National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Russell Cave National Monument

Natural Resource Report NPS/RUCA/NRR—2019/1942

ON THIS PAGE
View of the cave opening from the pedestrian walkway showing some of the restoration work being done to preserve the cave's cultural history. Parts of the signs explaining the history and cultural significance are visible at the bottom edge of the photo.
Image by J. W. Aber, MTSU Geospatial Research Center, 2017.

ON THE COVER
View of the main opening to Russell Cave from the pedestrian walkway.
Image by J. W. Aber, MTSU Geospatial Research Center, 2017.

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Natural Resource Report NPS/RUCA/NRR—2019/1942

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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

Roughly nine-thousand years ago following the last glacial maximum, early humans of North America sought shelter from the harsh winters in a small cave located in northern Alabama. Thanks to regular flooding of that cave, Russell Cave National Monument (RUCA) contains one of the longest stories of continuous habitation in North America. RUCA is in Jackson County in northeastern Alabama, less than a mile south of the Tennessee border. Today the monument site consists of twenty-three different archaeological sites and seventeen subsites marking various features and/or locations of prehistoric importance.

This Natural Resource Condition Assessment (NRCA) for RUCA compiles existing reports and data to assess current conditions and trends within the monument where possible. The primary objective of this report is to use these condition and trend assessments to augment the informational toolsets available to parks managers. It also helps identify current and future threats to the environmental conditions at RUCA, as well as finding data gaps where more work is necessary. What follows are the collaborative efforts of Middle Tennessee State University (MTSU), the Cumberland Piedmont Inventory and Monitoring Network (CUPN), the National Park Service (NPS) Southeast Regional Office, and RUCA.

The data used herein was collected from RUCA staff, NPS's online data portals, published reports from universities and research companies, and personal communications with subject matter experts. Per the terms of the cooperative agreement, no original research was conducted and no new data was generated; only those reports which fell within the requirements set forth by the scoping table developed in collaboration between MTSU and the NPS were used. Evaluation of environmental conditions is based on published documentation of state and federal regulations and technical reports.

Of the 25 components analyzed, five are assigned no condition, eight are assigned good condition, eight warrant moderate concern, and four warrant significant concern. Those components that receive no condition either have a lack of data for assessment, or an assessment was not applicable, including topics such as weather and geology.

The component that warrants the most concern is invasive/exotic plant species within the monument. The staff at RUCA continue to combat these species, but ten of Alabama's listed exotic species, including three of the worst 10 in the state, are present at the monument. Continued management will likely be necessary in perpetuity to keep these species at bay. The other categories that warrant significant concern are all related to atmospheric conditions primarily affected by external factors such as federal and state air quality regulations and local industrial activities. These categories include sulfur and nitrogen deposition, as well as visibility. While they currently fall in the significant concern category, the available data shows that they are all improving year-to-year.

Some of the most important natural resources at RUCA involve the geology of the cave system, as well as the animal life within the cave including cave bats. These components face serious threats in the form of natural processes eroding and affecting the cave's structural integrity, and the spread of white-nose syndrome in the bat populations.

One aspect that could be better leveraged to monitor and manage environmental factors at RUCA is the use of Geographic Information Systems (GIS) resources. While GIS technology has been employed at the monument, it is not being utilized to its full potential. Better data handling practices including proper metadata implementation and an expanded push to digitize spatial information would provide a positive impact to the overall management of RUCA.

RUCA may be one of the smaller units in the NPS, but it plays host to an important piece of human history. Having a better understanding of the threats and stressors to the natural resources of the monument, along with identifying data gaps, helps provide support for efficient allocation of the limited resources available to RUCA.

Acknowledgments

We wish to acknowledge and thank all of the individuals at the National Park Service and related subject experts who provided their knowledge, technical expertise, feedback, and support throughout the process of scoping, review, and production of this report. In particular, we would like to thank Superintendent Steve Black and Resource Management Specialist Mary Shew from Russell Cave National Monument; Clare Bledsoe, Kurt Helf, Johnathan Jernigan, Teresa Leibfreid, Joe Meiman, Bill Moore, and Steven Thomas from the Cumberland Piedmont Network; and Dale McPherson from the Southeast Regional Office, all of whom were crucial to the preparation of this report.

List of Acronyms

ADEM: Alabama Department of Environmental Management

ARD: Air Resources Division, National Park Service

AWQP: Alabama Water Quality Program

CASTNet: Clean Air Status and Trends Network

CUPN: Cumberland Piedmont Inventory and Monitoring Network

CWA: Clean Water Act

DOI: Department of the Interior

EPA: Environmental Protection Agency

FMU: Fire Management Unit

GIS: Geographic Information Systems

GPS: Global Positioning System

GRI: Geologic Resources Inventory

I&M NPS: Inventory and Monitoring Program

MTSU: Middle Tennessee State University

NADP: National Atmospheric Deposition Program

NOAA: National Oceanic and Atmospheric Administration

NPS: National Park Service

NRCS: Natural Resources Conservation Service

NRR: Natural Resource Report

NWS: National Weather Service

POMS: Portable Ozone Monitoring System

RUCA: Russell Cave National Monument

USDA: U.S. Department of Agriculture

USFWS: U.S. Fish and Wildlife Service

USGS: U.S. Geological Survey

VSWQM: Vital Signs Water Quality Monitoring Program

WRD: National Park Service Water Resources Division

Chapter 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 Geographic Information System (GIS) products;[4]
- Summarize key findings by park areas;[5] and
- 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 an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

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

NRCA Reporting Products…

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

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

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

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

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

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

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Roughly nine-thousand years ago following the last glacial maximum (LGM), early humans of North America sought shelter from the harsh winters in a small cave located in northern Alabama. Thanks to regular flooding of that cave, Russell Cave National Monument (hereafter, also referred to as RUCA, the monument, and Russell Cave NM) contains one of the longest stories of continuous habitation in North America. Through the remains of its material culture, burials, and geologic history, the cave presents a compelling story of mankind's determination and the hardships of early settlement of the North American continent.

Russell Cave's journey to becoming a national monument started in 1951, when an amateur archaeologist from the Tennessee Valley Authority working in the area was shown some projectile points and determined that the cave would be a likely source of more artifacts (Establishment of Russell Cave 2015). The owner of the land, Oscar Ridley, authorized excavations at the site in 1953, and in 1956, the land was purchased by the National Geographic Society from Ridley in order to preserve the cave for further study. After several years of excavations, the National Geographic Society donated the land to the American people, and the cave was established as Russell Cave National Monument in 1961 by the Presidential Proclamation of John F. Kennedy (Proclamation No. 3413 1961). The text of the proclamation highlights the historic, scientific, and educational importance of the site:

> *Whereas* Russell Cave, in the State of Alabama, is recognized by scientists to contain outstanding archeological and ethnological evidences of human habitation in excess of 8,000 years; and
>
> *Whereas the Advisory Board on National Parks, Historic Sites, Buildings and Monuments, established pursuant to the act of August 21, 1935, 49 Stat. 666 (16 U.S.C. 463), impressed by the scientific importance and educational value of Russell Cave, has recommended that the cave be permanently preserved as a unit of the National Park System;"* (Proclamation No. 3413 1961).

The cave site itself has been on the National Historic Register since 1966 (National Register of Historic Places 1999).

2.1.2. Geographic Setting

Russell Cave is in Jackson County in northeastern Alabama, less than a mile south of the Tennessee border (Figure 1). Today the monument site consists of twenty-three different archaeological sites and seventeen subsites marking various features and/or locations of prehistoric importance, all of which are contained within a single, irregularly shaped 310.45-ac parcel, see Figure 2.

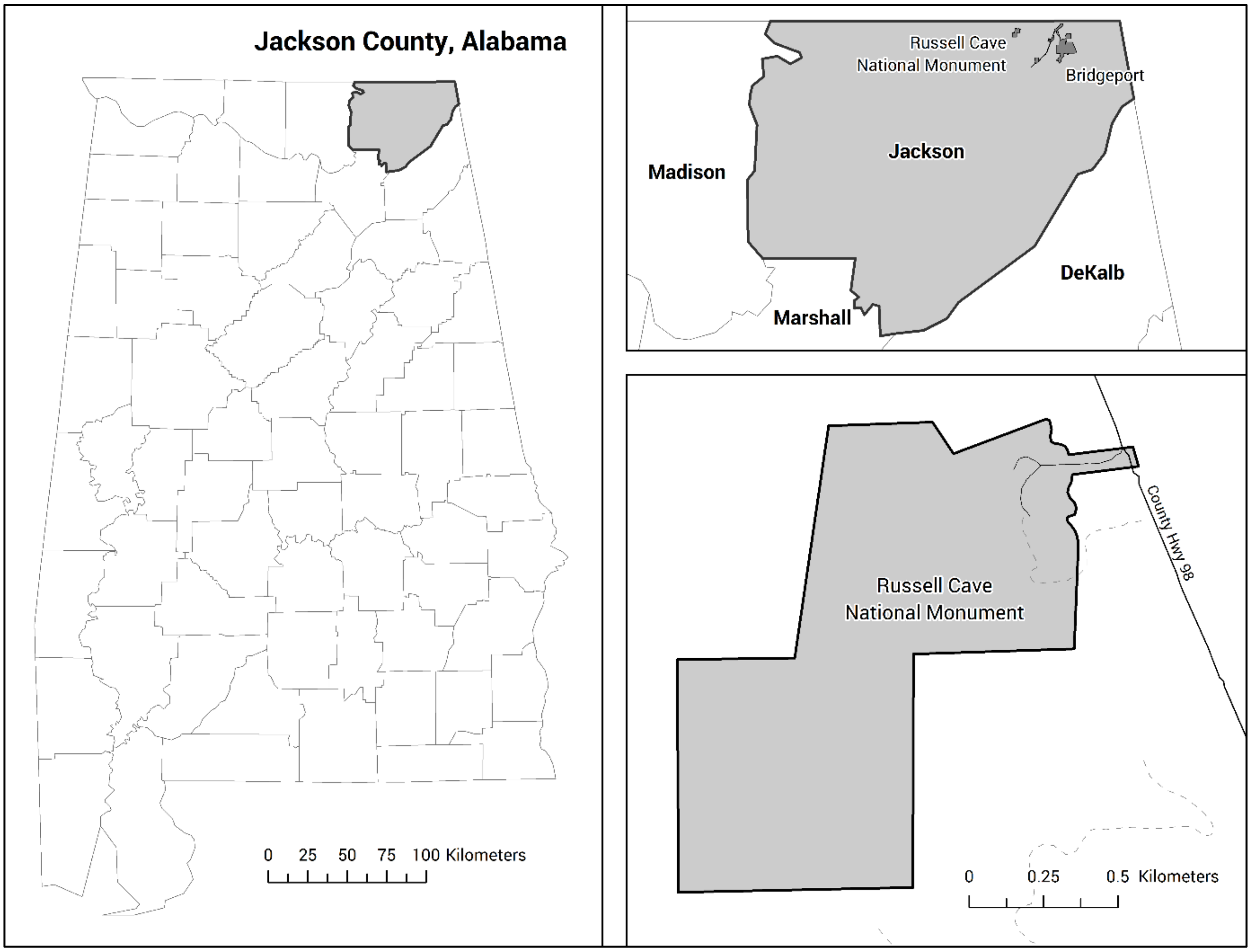


Figure 1. Geographical location of Russell Cave National Monument (J. Aber).

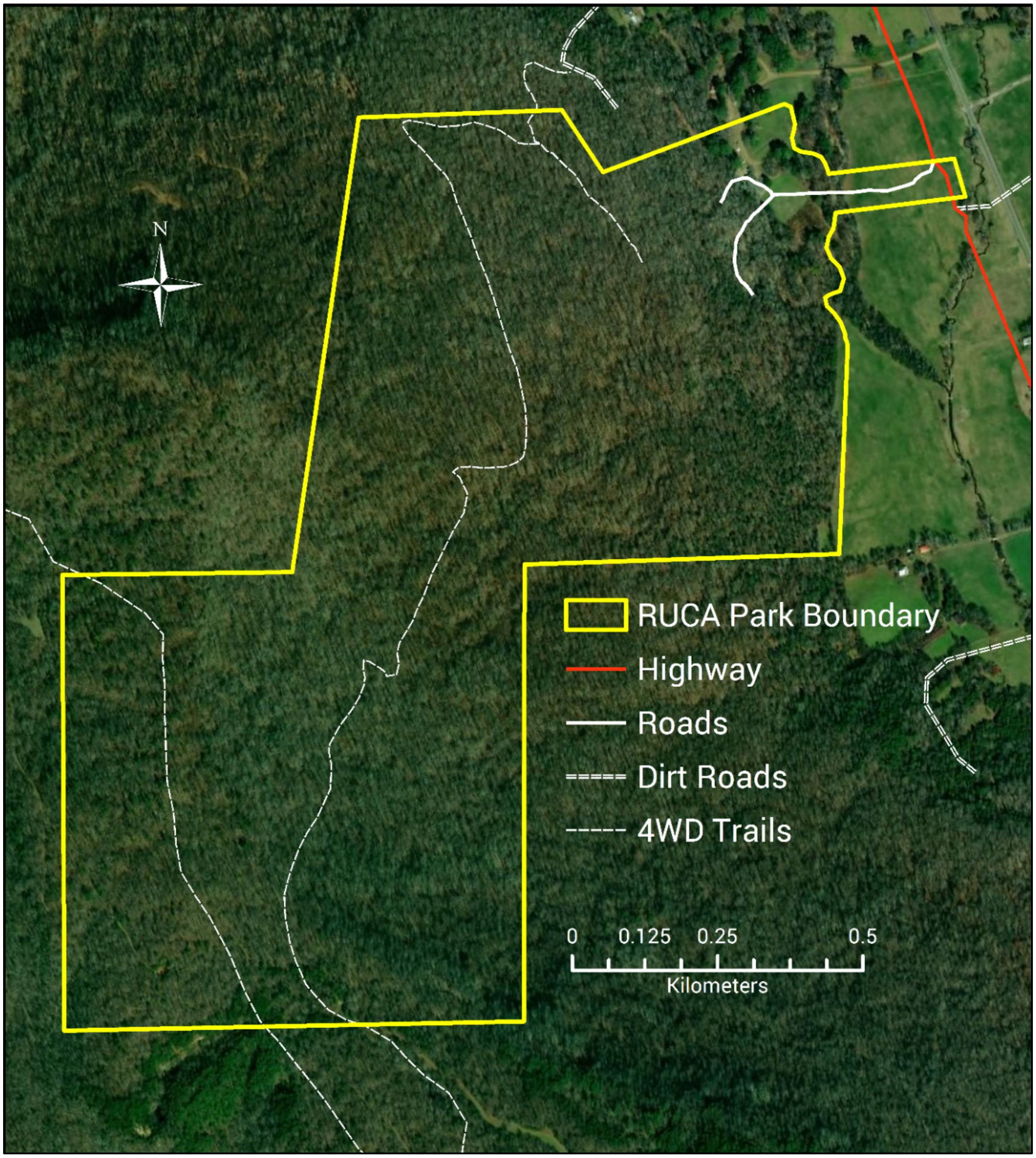


Figure 2. The monument boundary with roads, trails, and aerial imagery for context (J. Aber).

The monument is located in the Southwestern Appalachian ecoregion, specifically in the Level IV subregion known as a Plateau Escarpment. This particular ecoregion is known for having steep forested slopes and high gradient stream channels. The monument is typical of the region in that is has a large elevation range with the lowest point being 195 m above sea level, and the highest being 512 m. Within the monument's boundaries multiple landforms exists, including floodplain, the cave entrances, mountain slope, a bluff line, and rolling plateaus along the highest points (National Register of Historic Places 1999).

The nearest community to the monument is Bridgeport, AL, approximately 13 km away by car. As of 2016, Bridgeport has a population of 2,525, with approximately 27% being under the age of 18, and 2.4 persons per household (United States Census Bureau 2016a). The median household income is $29,122 and the per capita income is $16,695 (United States Census Bureau 2016b). Both household and per capita income figures are approximately two-thirds of the statewide Alabama figures, and 30.5% of population of Bridgeport lives below the poverty line. The nearest large population center is Chattanooga, TN, roughly 40 minutes' drive to the east and just over the border into the Eastern Standard Time Zone.

2.1.3. Visitation Statistics

Reports on visitor satisfaction go back as far as 1998 and satisfaction has remained consistently high, with most categories above 95% year over year, see Table 1. In particular, satisfaction with monument employees has remained consistently high. Reports for age and sex statistics for three years, starting in 2011, show that the monuments visitors are majority women, with middle-aged and elderly individuals comprising the majority of visitors (Cooperative Parks Studies Unit 2011, Cooperation Park Studies Unit 2013).

Outreach has been attempted and maintained through a monument newsletter (no longer produced) and several ranger-led educational outreach programs such as the Teacher-Ranger-Teacher program (Gate 2017). Given that the history of the monument is one that heavily features climate change as a driving force, RUCA offers several thematically appropriate educational attractions on this topic[1]. In addition to activities pursuant to continuing education on climate change, RUCA offers free access to a museum showing the lifeways of people who used prehistoric shelters, ranger guided tours of the rock shelter, and opportunities for birdwatching.

Based on the gathered reports, the primary draw to RUCA are the historical and cultural attractions the monument offers, followed by picnic areas, with visitor demographics representative of the surrounding counties based on available census data. The only opportunities for dramatic improvement to visitor satisfaction lie in the lack of commercial services offered at the monument.

[1] Interpretative staff have planted gardens of crops demonstrating how earlier climates were better suited for different crops in the past, offers archaeologist and ethnobotanist led presentations of prehistoric plant life, and has planted several rain-barrels and other items as conversation-starters for park rangers and visitors to discuss climate change.

Table 1. Numbers showing visitor statistics from 1998 to 2013 along with the 15-year averages (Cooperative Park Studies Unit 1998-2013).

