as active, with most of these issued from 2001-2009 (Figure 22).

Table 10. All historical well drilling permits issued within the 30 km AOA surrounding NERI, categorized by well type, well use, and well status from databases manintained by the West Virginia Dept. of Environmental Protection (WV DEP 2017). * Note that two vertical well permits are not shown because their well use and well status fields were left blank.

Well Type by Well Use	**Well Status**						
	Abandoned Well	**Active Well**	**Future Use**	**Never Drilled**	**Never Issued**	**Plugged**	**Grand Total**
Coal Bed Methane Well	19	64	7	36	14	55	195
Gas Production	19	64	7	36	14	55	195
Horizontal	n/a	n/a	n/a	9	5	n/a	14
Unknown	n/a	n/a	n/a	9	5	n/a	14
Not Available	10	1	n/a	1	n/a	58	70
Not Available	10	1	n/a	1	n/a	58	70
Vertical*	277	2831	5	393	17	1655	5178
Brine Disposal	n/a	18	n/a	n/a	n/a	n/a	18
Gas Production	169	1806	3	1	1	125	2105
House Gas	5	5	n/a	n/a	n/a	2	12
Not Available	36	7	n/a	39	n/a	1167	1249
Oil Production	n/a	8	n/a	n/a	n/a	n/a	8
Storage	n/a	4	n/a	n/a	n/a	n/a	4
Unknown	67	983	2	353	16	361	1782
Grand Total	306	2896	12	439	36	1768	5457

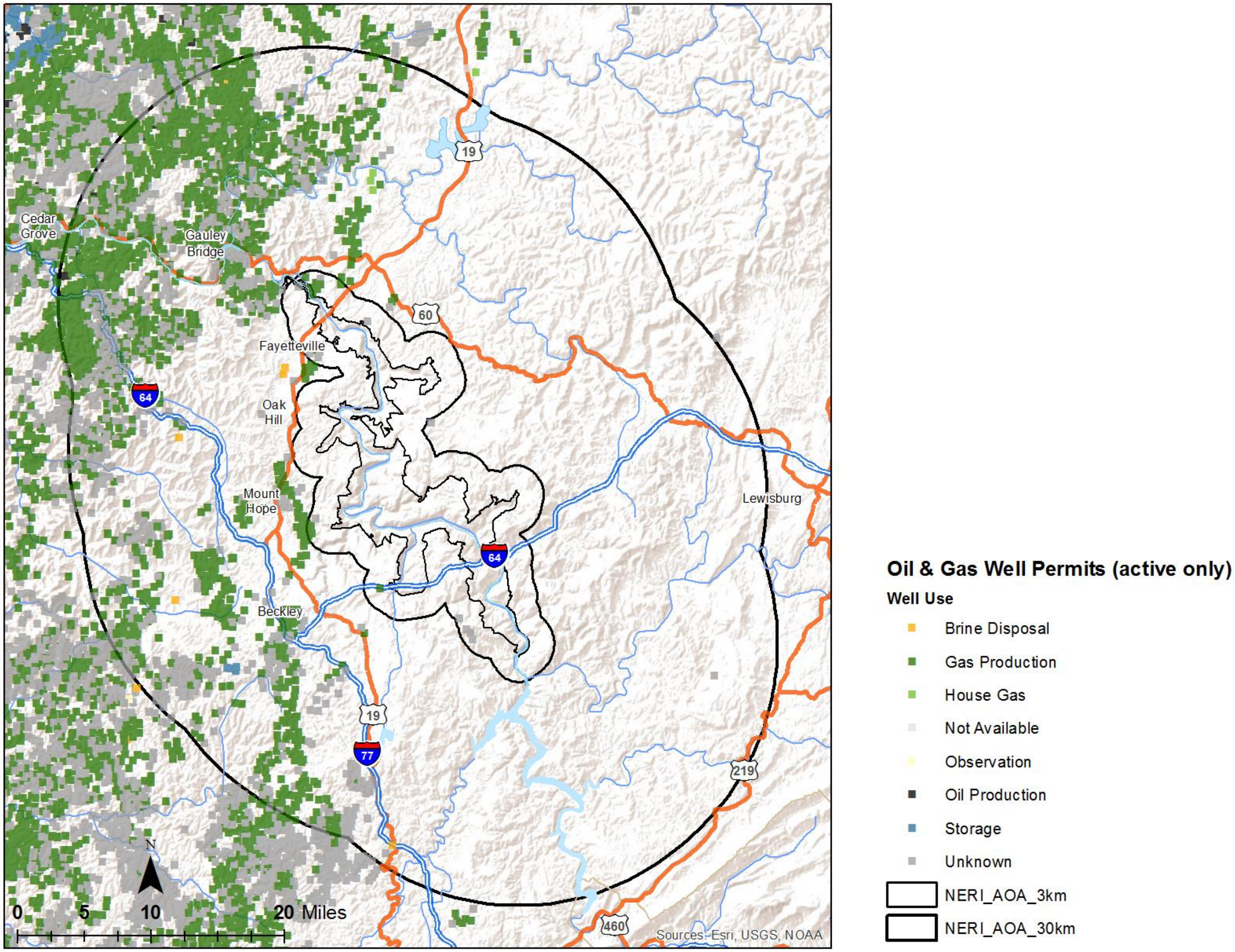


Figure 21. Active oil and gas well drilling permits in the area surrounding New River Gorge National River (NERI), categorized by well use type (source: WV DEP, 2017).

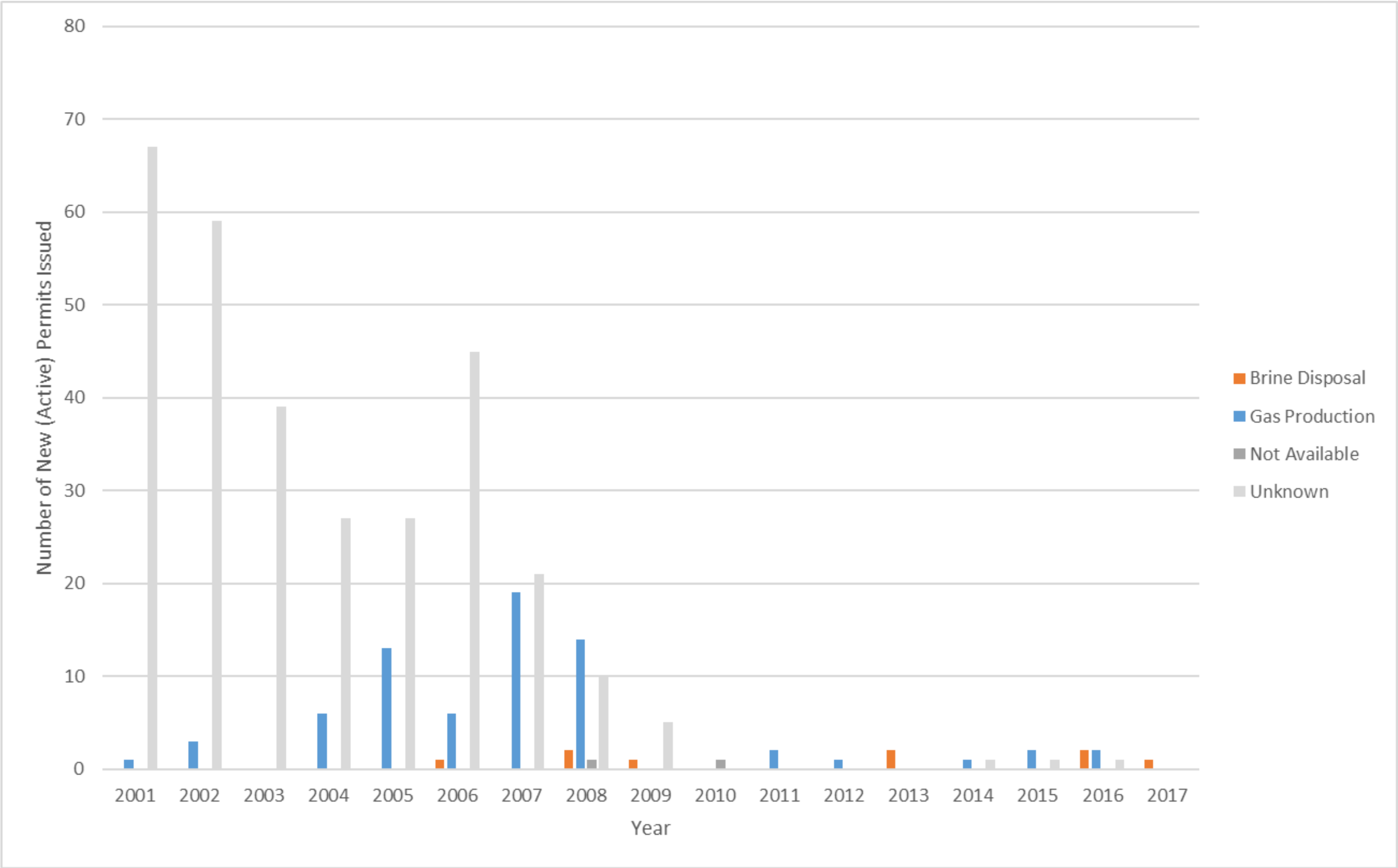


Figure 22. Active well permits recently issued by year since 2001 in the 30 km AOA surrounding New River Gorge National River (NERI).

The TNC model of future natural gas development (Dunscombe et al. 2014) predicts a high probability of future gas extraction in many of the same places previously drilled (Figure 23). However, some areas not currently developed, such as the I-64/I-77 corridor west of Oak Hill, WV and the area between Highway 19 and Highway 60 to the northeast of the park are predicted to be high probability areas for future gas development.

Coal extraction activities also take place within the 30 km AOA surrounding NERI (Figure 24), generally to the north and west of the park. Based on mapped boundaries (polygons) available from the WV DEP as of 2009, there were 7.9 km^2 (1,954 acres) of coal mining refuse structures (including slurry impoundments) and 51.4 km^2 (12,701 acres) of valley fills (overburden) within the 30 km AOA of NERI (WV DEP 2017). There are also extensive areas mapped as underground mining limits in the 30 km AOA, but the extent to which these underground areas have been fully exploited is unclear from this data (WV DEP 2017). The TNC energy development potential model for coal (Dunscombe et al. 2014) matches fairly closely with existing coal development, but suggests the opportunity for potential future expansion of these activities, given suitable market and political conditions (Figure 24).

4.15.2. Data Gaps and Needs

The NLCD has limitations in both the mapping (spatial) and map class (thematic) resolution that may introduce errors in the land cover map used in this summary. While generally accurate for regional assessment (81-87% accuracy for the region, Wickham et al. 2010), the inability to resolve small land areas (less than 900 m^2 [9,687.5 ft^2]) places limitations on the ability to represent small linear and edge features, and the broad land cover classes may obscure several subtypes of land cover that may be of relevance. However, a substantial effort has been made to insure that the NLCD change products are consistent between years (Jin et al. 2013).

Oil, gas, and coal development data from the WV DEP may have limitations in accuracy and completeness that may omit areas previously developed, but in close proximity to the park. Lacking in this analysis are rates of spills, leaks, runoff, or other pollution occurring downstream due to these activities. Although validated against training data, the TNC coal and gas models are at a coarse spatial scale that generalizes future areas of development, and are derived from other spatial data layers that may have their own sources of unspecified error.

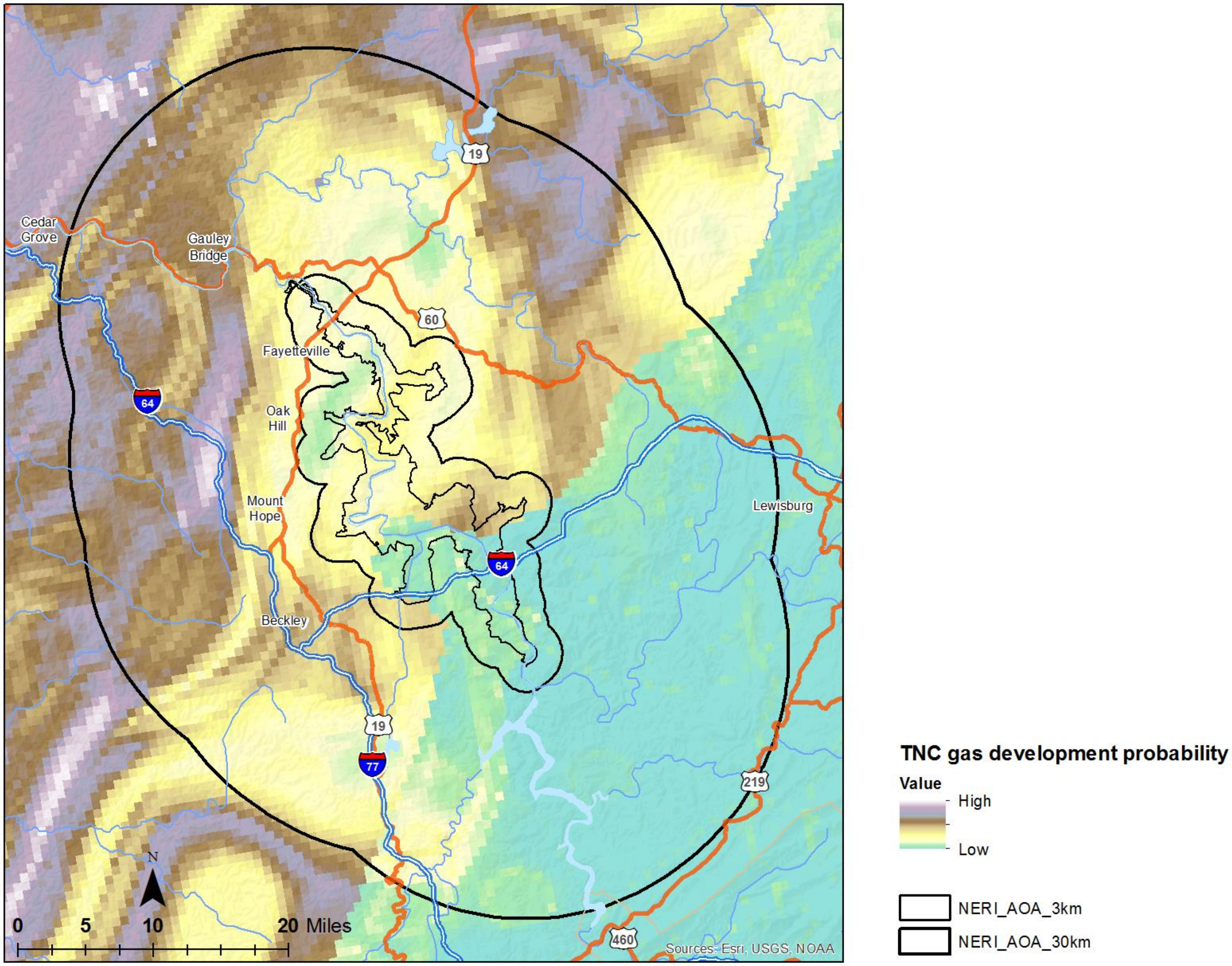


Figure 23. TNC probability surface for future development of natural gas resources in the region surrounding New River Gorge National River (NERI).

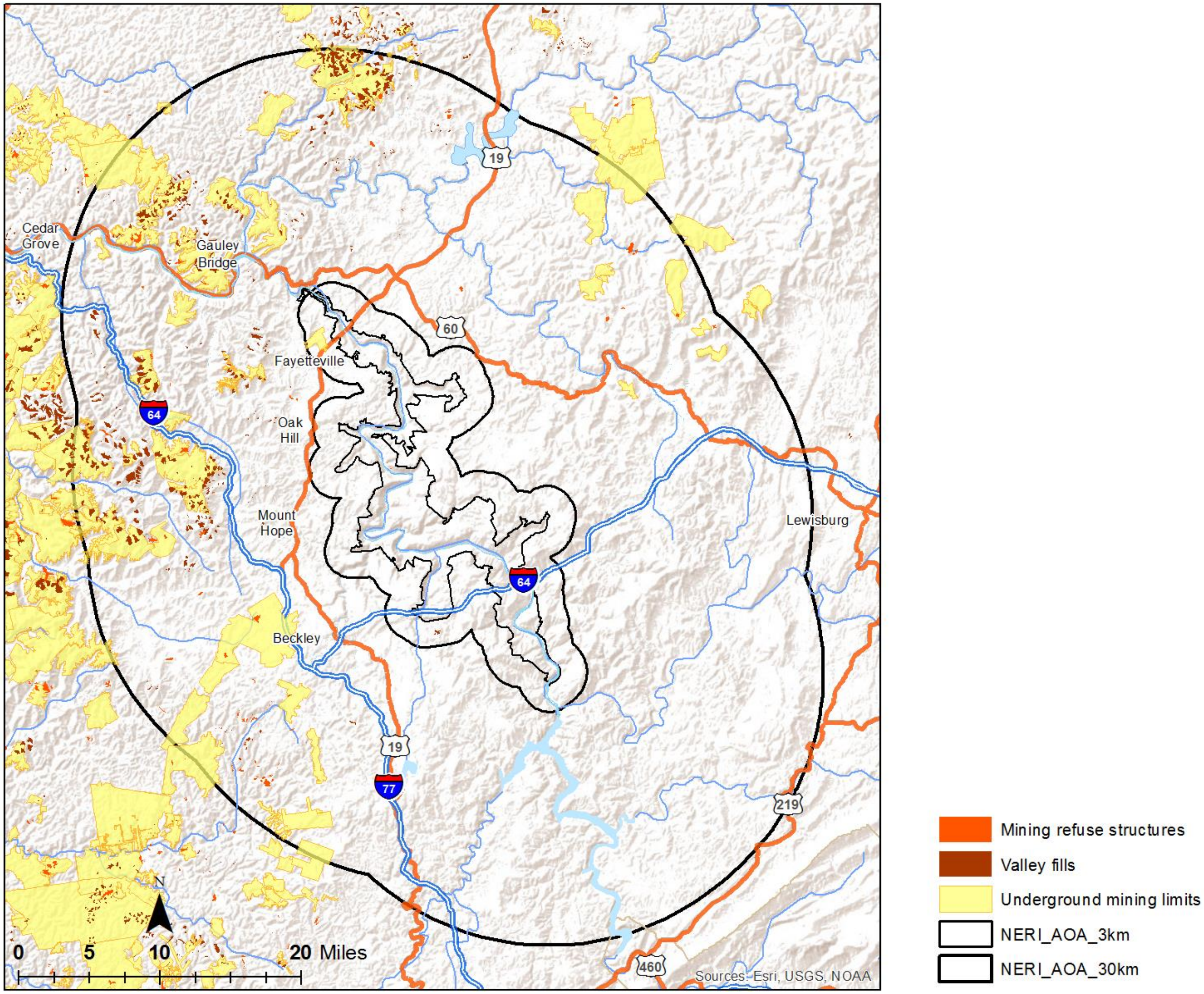


Figure 24. Coal mining activity in the 30 km AOA surrounding New River Gorge National River (NERI) including mining refuse structures, valley fills, and underground mining.

4.16. Forest Fragmentation from Roads

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Road-induced fragmentation is a well-studied landscape influence, and existing and newly developed roads have been shown to reduce the size of interior core forests and increase the amount of edge habitat (Heilmann et al. 2002). Quantification of the size and location of roadless blocks can help to assess the amount of forest habitat fragmentation in a park or the surrounding region, and can serve as a monitoring tool for landscape resilience, diversity, and connectivity. Roadless blocks were previously assessed by Mahan et al. (2009), but that analysis was developed for areas inside the park only and did not consider road induced fragmentation in the larger regional landscape.

We used data from the ESRI Streetmap (ESRI 2012) database and implemented an SOP from the NPScape program to assess road influenced fragmentation (NPS 2013). The NPScape SOP computes metrics of distance from roads, road density, road density weighted by road type, and size of roadless areas from road maps using GIS processing. Weighted road density metrics give extra weight to larger, more heavily traveled roads by multiplying the length of interstate highways by a factor of 5 and multiplying the length of other major roads by a factor of 3 (NPS 2013).

The reference condition for this indicator would be a park landscape and surrounding landscape matrix devoid of roads. This condition has not existed in this area since prior to European settlement (~ 1750 or before).

Due to the large number of roads of any type within the 30 km AOA surrounding NERI, the majority of areas in the surrounding landscape matrix are near to some type of road, especially to the south and east of the park (Figure 25). Within the 30 km AOA surrounding the park, the mean distance to any road is relatively low (μ = 424.4 m [1,398.1 ft], std. dev. = 416.6 m [1,366.8 ft]), but the maximum distance to a road is 3180.1 m (10,433.4 ft). Within the 3 km AOA the mean and standard deviation are slightly lower (μ = 435.6 m [1,429.1 ft], std. dev. =4 02.7 m [1,321.2]), and the maximum (2,238.8 m [7.345.1]) is lower, due in part to the restricted search area within the smaller buffer area. Overall, the surrounding landscape matrix is relatively fragmented due to the existing road network. However, some of the roads depicted may be closed, or lightly traveled, reducing potential fragmentation impacts.

Road density is similarly high, with some areas in the surrounding landscape (30 km AOA) having as high as 16.5 km of roads per km^2 [26.4 mi/mi^2] (μ = 1.67 km/km^2, std. dev. = 1.52 km/km^2) (Figure 26). This is particularly true in areas surrounding the city of Beckley, WV, and along the Highway 19 corridor from Beckley to Fayetteville, WV. Weighting interstate highways by a factor of 5 and major roads by a factor of 3 produces a weighted road density metric where the maximum road density scales to 28.6 km of roads per km^2 [45.6 mi/mi^2] (μ = 2.51 km/km^2, std. dev. = 2.91 km/km^2). As expected, the pattern of weighted road density mirrors the interstate and major highway pattern and particularly impinges on the park along the I-64 and Highway 19 corridors (Figure 27).