Reporting Categories	Reporting Subcatetories	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	15 Year Average
Park Facilities	Visitor Center	95%	98%	100%	99%	99%	100%	95%	99%	99%	99%	100%	99%	97%	97%	99%	99%	98%
	Exhibits	93%	94%	99%	98%	99%	96%	96%	99%	95%	96%	98%	97%	97%	97%	97%	94%	97%
	Restrooms	92%	98%	99%	99%	95%	95%	93%	94%	99%	99%	99%	99%	100%	99%	100%	99%	97%
	Walkways, trails, and roads	100%	96%	98%	94%	94%	100%	93%	97%	100%	99%	100%	99%	100%	99%	100%	97%	98%
	Campgrounds and/or picnic areas	100%	98%	95%	93%	91%	86%	86%	97%	99%	96%	99%	97%	100%	94%	100%	98%	96%
	Combined Park Facilities	96%	97%	98%	97%	96%	95%	93%	97%	98%	98%	99%	98%	99%	97%	99%	97%	97%
Visitor Services	Assistance from park employees	100%	100%	100%	99%	98%	100%	99%	99%	100%	99%	100%	100%	100%	99%	100%	100%	100%
	Park map or brochure	96%	94%	98%	98%	92%	100%	98%	99%	99%	98%	98%	99%	97%	95%	99%	100%	98%
	Ranger Programs	98%	99%	96%	97%	97%	96%	98%	99%	99%	98%	99%	99%	100%	99%	100%	100%	98%
	Commercial Services	79%	78%	74%	81%	93%	69%	77%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79%
	Value for Entrance Fee Paid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Combined Visitor Services	93%	93%	92%	94%	95%	91%	93%	99%	99%	98%	99%	99%	99%	98%	100%	100%	96%
Recreational Opportunities	Learning about nature, history, or culture	99%	96%	98%	96%	99%	93%	96%	99%	99%	97%	100%	99%	97%	99%	100%	100%	98%
	Outdoor recreation	95%	83%	89%	87%	94%	79%	79%	96%	95%	97%	96%	97%	100%	93%	97%	98%	92%
	Sightseeing	97%	92%	90%	91%	98%	85%	88%	98%	97%	97%	98%	98%	98%	96%	N/A	N/A	95%
	Combined Recreational Opportunities	97%	90%	92%	92%	97%	86%	88%	98%	97%	97%	98%	98%	98%	96%	99%	99%	95%
	Overall Satisfaction	95%	93%	94%	94%	96%	91%	91%	98%	98%	98%	99%	99%	99%	97%	99%	99%	96%

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

As previously described in the Geographic Setting section (2.1.2), Russell Cave National Monument is a relatively small site contained within a single unit of land. RUCA falls within the Widows' Creek watershed (HUC 060300010204), as seen in Figure 3. At the southern end of the watershed, outflow runs through Widows' Creek towards Guntersville Lake, an artificially dammed portion of the Tennessee River that falls between Guntersville and Bridgeport, AL.

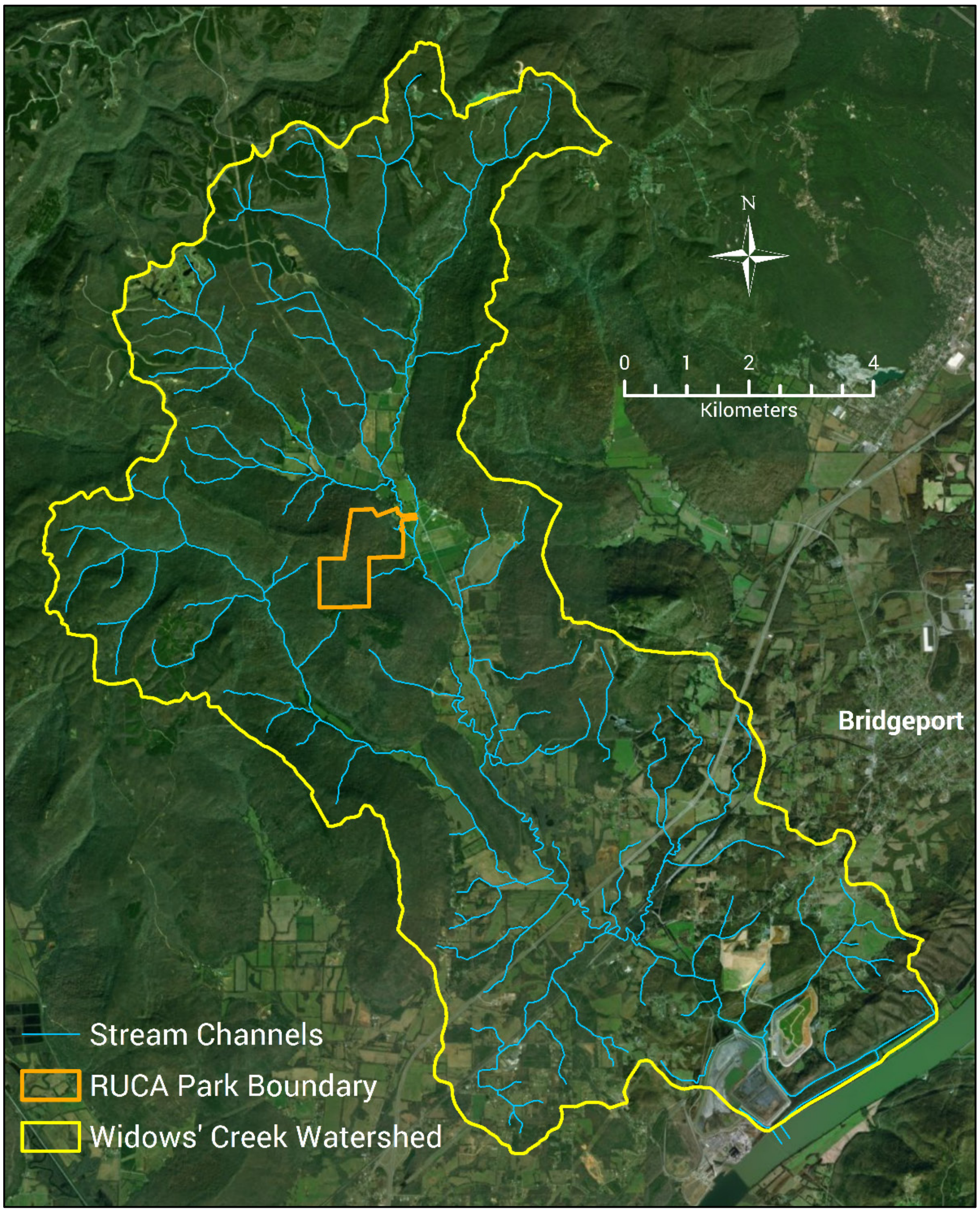


Figure 3. The location of Russell Cave National Monument within the Widows' Creek watershed (J. Aber).

2.2.2. Resource Descriptions

In Chapter 4, natural resource categories will be described in detail, many of which are common to multiple parks within the NPS. What follows here is a short description of some of the more unique and important natural resources that exist at RUCA. Longer discussions of these resource categories can be found in Chapter 4.

Cultural Landscape

RUCA is home to important prehistoric sites that document early human habitation in North America. In addition to the already excavated sites within the monument, there are other locations that show potential as sites which may have further artifacts. There are several potential threats to these sites, including erosion, the potential for cave collapse, and looting. There is no evidence of looting at this time and while the monument is taking reasonable actions to prevent it from occurring, it remains a concern.

Cave Aquatic Biota

The cave and its ecosystem are a crucial part of the monument, and approximately 10 km of caverns exist within Russell Cave alone. The cave has both open portions near the mouth of the cave, as well as dark zones of the cave that support a variety of species. Flooding is an important part of the cave system, as floods deliver allochthonous material providing energy and nutrients to the aquatic biota within (Poulson and White 1969). Consequently, disturbances to the watersheds upstream of the cave system have the potential to disrupt and threaten the aquatic biota of RUCA. Several species that live in the cave system are vulnerable or near-threatened, including the Tennessee cave salamander (*Gyrinophilus palleucus*) and the Southern cavefish (*Typhlichthys subterraneus*).

Cave Bats

Eight different species of bats have been observed at Russell Cave: The gray bat (*Myotis grisescens*), northern long-eared bat (*Myotis septentrionalis),* tri-colored bat (*Perimyotis subflavus*), big brown bat (*Eptesicus fuscus*), little brown bat (*Myotis lucifugus*), eastern red bat (*Lasiurus borealis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), and evening bat (*Nycticeius humeralis*). Of these, the big brown bat was the most plentiful, while the gray bat is a federally endangered species (Grow et al. 2010). The northern long-eared bat is federally listed as threatened, and Rafinesque's big-eared bat is a species of concern. Like other bat populations in North America, the fungal disease known as white-nose syndrome is a major concern that was confirmed in 2012 to exist in Russell Cave (Thomas et al. 2016). Other threats to bat populations include more general environmental issues like fires, air and water pollution, human disturbance, the potential for cave collapse, flooding, and in-cave modifications.

2.2.3. Resource Issues Overview

Beyond the resources described in Chapter 4, other factors affecting natural resources at RUCA require monitoring and management attention as well. Elements such as the potential for fire or the impact of development on the night sky are also capable of having a significant impact on environmental conditions and may negatively affect the visitor experience. Environmental concerns such as the presence of invasive/exotic plants, air quality and the landscape dynamics of the area are also factors that affect many elements of the monument. These topics are not unique to RUCA though, and are commonly monitored throughout the park system.

Fire Management

RUCA has developed a fire management plan based on the NPS Wildland Fire Management Guidelines (DO-18) which states that "all parks with vegetation that can sustain fire must have a fire management plan" (Mangi Environmental Group 2004). RUCA's fire management plan is a synthesis of NPS DO-18, the NPS Fire Monitoring Handbook's recommended standards, and RARCM from the LANDFIRE project. In a 2003 Finding of No Significant Impact Report it was decided that due to RUCA's small size and uniformity it would be treated as a single fire management unit (FMU) (Mangi Environmental Group 2004). Under this plan, all fires whether human caused or naturally ignited will be declared wild, and fires and fire response will adhere to Minimum Impact Suppression Tactics (MIST). As a part of that 2003 plan, the tactics determined to be appropriate for RUCA include:

- Keeping fire engines or slip-on units on existing roads.
- Not using heavy equipment (bulldozers/plows) for constructing firelines.
- Not using fireline explosives.
- Using existing natural fuel breaks and human-made barriers, wet line, or cold trailing the fire edge in lieu of handline construction whenever possible.
- Keeping fireline width as narrow as possible when it must be constructed.
- Avoiding ground disturbance within known natural and archeological/cultural/historic resource locations. When fireline construction is necessary in proximity to these resource locations it will involve as little ground disturbance as possible and be located as far outside of resource boundaries as possible.
- Using water in lieu of fire retardant.
- Using soaker hose, sprinklers or foggers in mop-up; avoiding boring and hydraulic action.
- Minimizing cutting of trees.
- Scattering or removing debris as prescribed by the incident commander.
- Protecting air and water quality by complying with the Clean Air Act, the Clean Water Act, and all other applicable federal, state, and local laws and requirements.
- Manual and mechanical thinning techniques, including mowing will be used to maintain open areas in a defensible area of 15.25 m around all park buildings. Tree thinning will occur primarily on small diameter woody shrubs and trees.

Additionally, fire management at national parks and monuments is used to determine the overall risk of fire and best practices for containing wildfires. Controlled burns are used to address invasive species, outbreaks of blight (although blight is not a concern at RUCA), and to create fire breaks in case of large, uncontrolled outbreaks of fire. Fire management at RUCA is determined by plots using the rock chestnut oak (*Quercus montana*) as a measurement unit (Mangi Environmental Group

2003). Despite a general lack of data post-creation of a long-term fire management plan, the 2009 and 2010 fire ecologies showed a 20-60% pole reduction in *Quercus montana* trees (NPS 2010-2013a, NPS 2014a).

Dark Night Sky

While much of RUCA's importance as a site of archaeological note is contained within a cave, a clear view of the night sky remains of concern. More than 80% of the world suffers from light pollution, and in the United States more than 99% of people live with light pollution (Falchi et al. 2016). While RUCA is not in an area affected as strongly as many American urban areas are, the monument still suffers from a diminished view of the night sky due to light pollution from developed areas in the surrounding region. Data sources describing light pollution are not precise enough to say exactly how much RUCA's view of the night sky is affected, but it remains a concern. However, beyond assessing local lighting types and positioning, the larger causes of light pollution are largely out of the hands of RUCA staff. For those local lighting choices that are controlled by RUCA, the monument plans to undertake an assessment of how local lighting can be adjusted to reduce energy consumption and reduce night sky light pollution.

Invasive and Exotic Plants

Invasive and exotic plant species are a common problem for many NPS units, and RUCA is no exception. Invasive plants are a serious threat to the biodiversity of the monument, as they compete with native species for resources. Approximately 12% of the plants at RUCA are introduced species. Of the exotic plants occurring at the monument, three species are listed as Alabama's worst 10 and seven species are listed as extensive and densely infested in Alabama. Only four out of ten vegetation communities at RUCA are without invasive species/exotic plants at this time. Treatments for some invasive species have been ongoing since 2000, yet continued efforts will be needed for full recovery of vegetation and prevention of natural vegetation communities. The presence of these invasive and exotic species in the monument is the single most concerning natural resource category at RUCA; more details can be found in section 4.4.5.

Air Quality

Air quality is the second-most concerning resource category for RUCA behind invasive/exotic plants. The levels of ozone, sulfur, nitrogen, and haze at the surface of the monument have direct impacts on the health of plant, animal, and human life, and all are of moderate or significant concern. These air quality factors are affected strongly by industrial activities and the burning of fossil fuels, which leads to increased levels of acidic atmospheric pollutants and affects nutrient cycles.

Air quality measures are primarily gathered from NPS Air Resources Division (ARD) interpolations used across the NPS for estimating atmospheric pollutants. Fortunately, despite being of significant concern in multiple categories, these measures all show improvement over the 2009-2015 timeframe of available ARD data. State and federal emissions standards are central components of improving air quality both in general and specifically at RUCA. A more detailed look at air quality factors can be found in section 4.1.

Landscape Dynamics

The land cover and land use of areas surrounding the monument have a strong, direct influence on the environmental conditions within RUCA. These landscape dynamics affect all elements of the monument, including the biological populations of plants and animals, water quality, and air quality. For some vital sign measures, such as water quality, the surrounding area is directly linked to monument conditions as it literally flows into the monument. Because of these direct linkages, the landscape dynamics of the region are quite important for understanding RUCA conditions and potential environmental preservation and conservation practices.

For a better understanding of the broader landscape context, the NPS has provided tools and data products to assess landscape dynamics via their NPScape program, available at https://science.nature.nps.gov/im/monitor/npscape/. These products are based on various federal data sources including the U. S. Census Bureau, the National Land Cover Dataset, and the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program. They are intended to provide a standardized look at landscape conditions throughout the United States and allow for comparison over time and location. NPScape data is used in section 4.5.2 of this report to assess land cover change in the area around RUCA, specifically in regards to any shifts from natural to human-converted land covers in the proximity of the monument that might lead to increased environmental stress. The immediate area around RUCA has not seen much transition from natural to converted classes, although changes have occurred within a 30 km buffer of the monument and their potential impact should be considered.

2.3. Resource Stewardship

2.3.1. Management Directive and Planning Guidance

RUCA has a long-range interpretive plan that guides the management objectives for the park unit (Edquist Davis Exhibits 2009). The following objectives of the monument are drawn from this plan:

- Provide a setting in which visitors feel welcome, safe, and able to enjoy and benefit from park programs and resources.
- Help park audiences relate to Russell Cave National Monument, its resources, interpretive story and to the National Park System as a whole.
- Provide opportunities for visitors to interact with park personnel and have hands-on experiences relevant to the park stories.
- Provide educational opportunities for park audiences.
- Provide meaningful and memorable experiences for park audiences.
- Establish a sense of ownership and stewardship by visitors toward Russell Cave National Monument.

A 2014 Foundational Document provides the latest guidance on management goals and plans relating to specific topics of importance and concern to meeting the primary park objectives (NPS 2014b).

2.3.2. Status of Supporting Science

Throughout 2002, the CUPN held a series of workshops which identified key resources for each of the parks within the network. These resources are called 'Vital Signs' and have been used to determine the overall health of the individual parks. CUPN released a Vital Signs Monitoring Plan in 2005 (Leibfreid et al. 2005). Table 2 shows the Vital Signs that were selected for monitoring for all parks in the CUPN including RUCA.

Table 2. Vital signs selected for each of the parks in the CUPN (Leibfreid et al. 2005).*

Level 1 Name	Level 2 Name	Vital Sign	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Air and Climate	Air Quality	Ozone and Ozone Impact	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Visibility and Particulates	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Atmospheric Deposition	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Air Contaminants	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Weather and Climate	Weather	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Geology and Soils	Geomorphology	Stream/River Morphology	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Subsurface Geologic Processes	Cave Air Quality	–	–	●	–	●	–	–	–	–	●	–	●	–	–
	Soil Quality	Soil Chemistry and Structure	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Soil Invertebrates and Associated Predators	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Water	Water Quality	Water Quality and Quantity	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Benthic Macro-invertebrates	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Microbes	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biological Integrity	Invasive Species	Invasive Species Early Detection	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Infestations and Disease	Forest Pests	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Focal Species or Communities	Amphibians	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Birds	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Cave Aquatic Biota	–	–	–	–	●	–	–	–	–	●	–	●	–	–
		Cave Crickets	–	–	–	–	–	–	–	–	–	●	–	–	–	–
		Vegetation Communities	●	●	●	●	●	●	●	●	●	●	●	●	●	●
		Mussel Diversity	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Fish Diversity	–	–	–	–	–	–	–	–	–	–	–	–	–	–
		Cave Bats	–	–	●	–	●	–	–	–	–	●	–	●	–	–
		Deer	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	At-risk Biota	Allegheny Woodrats	–	–	–	–	–	–	–	–	–	●	–	–	–	–
		Plant Species of Concern	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Human Use	Consumptive Use	Poached Plants	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Landscapes	Landscape Dynamics	Adjacent Land Use	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Fire and Fuel Dynamics	Fire	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Nutrient Dynamics	Guano Deposition in Caves	–	–	–	–	–	–	–	–	–	–	–	–	–	–

* Black dot indicates a selected vital sign.

Chapter 3. Study Scoping and Design

This NRCA is a collaborative project between the NPS and Middle Tennessee State University (MTSU) to evaluate natural resource conditions within RUCA. The project stakeholders include the RUCA resource management team, the Cumberland Piedmont Network (CUPN) I&M Program team, NPS Southeast Regional Office, and the MTSU team (faculty and undergraduate and graduate students from the Departments of Geosciences and Biology).

3.1. Preliminary Scoping

A pre-scoping conference call was held on December 15th 2016 involving representatives of the MTSU team, the CUPN team, the RUCA team, and the NPS Southeast Region NRCA coordinator. The NRCA coordinator presented a short PowerPoint description of the NRCA program and how the RUCA assessment fits within the larger program's objectives. Important characteristics of the NRCA project were described during the presentation. Initial planning activities related to the in-person scoping meeting were discussed during this call as well.