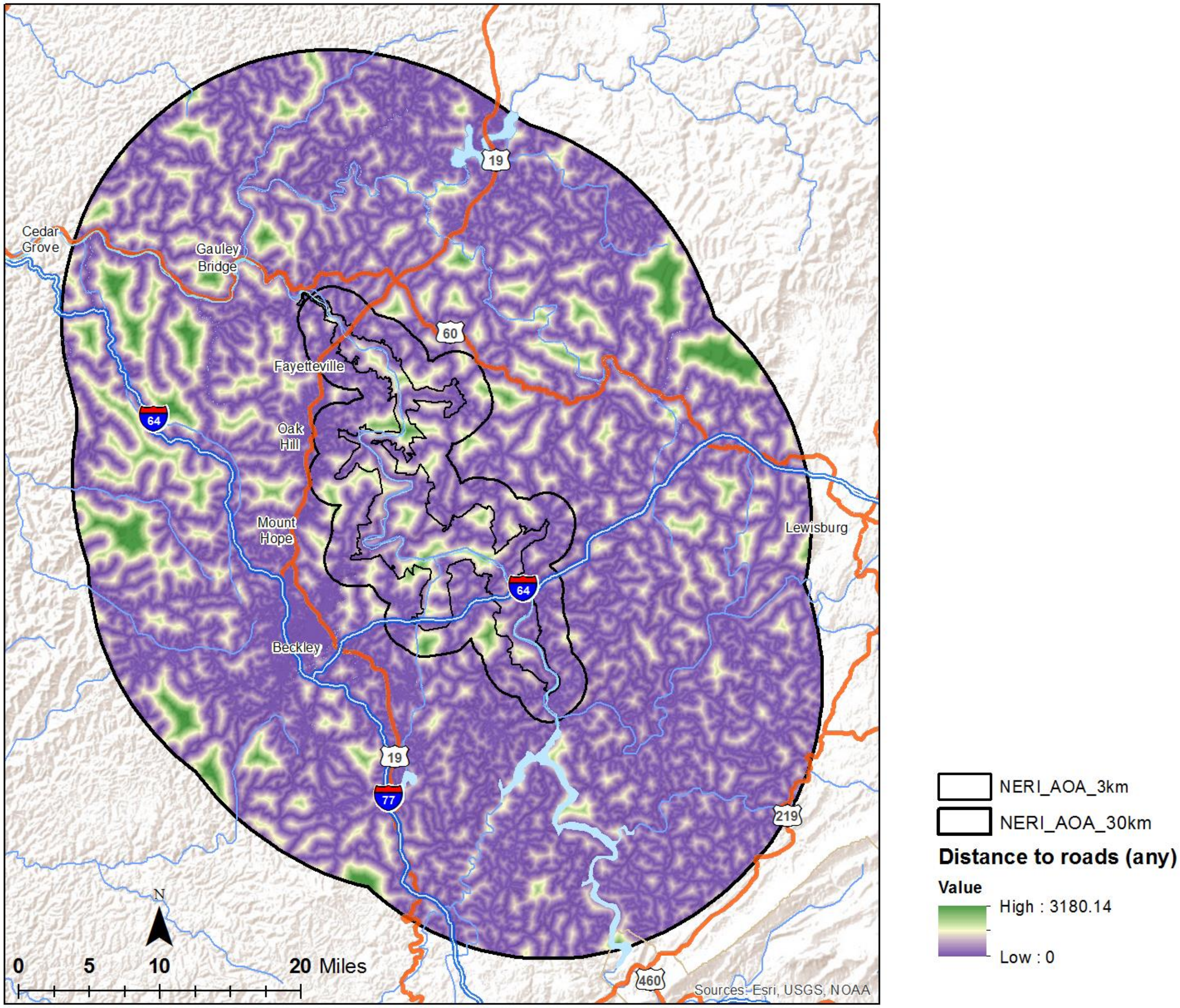


Figure 25. Distance to (any) road within the 30 km AOA surrounding New River Gorge National River (NERI) (source: ESRI Streetmap, 2012).

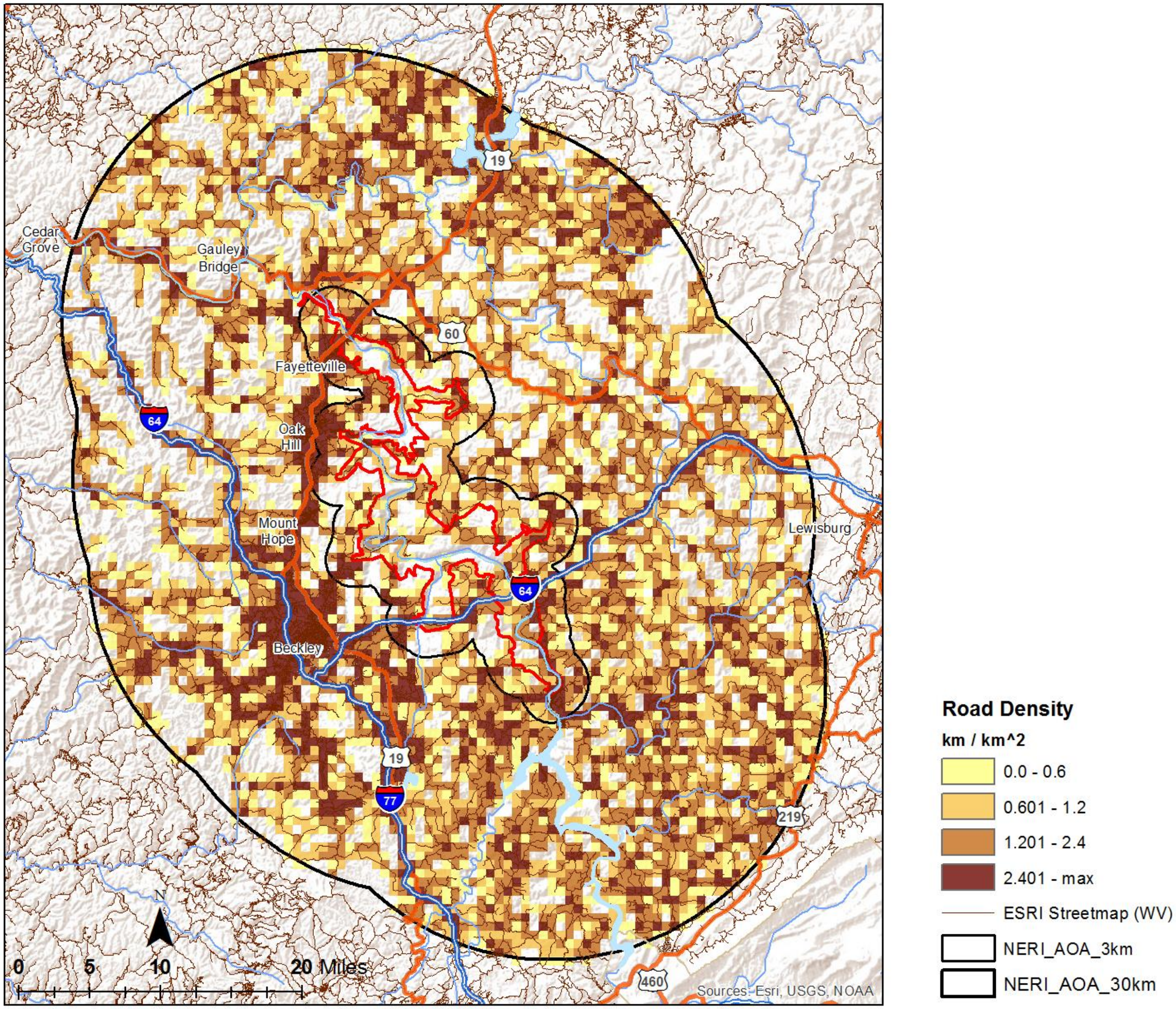


Figure 26. Road density pattern in the 30 km AOA surrounding New River Gorge National River (NERI) (source: ESRI Streetmap, 2012).

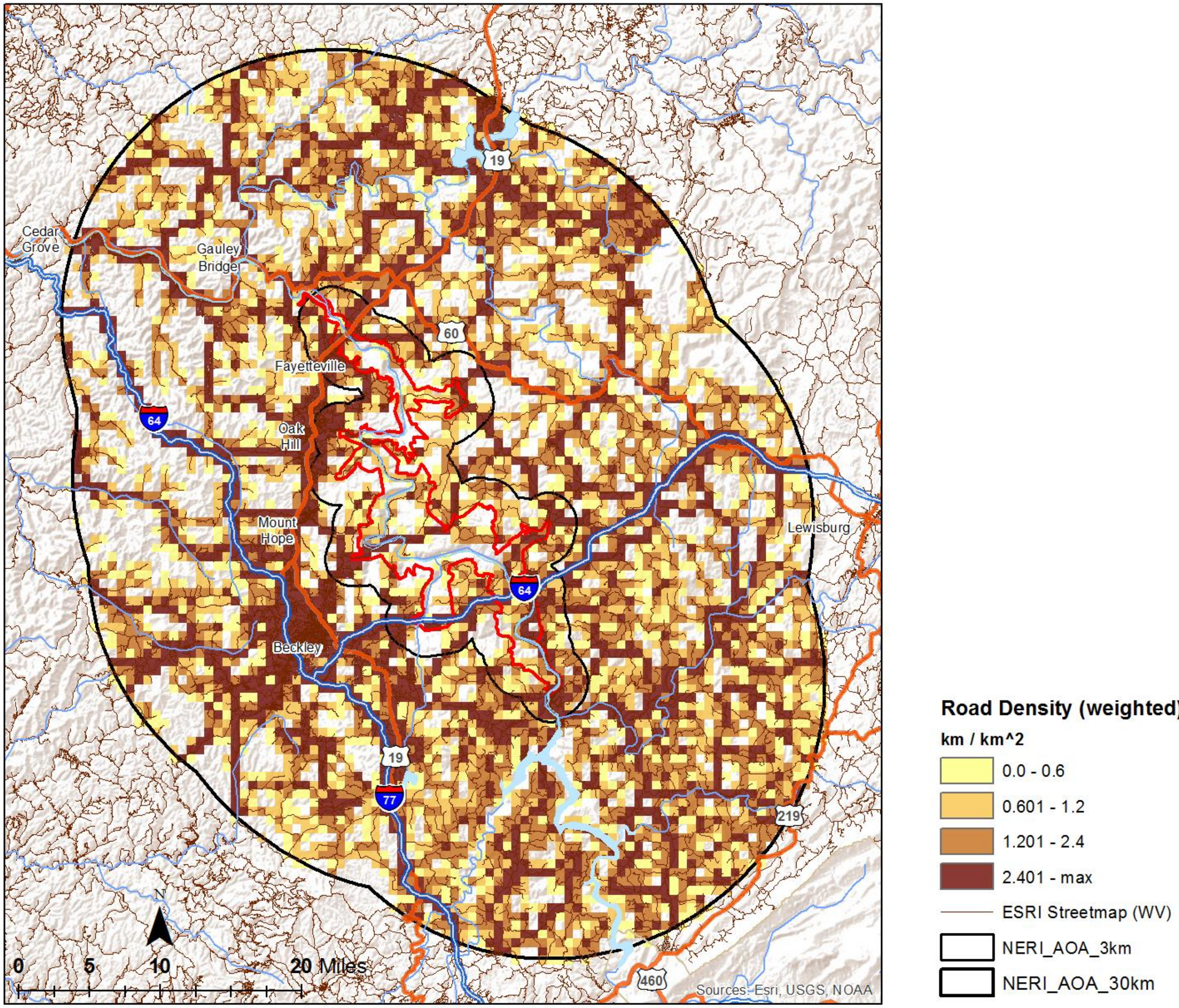


Figure 27. Road density pattern in the 30 km AOA surrounding New River Gorge National River (NERI), weighted by a factor of 5 for Interstate highways, and by a factor of 3 for other major roads (source: ESRI Streetmap, 2012).

Consideration of the size of roadless patches using the NPScape SOP (NPS 2013) reveals some relatively large roadless areas (max = 190.8 km^2 [46,950 acres]), but overall the remaining areas without roads are somewhat small (μ = 2.80 km^2, std. dev. = 10.90 km^2) (Figure 28). NERI helps to preserve several large roadless tracks in the 30 km AOA landscape. The largest blocks identified in this analysis occur in the Glade Creek – Meadow Creek area (133.88 km^2 [33,082.5 acres]), in the Endless Wall – Mann's Creek – Arbuckle Creek area (111.14 km^2 [27,463.3 acres]), and in the McKendree area (61.5 km^2 [15,197.0 acres]). These areas were also identified as contiguous roadless blocks in the analysis by Mahan et al. (2009) (Figure 29). Additionally, relatively large roadless areas are also present in the surrounding landscape matrix, both straddling I-64 to the northwest of Mount Hope, WV, and surrounding Bluestone Lake to the south.

The *trend* in road influenced fragmentation can only be assessed by reliably mapped time series of road establishment, development, and abandonment. Since we did not have access to reliable time series maps of these conditions, we could not assess trend in this indicator, only the condition as of the date of our road map layer (2012).

4.16.1. Data Gaps and Needs

The accuracy of this indicator is highly reliant on the accuracy, completeness, and timeliness of the input road data layer. The road layer employed is a national database of roads published by ESRI as of 2012, but may use source data of an earlier date. Within the scope of this project it was not possible to determine the positional accuracy of the road segments included on this map, the completeness of the roads included, or the omission of road segments that could influence fragmentation.