The scoping meeting held at the RUCA site took place on January 5th 2017. The RUCA team provided a tour of the site and facilities, highlighting key natural and cultural resources of the monument. After the tour, the participants sat down and worked through the scope of the report, identified sources of data, identified resource categories to be included in the assessment, and set expectations for the involved parties. Some points of note that were during the meeting include:

- The NRCA represents a 'snap-shot' in time of the park's natural conditions
- Only resources identified by stakeholders as relevant to the park are included in the assessment
- The report should identify critical gaps in studies and data relevant to the park's mission and long-term resource management operation
- Condition assessments for the NRCA report are performed using existing data in the form of published reports and studies
- The NRCA also extends to spatial data by including and organizing geographic information systems (GIS) datasets relevant to RUCA natural resources
- When applicable, reference conditions are defined for individual resources. If multi-temporal information is available for a resource with reference conditions, temporal trends are also defined for the resource.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

During the scoping process, the NPS ecological monitoring framework (EMF) introduced by Fancy et al. (2009) was chosen as the structure through which to view environmental conditions at RUCA. This framework uses three levels to describe scales of analysis (Table 3). In the first level, resources are divided into six broad categories, which are then subdivided into more focused categories within the area of study in levels two and three. This NPS EMF was used as the basis for the scoping table defined by the stakeholders during the scoping meeting (Table 4). The environmental categories included in this NRCA were determined based on which categories were identified as vital by the RUCA resource management team and the availability of data from published reports. The scoping table was used as a common guide for stakeholders during the preparation of this report.

Table 3. The Ecological Monitoring Framework selected for the RUCA NRCA project (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 category
Air and Climate*	Air Quality*	Ozone*
		Wet and Dry Deposition
		Visibility and Particulate Matter
		Air Contaminants*
	Weather and Climate*	Weather and Climate*
Geology and Soils*	Geomorphology	Windblown Features and Processes
		Glacial Features and Processes
		Hillslope Features and Processes
		Coastal/Oceanographic Features and Processes
		Marine Features and Processes
		Stream/River Channel Characteristics
		Lake Features and Processes
		Geothermal Features and Processes
	Subsurface Geologic Processes*	Cave/Karst Features and Processes*
		Volcanic Features and Processes
		Seismic Activity
	Soil Quality*	Soil Function and Dynamics*
	Paleontology	Paleontology
Water*	Hydrology*	Groundwater Dynamics*
		Surface Water Dynamics*
		Marine Hydrology
	Water Quality*	Water Chemistry*
		Nutrient Dynamics
		Toxics
		Microorganisms
		Aquatic Macroinvertebrates and Algae
Biological Integrity	Invasive Species*	Invasive/Exotic Plants*
		Invasive/Exotic Animals
		Insect Pests
	Infestations and Disease	Plant Diseases

* Indicates an area of interest identified by stakeholders as important to RUCA during the scoping process.

Table 3 (continued). The Ecological Monitoring Framework selected for the RUCA NRCA project (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 category
Biological Integrity	Infestations and Disease (continued)	Animal Diseases
	Focal Species or Communities	Marine Communities
		Intertidal Communities
		Estuarine Communities
		Wetland Communities*
		Riparian Communities
		Freshwater Communities
		Sparsely Vegetated Communities
		Cave Communities*
		Desert Communities
		Grassland/Herbaceous Communities
		Shrubland Communities
		Forest/Woodland Communities*
		Marine Invertebrates
		Freshwater Invertebrates*
		Terrestrial Invertebrates*
		Fishes*
		Amphibians and Reptiles*
		Birds*
		Mammals*
		Vegetation Complex (use sparingly)
		Terrestrial Complex (use sparingly)
Human Use*	Consumptive Use	Consumptive Use
	Visitor and Recreation Use*	Visitor Use*
	Cultural Landscapes*	Cultural Landscapes*
Landscapes (Ecosystem Pattern and Processes)*	Fire and Fuel Dynamics*	Fire and Fuel Dynamics*
	Landscape Dynamics*	Land Cover and Use*
	Extreme Disturbance Events	Extreme Disturbance Events
	Soundscape	Soundscape
	Viewscape*	Viewscape/Dark Night Sky*
	Nutrient Dynamics	Nutrient Dynamics
	Energy Flow	Primary Production

* Indicates an area of interest identified by stakeholders as important to RUCA during the scoping process.

Table 4. Summary of specific resource components, standards, and data sources identified and used in the NRCA of RUCA.

Biotic Composition/ Envirionmental Quality	Component	Primary Data Sources	Primary Resource Stressors	Primary Reference Conditions
Ecological Communities	Freshwater Wetland Communities	Roberts and Morgan (2007)	Over usage	plant indicator species list
	Forest Vegetation Communities	Schotz et al. (2006), Bledsoe (2017), CUPN (2013b)	Aggressive invasive species, particularly in mesic hardwood forests and floodplain forests throughout RUCA	Vegetation community composition and diversity
	Cave Aquatic Biota	Hobbs (1994), Zimmerman (2007)	Threats to groundwater quality (potential contamination of surface water by human activities); human disturbance	Species composition and diversity
Mammals	Cave Bats	Grow et al. (2010), Thomas et al. (2016)	White-nose syndrome, habitat loss and habitat impact (e.g., in cave modifications, land use changes, human disturbance, flooding, feral predators)	Species composition and diversity
	Mammal Assemblages	Grow et al. (2010)	Habitat loss and modification in surrounding areas may impact park mammalian diversity	Species composition and diversity
Birds	Bird Assemblages	Stedman and Stedman (2006)	Weather events, prescribed burns, historic mining activity in area	Species composition and diversity
Insects	Aquatic Insects	Parker et al. (2009, 2012, 2015)	Alterations to habitat, agricultural runoff, solid waste accumulations, human activities	Site sensitivity index and conservation score
Fish	Fish	Zimmerman (2007)	Clear cutting and introduction of chip mills, Dry Creek stabilization led potential for increased sediment transport into Russell Cave	Species richness and diversity factors
Herpetofauna	Amphibian and Reptile Assemblages	Accipiter Biological Consultants (2006)	Microhabitat disturbance, mower blades, vehicle traffic	Species composition and abundance

Table 4 (continued). Summary of specific resource components, standards, and data sources identified and used in the NRCA of RUCA.

Biotic Composition/ Envirionmental Quality	Component	Primary Data Sources	Primary Resource Stressors	Primary Reference Conditions
Plants	Vascular Plants	Schotz et al. (2006), DiPietro (1994), Bledsoe (2017), CUPN (2013b)	Aggressive invasive species	Species composition and abundance, presence of invasives
	Non-vascular Plants	Smith and Davidson (1995)	Changes in microhabitats; microclimate, vegetation communities	Species composition and abundance, presence of invasives
	Invasive/Exotic Plants	Schotz et al. (2006), Keefer et al. (2014)	Aggressive invasive species	Control or eradication of existing invasive species, prevent introduction of new invasive species
Geology	Geologic Resources	Thornberry-Ehrlich (2014)	N/A	N/A
	Cave/Karst Features and Processes	Meiman (2007), Ehrlich (2014)	Erosion, flooding, karst topography (sinkholes, breakdown), Radon potential--data gap, vandalism	N/A
	Soil Function and Dynamics	Meiman (2011), Thornberry-Ehrlich (2014)	Erosion, flooding, karst topography (sinkholes, breakdown)	N/A
	Paleontological Resources	Thornberry-Ehrlich (2014), Hunt-Foster et al. (2009)	Data Gap	N/A
Water	Water Quality	Meiman 2007, CUPN 2012 & 2013, Diggs, 2006	Development within the Doran Cove watershed, rainfall events washing surface pollutants into cave	Temperatures <32.2° C; pH between 6.0 & 8.5 SU; Dissolved oxygen not to deceed 5.5 mg/l; Fecal coliform <298 MPN/100ml
Atmosphere	Ozone/Foliar Injury	Taylor, (2017), Jernigan et al. (2013).	Elevated ozone levels due to increased development in the area	Ozone: > 54ppb Foliar Injury: SUM06 >8 ppm-hrs, W126 >7 ppm-hrs

Table 4 (continued). Summary of specific resource components, standards, and data sources identified and used in the NRCA of RUCA.

Biotic Composition/ Envirionmental Quality	Component	Primary Data Sources	Primary Resource Stressors	Primary Reference Conditions
Atmosphere (continued)	S and N deposition	Sullivan et al. (2011), Sullivan (2016)	Increased development in the area, the potential for deregulation of air pollution	Deposition greater than 3 (kg/ha/yr) of N or S
	Weather & Climate	Monahan and Fisichelli (2014), Davey et al. (2007)	Climate Change, potential development in the area	Deviation from 1901-2012 averages
Landscapes and Human Use	Cultural Landscapes	(Shew 2017)	Potential geologic instability, potentially looting in non-cavern areas.	N/A
	Land Cover and Use	NPScape	Urbanization, increase in rural development	Land use conversion

3.2.2. Reporting Areas

Because Russell Cave is a relatively small monument, it is treated as a single reporting unit. Despite this, there are multiple sites of cultural and natural importance that have been identified within the monument and may be specifically described within individual resource sections despite being smaller than the monument boundaries. In particular, specific cultural sites are described in section 4.5.1, Cultural Landscapes.

3.2.3. General Approach and Methods

The primary sources of information for this study were drawn from existing published reports and data describing scientific or quantitative students of individual resource components. No new data was collected, nor were any new studies conducted. When appropriate, information from multiple data sources was merged and summarized in order to evaluate any potential temporal trends. Condition, trend, and confidence levels were assigned by first comparing current conditions to the established standards, or reference conditions. Condition, trend, and confidence levels were assigned by comparing current conditions to the established standards, or reference conditions. Depending on this comparison, a condition value of “Significant Concern,” “Moderate Concern,” or “Resource is in Good Condition” was assigned to each of the various resource components (Table 5). Comparing and analyzing resource data sets from multiple time periods provided information on condition trends. Depending on the conclusions of this analysis, the resource was noted as “Improving,” “Unchanging,” or “Deteriorating.”

Overall confidence in the data sources relies upon several different factors. Both datedness of the data and frequency of data collection affect the confidence of the assessment of condition and trend. Other factors, such as spatial relevancy to RUCA and type of data source, were also considered when assessing confidence values. Confidence grades of “High,” “Medium,” or “Low” were assigned based on the overall quality and relevance of the respective data sources (Table 5). A confidence assessment is useful for highlighting areas of scant or weak data. For future studies, resource condition assessments with low confidence could be a focus for further data gathering and analysis.

Summary Indicator Symbols

A summary indicator table exists for the individual categories of natural resources described in Chapter 4. Each of these tables uses a visual symbol in addition to the text to highlight the state of the resource. Tables 5 & 6 describe these symbols and show how to interpret them throughout the report.

Table 5. Indicator symbols used to indicate condition, trend, and confidence in 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

Table 6. Example indicator symbols and descriptions of how to interpret them.

Symbol Example	**Description of Symbol**
	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.

Chapter 4. Natural Resource Conditions

4.1. Atmosphere

4.1.1. Ozone

Relevance and Context

While ozone is a natural and necessary component of the atmosphere that blocks incoming ultraviolet radiation in the stratosphere, human-produced ozone is considered a pollutant at the ground level. It is a byproduct of industrial and transport activities and is harmful to both animal (including human) and plant life. Sensitivity to ozone exposure can cause respiratory issues in humans, and it can weaken plants and affect growth, although the impact of ozone varies by species (Ray 2004). Ozone monitoring for human health is measured in parts per billion (ppb), and the 3-year average of the 4th-highest daily maximum 8-hour average critical threshold is 70 ppb ozone (Taylor 2017). Table 7 shows the value ranges corresponding to good, moderate, and significant concern for ozone concentrations.

Table 7. Ozone concentration thresholds for human health (Taylor 2017).

Status Category	Ozone concentration (ppb)
Warrants significant concern	≥ 71
Warrants moderate concern	55-70
Resource is in good condition	≤ 54

Resource Knowledge

The NPS Air Resources Division (NPS-ARD) method of assessing ozone concentrations is based on a spatial interpolation approach using data from air quality stations across the country (Taylor 2017). For these atmospheric measures, an Inverse Distance Weighted (IDW) approach is employed. For ozone, data is collected from the EPA Air Quality System, but prior to 2012, some data was pulled from the EPA Clean Air Status and Trends Network (CASTNet) (Taylor 2017). Table 8 shows the ARD interpolated ozone values for RUCA from 2009 to 2015.

Table 8. Ozone concentrations in parts per billion (ppb) as estimated by ARD interpolations (NPS-ARD 2018).

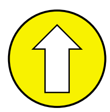
Year	Estimated ozone levels
2015	66.8 ppb
2014	68.3 ppb
2013	68.7 ppb
2012	71.2 ppb
2011	73.1 ppb
2010	74.9 ppb
2009	75.8 ppb

Condition Status
Ozone concentrations warrant moderate concern with ARD interpolated values in the most recent year (2015) being 66.8 ppb.

Trend in Condition
A trend of improvement is assigned to the atmospheric ozone concentrations, as the conditions have gone from the significant concern range in earlier years to the moderate concern range in the most recent data.

Confidence in Assessment
The methods employed are appropriate and rigorous. However, ozone concentration confidence is medium, as the data is interpolated from air quality stations not on-site (Table 9).

Table 9. The conditions of ozone and foliar injury at RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Ozone	Ozone concentrations in ppb ≤70		Condition warrants moderate concern. The trend is positive with concentrations falling each year. The interpolated data used to reach this assessment is of a medium confidence, as it is based on air quality stations not on-site.

4.1.2. Ozone-Caused Foliar Injury

Resource Knowledge
Direct observation of foliar injury is a method of monitoring the impact of ozone on plant life. The indices used to assess the impact of ozone in the atmosphere on plant life measure the sum of hourly concentrations greater than 60ppb (SUM06) and the sum of hourly concentrations weighted by a sigmoidal function (W126). The EPA uses different ozone measures relating to human health, but the SUM06 and W126 measures that the NPS and other scholars employ to assess ozone are far more stringent. Table 10 shows the concentration levels of ozone that are considered good, moderate, and warranting significant concern measured in parts per-million per hour (Jernigan et al. 2012).

Table 10. Thresholds used by the NPS-ARD for measuring the level of concern for ozone concentrations (Jernigan et al. 2012).

Condition	SUM06	W126
Significant Concern	>15 ppm-hrs	>13 ppm-hrs
Moderate	8-15 ppm-hrs	7-13 ppm-hrs
Good	<8 ppm-hrs	<7 ppm-hrs

In the CUPN, the original plan to measure ozone was a six-year rotation cycling through each park. In the off years, nearby test sites are used as proxies for ozone concentrations at the individual parks.

For RUCA, this off-site proxy is in Hamilton County, TN, which is approximately 31 km away at its closest point. Hamilton County contains the city of Chattanooga, TN, which is a large urban hub for the region containing many industrial activities. 2011 marks the only year thus far that ozone levels have been tested on-site at RUCA, using a portable ozone monitoring station (POMS), a Model 202 by 2B Technologies, Inc., Federal Equivalent Method EQOA-0410-190 (April 27, 2010 Federal Register Notice). Because the unit does not have an ozone generator, the data collected cannot be directly compared to EPA-based numbers.

Sampling at RUCA was carried out from April 6th 2011 through November 2nd 2011, and the sampling equipment was placed near the Visitor's Center. Table 11 and Figure 4 show the results of this testing. The POMS measured a SUM06 of 3.4, and a W126 of 3.9, well below the danger zone for human and plant life. For comparison, the Hamilton County numbers from 2011 are also included in Table 11. These numbers are significantly higher, likely reflecting a closer proximity to Chattanooga. Off-year ozone values for RUCA collected at the Hamilton County site are available beyond 2011, but the discrepancy between on- and off-site testing is quite large. The Hamilton County figures in other years are similar to the 2011 figures, indicating a similar disconnect likely persists in the data. Because of this low confidence level, they are not included in the table.

Table 11. 2011 Ozone concentration numbers for RUCA and test site used for RUCA in off years (Jernigan et al. 2013).

Site	SUM06 (ppm-hrs)	W126 (ppm-hrs)	Percent Valid (percent)
RUCA POMS	3.4	3.9	91.0
Hamilton County, TN	27.39	21.92	99.1

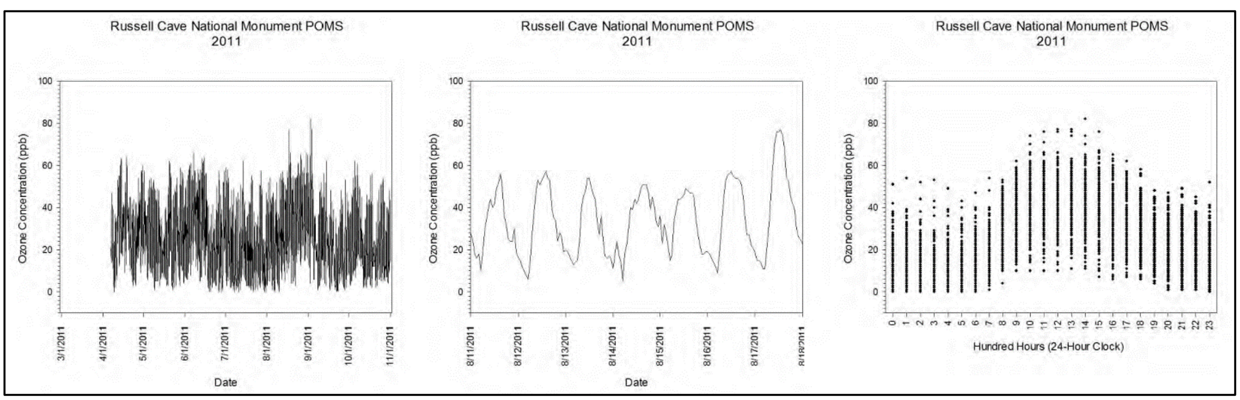


Figure 4. Charts showing the daily concentrations, the concentrations in a one-week period around the foliar injury assessment, and an hourly scatterplot (Jernigan et al. 2013).

NPS-ARD also estimates the risk of foliar injury by interpolating data just as they do for overall ozone concentration levels. CUPN has switched to relying on this data due to the cost of the on-site testing and the broad acceptance of ARD data. Table 12 shows these W126-scale estimates from 2009-2015. Given that the on-site observed W126 values from 2011 are considerably lower (3.9

observed vs. 11.8 estimated), it raises questions about the quality of the interpolated estimates. Any interpolation should be considered an 'educated best guess', as the technique is explicitly designed to fill in gaps in real world datasets. Although the on-site observations only ran for six months and not the full year, it raises the possibility that the interpolated data is over-estimating the ozone concentration values in all years. That being said, the overall trend shown in the interpolated data is positive, with values dropping from 13.8 ppm-hrs in 2009 to 7.9 ppm-hrs in 2015.

Table 12. Interpolated ozone concentration levels measured using W126 ppm-hrs (NPS-ARD 2018).

Year	Estimated ozone concentrations in W126 (ppm-hrs)
2015	7.9
2014	8.8
2013	8.5
2012	10.1
2011	11.8
2010	13.2
2009	13.8

Plants at RUCA were also visually inspected in RUCA's ozone biogarden near the Visitor's Center. Four plants were identified as having foliar injury, and injured leaves were sent to a US Forest Service regional expert on ozone injury. The expert looks for evidence whether or not the specimens in question exhibit injuries caused by ozone. In the case of RUCA in 2011, four plants were identified and confirmed as having foliar injury, as seen in Table 13 (Jernigan et al. 2013). A 2017 report found no evidence of foliar injury (NPS 2017).

Table 13. Presence of confirmed foliar injury at the RUCA Visitor Center in 2011 (Jernigan et al. 2013).

Species	Date	Amount	Severity	Plant Number
Blackberry	8/18/2011	1	1	24
Blackberry	8/18/2011	1	1	26
Blackberry	8/18/2011	1	2	18
Blackberry	8/18/2011	1	2	19

Condition Status

Based on the available data, foliar injury status is good, with low levels of atmospheric ozone measured on-site and only a small number of affected plants identified in 2011. ARD interpolated data suggests that the condition would warrant moderate concern, but the disconnect between the interpolated values and the on-site measurements suggests that these values may be over-estimated. These results combined with the 2017 survey that found no injured plants suggests that foliar injury is not a major concern at RUCA.

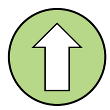
Trend in Condition

A trend of improvement is assigned due to the drop in the interpolated estimates.

Confidence in Assessment

The methods employed are appropriate and rigorous. However, the confidence is medium, as there are few on-site data points, the interpolated data does not match the on-site observations well, and the only on-site measurements of ozone concentrations are more than five years old (Table 14).

Table 14. The conditions of ozone and foliar injury at RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Foliar Injury	Number of injured plants observed and observed SUM06 and W126 values		Condition is good, as ozone concentrations on-site were low and few plants presented evidence of foliar injury. A positive trend is assigned due to the improvement in the ARD estimated values over time. Confidence is medium because of the nature of interpolated data and the small number of on-site observations.

4.1.2. Sulfur and Nitrogen Deposition

Relevance and Context

Sulfur and nitrogen pollutants in the atmosphere can lead to acidification of water systems, including streams, lakes, and soils, leading to negative environmental outcomes for plant and animal life at the monument. RUCA is not alone in the risk of this occurring, as all of the parks in the CUPN have high levels of atmospheric sulfur (S) and nitrogen (N) deposition (Sullivan 2016). Nitrogen deposition can also lead to an unnatural and undesirable nutrient enrichment of an ecosystem, which can affect the diversity of plant species and disrupt natural soil nutrient cycling. The addition of S and N compounds in the atmosphere are unsurprisingly related to human activities such as the burning of fossil fuels (Environmental Protection Agency [EPA] 2016, EPA 2018). Table 15 shows the relative rankings of I&M parks within CUPN to the effects of acidic deposition from S and N compounds. Looking specifically at N compounds, the same rankings are described in Table 16.

Table 15. Relative ranking of parks exposure and vulnerability to acidic deposition pollutants in CUPN. RUCA is bolded and highlighted. The ranks are designated by quintile among all I&M parks, from the lowest (very low risk) to the highest (very high risk) (Sullivan et al. 2011a).

Park Name	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Abraham Lincoln Birthplace	Very High	Moderate	Moderate	High
Carl Sandburg Home	High	Very High	Moderate	High
Chickamauga and Chattanooga	Very High	Very High	Moderate	Very High
Cowpens	High	Very Low	Moderate	Moderate
Cumberland Gap	High	Very High	Moderate	High

Table 15 (continued). Relative ranking of parks exposure and vulnerability to acidic deposition pollutants in CUPN. RUCA is bolded and highlighted. The ranks are designated by quintile among all I&M parks, from the lowest (very low risk) to the highest (very high risk) (Sullivan et al. 2011a).

Park Name	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Fort Donelson	Very High	Moderate	Moderate	High
Guilford Courthouse	Very High	Very Low	Moderate	Moderate
Kings Mountain	High	Low	Moderate	Moderate
Little River Canyon	Very High	Very High	Moderate	Very High
Mammoth Cave	Very High	High	Very High	Very High
Ninety Six	High	Very Low	Moderate	Moderate
Russell Cave	**Very High**	**High**	**Moderate**	**High**
Shiloh	High	Low	Moderate	Moderate
Stones River	High	Very Low	Moderate	Moderate

Table 16. Relative ranking of parks' exposure and vulnerability to atmospheric nutrient N enrichment within CUPN. RUCA is bolded and highlighted. The ranks are designated by quintile among all I&M parks, from the lowest (very low risk) to the highest (very high risk) (Sullivan et al. 2011b).

Park Name	Pollutant Exposure	Ecosystem Sensitivity	Park Protection	Summary Risk
Abraham Lincoln Birthplace	Very High	Low	Moderate	Moderate
Carl Sandburg Home	High	Moderate	Moderate	Moderate
Chickamauga and Chattanooga	Very High	Very Low	Moderate	Moderate
Cowpens	High	Very Low	Moderate	Low
Cumberland Gap	High	Very Low	Moderate	Low
Fort Donelson	High	Very Low	Moderate	Moderate
Guilford Courthouse	Very High	Very Low	Moderate	Low
Kings Mountain	High	Very Low	Moderate	Low
Little River Canyon	Very High	Very Low	Moderate	Moderate
Mammoth Cave	Very High	Very Low	Very High	Very High
Ninety Six	High	Low	Moderate	Low
Russell Cave	**High**	**Very Low**	**Moderate**	**Low**
Shiloh	High	Low	Moderate	Moderate
Stones River	High	Very Low	Moderate	Low

Resource Knowledge

A hybrid model for deposition was developed by Schwede and Lear (2014) for the National Atmospheric Deposition Program (NADP) Total Deposition (TDEP) Science Committee which combined data from CASTNet, the NADP Ammonia Monitoring Network (AMoN), and the

Southeastern Aerosol Research and Characterization (SEARCH) network. This approach allows for improved models when compared to earlier work, as it involves more data sources, both dry and wet deposition information, and includes N compounds that were previously not accounted. Based on this modeling, total S, N, nitrogen oxides (NO_x), and ammonia (NH_3) deposition can be estimated for the CUPN parks. The results of this modeling for RUCA can be seen in Table 17. The numbers are three-year averages centered on 2001 and 2011 for an approximately 4 km grid cell in each park.

Table 17. The amounts and change in S and N deposition in 2001 and 2011 in RUCA (Sullivan 2016).

Parameter	2001 Average (kg/ha/yr)	2011 Average (kg/ha/yr)	Absolute Change (kg/ha/yr)	Percent Change	2011 Minimum (kg/ha/yr)	2011 Maximum (kg/ha/yr)	2011 Range (kg/ha/yr)
Total S	14.02	7.38	-6.64	-47.4%	7.23	7.38	.015
Total N	13.94	11.38	-2.55	-18.3%	11.11	11.39	0.29
NO_X	9.44	5.37	-4.07	-43.1%	5.22	5.38	0.16
NH_3	4.50	6.01	1.52	33.8%	6.89	6.02	0.13

NPS-ARD also has interpolated estimates of N and S deposition for RUCA, but unlike Schwede and Lear's (2014) approach,they only include wet deposition. Table 18 shows the amount of wet deposition estimated via the ARD interpolation method.

Table 18. Atmospheric nitrogen and sulfur deposition as estimated by ARD interpolations (NPS-ARD 2018).

Year	N deposition (kg/ha/yr)	S deposition (kg/ha/yr)
2015	4.4	3.0
2014	4.6	3.3
2013	4.5	3.5
2012	4.6	4.0
2011	4.9	4.8
2010	5.3	5.6
2009	5.5	6.2

Threats and Stressors

As atmospheric S and N deposition are largely driven by the burning of fossil fuels, the largest threats come from increased development in the region. Overall, emissions of these compunds have decreased due to air pollution regulations at the state and federal levels, but a rollback of existing regulations and/or increased burning of fossil fuels will lead to more deposition.

Condition Status

The condition status warrants significant concern, as the levels are well above the 3 kg/ha/yr threshold, both in the ARD estimates and the Schwede and Lear (2014) estimates. RUCA is more sensitive to the acidification effects of S and N deposition than to nutrient disruption effects, so the increase in NH_3 deposition is less concerning than it might otherwise be. The decrease in S and NO_X compounds is good news since RUCA has a high sensitivity to their effects (see Table 15), but the numbers are still much higher than the desired figures.

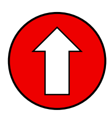
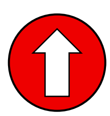
<u>Trend in Condition</u>

The trend in condition is improving, with total S and N deposition dropping substantially over the years included in the modeling. NH_3 deposition has increased, but when looking at total N compounds, it is offset by decreased NO_X deposition. Despite this increase, RUCA is far more sensitive to the acidification effects (see Table 15), so the overall decrease in deposition is positive.

<u>Confidence in Assessment</u>

The confidence used to make the assessment is medium. Data was collected and processed using scientifically-sound methods and involved multiple agencies. However, having only two time points to compare, and using an interpolation approach rather than measuring at the site, reduces confidence in the assessment. The ARD numbers are more recent, with the latest figures coming from 2015, but other values are more than five years old (Table 19).

Table 19. The condition of total S and N deposition in RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Atmospheric Sulfur and Nitrogen deposition	Total S deposition		The data was collected and processed in an appropriate scientific manner and shows that total deposition of sulfur compounds has dropped significantly over the reported time period. The deposition rates are still well above the recommend rates, and the data being interpolated leads to significant concern and a medium confidence.
Atmospheric Sulfur and Nitrogen deposition	Total N deposition		The data was collected and processed in an appropriate scientific manner and shows that total deposition of nitrogen compounds has dropped significantly over the reported time period. The deposition rates are still much higher than the recommend rates, and deposition of NH_3 compounds have increased leading to an assessment of significant concern. The data being interpolated leads to a medium confidence.

4.1.3. Visibility

<u>Relevance and Context</u>

Haze is one of the most obvious signs of air pollution, and it can impact the quality of the landscape dramatically. Particulate matter in the atmosphere absorbs and scatters light, shortening the length of visual range, and affecting the color and feel of the land. In the eastern part of the US, air pollution has reduced the visual range from around 145 km to 25-40 km, and in the west, the range has been reduced from 225 km to 55-145 km (EPA 2017). In addition to affecting the view, the particulate matter that reduces visibility has been linked to various respiratory health problems in humans.

Resource Knowledge

NPS-ARD has interpolated estimates of visibility based on the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The amount of haze in the atmosphere is marked by a haze index, with values reported in deciviews (dv) above the estimated natural conditions. NPS-ARD defines conditions warranting significant concern as having a dv value of eight or greater, as seen in Table 20. Table 21 shows the interpolated haze index numbers for RUCA from 2009-2015.

Table 20. Ozone concentration thresholds for human health (Taylor 2017).

Status Category	Visibility (dv)
Warrants significant concern	>8
Warrants moderate concern	2-8
Resource is in good condition	<2

Table 21. Atmospheric haze in deciviews above the estimated natural conditions at RUCA as estimated by ARD interpolations (NPS-ARD 2018).

Year	Haze Index in dv
2015	9.0
2014	9.8
2013	10.0
2012	10.9
2011	11.8
2010	12.3
2009	13.0

Threats and Stressors

Haze-causing air pollutants come from a variety of natural and manmade sources. The potential for increased development and industrial activity in the region could lead to increased haze in the atmosphere. Overall, emissions of haze-producing pollutants have decreased due to air pollution regulations at the state and federal levels, but a rollback of existing regulations and/or increased burning of fossil fuels will lead to reduced visibility.

Condition Status

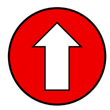
The condition warrants significant concern in all years for which estimates exist, as the values are all above the 8.0 dv threshold.

Trend in Condition

A positive trend is assigned, as the haze index values have improved each year.

Confidence in Assessment
The confidence used to make the assessment is medium. Data was collected and processed using scientifically-sound methods, but values are based on an interpolation approach (Table 22).

Table 22. The condition of visibility at RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Visibility	Haze index in deciviews (dv) > 8		The data was collected and processed in an appropriate scientific manner and shows that haze has decreased during the observation period. The visibility values are still well above the recommend rates, and the data being interpolated leads to significant concern and a medium confidence.

4.1.4. Weather and Climate

Relevance and Context
Weather and climate are factors that affect all of the other resource conditions within RUCA. Weather refers to the current short term atmospheric conditions in a location, whereas climate refers to the long-term pattern and trend of weather conditions in a location. As Fisichelli et al. (2015) point out, climate changes affect the biodiversity, land use, and stability within the monument, and this is why the NPS has identified climate monitoring as one of the 12 basic inventories to be completed for all NPS I&M networks. Climate change is especially important to RUCA, as it is one of the primary lenses through which cultural interpretation of the monument is presented to visitors (Institute at the Golden Gate 2017). Changing climates are also likely to influence the monument visitation habits of the public, as they shift in relation to warming (Fisichelli et al. 2015). Visitors may avoid the monument during the increasingly hotter summer months and extend the visitation season further into the warmer spring and fall seasons.

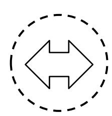
Resource Knowledge
Monahan and Fisichelli (2014) looked at climate data from 1901-2010 for RUCA and the surrounding 30 km area. They looked at 25 biologically relevant climate variables from the past 10-30 years to see which were considered ‘extreme’, where extreme means the variable exceeded 95% of the historical range of 1901-2012 variability. Only one of the factors, the mean temperature of the wettest quarter, was found to be extreme.

Davey et al. (2007) looked at climate monitoring efforts for the entire CUPN. While the focus wasn’t on looking at the climate values in particular, they highlight a need for better climate data for RUCA. The monument staff do report temperature and precipitation data to the National Weather Service, but aside from the POMS station that is periodically employed, there is only one full climate station within 30 km of the monument with a complete and current record of data. Unfortunately, that station is 27 km away and roughly 230 m higher in elevation making it a poor proxy for RUCA’s conditions:

Only three of the 12 COOP stations we identified within 30 km of RUCA are active currently. The previously-discussed SAO station at Monteagle is also co-located with a COOP station (Monteagle) which has a very reliable data record (1930-present). The longest data record comes from the COOP station "Sewanee," located 26 km northwest of RUCA. Unfortunately, this station's data record is unreliable. The closest COOP station to RUCA is "Bridgeport 5 NW," located just southeast of RUCA. This station had a significant gap in observations between April 1973 and September 1982 but has an otherwise complete data record. (Davey et al. 2007, 41)

<u>Condition, Trend, and Confidence</u>
RUCA, like many other locations in the United States, is currently affected by average rising temperatures, but beyond that atmospheric conditions within and near the monument are within 95% of the average ranges established by the 1901-2012 averages (Monahan and Fisichelli 2014). Establishing a condition for weather and climate is not suitable in the same way that it would be for other resource conditions. Regardless, doing so would require more reporting on the monument, and so a condition will not be assigned in this report (Table 23). Likewise, the reliability of the climate data that does exist is somewhat questionable due to spotty long-term records and distance from the monument in the case of the one active weather station that has a reliable, long-term record. 27 km may not seem a long distance, but in the case of other atmospheric data available for the monument, comparable distances have demonstrated dramatic shifts in conditions. Confidence in the assessment will be considered low due to the aforementioned issues.

Table 23. The condition of weather and climate within RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Weather and Climate	Temperature and other atmospheric measurements		Due to the nature of weather and climate, a condition assessment is not suitable. The little data available suggests that most atmospheric conditions beyond average temperatures are remaining steady. Due to the small amount of published reports on the monument, the confidence is low.

4.2. Geology and Soil

This section provides a description of the geology, cave and karst, soil, and paleontological resources at the monument. RUCA is one of seven NPS units created to protect caves and houses rare species of salamander whose conservation status is tied to the structural integrity of their habitat (Thornberry-Ehrlich 2014). In addition to these zoological resources, the primary goal in establishing RUCA was to protect the 9,000 years' worth of archaeological resources related to past human habitation in the cave (Griffin 1974). The NPS currently manages 3.10 ha (310.45 ac) of the 13-mile cave system and surrounding land.

4.2.1. Geologic Resources

Relevance and Context

RUCA falls within the CumberlandPlateau physiographic provice (Figure 5). Within the monument, there are two major geological units: Paleozoic-aged sedimentary bedrock hundreds of MYA, and Quaternary-aged surficial deposits up to a few million MYA (Thornberry-Ehrlich 2014). The bedrock for RUCA formed during the Mississippian and Pennsylvanian Periods more than 300 MYA at the bottom and margins of an inland sea. The older Mississippian bedrock is primarily Monteagle and Bangor fossiliferous limestone and Pennington Formation shale, with karst making up sixty-three percent of land within the monument boundary (Thornberry-Ehrlich 2014). The dry shelter cave in which Native Americans took refuge, stored food, and worked chert for toolmaking is 30 m wide, 8 m high, and 45 m deep (Griffin 1974). In addition to the main unit, there are several other shelter sites and archaeological sites within this same environment.

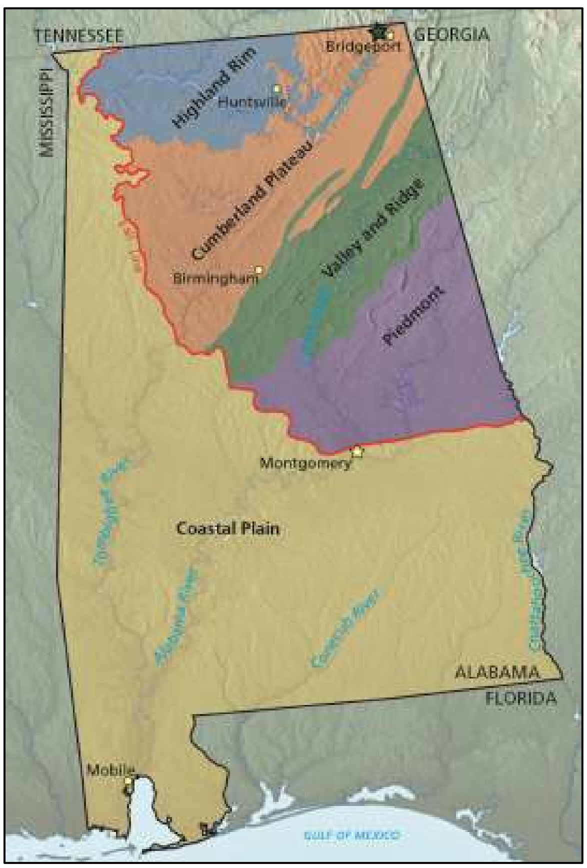


Figure 5. Physiographic provinces of Alabama. RUCA (green star) is located within the Cumberland Plateau. Map by Tom Patterson (NPS).