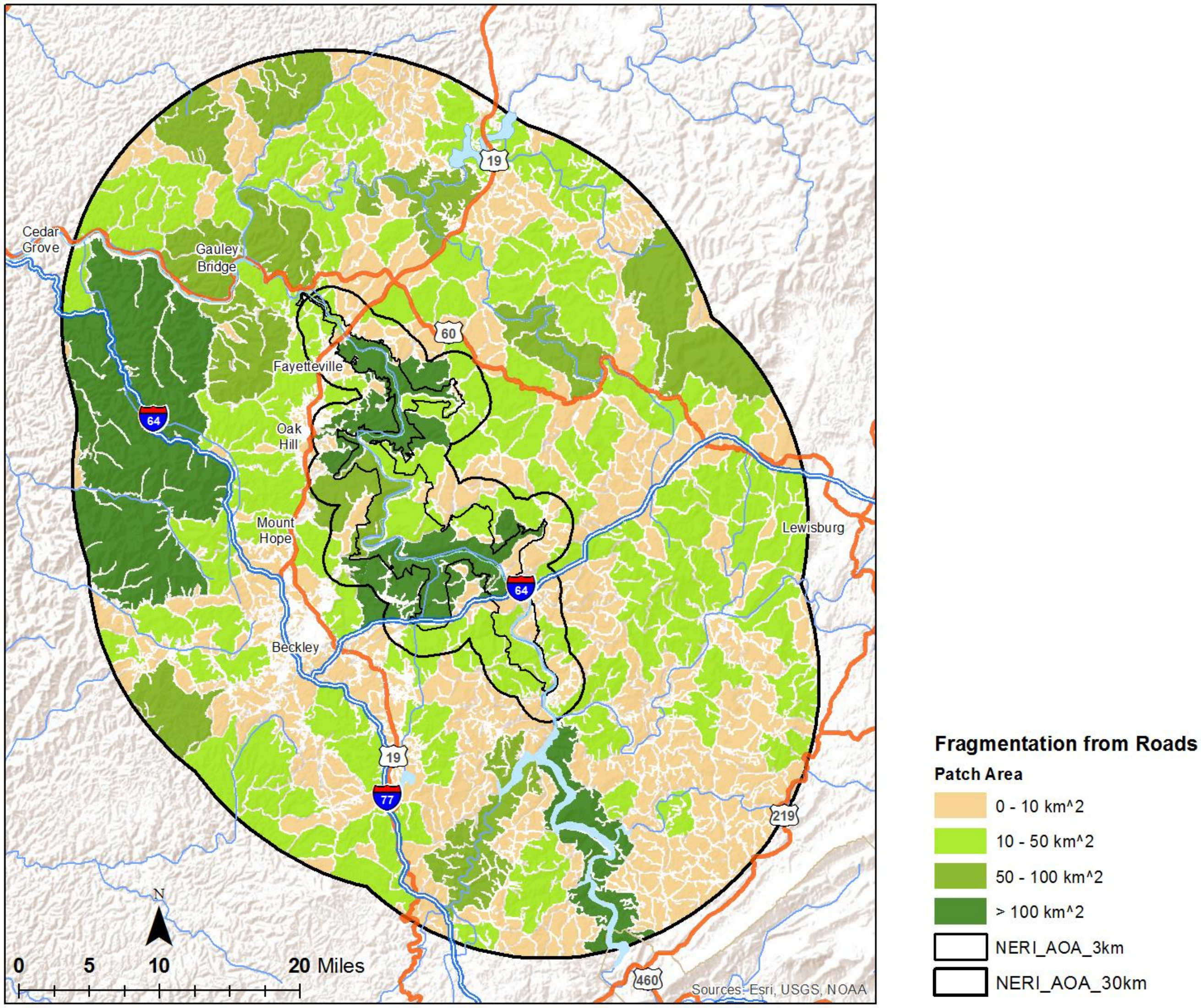


Figure 28. Landscape fragmentation due to roads in the 30 km AOA surrounding New River Gorge National River (NERI). Remaining roadless blocks are identified by size.

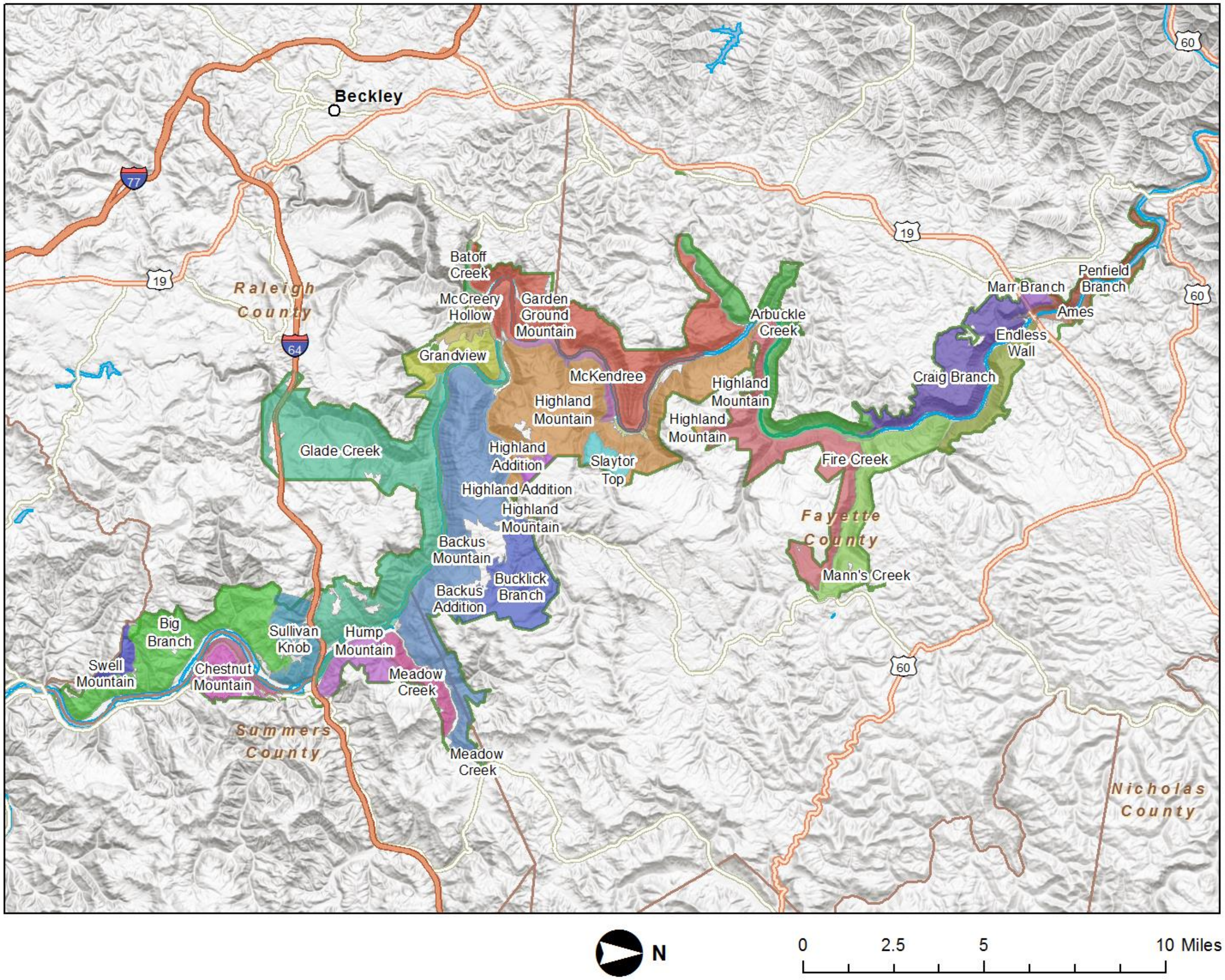


Figure 29. Roadless blocks within New River Gorge National River (NERI) identified in Mahan et al., 2009.

4.17. Forest Density, Pattern, and Connectivity

Description: (includes [if known]: current condition, reference condition, thresholds, trends, threats/stressors)

Landscape pattern assessments have been used in forestry, landscape ecology and conservation biology studies for some time to assess habitat size, configuration, and connectivity of forest areas on the basis of mapped land cover (O'Neill et al. 1988, O'Neill et al. 1999). Typically the goal is to assess the relationship between landscape pattern and ecological processes, usually with the end goal of determining forest habitat configuration impacts on bird or mammal species occurrence, movement, or persistence (Uuemaa et al. 2009). However, assessment of forest pattern can be quite useful as a standalone analysis as it can provide information, for example, on the amount of edge versus interior habitat, and/or the connectivity or isolation of forest patches to core forest areas in a generalized analysis that can then be applied to any number of potential species groups. This information may be valuable for assessing, for instance, the amount of edge habitat that might be subject to exotic species invasion, or the minimum area of interior forest that is needed to support a population of forest interior birds.

In addition, assessment of the change in landscape configuration over time can be a useful monitoring tool for assessing broad scale changes in available forest habitat that can have ripple effects on forest-dependent species (Wickham et al. 2007). By varying the scale of analysis (i.e. the size of the analysis window), varying scales of pattern can be assessed. This can be useful for changing the scale or definition of the forest edge to match the scale of a process of interest (i.e. propagation of wind-blown seeds, noise propagation).

Numerous metrics have been proposed to assess habitat pattern and most are easy to compute using GIS techniques. However, many metrics have been found to be duplicative, and some are hard to justify or explain from an ecological perspective (Riitters et al. 1995, Li and Wu 2004, Kupfer 2012). The NPScape program has developed SOPs for two general types of landscape pattern metrics: forest density assessments, and forest connectivity metrics through morphological spatial pattern analysis (MSPA) techniques (NPS 2013). Forest density metrics allow for the classification and scaling of forest patches into large intact core areas, versus small isolated patches, and transitional areas in between (Riiters et al. 2003). MSPA was originally proposed by Vogt et al. (2007) and assesses the connectivity of forested landscape patches as fully connected core forests (in contrast to edge forest), as well as remaining bridges between core forest patches that maintain connected forest corridors, among other classes.

Since the computation of forest density and MSPA metrics requires additional software and pre-processing, the NPScape program provides pre-packaged data sets of forest density and MSPA metrics for the conterminous United States computed at various spatial scales (https://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm). The NPScape SOPs use these national datasets to clip and summarize the metric data to a user selected AOA (NPS 2013). Both the forest density metric and the MSPA can be computed at various spatial scales, and land cover data processed at standardized scales are available from the NPScape website. Although it is possible to use other datasets, such as the 2001 NLCD for similar computation such that a time series could be assessed, and a software package is freely available to calculate the metrics (GUIDOS, http://forest.jrc.ec.europa.eu/download/software/guidos/) outside of the NPScape SOP, a significant effort is involved with pre-processing and computing theses metrics. We therefore used the most recent NLCD 2011 version of the dataset which was pre-processed and available for download and analysis from the NPScape website.

Forest density is computed using a moving window analysis in GIS such that a pre-set window size is passed over the raster map data and forest density classes are computed at that analysis scale based on the percentage (p) of forest pixels within the analysis window (Riitters et al. 2003). Forest density classes computed are Intact ($p = 1.0$), Interior ($0.9 \leq p < 1.0$), Dominant ($0.6 \leq p < 0.9$), Transitional ($0.4 \leq p < 0.6$), Patchy ($0.1 \leq p < 0.4$), and Rare ($0.0 \leq p < 0.1$. At larger window sizes, more chance exists for land cover other than forest to be present in the analysis window. Forest density metrics for the 2011 NLCD land cover data were computed by the NPScape program at analysis window (e.g. pixel) sizes of 7x7, 13x13, and 27x27 (NPS 2013). At the NLCD land cover pixel size of 30x30 meters, this equates to focal areas of 0.04, 0.15, 0.66 km^2 (10.9, 37.6, and 162 acres) analysis areas, respectively. Different focal area analyses can be used to assess the available size of core forest areas for organisms that have different habitat size requirements, for example a forest interior bird with a small home range size, versus a large-bodied mammal that might range over a much larger area.