RUCA contains Paleozoic sedimentary rocks from the Mississippian Monteagle and Bangor Limestones. The nearby mountains including Montague Mountain where RUCA is located are topped by the Pennsylvanian Pottsville Formation. These are the youngest geologic bedrock units in the area, and were formed in prodelta, barrier, and back-barrier settings. The cave itself is in the Monteagle Limestone Formation (Thornberry-Ehrlich 2014).

The cave entrance sits just to the northwest of the Sequatchie anticline, near the leading edge of the Alleghenian thrust belt of the Valley and Ridge provinces. Several perennial springs are present within the monument and Dry Creek, an ephemeral stream, runs across the monument and flows into the entrance of Russell Cave (Thornberry-Ehrlich 2014).

4.2.2. Cave & Karst Features and Processes

Relevance and Context

Russell Cave is the primary cultural resource found within the monument and is its raison d'etre. Russell Cave is a karst cave, more properly termed a solution cave—one formed by chemical reactions between water and bedrock composed of bicarbonate material like dolomite or limestone (Toomey 2009). For those wishing for an extremely detailed discussion of this section, Meiman (2007) and Thornberry-Ehrlich (2014) offer an excellent examination of geological processes proximal to RUCA.

Relevant pieces of NPS code to consider when discussing the karst environment include:

- Section 4.8.1.2 requires NPS to maintain karst integrity and minimize impacts.
- Section 4.8.2 requires NPS to protect geologic features from adverse effects of human activity.
- Section 4.8.2.2 requires NPS to protect caves, allow new development in or on caves if it will not impact cave environment, and to remove existing developments if they impair caves. (Toomey 2009).

Threats and Stressors

Currently, there are several potential hazards inherent to the unstable karst environment at RUCA's caves: sinkhole flooding after significant rainfall, sinkhole collapse, ceiling collapse, and rockfall. A cover-collapse sinkhole first exposed the opening to Russell Cave and may yet be its undoing, as the slopes adjacent to the sinkholes are subsiding (Thornberry-Ehrlich 2014).

Karst geology lends itself to erosion. The structural integrity is aggravated by water dynamics, but it is difficult to predict sudden, dramatic changes. The geologic foundation of the monument contains a good deal of soluble carbonate rock subject to regular and abundant precipitation. While NPS has taken measures to investigate and limit the causes thereof there is substantial evidence of erosion occurring within the cave. According to the 2014 Geologic Resources Inventory (GRI), erosion is concentrated along the northwest wall coincident with the location of Griffin's 1974 archeological excavations.

An interview with Mary Shew revealed that erosion might be related to regular flooding in the nearby Dry Creek channel (2017). As previously mentioned, a ceiling collapse event was integral in the formation of the cave opening, and to mitigate the risk of further collapse, bolts were installed in the cave ceiling attempt to lessen this hazard for visitors. While radon exposure is possible for work crews and visitors in the cave, entry has been restricted for some time now after discovery of white-nose syndrome in the native bat population, minimizing these risks (Thornberry-Ehrlich 2014).

4.2.3. Soil Function and Dynamics

Relevance and Context

The soils found within the RUCA boundaries are varied, but the monument is dominated by two particular soil types, rough stony land, Muskingum soil material (RsM) and Limestone rockland rough (Lr), which account for approximately 73% of the surface area. More detailed information about the soils in RUCA can be obtained through the United States Department of Agriculture (USDA) Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov). Table 24 shows the soils types found within the monument, and Figure 6 shows their locations.

Table 24. A breakdown of the soil types found within RUCA boundaries (United States Department of Agriculture [USDA] 2018).

Soil Unit Symbol	Soil Unit Name	Acres
RsM	Rough stony land, Muskingum soil material	144.9
Lr	Limestone rockland rough	88.44
Hfg	Hartsells fine sandy loam, rolling, shallow phase	24.54
Mfl	Muskingum (Gorgas) fine sandy loam, 10 to 20 percent slopes	24.32
Qa	Quarry	10.08
Sfv	Sequatchie fine sandy loam, level phase	9.24
Jfn	Jefferson fine sandy loam, eroded, rolling phase	5.89
Huv	Holston loam, level phase	3.87
Lh	Limestone rockland, hilly	2.36
Ade	Allen fine sandy loam, eroded, undulating phase	2.07
Adn	Allen fine sandy loam, eroded, rolling phase	1.95
Msz	Muskingum (Gorgas) stony fine sandy loam, 20 to 45 percent slopes, very stony	1.27
Jfe	Jefferson fine sandy loam, eroded, undulating phase	0.52

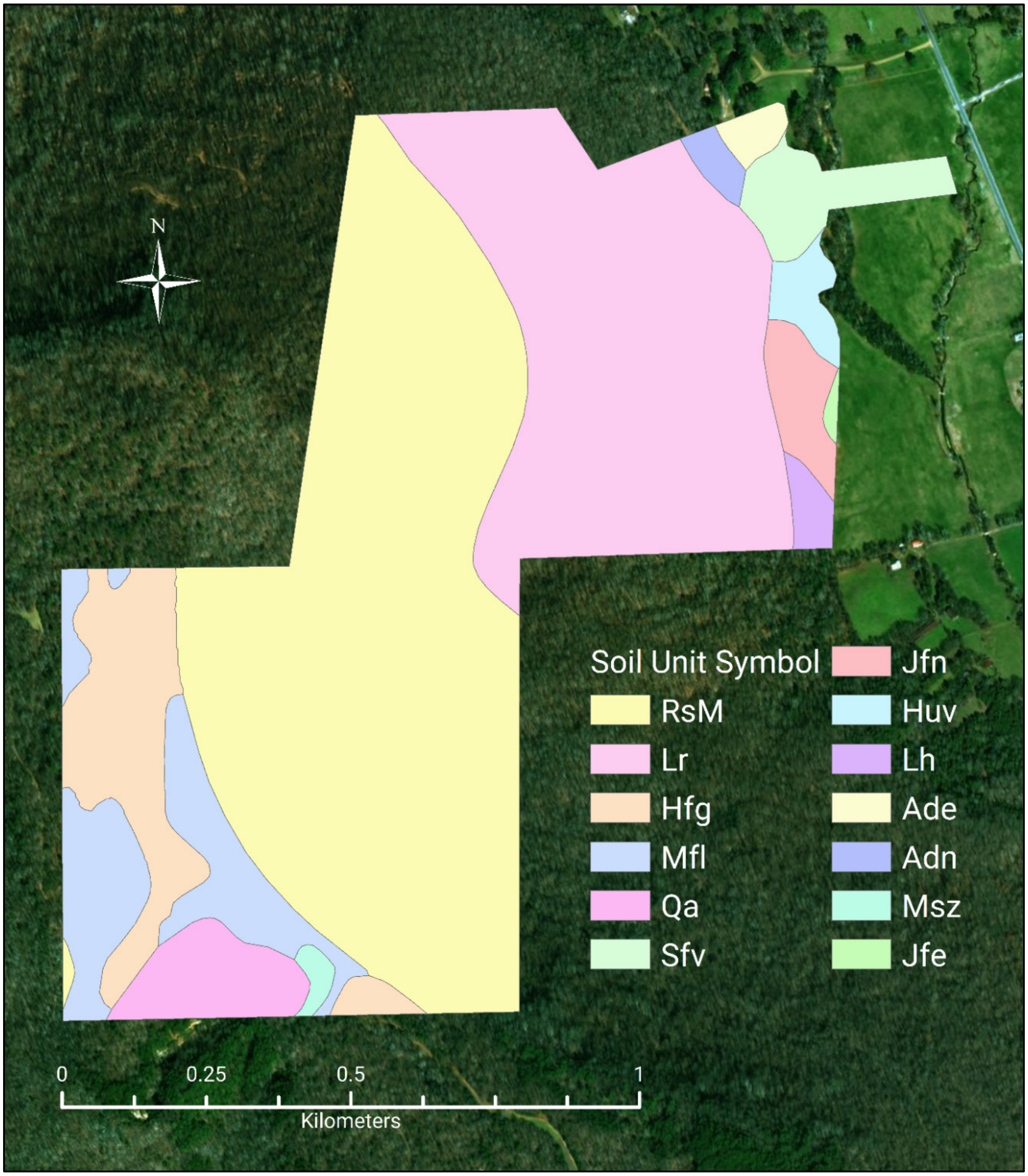


Figure 6. Soil units found inside the monument boundaries. The units are listed in the legend from the largest to the smallest surface area. Data from USDA (2018).

Threats and Stressors

In addition to the erosion caused by flooding along Dry Creek, erosion is removing sediment from within the cave, which could lead to the potential loss of unexamined cultural resources. Both subsidence and slumping have occurred along the wall in the northwest corner of the cave, the location of an excavation from the NGS in 1951. GPR scans conducted by Nick Hermann of Mississippi State University in 2011 indicated the issue is in potential need of treatment, having revealed that more than five cm of cave floor had subsided in an 18-month timespan (Thornberry-Ehrlich 2014). Although the exact cause or causes of the erosion has yet to be definitively determined, the most likely cause is the hydrological environment within the caves. Written communication from Meiman indicated the changes to be increasing over time and in urgent need of action. The erosion in the dry shelter is clearly caused by flowing water removing material, though the underlying processes are not well understood (Ehrman 2014). According to Meiman (written communication, 2011), the most likely cause is poorly compacted backfill from earlier excavations, though it is unknown why this would take more than fifty years to manifest.

4.2.4. Paleontological Resources

Relevance and Context

Fossil resources present opportunities for resource management including field surveys, inventory, monitoring, education, and interpretation. According to Hunt-Foster et al. (2009), the Monteagle Limestone contains crinoid disks, the remains of brachiopods, and blastoids, all of which occur on the roof of Russell Cave itself (Santucci et al. 2001). The Mississippian limestone blocks outside of the monument contain corals, gastropods, brachiopods, bryozoans, echinoderms, crinoids and *Pterotocrinus triebrachiatus* (Thornberry-Ehrlich 2014). In nearby Little River Canyon National Preserve, the Pottsville Formation contains plant remains including lepidodendron, calamites, bark impressions, as well as crinoids (Thornberry-Ehrlich 2014). It may be assumed that those same formations in RUCA are likely to contain similar paleontological resources.

RUCA contains a number of zooarchaeological and ethnobotanical specimens, counting among their number more than sixty species of vertebrates, chenopodium, and mollusks which are indicative of the local Native American diets (Thornberry-Ehrlich 2014, Griffin 1974). Santucci, Kenworthy, and Kerbo's (2006) America's Antiquities: 100 Years of Managing Fossils on Federal Lands provides recommendations and a CRM context for management of these resources.

4.3. Water Quality

The NPS has determined that water quality in its parks is a priority concern and continually examines water quality issues via its Vital Signs Water Quality Monitoring Program (VSWQM). VSQWM is designed to track the accomplishment of Department of the Interior (DOI) goals and standards. This includes the maintenance of acceptable water quality and the improvement of subpar water quality pursuant to the Clean Water Act (CWA). The CWA was passed with the purpose of minimizing pollution of waterways in the US. The CWA requires that all federal agencies follow state standards of quality, so RUCA is subject to the Alabama Water Quality Program (AWQP) managed by the Alabama Department of Environmental Management (ADEM). Title 22, Section 22-22-1 et seq. of the AWQP states its purpose as:

> *... to conserve the waters of the State and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide for the prevention, abatement and control of new or existing water pollution; and to cooperate with other agencies of the State, agencies*

> *of other states and the federal government in carrying out these objectives.* (ADEM Admin. Code r. 335-6-10-.01 2017)

RUCA is home to both surface and groundwater systems due to the local karst geology. Because of this geology, swallets, sinkholes, karst windows, seeps, and springs allow water to move between surface and groundwater conditions with relative ease (The Center for Cave and Karst Studies 2008). The cave is located in the Doran Cove watershed, fed by a natural spring. After passing through the cave system, the stream joins Widow's Creek. Other streams near the head of the Doran Cove watershed have also been linked to the Russell Cave system via dye tracing (The Center for Cave and Karst Studies 2008).

4.3.1 Water Chemistry

Resource Knowledge

The NPS Water Resources Division (WRD) has identified four core field parameters to monitor to assess water quality: water temperature, pH, specific conductance, and dissolved oxygen. Beyond those four categories, the acid neutralizing capacity (alkalinity) and presence of fecal coliform bacteria are also commonly tested in RUCA reporting. Other testing has been carried out to determine the concentration of specific elements in the water, but much of this is based on laboratory work rather than field tests. These lab tests have been described as being of low quality, and none have shown any measures high enough to be of concern for water quality at RUCA (Meiman 2007). Based on testing from the early 1990s to 2014 in and at sites around RUCA, water chemistry values have not changed much over time, and the four important categories hold relatively steady (Hobbs 1994, NPS WRD 1999, Meiman 2007, Cumberland-Piedmont Inventory and Monitoring [CUPN] 2012, CUPN 2013a). The most recent testing in 2012-2013 show that the water is considered "Outstanding Alabama Water" per the measures set by the CWA as formally proclaimed by the state of Alabama (CUPN 2012, CUPN 2013a).

Threats and Stressors

The largest threats to water quality at the monument come from the potential for increased non-point source pollutants related to increased development and industrial activities in the Doran Cove watershed (CUPN 2012, CUPN 2013a). Clear cutting of the nearby woods, new housing developments, septic systems, and the presence of informal garbage dumps in the watershed are all considered to be potential sources of contamination that may negatively impact water quality at the monument (Diggs 2006, Hobbs 1994).

Condition Status

Water quality as measured by chemistry parameters is good at RUCA. Values for individual measures are within state and federal guidelines, with the exception of *E. coli* concentrations spiking after heavy rainfall events, which is a natural pattern as non-point source pollutants are washed into the streams.

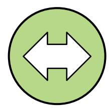
Trend in Condition

The trend is unchanging, as reports ranging from the early 1990s to 2013 show similar values for water chemistry.

Confidence in Assessment

Reporting was carried out using appropriate scientific methods by individuals with the proper training. However, the confidence is medium, as the most recent data is more than five years old at this point (Table 25). Monthly water quality sampling is scheduled to resume in October of 2018 for two years, which should provide an updated view of water quality at the monument.

Table 25. The condition of water chemistry at RUCA.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Water Chemistry		Condition is good based upon measured water chemistry values. Trend is unchanging, as studies beginning in the early 1990s to as recently as 2013 show no major shifts in observed values. Confidence in data quality is medium; proper procedures in sampling methodology were employed, but the most recent information is more than five years old.

4.3.2 Bacteria

Resource Knowledge

The presence of fecal indicator bacteria may indicate the presence of waterborne disease-causing organisms, and their measurement is used as a proxy for these pathogens (Meiman 2007). The indicator bacteria used most often are the total coliform, fecal coliform, enterococci, and fecal streptococci groups, as well as *Escherichia coli* (Meiman 2007). The state of Alabama defines Outstanding Alabama Water as having *E. coli* concentrations no higher than 235 Most Probable Number (NPM)/100 ml, and the EPA recommends that values higher than 298 MPN/100 ml are of concern (Alabama Department of Environmental Management 2016). Bacteria levels are typically below these numbers at RUCA, but they spike following precipitation and flooding events, as animal waste is washed into the cave system. Animal waste is held in storage on the surface and when rainfall events occur, this waste is washed into karst features or the stream channel that feeds RUCA. Figure 7 shows *E. coli* bacteria levels, measured in MPN/100 ml.

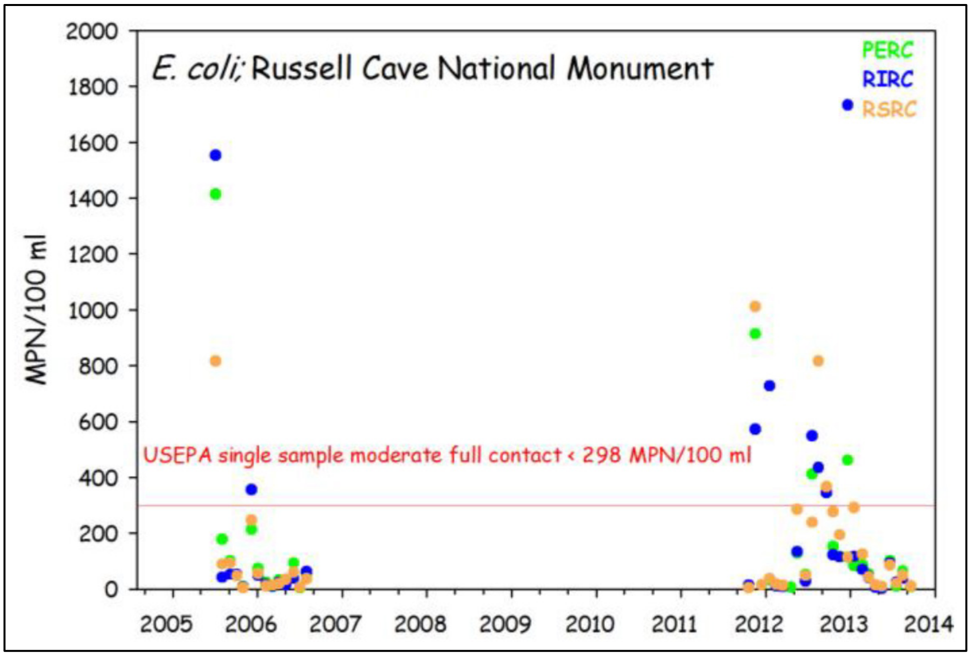


Figure 7. *E. coli* volumes for 2005-2013 as measured in MPN/100 ml (CUPN 2013a).

Threats and Stressors

Rainfall events leading to increased bacterial levels is a natural pattern, but increased development within Doran's Cove is likely to exacerbate the situation. Livestock are raised within the watershed, and no vegetation buffers exist between the livestock and stream channels to reduce contaminants. Additionally, all plumbing in the region is based on septic systems, which have the potential to leak and contaminate water.

Condition Status

The condition warrants moderate concern, as levels of bacteria frequently rise higher than Alabama and EPA standards recommend.

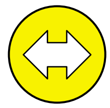
Trend in Condition

There is no change in trend, as measurements over more than a decade indicate that levels regularly fluctuate.

Confidence in Assessment

Reporting was carried out using appropriate scientific methods by individuals with the proper training. However, the confidence is medium, as the most recent data is more than five years old at this point (Table 26). Monthly water quality sampling is scheduled to resume in October of 2018 for two years, which should provide an updated view of water quality at the monument.

Table 26. The condition of RUCA bacterial contaminants in water.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Bacterial Presence		Condition warrants moderate concern based upon measured bacterial volume in water. The volume of bacteria measured regularly fluctuates along with precipitation events. Trend is unchanging, as studies beginning in the mid-2000s to as recently as 2013 show no major shifts in observed values. Confidence in data quality is good due to evidence of proper procedure in sampling methodology.

4.4. Biological Integrity

4.4.1. Freshwater Wetland Communities

Resource Knowledge

Wetlands are low-lying areas that are covered with shallow water all or part of the time. In addition to the moisture component, distinctive aquatic plants adapted to the saturated soil conditions are a common feature of wetlands. Wetlands are an essential source of food, water, and shelter for many species that often rely on wetlands for their survival. Based on the National Wetland Inventory (NWI), there were zero wetlands present at RUCA. That being said, the differences between the many types of wetlands necessitate the use of several classification systems to accurately survey an area. Roberts and Morgan (2007) assembled data for a wetland inventory using two different classification systems: Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979) and Hydrogeomorphic Classification for Wetlands (HGM) (Brinson 1993). The Wetland Delineation Manual constructed by the 1987 U.S. Army Corps of Engineers also aided researchers in their search for wetlands. Roberts and Morgan (2007) reported three wetlands located at RUCA that totaled approximately 0.07 ac with the average wetland size being roughly 0.02 ac. These sites are marked in Figure 8 by teal dots.

The HGM classification system categorized two of the sites as depression wetlands and one as a slope/seep wetland. The wetlands at RUCA maintain both woody and herbaceous vegetation with common species including: red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), and clearweed (*Pilea pumila*). Table 27 lists all plants identified at the sites. Using the Cowardin system, two of the wetlands were dominated by deciduous trees (PFO1) and were temporarily flooded, and the other wetland was dominated by persistent, herbaceous vegetation (PEM1) and was seasonally flooded. Roberts and Morgan (2007) reported that wetlands at RUCA are in good condition and could be utilized in model development projects. All three wetlands sustained the plants found primarily in wetland habitats, and one had some suggestion of supporting various breeding habitats of amphibians. Figures 9-11 show images of the wetland sites.

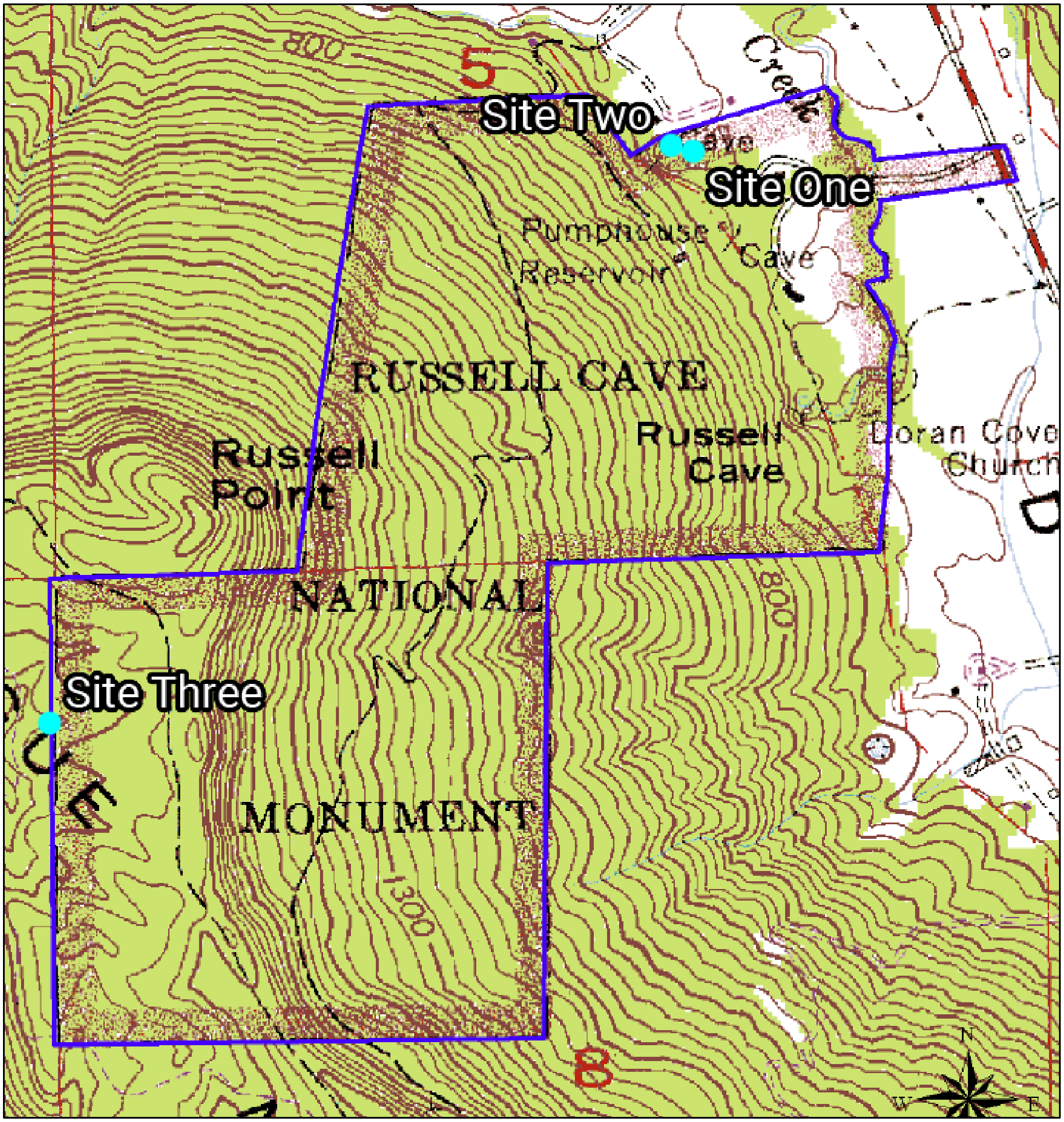


Figure 8. The locations of the three wetlands identified within RUCA marked by teal dots on the map. Adapted from Roberts and Morgan (2007).

Table 27. All plant species identified within the wetlands (Roberts and Morgan 2007).

Scientific Name	**Common Name**	**Indicator Status**
Acer negundo	Boxelder	Facultative Wetland
Acer rubrum	Red Maple	Facultative
Chasmanthium laxum	Slender Woodoats	Facultative Wetland
Fraxinus pennsylvanica	Green Ash	Facultative Wetland
Ligustrum vulgare	European Privet	Facultative
Panicum sp.	Panic Grass	Unknown
Pilea pumila	Clear Weed	Facultative Wetland
Polygonum sp.	Smartweed	Unknown
Sphagnum sp.	Sphagnum	Unknown
Ulmus rubra	Slippery Elm	Facultative

Site ID – RC 1

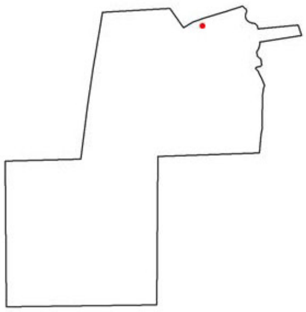
Area (ac) – 0.02

UTM – E 608473

N 3871554

Cowardin Class – PFO1A

HGM Class – Depression



Dominant Species: ***Aster simplex, Pilea pumila, Fraxinus pennsylvanica***

Figure 9. Wetland site one, image from Roberts and Morgan (2007).

Site ID – RC 2

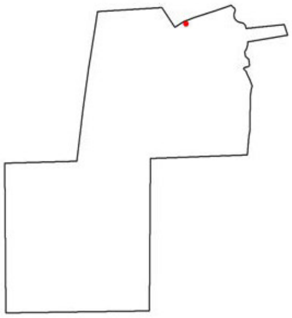
Area (ac) – 0.04

UTM – E 608441

N 3871564

Cowardin Class – PEM1C

HGM Class – Depression



Dominant Species: ***Pilea pumila, Panicum sp., Ligustrum vulgare, Acer negundo***

Figure 10. Wetland site two, image from Roberts and Morgan (2007).

Site ID – RC 3

Area (ac) – 0.01

UTM – E 607439

N 3870608

Cowardin Class – PFO1A

HGM Class – Slope

Dominant Species: ***Chasmanthium laxum, Acer rubrum***

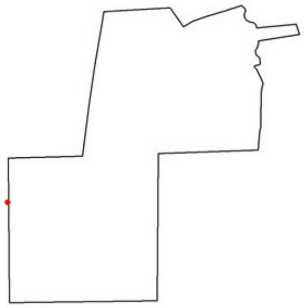


Figure 11. Wetland site three, image from Roberts and Morgan (2007).

Threats and Stressors

The scattered wetlands have a potential threat of over usage that generates moderate concern. While Roberts and Morgan (2007) describe the wetlands as "generally good," these small, isolated islands may face depletion due to their high demand. The wetlands served several purposes including: surface water storage, groundwater discharge to streams, carbon and nutrient export, provide wildlife habitat, support wetland plants, cultural value, research/scientific value, and economic value, and education potential. The NWI reported zero wetlands and Roberts and Morgan (2007) reported three, it is presumed they were missed largely due to the size of the wetlands. The total area inside the RUCA boundary line was surveyed by foot which allowed Roberts and Morgan (2007) to uncover the hidden areas. Additionally, the three wetlands located could serve as a reference for scientific studies since they have not been especially impacted like most wetlands on private property.

Trend in Condition

No trend was assigned to the wetland communities, since a single baseline study is insufficient to establish a trend.

Confidence in Assessment

The confidence to construct the assessment is medium (Table 28).. Thematic information was collected using numerous organized and controlled methods; the data was gathered throughout the monument covering all areas and habitats. Spatially, the site of each wetland was established while Thomas and Morgan (2007) collected data on foot and geospatially recorded locations. The researchers leading this study had expertise in surveying and identifying wetlandsTemporal data quality is insufficient since it has been more than five years since the wetlands assessment occurred.

Table 28. The condition of RUCA freshwater wetlands.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Wetlands	Wetland Communities		Condition warrants moderate concern based upon the small isolated nature of the three wetlands. No trend can be assigned based upon a single study. Confidence in thematic and spatial quality of data is good, in that sites where documented and survey conducted by experts (Roberts and Morgan 2007). Survey was conducted more than 5 years ago, which makes temporal data insufficient, therefore confidence in the assessment is medium.

4.4.2. Forest Vegetation Communities

Relevance and Context

Although initially established to protect cultural resources associated with Russell Cave, RUCA also preserves some high-quality examples of the surrounding mixed forest communities found at the southern end of the Appalachian Mountains (Schotz et al. 2006). While most of the forest communities found at RUCA are fairly common and relatively secure, the Shumard Oak - Chinquapin Oak Mesic Limestone Forest is considered uncommon or rare throughout its range

(Schotz et al. 2006). RUCA has high quality examples of this forest community, which is considered a high priority community in terms of conservation (Schotz et al. 2006). As part of a broader effort to evaluate the condition of the natural resources found at RUCA, information regarding the forest vegetation communities at the site can be a useful tool for monument managers and their partners in their efforts to make informed decisions about resource management (Schotz et al. 2006).

Resource Knowledge

Schotz et al. (2006) conducted a baseline study of the vascular plants and vegetative communities within RUCA during 2003-2004. After establishing 12 1-ha plots positioned to sample all the vegetative communities within the site, the researchers chose representative quadrats within each plot and recorded the plant species present, percent cover, and other environmental characteristics (Schotz et al. 2006). The plots were revisited at different times of the year to ensure a more accurate species list (Schotz et al. 2006). Based on species composition and observed environmental factors, the ecological community of each plot was determined using the National Vegetation Classification (Anderson et al. 1998, Grossman et al. 1998).

A total of 10 distinct vegetative communities were identified at RUCA (Table 29): Rich Low-Elevation Appalachian Oak Forest, White Oak - Mixed Oak Dry-Mesic Alkaline Forest, Shumard Oak - Chinquapin Oak Mesic Limestone Forest, Xeric Ridgetop Chestnut Oak Forest, Chestnut Oak - Shagbark Hickory - Sugar Maple Forest, Rich Levee Mixed Hardwood Bottomland Forest, Cultivated Meadow, Appalachian Mafic Cliff, and Cumberland Plateau Sandstone Cliff (Schotz et al. 2006). Although most of the forest communities documented at RUCA are regarded as rather common or reasonably secure, the Shumard Oak-Chinquapin Oak Mesic Limestone Forest has a high conservation priority (G2G3) due to its restricted distribution and its designation as a globally rare forest community (Schotz et al. 2006).

In addition to this initial baseline study, twenty permanent monitoring plots were later established at RUCA as part of a broader long-term effort to monitor forest vegetation communities within CUPN parks (Bledsoe 2017). To date, this has resulted in two resource briefs for RUCA: Forest Vegetation Resource Brief – Russell Cave National Monument (CUPN 2013b) and Russell Cave National Monument Forest Vegetation Monitoring Summary, 2011-2015 (Bledsoe 2017). The plots measure 20 meters x 20 meters, with data collected grouped into several broad categories (e.g., species presence, canopy cover, plot characteristics, tree growth and health, forest community classification, and evidence of pests) (Bledsoe 2017). Of the 20 plots established in the monument, six (30%) were classified as the Shurmard Oak-Chinquapin Oak Mesic Limestone Forest. These six plots were also the most diverse of all of the 20 monitoring plots (Bledsoe 2017).

Table 29. Ecological systems and associations of vegetation identified at RUCA (Table 6 from Schotz et al. 2006). Based on the National Vegetation Classification (NVC) system.

Ecological system	NVC association (Scientific name)	NVC association (Common name)	Global Rank[1]
Semi-natural Forest	*Juniperus virginiana* var. *virginiana* – (*Quercus* spp.) Forest	Red-cedar Successional Forest	GNR
South and Central Appalachian Cove Forest[2]	*Quercus alba* – (*Q. rubra, Acer saccharum, Fagus grandiflora*)/*Aesculus flava* Forest	Rich Low-Elevation Appalachian Oak Forest	G4
Southern Ridge and Valley Dry Calcareous Forest[2]	*Quercus alba-Q. rubra-Q. muehlenbergii/Cercis canadensis*	White Oak-Mixed Oak Dry Mesic Alkaline Forest	G4G5
Southern Ridge and Valley Dry Calcareous Forest[2]	*Quercus shumardii-Q. muehlenbergii-Acer* (*barbatum, leucoderme, saccharum*)/*Ostrya virginiana*	Shumard Oak-Chinquapin Oak Mesic Limestone Forest	G2G3
Southern Appalachian Oak Forest[2]	*Quercus prinus*-(*Q. coccinea*)/*Carya pallida/Vaccinium arboretum-V. pallidum* Forest	Xeric Ridgetop Chestnut Oak Forest	G4G5
Southern Interior Low Plateau Dry Oak Forest[2]	*Quercus prinus-Carya ovata-Q. rubra/Acer saccharum* Forest	Chestnut Oak-Shagbark Hickory-Sugar Maple Forest	G4?
South-Central Interior Small Stream and Riparian[2]	*Platanus occidentalis-Celtis laevigata-Liriodendron tulipifera/Lindera benzoin-Arundinaria gigantean/Amphicarpaea bracteata* Forest	Rich Levee Mixed Hardwood Bottomland Forest	G3G4Q
Exotic-dominated Community	*Lolium* (*arundinaceum, pretense*) Herbaceous vegetation	Cultivated Meadow	GNA
Southern Appalachian Montane Cliff and Talus[2]	(*Hydrangea arborescens, Toxicodendron radicans*)/*Heuchera americana*-(*Dichanthelium depauperatum, Woodsia obtusa*) Shrubland	Appalachian Mafic Cliff (Low-Elevation Type)	GNR
Central Interion Highlands Dry Acidic Glade and Barrens[2]	*Asplenium montanum-Heuchera parviflora var. parviflora-Silene rotundifolia* Sparse Vegetation	Cumberland Plateau Sandstone Cliff (Dry Type)	G3G4

[1]Definition for interpreting NatureServe global rank:

G1 = Critically imperiled globally

G2 = Imperiled globally

G3 = Rare or uncommon

G4 = Widespread, abundant, and apparently secure, but with cause for long term concern

G5 = Demonstrably widespread, abundant and secure

GNA = Not ranked (usually because an exotic species dominated type or human modified)

GNR = Not ranked yet

Qualifiers:

? = Inexact numeric rank

Q = Questionable Taxonomy

[2] = Natural community

Threats and Stressors

A majority of RUCA is comprised of second and third growth forests, with some areas near the interpretive center and resident cabin mowed to maintain a lawn and early successional field (Schotz et al. 2006). Notable stressors affecting forest vegetation communities include non-native plant species, climate change, and insect pests (Bledsoe 2017). Invasive species that are particularly problematic for the mesic hardwood and floodplain forests throughout the site include Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), and Japanese stiltgrass (*Microstegium vimineum*) (Bledsoe 2017, Schotz et al. 2006). However, RUCA had the fourth-lowest average percentage of non-native plant species (1.2%) in monitored plots of all the CUPN parks, with no new non-native plants found that had not been previously documented (Bledsoe 2017).

Importantly, evidence indicating the presence of emerald ash borer (*Agrilus planipennis*) was documented in RUCA in 2016, which aligns with confirmation of this insect pest in northern Alabama by the USDA (Bledsoe 2017). Data collected from the permanent monitoring plots also suggests potential changes to forest composition and regeneration. Preliminary data from 2011-2012 also indicate a possible future transition in the canopy from oak-hickory towards species with a higher shade tolerance such as maples, which may have negative consequences for other wildlife species found in RUCA (CUPN 2013b).

Condition Status

The forest vegetation communities are in good condition. A total of 10 distinct vegetative communities were identified at RUCA, indicating a high level of forest biodiversity for the relatively small size of the site. In addition, RUCA contains a relatively high level of per-plot species diversity and has the fourth-lowest percentage of non-native plant species among the CUPN parks (Bledsoe 2017).

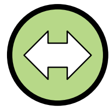
Trend in Condition

Data collected from the baseline study (Schotz et al. 2006) and the permanent monitoring plots (Bledsoe 2017, CUPN 2013b) indicate that the condition of the forest vegetation communities at RUCA is largely unchanging.

Confidence in Assessment

The confidence used to make the assessment was high (Table 30). Data on the forest vegetation communities reviewed were collected from 2003-2004 (Schotz et al. 2006) and also from 2011-2015 using scientifically-sound sampling techniques by researchers with comprehensive experience in identifying and examining regional vegetative communities. In addition, all of the communities were documented with photos and geolocation information and identified using the National Vegetation Classification developed by Anderson et al. (1998) and Grossman et al. (1998).