MSPA analysis can be similarly computed at varying spatial scales to assess changes in connectivity relationships, but in this case the size of the edge width is varied. We assessed two scales of edge width for NERI using the NPScape SOP, 30 and 150 meters (NPS 2013). The MSPA analysis classifies the landscape into connectivity classes of Core and Edge but also computes Bridges (which connect core forests, but are too thin to be non-Edge habitats), Branches (which are thin forest habitats that don’t connect core forests), disconnected patches called Islets or Loops, and Perforated core (small non-forest areas completely within core forests).

Landscape-based integrity thresholds are dependent on the response of particular organisms to habitat requirements, and thus it can be difficult to arrive at a single numerical threshold beyond which impairment occurs. In a previous study, we reviewed the literature on landscape-based thresholds and concluded that a reasonable threshold range for percent intact forest was > 70% of the landscape for ideal conditions, and at a minimum > 30% before impairment occurs (Mahan et al. 2015). In relation to the forest density pattern metric, if the majority of the landscape is in Intact or Interior forest (i.e. > 90% of pixels in the analysis window in forest cover), we rate the landscape condition as very good to excellent. If the majority is in Intact, Interior, or Dominant, (i.e. > 60% of pixels in the analysis window in forest cover) we rate the condition as good.

Previous studies evaluating thresholds of landscape connectivity through GIS-based simulation studies have suggested a critical threshold of 58.29% of the landscape in connected core forest habitat (Gardner et al. 1987). Below that level, the landscape becomes fragmented to the extent that continuous movement through core forest habitat becomes disrupted. If greater than 59% of the landscape is in connected Core habitat, we rate the landscape as excellent.

4.17.1. Forest Pattern Trends

Beginning with forest density metrics, at the 7x7 pixel (0.04 km^2 [10.9 acre]) analysis window, the majority of the landscape (61.6%) in the 30 km AOA surrounding NERI is in either Intact or Interior forest density classes (Table 11, Figure 30). Another 19.6% of the landscape has forest as the Dominant land cover. Therefore, at the 0.04 km^2 [10.9 acre scale], the forest density surrounding NERI is excellent. At the 13 x 13 pixel (0.15 km^2 [37.6 acre]) analysis scale, 52.9% of the landscape is in either Intact or Interior forest density classes, while another 28% is in the Dominant class (Figure 31). The forest density metric at this analysis scale is still rated as very good. At the 27 x 27 pixel (0.66 km^2 [162 acre]) scale, Intact and Interior forest together comprise only 44.2% of the surrounding landscape, while the Dominant class represents another 39.3% (Figure 32). We therefore rate the forest density metric at this scale as good.

For the MSPA analysis using the 30-meter edge buffer width, 67% of the 30 km AOA in the NERI landscape is classified as connected Core (Table 12, Figure 33). Since this is well over the 58.29% threshold for connectivity, this metric is rated as excellent. Increasing the edge width to 150 m (492.1 ft) reduces the connected core area to only 39.6 % of the landscape (Figure 34). Since this is below the 59.29% threshold, the forest connectivity at this scale is rated as marginal.

Table 11. Forest density landscape class summary at various computation scales, including class area within the 30 km AOA surrounding New River Gorge National River (NERI), and the percentage of the landscape in each class. Analysis scales are shown as 7x7 pixel, 13x13 pixel, and 27x27 pixel.

Class Name	7x7 pixel (4.4 ha)		13x13 pixel (15.2 ha)		27x27 pixel (65.6 ha)	
	Area (km^2)	Percent	Area (km^2)	Percent	Area (km^2)	Percent
Rare	143.81	2.2	124.84	1.8	51.5	0.8
Patchy	583.33	8.8	548.41	8.1	412.24	6
Transitional	523.96	7.9	625.21	9.2	668.98	9.8
Dominant	1304.71	19.6	1905.77	28	2691.25	39.3
Interior	695.38	10.5	1397.6	20.6	2243.74	32.8
Intact	3400.67	51.1	2198.16	32.3	777.35	11.4

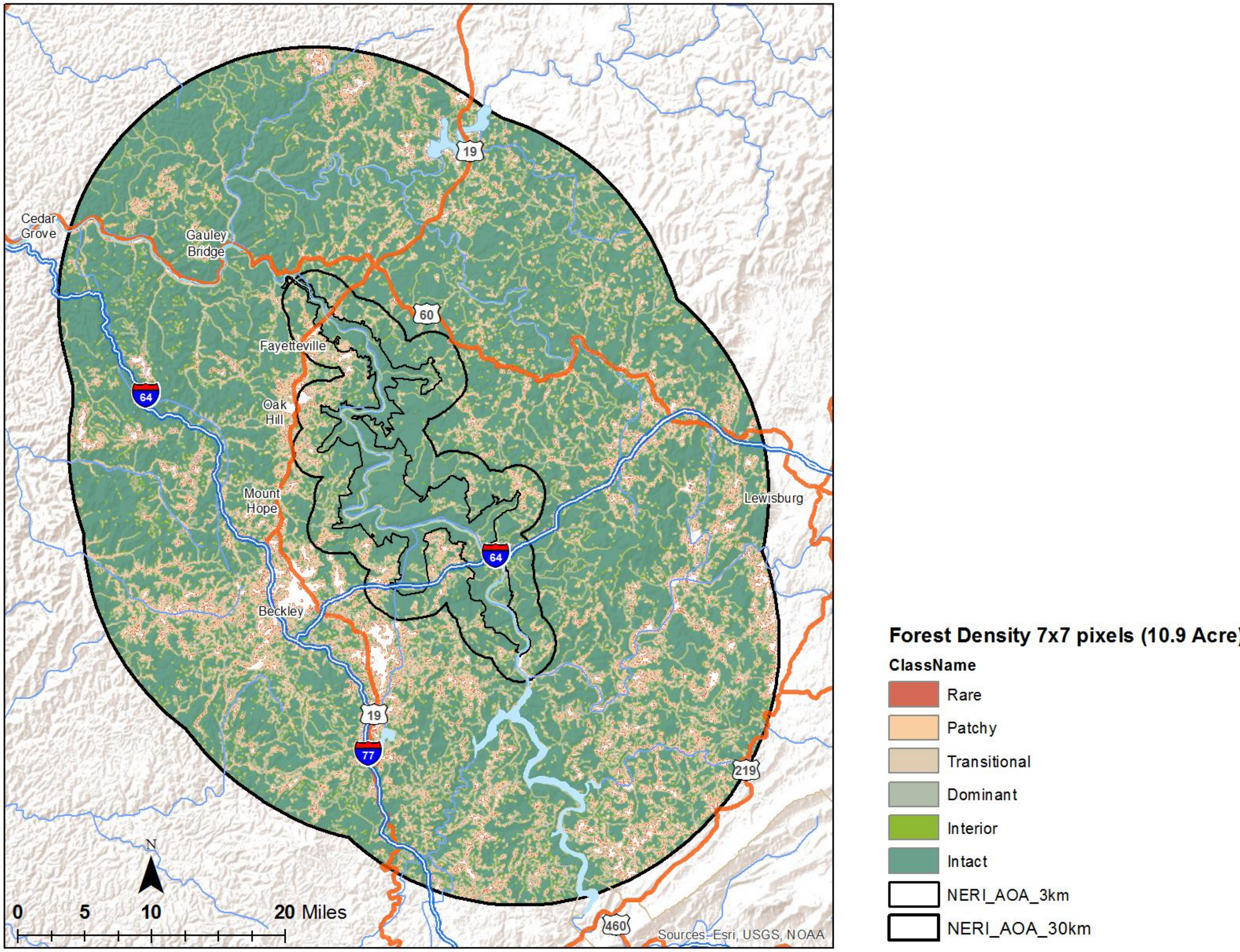


Figure 30. Forest density class metric for the 30 km AOA surrounding New River Gorge National River (NERI) at the 7x7 pixel (4.4 ha, 10.9 ac) analysis scale.

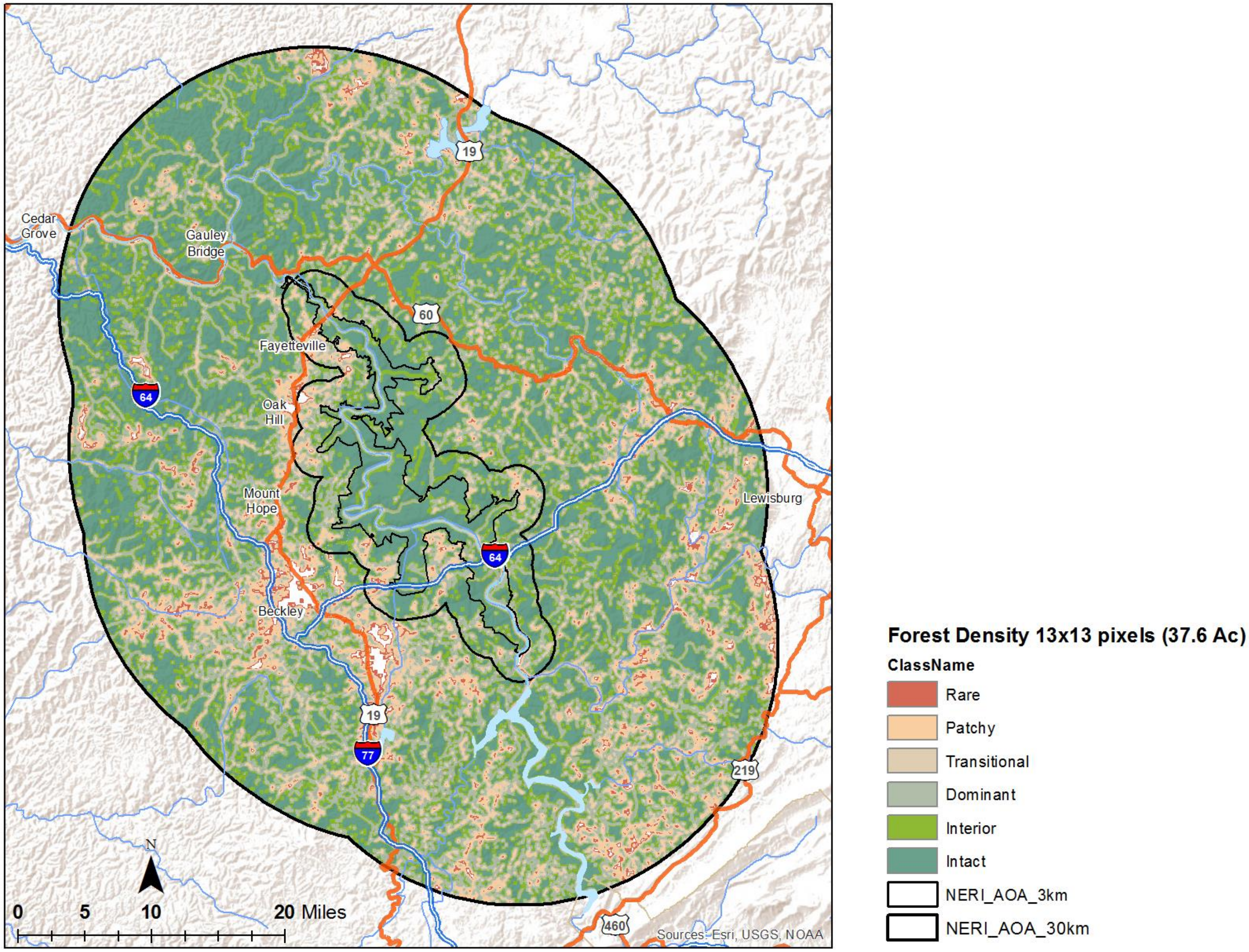


Figure 31. Forest density class metric for the 30 km AOA surrounding New River Gorge National River (NERI)at the 13x13 pixel (15.2 ha, 37.6 ac) analysis scale.

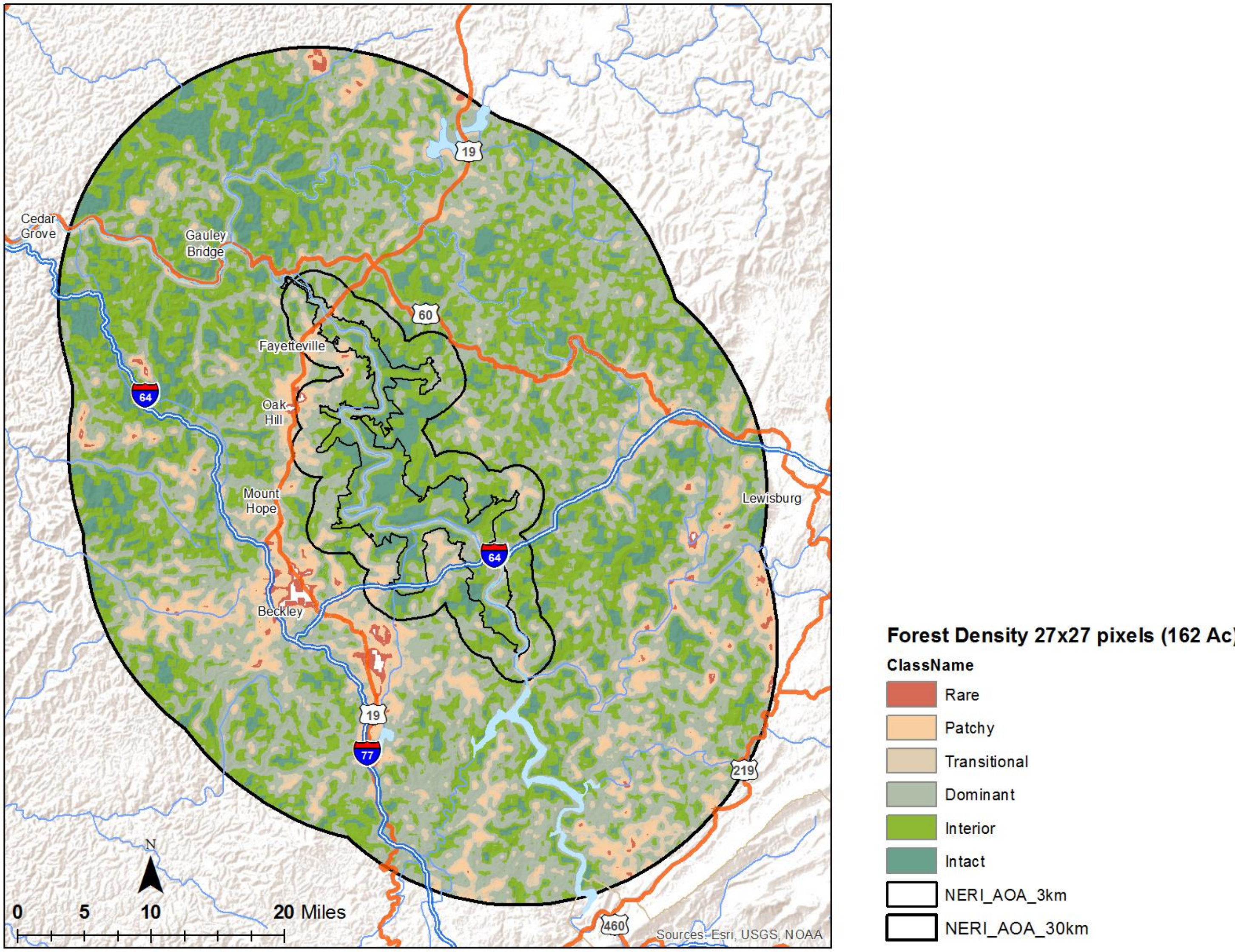


Figure 32. Forest density class metric for the 30 km AOA surrounding New River Gorge National River (NERI) at the 27x27 pixel (65.6 ha, 162 ac) analysis scale.

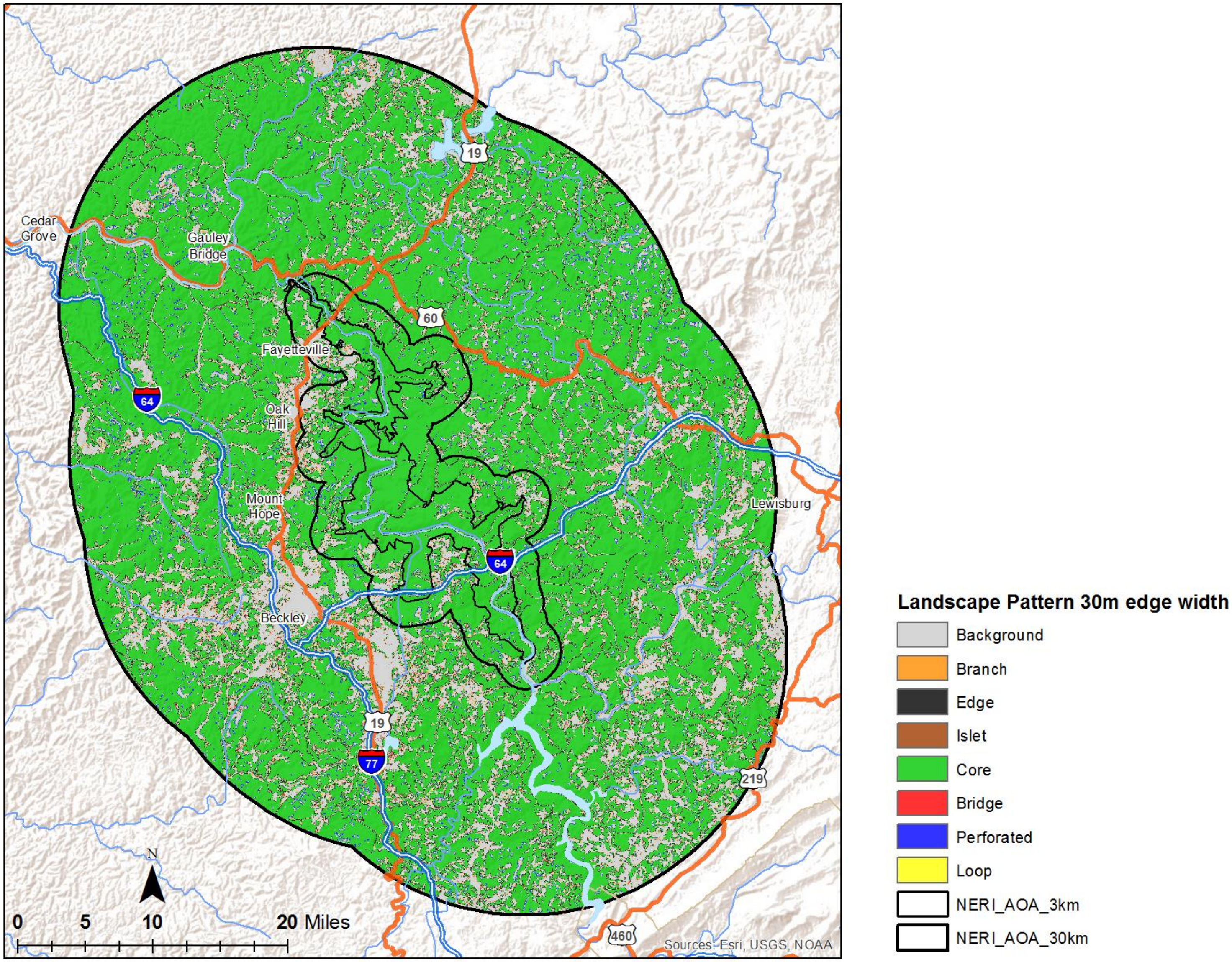


Figure 33. Forest connectivity class metric computed using the Morphological Spatial Pattern Analysis (MSPA) approach using a 30-meter edge width for the 30 km AOA surrounding New River Gorge National River (NERI).

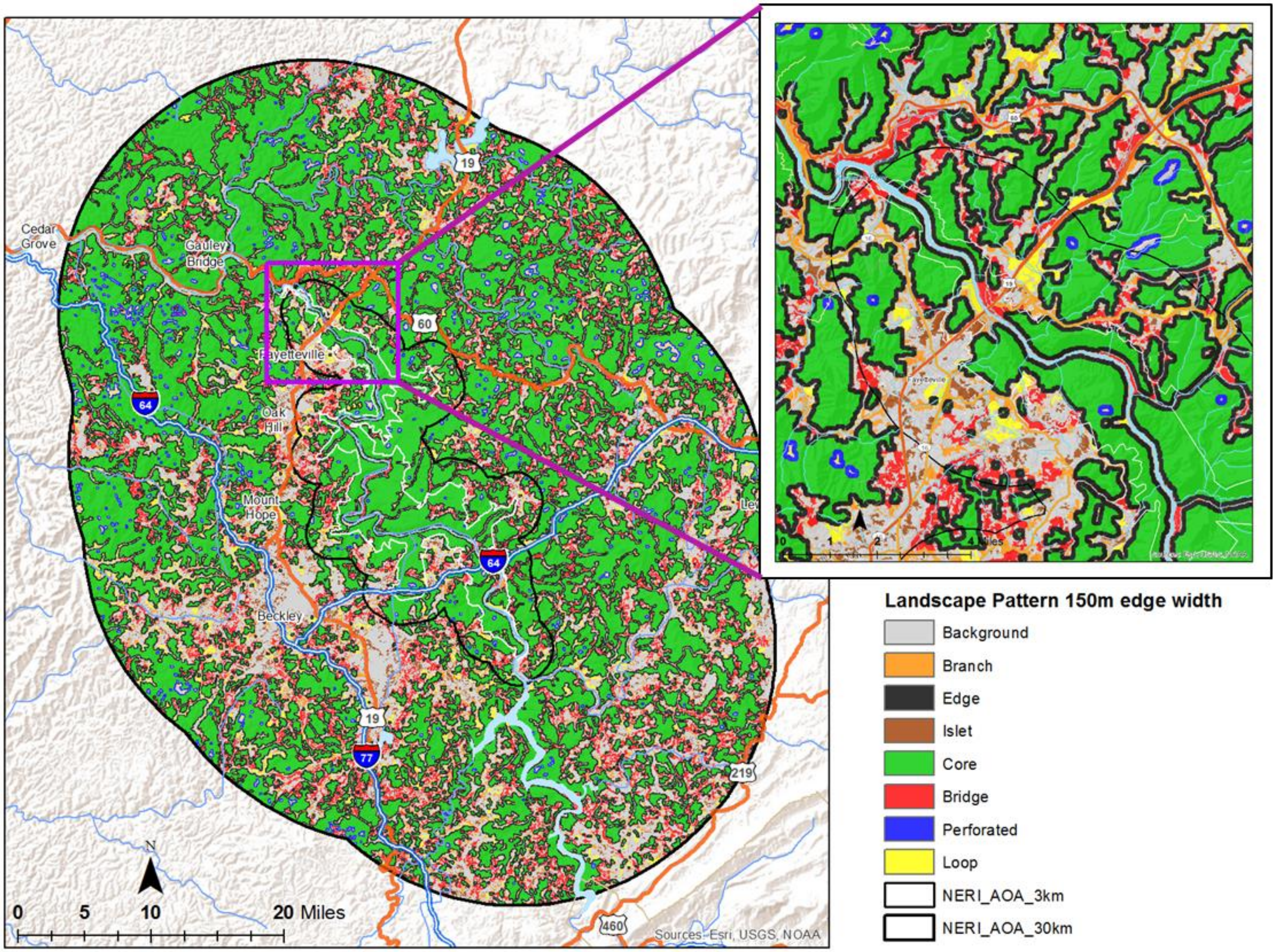


Figure 34. Forest connectivity class metric computed using the Morphological Spatial Pattern Analysis (MSPA) approach using a 150-meter edge width for the 30 km AOA surrounding New River Gorge National River (NERI). Inset, area surrounding the Highway 19 corridor illustrating the remaining "bridge" forest habitat connecting larger core forests.