Table 30. The condition of RUCA forest vegetation communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Forest Vegetation Communities	Forest Vegetation Communities Composition and Diversity		The condition of the RUCA forest vegetation communities is good. 10 distinct vegetative communities were identified, indicating a relatively high level of forest biodiversity. Data collected from 2003 – 2004 (Schotz et al. 2006) and also from 2011 – 2015 (Bledsoe 2017, CUPN 2013b) indicated the condition of the forest vegetation communities is largely unchanged. Confidence in the assessment was high.

4.4.3. Vascular Plants

Relevance and Context

Forests in eastern United States are undergoing dynamic changes in composition due to altered land use and fire, increased herbivories, and changing moisture regimes (Adams et al. 2012). They stated that the vegetation composition and structure may change in the future based on the comparison of the canopy tree versus understory species. National parks are susceptible to invasion on introduced plant species and the existence of non-native species may influence biodiversity in native ecosystem at any scales.

Resource Knowledge

The vegetation classification plots at RUCA were established by NatureServe using GIS layers supplied by National Park Service's Cumberland Piedmont Network (Schotz et al. 2006), and vegetation maps were completed by the University of Georgia (Jordan and Madden 2010). Nine permanent plots (1-ha each) on a grid system and three additional plots off the grid were established, ecological community inventory/classification of all vegetation association as defined by the National Vegetation Classification (Grossman et al. 1998) were documented, and any species found in the plot that were not already in the herbarium collection were collected. Any unknown species were classified using the Integrated Taxonomic Information System (ITIS) (USDA 2004). To assess the inventory, PC-ORD and "jackknife" methods (McCune and Grace 2002, McCune and Mefford 1999) were used; the overall estimate predicted that between 86 and 98% of the species in the monument were documented during the survey (Schotz et al. 2006). The CUPN has gathered updated information on vascular plants through the forest vegetation monitoring (CUPN 2013b, Bledsoe 2017).

Currently, over 500 vascular plant species are present at RUCA (NPSpecies 2018), which is impressive for the monument's small size. DiPietro (1994) documented 448 vascular plant species during her inventory and Schotz et al. (2006) reported 460 vascular plant species (excluding varieties and subspecies) during their inventory. CUPN vegetation monitoring has documented an additional 32 species (Bledsoe 2017) and three new species have also been observed and identified on iNaturalist by RUCA resource manager Mary Shew (iNaturalist 2018a, b, c, d). Despite its small size, RUCA has the third highest plot-level diversity within the CUPN network, averaging 65 species per plot (Bledsoe 2017). The monument also contains one of the 20 most diverse plots across the network. Out of all the vascular plant species in the monument, one species-ghost plant (*Monotropa uniflora*)-is federally ranked as a species of concern (USFWS 2017). No other federally endangered, threatened, or candidate list species are present and most species are considered globally secure (G4 or G5 NatureServe ranking).

A few species on the monument list are highly ranked in the state of Alabama (Natureserve 2018). One species, twoleaf miterwort (*Mitella diphylla*) is considered critically imperiled (S1) and has not been observed since the DiPietro (1994) inventory. A few species are considered imperiled (S2), including goldenseal (*Hydrastis canadensis*), American smoketree (*Cotinus obovatus*), American beakgrain (*Diarrhena americana*), cream avens (*Geum virginianum*), white bergamot (*Monarda clinopodia*), Canadian lily (*Lilium canadense*), American bittersweet (*Celastrus scandens*), and pinesap (*Monotropa hypopithys*). One vegetation community, the Shumard Oak – Chinquapin Oak Mesic Limestone Forest (CEGL008442), is currently a G2G3 based on NatureServe global ranking system. This means that this community is "rare or uncommon and at worst imperiled globally" (Schotz et al. 2006). This forest is restricted to relatively small patches of soil derived from Bangor and Monteagle Limestones and considered the highest priority in terms of conservation concern in RUCA. The relatively high per-plot species diversity at RUCA is likely attributed to the fact that more than half of the plots were located on limestone-derived soils on middle and lower slopes, including the Shumard Oak – Chinquapin Oak Mesic Limestone Forest (Bledsoe 2017).

Threats and Stressors

RUCA contains a high diversity of vascular plant species, with most of them considered globally secure and a few of them being criticially imperiled/imperiled in the state of Alabama. Because RUCA is located in a rural area, threats to the overall vascular plant community are low. Invasive exotic plants are present at RUCA, but they are not prevalent. Of the 249 plant species identified at RUCA during forest vegetation monitoring between 2011 and 2015, only 7 of them (2.8%) were non-native, and non-native plants comprised only 1.2% of the overall average plot-level species diversity at RUCA, the fourth-lowest of all the CUPN parks (Bledsoe 2017). See Section 4.4.5 for more detail on invasive/exotic plant prevalence at RUCA. Emerald ash borer is also likely to become an emerging concern at RUCA as mentioned in Section 4.4.2, as ash tree species are common throughout the monument.

Condition Status

Due to the high vascular plant diversity and low exotic invasive plant prevalence, the condition of RUCA vascular plants is in good condition. Although most of the non-native species present are harmless and only few of them are aggressive, management practices to remove or reduce the abundance of exotic species is needed to make sure native vegetation will not be adversely harmed. This includes monitoring/management of emerald ash borer as it becomes established in the monument in the near future.

Trend in Condition

No trend was assigned to the vascular plants, since single baseline studies or inventories are inadequate to establish a trend, and current monitoring has not been implemented long enough yet for analysis of vascular plant trends.

Confidence in Assessment

The confidence used to make the assessment was medium (Table 31). Data were collected using a variety of scientifically-sound methods and were collected from plots within the monument. Two thorough vegetation inventories have occurred at the monument and forest vegetation monitoring is currently being implemented. The researchers conducting all of these studies have had extensive experience sampling the vegetation of the region.

Table 31. The condition of RUCA vascular plants.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Vascular Plants	Vegetation Community Quality		The condition of RUCA vascular plants is good, due to the high vascular plant diversity and low exotic invasive plant prevalence. No data were available to evaluate trends. Although data were adequately collected, analyses of additional data currently being collected over time would increase confidence.

4.4.4. Non-vascular Plants

Relevance and Context

Alabama is home to more than 400 species of bryophytes and the greatest diversity is found in the Cumberland Plateau physiographic section in northern Alabama (Davidson 2017). Bryophytes are mostly terrestrial, generally small, and abundant in moist areas, and they can grow on rocks, logs, soil, and trees. Due to their small size, they look unfamiliar to the general public and can be easily overlooked, trampled, and disturbed.

Resource Knowledge

Smith and Davidson (1995) conducted an inventory of the bryophytes at RUCA in June 1993 to December 1994. Three field surveys were conducted to sample bryophytes that covered sites such as cap rock and sandstone outcrops, upper slope boulder fields, lower slope outcrops, and Big Sink Hole. Floristic information on the mosses of Alabama was obtained via correspondence and literature surveys. In addition, voucher specimens were collected and rare or significant species found were reported to the Alabama Natural Heritage Program.

RUCA has high species richness for bryophytes, see Table 32. In RUCA, 120 mosses (including varieties) and 39 liverworts (including subspecies) were documented (Smith and Davidson 1995). No hornworts were reported from this inventory. Of all bryophytes collected, 11 mosses and 3 liverworts were new records to Alabama and 100 mosses and 39 liverworts were first reports to Jackson County. The occurrence and distribution of bryophytes observed and sampled in RUCA considered to be: “Rare and restricted” was 32 (24%) taxa, “Infrequent and Restricted” was 24 (18%) taxa, “Infrequent and Scattered” was 38 (29%) taxa, “Common and Scattered” was 6 (5%) taxa, and “Common and Widespread” was 31 (24%) taxa. The occurrence of epiphytic lichens and bryophytes is strongly influence by suitable substrate, stand age, and forest continuity (Fritz et al. 2008). Minimizing disturbance in the vegetation communities will help conservation of non-vascular plants.

Table 32. Checklist of Bryophytes of RUCA (from Smith and Davidson, 1995). Occ/Dist: Occurrence and Distribution; CS: Common and Scattered. CW: Common and Widespread; IR: Infrequent and Restricted; IS: Infrequent and Scattered; RR: Rare and Restricted.

Bryophyte Assemblage	**Scientific Name**	**Occ/Dist**
Mosses	*Amblystegium serpens* (Hedw.) B.S.G.	IS
	Anomodon attenuates (Hedw.) Heub.	CW
	Anomodon minor (Hedw.) Feurnr.	IR
	Anomodon rostratus (Hedw.) Schimp.	CW
	Anomodonviticulous (Hedw.) Hook. & Tayl.	RR
	Atricum angustatum (Brid.) Bruch & Schimp. In B.S.G.	CW
	Atricum undulatum var. *oerstedianum* (Hedw.) P.-Beauv.	IS
	Aulacomnium heterostichum (Hedw.) Bruch & Schimp. In B.S.G.	CW
	Barbula reflecta (Brid.) Brid.= *Didymodon fallax* var. *reflexus*	RR
	Batramia pomiformis Hedw.	IS
	Brachythecium oxycladon (Brid.) Jaeg.	CS
	Brachythecium plumosum (Hedw.) Schimp. In B.S.G.	RR
	Brachythecium rivulare B.S.G	RR
	Brotherella tenuirostris (Bruch & Schimp in Sull.) Broth. = *Pylaisiadelpha tenuirostris* (Bruch & Schimp in Sull.) Buck	RR
	Bryhnia graminicolor (Brid.) Grout	IR
	Bryhnia novae-angliae (Sull. & Lesq. In Sull.) Grout	IR
	Bryoandersonia illicebra (Hedw.) Robins.	CW
	Bryum argenteum Hedw.	IR
	Bryum capillare Hedw.	IS
	*Campylium chrysophyllum (*Brid.) J. Lange	CW
	Campylium hidpidulum (Brid.) Mitt.	IS
	Clasmatodon parvulus (Hampe) Hook. & Wils. Ex Sull. In Gray	CW
	Cryphaea glomerata Bruch & Schimp. Ex Sull	IS
	Ctenidium molluscum (Hedw.) Mitt.	IS
	Dicranella heteromalla var. *sericea* (Schimp.) Pfeff.	IR
	Dicranum fulvum Hook	IR
	Dicranum montanum Hedw.	CS

Table 32 (continued). Checklist of Bryophytes of RUCA (from Smith and Davidson, 1995). Occ/Dist: Occurrence and Distribution; CS: Common and Scattered. CW: Common and Widespread; IR: Infrequent and Restricted; IS: Infrequent and Scattered; RR: Rare and Restricted.

Bryophyte Assemblage	**Scientific Name**	**Occ/Dist**
Mosses (continued)	*Dicranum scoparium* Hedw.	IS
	Diphyscium foliosum (Hedw.) Mohr.	IS
	Ditricum pallidum (Hedw.) Hampe	IS
	Ditricum rhyncostegium Kindb	RR
	Drummondia prorepens (Hedw.) Britt.	CW
	Encalypta procera Bruch	RR
	Entodon macropodus (Hedw.) C. Meull.	CW
	Entodon seductrix (Hedw.) C. Meull.	IS
	Eucladium verticillatum (Brid.) Bruch & Schimp. In B.S.G.	RR
	Eurhynchium hians (Hedw.) Sande Lac.	IR
	Eurhynchium pulchellum (Hedw.) Jenn.	IR
	Fissidens bryoides Hedw.	IS
	Fissidens bushii (Card. & Ther.) Card. & Ther.	IS
	Fissidens cristatus Wils. Ex Mitt. = F. dubius P Beauv.	CW
	Fissidens ravenelli Sull.	IR
	Fissidens subbasilaris Hedw.	CS
	Fissidens taxifolius Hedw.	IS
	Forrstroemia trichomitria (Hedw.) Lindb.	CW
	Grimmia alpicola Sw. ex. Hedw.	CS
	Grimmia alpicola var. *rivularis* (Brid.) Wahlenb. = *Schistidium rivulare* var. *rivulare* (Brid.)	CS
	Grimmia pilifera P. Beauv.	IS
	Gymnostomum aeruginosum Sm.	RR
	Haplohymenium triste (Ces. In De Not.) Kindb.	CW
	Hedwigia ciliate (Hedw.) P. Beauv.	IS
	Homalotheciella subcapillata (Hedw.) Broth.	IS
	Hygroambystegium tenax (Hedw.) Jenn.	IR
	Hypnum curvifolium Hedw.	IS
	Isopterygium elegans (Brid.) Lindb. = *Pseudotaxiphyllum elegans* (Brid.) Iwats.	IS
	Isopterygium pulchellum (Hedw.) Jaeg. = *Isopterygium pulchella* (Hedw.) Iwats.	RR
	Leucobryum albidum (Brid. Ex P. Beauv.) Lindb	CW
	Leucodon brachypus Brid.	RR

Table 32 (continued). Checklist of Bryophytes of RUCA (from Smith and Davidson, 1995). Occ/Dist: Occurrence and Distribution; CS: Common and Scattered. CW: Common and Widespread; IR: Infrequent and Restricted; IS: Infrequent and Scattered; RR: Rare and Restricted.

Bryophyte Assemblage	Scientific Name	Occ/Dist
Mosses (continued)	*Leucodon julaceus* (Hedw.) Sull.	CW
	Mnium affine var. *ciliare* (C. Muell.) Schimp. = *Plagiomnium ciliare* (C. Muell.) T. Kop.	CW
	Mnium cuspidatum Hedw. = *Plagiomnium cuspidatum* (Hedw.) T. Kop.	CW
	Mnium lingirostre Brid. = Plagiomnium rostratum (Schrad.) T. Kop.	IS
	Mnium marginatum (With.) Brid. ex. P. Beauv.	RR
	Mnium punctatum Hedw.	RR
	Mnium stellare Hedw.	RR
	Myurella sibirica (C. Muell.) Reim.	RR
	Orthroticum ohioense Sull. & Lesq. In Aust.	IS
	Orthroticum strangulatum P. Beauv.	IS
	Philonotis fontana (Hedw.) Brid.	IR
	Physcomitrium pyriforme (Hedw.) Hampe	IR
	Plagiotheciumcavifolium (Brid.) Iwats.	RR
	Platydictya confervoides (Brid.) Crum	RR
	Platygyrium repens (Bruid.) Schimp. In B.S.G.	CW
	Pogonatum pensilvanicum (Hedw.) P. Beauv.	IR
	Pohlia nutans (Hedw.) Lindb.	IR
	Polytrichum commune Hedw.	IR
	Ptychomitrium incurvum (Schwaegr.) Spruce	IR
	Rhodobryum roseum (Hedw.) Limpr.	IS
	Rhynchostegium serrulatum (Hedw.) Jaeg. = *Steerecleus serrulatus* (Hedw.) Robins.	IS
	Schwetschkeopsis fabronia (Schwaegr.) Broth.	IS
	Sematophyllum demissum (Wils.) Mitt.	CS
	Taxiphyllum deplanatum (B.S. ex. Sull.) Fleisch.	RR
	Taxiphyllum taxirameum (Mitt.) Fleisch.	IR
	Thamnobryum alleghaniense (C. Muell.) Nieuwl.	RR
	Thelia hirtella (Hedw.) Sull in Sull. & Lesq.	CW
	Thuidium delicatum (Hedw.) Schimp. In B.S.G.	IS
	Thuidium pygmaeum (Hedw.) Lindb. = *Cyrto-hypnum pygmaeum* (Schimp. In B.S.G.) Buck & Crum	IR
	Timmia megapolitana Hedw.	RR

Table 32 (continued). Checklist of Bryophytes of RUCA (from Smith and Davidson, 1995). Occ/Dist: Occurrence and Distribution; CS: Common and Scattered. CW: Common and Widespread; IR: Infrequent and Restricted; IS: Infrequent and Scattered; RR: Rare and Restricted.

Bryophyte Assemblage	**Scientific Name**	**Occ/Dist**
Mosses (continued)	*Tortella humilis* (Hedw.) Jenn	IS
	Tortula pagorum (Milde) De Not.	IR
	Trichostomum tenuirostre (Hook. & Tayl.) Lindb. = *Oxystegus tenuirostris* (Hook. & Tayl.) A.J.E. Sm.	RR
	Wessia controversa Hedw.	CW
Liverworts	*Asterella tennella* (L.) P. Beauv	RR
	Calypogeia fissa ssp. *neogaea* Schust.	CW
	Cephaloziella rubella (Nees) Warnst.	RR
	Chiloscypus pallescens (Ehrh.) Dumort.	IR
	Cololejeunea biddlecomiae (Aust.) Evans	CW
	Cololejeunea minutissima (Smith) Schiffin.	RR
	Cololeujenea ornata Evans	RR
	Conocephalum conicum (L.) Lindb.	IR
	Diplophyllum apiculatum (Evans) Steph.	CW
	Dumorrtiera hirsute (Sw.) Nees	IR
	Frullania tamarisci ssp. *asagrayana* (Mont.) Hatt.	IS
	Frullania eboracensis ssp. *virginica* (Gott.) Schust.	CW
	Frullania ericoides (Nees) Mont.	CW
	Frullania inflate Gott.	CW
	Frullania kunzei Lehm. & Lindenb.	CW
	Frullania riparia Hampe ex Lehm.	RR
	Lejeunea laetevirens Nees et Mont.	IS
	Lejeunea sharpie (Schust.) Schust.	RR
	Lejeunea ulicina (Tayl.) Gott.	IS
	Leucolejeunea clypeata (Schwein.) Evans	CW
	Leucolejeunea unciloba (Lindenb.) Evans	CW
	Lophocolea cuspidata (Nees) Limpr.	IR
	Locopholea heterophylla (Schrad.) Dum.	CW
	Marchantia polymorpha L.	RR
	Metzgeria myriopoda Lindb.	CW
	Odontoschisma prostatum (Sw.) Trev.	IR
	Plagiochila asplenioides ssp. *porelloides* (Torrey ex Nees) Schust.	RR
	Plagiochila invisa (Schust.) Schust.	RR

Table 32 (continued). Checklist of Bryophytes of RUCA (from Smith and Davidson, 1995). Occ/Dist: Occurrence and Distribution; CS: Common and Scattered. CW: Common and Widespread; IR: Infrequent and Restricted; IS: Infrequent and Scattered; RR: Rare and Restricted.