Table 12. Forest connectivity class metrics (2011) computed using Morphological Spatial Pattern Analysis (MSPA) at two scales, including area and percentage area in each class in the 30 km AOA surrounding New River Gorge National River (NERI), and percent change in area from 2006. Analysis scales are shown as 30-meter edge width and 150-meter edge width.

Class Name	30-Meter Edge Width			150-Meter Edge Width		
	Area (km^2)	Percent	% Change from 2006	Area (km^2)	Percent	% Change from 2006
Background	1382.18	20.2	0.90	1382.18	20.2	0.90
Branch	104.6	1.5	0.08	192.85	2.8	0.11
Edge	595.68	8.7	0.25	1750.61	25.5	0.74
Islet	19.55	0.3	0.01	85.93	1.3	0.01
Core	4589.67	67.0	-1.49	2711.32	39.6	-2.55
Bridge	29.08	0.4	0.03	499.57	7.3	0.62
Perforated	105.91	1.5	0.20	112.24	1.6	0.09
Loop	27.24	0.4	0.02	119.2	1.7	0.07

Comparing these percentages to MSPA conducted using the 2006 NLCD shows a decrease in the connected Core class of approximately 1.5% at the 30 meter scale and a decrease of approximately 2.6% at the 150 meter scale, and increases in all other classes. Although the park itself is still primarily in connected core at the 30 meter analysis scale, a loss of core habitat is evident over the 5-year time period from 2006-2011 and the surrounding landscape is becoming slightly more fragmented. Additionally, areas traversed by major highways are fragmented and reduced to still connected, but very narrow "Bridge" forest class habitats (i.e. at the Highway 19 crossing, Figure 34, inset). This area, and a similarly fragmented area near surrounding the I-64 corridor, could be monitored for future loss of forest habitat connectivity for organisms moving through the park that require large areas of connected core forest environments. The TNC conducted a similar (but not identical) analysis assessing the connectedness of forest habitats in an attempt to locate movement corridors that would be resilient to climate change (Anderson et al. 2016). They found a similar connected core habitat provided by the park itself, but also note only a narrow corridor of connected habitat at the Highway 19 Bridge crossing (Figure 35).

4.17.2. Data Gaps and Needs

As with other landscape metrics based on land cover data, the metric results are highly dependent on the scale, timeliness, accuracy, and completeness of the land cover dataset. While the NLCD has been shown to be reasonably accurate and is nationally consistent, the satellite image-derived nature of the classification and the resulting scale of forest cover mapping (900 m^2 pixels) may obscure some finer scale patterns of fragmentation. Since the most recent NLCD data set is circa 2011, there has been potentially 5 years of landscape development that may have affected the metric assessment. Subsequent analysis with the 2016 NLCD product, when available, is warranted to monitor changes in landscape pattern and configuration.

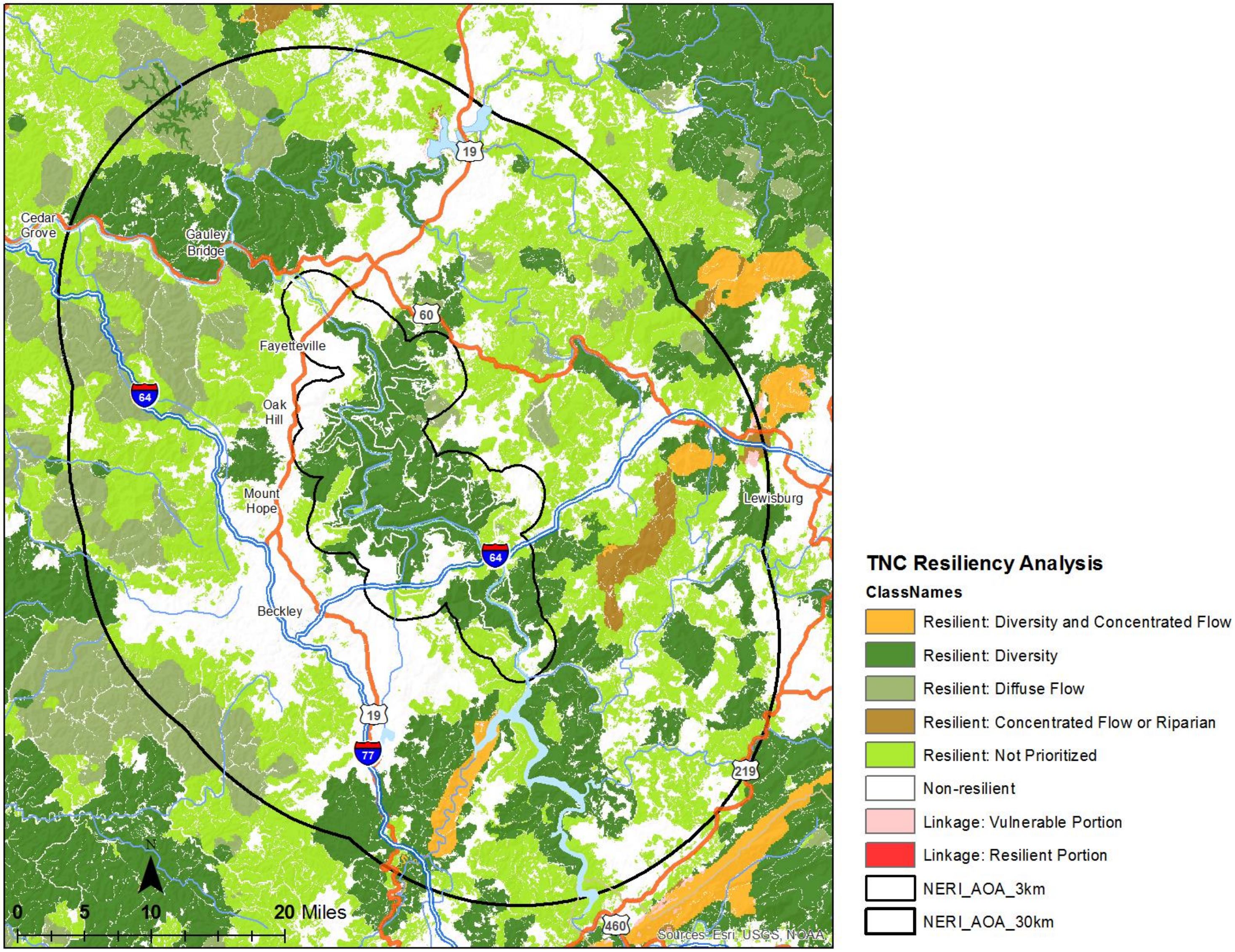


Figure 35. Result of TNC resilience and connectivity analysis (Anderson et al. 2016), overlaid with the 30 km AOA for the area surrounding New River Gorge National River (NERI).

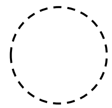
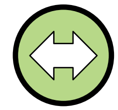
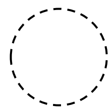
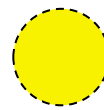
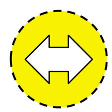
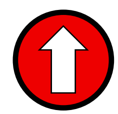
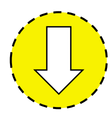
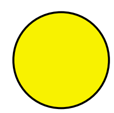
5. Discussion

Our approach to assessing the current condition of natural resources at NERI incorporated existing data to evaluate natural resources in the park. Thresholds for condition (good, moderate concern, and significant concern) were obtained from a variety of sources including federal and/or state regulations (e.g. water quality standards, air quality thresholds), scientific literature, natural resource reports, and best professional judgement. Where possible, trends in condition (improving, deteriorating, or unchanging) were determined. These trends were, in part, based on a comparison with conditions noted in the Natural Resource Assessment completed for NERI in 2004 (Mahan 2004). We also provided an estimate of confidence in our assessment (high, medium, low confidence) based on the quality and quantity of data available. We used standardized symbology provided by NPS NRCA guidelines (Table 13) and calculated composite scores of assessment as described in Study Scoping and Design section (above).

NERI contains a significant assemblage of natural resources which consists of abundant wildlife native to the Appalachian Mountains (Allegheny woodrats, wood warblers, diverse salamander community), diverse plant communities (Appalachian flatrock, cliff bryophytes, unfragmented forests), game fish (especially small-mouth bass populations), and dramatic geology (sandstone cliffs, steep river gorge). In addition, NERI supports world-class recreational opportunities including white-water rafting, fishing, rock climbing, hiking, and the opportunity to experience scenic vistas, natural sounds, and solitude.

In general, the condition of natural resources at New River Gorge have declined over the past decade (Table 13) with a composition condition score of 52 out of 100 in 2004 and a composite score of 44 out of 100 in 2017 (Table 13). The 2017 score is driven primarily by declines in native wildlife, persistence of poor water quality, and the assignment of low scores for air pollution (Table 13). This decline reflects conditions in, and threats to, national parks across the country. In particular, national park units including NERI are threatened by situations outside park boundaries and increased visitation, creating resource management challenges (Prato 2001, Fancy et al. 2009). At NERI, these threats include fragmentation of the surrounding landscapes (due to development, resource extraction), continued water pollution (due to sewage effluent), and the spread of infectious disease (white-nosed syndrome) and non-native species (Emerald Ash Borer, Hemlock Woolly Adelgid, variegate darter). Resource managers at NERI and the ERMN continue to inventory and monitor threats to natural resources and over the past few years have developed strategies to improve natural resource management at the park (Mahan and Darden 2014).

Table 13. Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

Resource	**Indicator**	**Condition/Trend 2004**[1]	**Condition/Trend 2017**[2]	**Comments**
Acoustics/Soundscape	L50 dBA impact (Sound level, -20 Hz - 20 Hz)			• Average acoustic impact of non-natural sounds is 1.3 dBA • A reduction (~25%) in the ability to hear natural sounds by humans or wildlife
Dark Night Skies	Anthropogenic Light Ratio (ALR)			• ALR is 1.8, indicating a departure from pristine dark night sky conditions • Anthropogenic light sources dominate natural celestial features to some degree • Could not determine trend
Visibility	Deciview (dv)			• 8.4 dv indicates significant concern • Degradation to visibility is due to pollutant particles likely from power plants, oil/gas development, vehicle exhaust, and industry
Ozone	Parts per billion/ 8-hour period (ppb) W126, parts per million/hrs (ozone exposure index)			• Average ozone concentration (2008-2012) was 64.5 ppb, this metric is below 75 ppb so attainment was obtained • W126 = 8.6, W126 was > 7 ppm so moderate concern is warranted • Could not determine trend

[1]Composite condition score based on 21 indicators (2004) = 52/100 with declining trend in condition.

[2]Composite condition score based on 27 indicators (2017) = 44/100 within declining trend in condition.

Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

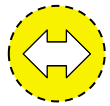
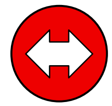
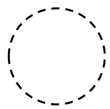
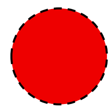
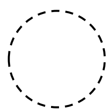
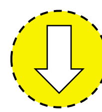
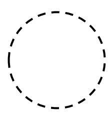
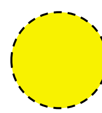
Resource	**Indicator**	**Condition/Trend 2004**[1]	**Condition/Trend 2017**[2]	**Comments**
Sulfur and Nitrogen Deposition	Wet deposition, Kg/ha/year Critical load, kg/ha/year			• Wet sulfur deposition = 2.9 kg/ha/yr, this measure is > 1 kg/ha/yr so moderate concern is warranted • Wet nitrogen deposition = 3.7 kg/ha/yr, this measure is > 1 kg/ha/yr, moderate so significant concern is warranted • Trend for sulfur and nitrogen improved and declined, respectively, compared to 2011 data • Critical load of Sulfur and Nitrogen is 9.0/kg/ha/year, this measure is > 3.0 kg/ha/year so significant concern is warranted
Mercury and toxics	Predicted methymercury concentration and mercury deposition.			• Methylmercury deposition is predicted to be low and the predicted concentration in park surface waters is low; however, there is a state-wide fish consumption advisory for mercury • Compared to other areas of the U.S., mercury deposition is high
Climate Change	North-South Connectivity and Resilience Study NatureServe Climate Change Exposure Index (1-0)			• CCEI = 0.5; where 0 indicates extreme departure from current condition • This value indicates that portions of the mountains in WV will have minimal predicted (mid-century) departure in current climate conditions
Scenic Vistas	Landscape characteristics of southern Appalachians: forests, bluffs, rivers			• Vistas within park boundaries are carefully managed • Future development outside of the park (e.g., residential/commercial) could diminish viewshed qualities

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Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

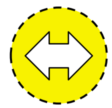
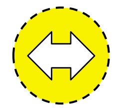
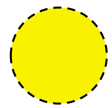
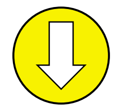
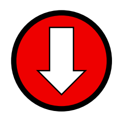
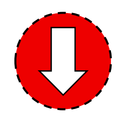
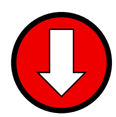
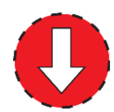
Resource	Indicator	Condition/Trend 2004[1]	Condition/Trend 2017[2]	Comments
Geology/Mass movements	Baseline mass-movement level			• Floods in 2016 set off mass movements, unknown if these are within historic/natural ranges • Associated sedimentation and bound pollutants are unknown
Cliff Communities	Coverage and species composition of cliff vegetation			• Cliff locations in the park are negatively affected by recreational behavior • Some non-vascular plant communities (lichens and mosses) only remain at unclimbed locations
Water Quality Main Stem New River	Fecal coliform colony counts (units/100 ml) Dissolved Oxygen pH Historic river flow			• Main Stem of New River recognized as impaired due to fecal coliform exceedances by WV DEP • DO = 9.8 mg/l; EPA/ WV standard is no lower than 5.0 mg/l • pH = 7.5; EPA/ WV standard is $\geq$ 6-9 • Historic flow compromised by Bluestone Dam impoundments, peak flow may be reduced by 50%
Water Quality: Wadeable Tributaries	Fecal coliform; sources Dissolved Oxygen pH Multimetric Index of Biologic Integrity (MIBI)			• Human sources of fecal coliform in tributaries confirmed, several tributaries recognized as impaired due to fecal coliform exceedances by WV DEP • DO ~ 11.0 mg/l • pH < 6.0 on Little Laurel Creek, Richlick Branch, Dowdy Creek • MIBI = 50.5/100, indicating departure from reference condition

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Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

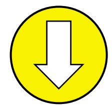
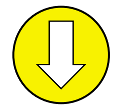
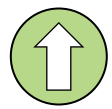
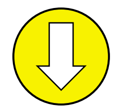
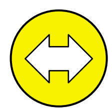
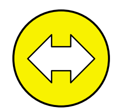
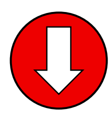
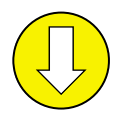
Resource	Indicator	Condition/Trend 2004[1]	Condition/Trend 2017[2]	Comments
Xeric Plant Communities: Oak and Rim rock pine	Hectares covered Mortality v recruitment rate			• Mortality exceeds recruitment, not sure if decline is natural due to end of industrialization and associated disturbances • Fire/disturbance regimes need to be maintained at rimrock and some oak locations • Emerging forest pests and pathogens threatened all forest types
Mixed Mesic	Hectares covered Mortality v recruitment rate			• Recruitment exceeds mortality for some mesic species (e.g., Serviceberry, Fraser Magnolia, Maples) • Emerald Ash Borer has decimated Ash populations –especially in riparian areas • Emerging forest pests and pathogens threaten all forest types
Eastern Hemlock	Hectares covered Mortality v recruitment rate			• Mortality matches recruitment although Hemlock Woolly Adelgid has been present since 2004 • Targeted HWA insecticide control coupled with recent cold winters is maintaining hemlocks at select locations
Appalachian Flatrock and Riverscour Prairies	Hectares covered Early successional species maintained.			• Decreased flooding regimes and invasive plants threatened the persistence of these habitat types • In the absence of scouring floods, natural succession occurs • Continued monitoring and active management is maintaining these communities at select locations

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Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

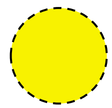
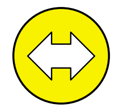
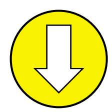
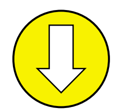
Resource	Indicator	Condition/Trend 2004[1]	Condition/Trend 2017[2]	Comments
Rare and Medicinal plants	Presence Persistence Regeneration Abundance			• Suitable habitat for four species of rare, medicinal plants (black cohosh, ginseng, bloodroot, goldenseal) was predicted using a GIS-based regression model of habitat suitability • Subsequent field investigations found American ginseng at only 1 of 10 sites surveyed • Goldenseal was not found in the park, but several sites surveyed included black cohosh (7 sites) and bloodroot (5 sites) • Illegal harvest potentially threatens these species
Fish	Species richness Abundance/biomass (g) Native v non-native species			• Fifty percent of the fish are non-native species • Approximately 50% of all wadeable tributaries sampled contain only native fish • Overall, native fish comprise 52% of species encountered in tributaries but represent 99% of individuals • Small-mouth bass are the most numerous non-native fish species by biomass (g) and support recreational fishery

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Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

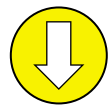
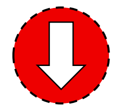
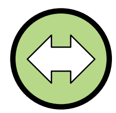
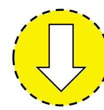
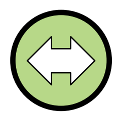
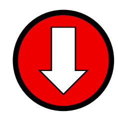
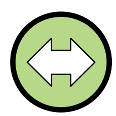
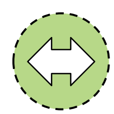
Resource	Indicator	Condition/Trend 2004[1]	Condition/Trend 2017[2]	Comments
Aquatic invertebrates (mussels/crayfish)	Species richness Abundance/biomass (g) Native v non-native species			• Occurrences of individual native mussel species have declined • Asiatic clam is pervasive • Over 50% of crayfish species are non-native • Invasive rusty crayfish is in park • Non-native crayfish are spread by anglers • Live bait use is still permitted
Allegheny Woodrat	Presence Abundance Distribution			• Status and trend of the population is unknown • Long-term monitoring program is being initiated
Bat Communities	Species richness Abundance Distribution			• In 2005, 2,346 individuals of 9 species captured • In 2015, 138 individuals of 6 species captured • White-nosed syndrome is cause of decline
Salamanders	Species richness Abundance Distribution			• Effect of amphibian pathogen, *Batrachochytrium dendrobatidis* (*Bd*) is unknown although no die-offs have been detected • Prevalence of *Bd* is 16% • Twenty-five percent of blackbellied-salamanders tested positive for *Bd* • Blackbellied-salamanders also threatened by bait collecting

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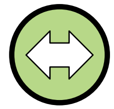
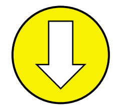
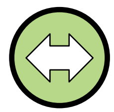
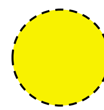
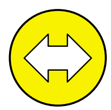
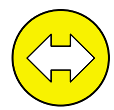
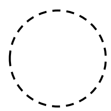
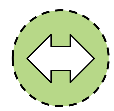
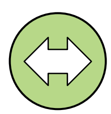
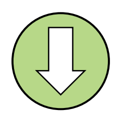
Table 13 (continued). Natural resource assessed, indicator used, condition/trend of resource in 2004 (Mahan 2004) and condition/trend of resource identified in this report for New River Gorge National River (NERI), 2017.

Resource	Indicator	Condition/Trend 2004[1]	Condition/Trend 2017[2]	Comments
Birds	Species richness Abundance Distribution			• Point count data indicate Cerulean Warbler, Acadian Flycatcher, and Black-throated Green Warbler have declined in abundance in last decade • No clear trend on other neotropical migrants • BCI = 62, which is the “highest” integrity category and excellent biotic integrity for breeding birds
Game species	Abundance and distribution of game species (white-tailed deer, black bear, turkey, ruffed grouse, woodcock) Infectious disease presence			• Ruffed grouse and woodcock are declining throughout the Appalachians • Chronic wasting disease which is fatal to white-tailed deer is present in West Virginia and will likely spread
Land cover change in surrounding area	Change in land cover class area Energy development activities			• Energy development (coal, well drilling) in surrounding landscape slowed somewhat in recent years • Large number of permitted gas wells may pose future issues
Forest fragmentation from roads	Density of roads (km/km^2) Area of unfragmented forest blocks			• Remaining blocks of unfragmented forest within park, but high road density in surrounding area • Unable to assess temporal change in roads
Forest density, pattern, and connectivity	Percent area in landscape fragmentation classes			• Generally good, but loss of core habitat evident • Threat of fragmentation at major road and bridge crossings

[1]Composite condition score based on 21 indicators (2004) = 52/100 with declining trend in condition.

[2]Composite condition score based on 27 indicators (2017) = 44/100 within declining trend in condition.

A few high-priority strategies may have the best chance of improving the overall condition of resources at the park. For instance, a robust, scientifically-based, water sampling protocol could be designed and implemented to determine the magnitude and trend of water pollution within the mainstem and tributaries in the park. Furthermore, the source of sewage pollution in the park could be identified and mapped and treatment infrastructure installed and/or improved. The introduction of non-native species can be reduced by eliminating the use of live bait, reducing habitat disturbance, and by continued inventory, detection, and removal of non-native aquatic and terrestrial species in the park.

Maintaining unfragmented, diverse forest communities with natural disturbance regimes in place (e.g. tree fall gaps, natural fire) may be the best approach to support native plant and animal communities in the park. It is increasingly accepted that national parks be managed as part of larger ecological systems (Fancy et al. 2009). Therefore, identifying and protecting forested corridors to connect the park to other forested areas could help ensure resilience of the park's ecosystems to global climate change and other threats to forest integrity. Forested areas outside of the park that straddle I-64 to the northwest of Mount Hope, WV, and surround Bluestone Lake to the south are unfragmented and habitat linkages to these areas could be identified and protected where possible. In addition, our analysis revealed an existing forested habitat bridge at the Highway 19 crossing that provides a corridor connecting NERI to other forested environments. These forested corridors could be maintained to provide connectivity for organisms moving through the park that require large areas of connected core forest environments.

The dual mandate of the Organic Act and the National Parks and Recreation Act (1978) to provide natural resource protection and public use is a major challenge for park managers (Prato 2001). These challenges are present at NERI where world-class recreational opportunities may affect the ecological integrity of some park resources. Park managers could consider determining the visitor carrying capacity for various areas of the park. Park carrying capacity is the number of visitors that an area can sustain without degrading natural resources and visitor experiences (Prato 2001). There are various approaches for calculating carrying capacity and these calculations could be part of a larger visitor management plan. For example, certain cliff areas may have to be protected from rock climbing, some riparian areas may have to be protected from rafting, and some trails located near Allegheny woodrat habitat may have to be re-directed or closed. These types of recreational management could necessitate increased investment in park rangers, visitor education, and partnerships with resource users (hunters, rock climbers, rafting companies). Finally, human activities (development, resource extraction, pollution) within airsheds and watersheds in which parks are located extend across management and political boundaries and affect park ecosystems and their management. Therefore, interagency cooperation, communication, and data sharing are critical to ensuring natural resource protection within NERI.

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