Bryophyte Assemblage	Scientific Name	Occ/Dist
Liverworts (continued)	*Plagiochila undulata* Sull.	IS
	Plagiochila virginica Evans	RR
	Porella piñata L.	IS
	Porella platyphylloidea (Schwein.) Lindb.	CW
	Radula australis Aust.	IS
	Radula mollis Lindb, et Gott.	IS
	Radula obconica Sull.	RR
	Reboulia hemisphaerica (L.) Raddi	IS
	Rectolejeunea maxonii Evans	IS
	Riccardia chamedryfolia (With.) Grolle	IS
	Scapania nemorosa (L.) Dum.	IS

Threats and Stressors

The specialized habitat of bryophytes in RUCA such as the non-calcareous sandstone palisades warrant attention/monitoring although they were less diverse than the cave sites due to dry, upland exposure (Smith and Davidson 1995). Since there is no official list of endangered or threatened species of bryophytes for Alabama, the protection of the species is only those provided by The National Park Service mandate. With 24% of bryophytes being rare and restricted and 42% have restricted distribution in RUCA, their critical habitat should have high priority for preservation and conservation.

Condition Status

The condition of bryophytes in RUCA warrants moderate concern. Most of the species have restricted or scattered distribution within the monument. With the existence of invasive species at the monument that could alter the native vegetation communities, it may also affect the bryophyte communities. Bryophytes are sensitive to natural fluctuations in humidity; therefore, many species are restricted to microhabitats with specific microclimates (Hallingback and Hodgetts 2000). Efforts to prevent and reduce disturbance in microhabitats for non-vascular plants will ensure their continuing presence within the monument.

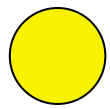
Trend in Condition

No trend was assigned to the non-vascular plants, since single baseline studies or inventories are inadequate to establish a trend.

Confidence in Assessment

The confidence used to make the assessment was medium (Table 33). Data were collected throughout the monument covering all habitats, using onsite field survey, correspondence and literature methods. The original bryophyte survey was conducted June 1993 to December 1994 (Smith and Davidson 1995). The researchers conducting the study have expertise and experience in the field.

Table 33. The condition of RUCA non-vascular plants.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Non-vascular Plants	Non-vascular plant community quality		The condition of non-vascular plants/bryophytes in RUCA warrants moderate concern. No trend was assigned at this time without more than a baseline study. Data quality fair, adequately collected and spatially explicit. The confidence in the assessment was medium. Although experts in their fields conducted sampling, the data were older than five years.

4.4.5. Invasive/Exotic Plants

<u>Relevance and Context</u>
Biological invasions affect biodiversity worldwide at various scales (Hejda et al. 2009). National parks are susceptible to invasion although some types of habitats are invaded more easily than others. Successful management of invasive plants will require active attempt to prevent new introductions, early detection and rapid response, and continuous effort to eradicate the most aggressive invaders (Rejmanek 2000).

<u>Resource Knowledge</u>
Currently, 73 non-native plant species are known to exist at RUCA (NPSpecies 2018). Schotz et al. (2006) conducted a comprehensive vascular plant inventory of RUCA between 2002 and 2004. Of the ten community types identified at RUCA, one was classified as an "exotic-dominated community" (Table 29). In addition to the exotic-dominated community, invasive exotic plants in RUCA were found in five other communities: Red-cedar Successional Forest (CEGL007124), White Oak-Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070), Shumard Oak-Chinquapin Oak Mesic Limestone Forest (CEGL008442), Rich Levee Mixed Hardwood Bottomland Forest (CEGL007268), and Appalachian Mafic Cliff (Low-Elevation Type) (CEGL004395) (Schotz et al. 2006). The Cumberland Piedmont Network established 20 permanent plots at RUCA for vegetation monitoring and revisits the plots every five years to monitor changes and trends in forest vegetation conditions (Bledsoe 2017). From the first phase of vegetation monitoring, seven (2.8%) of the 249 plant species identified at plots were non-native. The most commonly found non-native species included Japanese honeysuckle (*Lonicera japonica*), Chinese privet (*Ligustrum sinense*), and Japanese stiltgrass (*Microstegium vimineum*), occurring in six (30%), four (20%), and three (15%) plots, respectively. One additional non-native species, leatherleaf mahonia (*Mahonia bealei*) was reported to occur at RUCA by park resource manager Mary Shew (iNaturalist 2018b).

Although most of the non-native plants present at RUCA are not invasive, these species should be monitored for future changes in their invasiveness. Based on their invasive characteristics, exotic species in Alabama have been ranked as 1) extensive and dense infestations, or 2) scattered and localized infestations (ALIPC 2017). NatureServe also uses "I-Ranks" (Invasive Species Impact Ranks) with high, medium, and low threats to native species and ecological communities by exotic species based on their impact on native biodiversity (Morse et al. 2004). Nine of the non-native plants found during the Schotz et al. (2006) survey are currently ranked as 1 or 2 on Alabama's invasive plants list (NPSpecies 2018 and ALIPC 2017), and three of them are included in Alabama's "worst 10", considered aggressive invasive species and severe threats to the native species by the Alabama Invasive Plant Council (2012). Leatherleaf mahonia (*Mahonia bealei*), recently reported by Mary Shew (iNaturalist 2018b) is also on this list, bringing the total number to ten. Keefer et al. (2014) reported 49 species of invasive early detection candidate plant species for RUCA. Furthermore, Chinese privet (*Ligustrum sinense*), listed as one of Alabama's worst 10, was reported to have become established in portions of the Rich Levee Mixed Hardwood Bottomland Forest (CEGL008429) and "beginning to out-compete native vegetation" (Schotz et al. 2006). Remaley and Johnson (1997) reported the existence of large areas of privet and scattered populations of multiflora rose (*Rosa multiflora*), kudzu (*Pueraria montana* var. *lobata*), Japanese honeysuckle (*Lonicera japonica*), and vinca (probably *Vinca minor*). The first two species are also listed in Alabama's worst 10 invasive species. They stated that these exotic species "can be initially treated by a crew of four in eight days." The existence of aggressive exotic plants at RUCA is believed to be a threat to native species and can out-compete native vegetation. Treatments to privet and kudzu were done in 2000, covering approximately 400 ft^2 (Rogers and Johnson 2000), and work on exotic plant management continues (Shew 2018, pers comm).

Threats and Stressors

Invasive plants pose serious threats to global biodiversity by reducing resources available to native species and through ecosystem effects such as nutrient cycles and fire regimes (Simberloff 2013). The presence in RUCA of three exotics on Alabama's worst 10 invasive species list warrants concern.

Condition Status

Overall, it is clear that exotic species presence at RUCA pose a major threat to native plant communities. The presence of ten species of plants at RUCA that are listed by the AIPC (2012) has the potential to severely affect natural communities. If treated early, especially for early detection species, there is high probability of successful control of them. In addition, minimizing the amount of disturbance in the natural vegetation communities will reduce the invasion of exotic species. Although kudzu (*Pueraria montana* var. *lobata*) and Chinese privet (*Ligustrum sinense*) were treated in 2000 within the monument, continued efforts will be needed for full recovery of the vegetation.

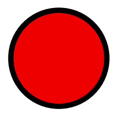
Trend in Condition

Because a single baseline study was considered insufficient to establish a trend, no trend was assigned to the invasive/exotic plants at RUCA.

Confidence in Assessment

The quality of the data used to make the assessment was good (Table 34). Data were collected using a variety of scientifically-sound methods and were collected throughout the monument covering all habitats.

Table 34. The condition of RUCA invasive/exotic plants.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Invasive/Exotic Plants	Invasive/Exotic Plant Species Threat		The condition of RUCA invasive exotic plants warrants significant concern, primarily due to the occurrence of ten of Alabama's listed exotic species. They are a high threat to native biodiversity. Rapid treatment to the early detection candidate pest and plant species would reduce the invasions. Continued management probably will always be needed to keep them under control. Confidence in the assessment was high due to scientifically sound data available.

4.4.6. Cave Aquatic Biota

Relevance and Context

Cave ecosystems are a central feature of the Russell Cave National Monument (RUCA), with approximately 10 km of caverns in Russell Cave alone. Streams and pools occur throughout much of the cave systems at RUCA. These aquatic habitats offer unique and challenging conditions for organisms, most of which derive energy and nutrients from allochthonous organic materials that enter the cave system from outside sources (Poulson and White 1969). Flooding is a major process by which allochthonous materials are brought into the cave system and is especially important for aquatic biota. Not only does flooding deliver detrital resources to cave inhabitants, it also carries living organisms into the threshold and dark zones of the cave system (Poulson and White 1969). Aquatic animals that are adapted to the threshold environment near cave entrances, and those that normally occur in habitats upstream of caves, can be carried deep into caves by flood conditions (Hobbs 1994). Some of these organisms survive and become living components of the living food webs within caves; those that do not survive contribute to the detrital base of the food webs. Flash floods are common at RUCA, greatly increasing water flow into the cave ecosystem and filling caverns from floor to ceiling (Figure 12A, Zimmerman 2007). These conditions are in sharp contrast with the typical flow of 1-4 ft^3/second from the entrance spring into Russell Cave (Figure 12B, Zimmerman 2007) and other hydrologic features within RUCA that are intermittent or ephemeral. The dynamic hydrology at RUCA must be considered to understand the ecological community inhabiting the aquatic cave environment and the potential threats to this community.

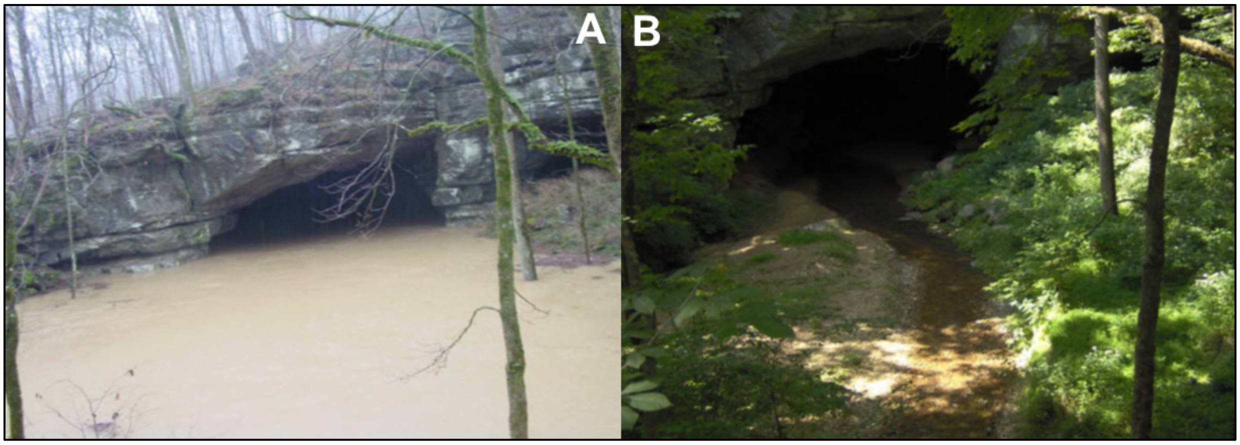


Figure 12. Flood conditions (A) and normal stream flow (B) at the entrance to Russell Cave (images from Zimmerman 2007). The photo in (A) was taken in February 2004 (credit: Shelia Reed), and that in (B) was taken in summer 2005 (credit: Joseph Zimmerman).

Resource Knowledge

One study has been conducted to document the aquatic community within caves at RUCA. Hobbs (1994) sampled the biota within Russell Cave and seven additional caves in RUCA, as well as a cave outside the Monument boundaries that is hydrologically connected to this system. This study used a variety of sampling methods for aquatic organisms, including minnow traps, Surber Samplers, kick samples, and baiting (cheese, peanut butter, sardines, and shrimp). Most samples were collected by hand with the help of bulb basters, strainers, and brushes. Sampling occurred from August 1992 to December 1993, totaling 174.5 worker-hours (142 worker-hours in Russell Cave) that included sampling both terrestrial and aquatic habitats. The aquatic biota found in this survey are summarized in Table 35. The study documented 17 taxa living in aquatic habitats and another three taxa observed in terrestrial habitats that have aquatic larvae. These taxa include two orders of segmented worms, three insect families, four amphipod species, two crayfish species, one isopod species, one ostracod species, three fish species, two anuran species and two salamander species. Cave-specialized species include the southern cave crayfish and the cavespring crayfish, as well as two taxa that live on the exoskeleton of cavespring crayfish. Hobbs et al. (1977) conducted a review of the troglobitic crayfish in the Americas and report that Russell Cave is home to the prickly cave crayfish (*Cambarus hamulatus* Cope), but this species was not reported in the Hobbs (1994) survey of Russell Cave. This discrepancy between studies may be due to a misidentification of the Southern cave crayfish in the Hobbs (1994) survey, which is more likely to have been the prickly cave crayfish. These two crayfish species do not co-occur in the same caves and the area surrounding Russell Cave is home to prickly cave crayfish (Buhay and Crandall 2007), whereas Southern cave crayfish occur on the western escarpment of the Cumberland Plateau (Buhay and Crandall 2008). In addition, three of the amphipod species in Table 35 are cave specialists, as are the Southern cavefish, the Tennessee cave salamander, and the cave salamander. Though banded sculpin occur in surface streams, they are well adapted for life in caves as well. Other species occurring in this list are primarily accidentals that have likely been carried into caves by flood waters, such as bluegill sunfish. These species may enter and survive in the cave near the entrance, but they are unlikely to survive for long if they are deep in the cave system. When they die in the cave, their corpses contribute energy to the stygobiont community, but beyond this they are not active contributors to the cave ecosystem. However temporary accidental species may be within the cave environment, they can be considered as components of the cave aquatic biota found at RUCA.

The Hobbs (1994) report also listed species of aquatic mollusks that could potentially occur in Russell Cave (Table 36). These species were documented based on the presence of shells uncovered during an archeological excavation of the cave (Clench 1974). Hobbs (1994) did not sample aquatic mollusks but noted that some of these species may presently occur in the cave system, while others may have occurred there historically or were brought in by human occupants.

Table 35. Cave aquatic biota documented by Hobbs (1994). Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses and notes indicate the sites where each taxon was observed.

Phylum	Class	Order	Family	Genus & Species	Common Name	Notes
Annelida	Clitellata	Branchiobdellida	Branchiobdellidae	–	Segmented worms	Russell Cave, ectosymbionts living on *Cambarus tenebrosus* crayfish
	Clitellata	Opisthopora	–	–	Segmented worms	Russell & Russell Road Pit Caves, found in fine sediments in pools and in organic mud substrates
Arthropoda	Insecta	Diptera	Culicidae	–	Mosquitoes	Ridley, Russell, & Russell Point pit caves, adults primarily seen in entrance zones, larvae are aquatic
	Insecta	Ephemeroptera	Baetidae	–	Mayflies	Russell Cave, epigean nymphs washed into caves, found on undersides of rocks in streams and silt-bottomed pools
	Insecta	Hemiptera	Gerridae	–	Water striders	Russell Cave, epigean in origin, primarily found on water surface in entrance and twilight zones
	Malacostraca	Amphipoda	Crangonyctidae	*Crangonyx antennatus* Cope & Packard	Appalachian valley cave amphipod	Russell Cave, found in pools
	Malacostraca	Amphipoda	Crangonyctidae	*Crangonyx floridanus* Bousfield	Amphipod	Russell Cave, found in gravel and cobble-bottomed pool
	Malacostraca	Amphipoda	Crangonyctidae	*Stygobromus* sp.	Amphipod	Boundary Sink & Russell Caves, found in low velocity, small streams beneath gravel and cobble, or in silt-bottomed pools

Table 35 (continued). Cave aquatic biota documented by Hobbs (1994). Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses and notes indicate the sites where each taxon was observed.

Phylum	Class	Order	Family	Genus & Species	Common Name	Notes
Anthropoda (continued)	Malacostraca	Amphipoda	Gammaridae	*Gammarus minus* Say	Amphipod	Russell Cave, found in gravel and cobble-bottomed pool
	Malacostraca	Decapoda	Cambaridae	*Cambarus tenebrosus* Hay	Cavespring crayfish	Ridley & Russell Caves, common in the main stream and larger tributaries in cobble-floored sections of stream and in silt-bottomed pools
	Malacostraca	Decapoda	Cambaridae	*Orconectes australis* Rhoades	Southern cave crayfish	Russell Cave, found in silt and cobble-covered sections of stream
	Malacostraca	Isopoda	Asellidae	*Caecidotea bicrenata bicrenata* Steeves	Isopod	Boundary Sink & Russell Caves, found in streams and pools
	Ostracoda	Podocopida	Entocytheridae	*Dactylocythere arcuata* Hart & Hobbs	Ostracod	Russell Cave, epizootic ostracod on *Cambarus tenebrosus* crayfish
Chordata	Actinopterygii	Perciformes	Centrarchidae	*Lepomis macrochirus* Rafinesque	Bluegill	Russell Cave, epigean sunfish, occassionally washed into caves
	Actinopterygii	Percopsiformes	Amblyopsidae	*Typhlichthys subterraneus* Girard	Southern cavefish	Russell Cave, specialized blind cave fish found in a deep pool
	Actinopterygii	Scorpaeniformes	Cottidae	*Cottus carolinae* Gill	Banded sculpin	Ridley & Russell Caves, sculpin that inhabits surface and cave streams
	Amphibia	Anura	Bufonidae	*Anaxyrus (Bufo) americanus* Holbrook	American toad	Russell & Russell Road Pit Caves, epigean adults found near cave entrances, larvae are aquatic

Table 35 (continued). Cave aquatic biota documented by Hobbs (1994). Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses and notes indicate the sites where each taxon was observed.

Phylum	Class	Order	Family	Genus & Species	Common Name	Notes
Chordata (continued)	Amphibia	Anura	Ranidae	*Lithobates sphenocephalus (Rana pipiens)* Cope	Southern leopard frog	Russell Cave, occasional inhabitant of cave pools
Chordata (continued)	Amphibia	Caudata	Plethodontidae	*Eurycea lucifuga* Rafinesque	Cave salamander	Boundary Sink, Roy's Plunge, Russell, Russell Point Pit, & Russell Road Pit Caves, terrestrial adults observed, but larvae are aquatic
Chordata (continued)	Amphibia	Caudata	Plethodontidae	*Gyrinophilus palleucus* McCrady	Tennessee cave salamander	Russell Cave, neotenic salamander found in pools
Chordata (continued)	Ichthyomyzon	Lamprey	Petromyzontidae	*Icthyomyzon castaneus*	Chestnut Lamprey	Identified by Kurt Helf deep inside the main stream passage in 2013.

Table 36. Aquatic mollusks documented by Clench (1974) that were reported by Hobbs (1994) as potentially occurring in Russell Cave. Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses. Notes reflect IUCN or Environmental Conservation Online System (ECOS) (USFWS 2018) conservation status when available.

Class	Genus	Species	Authority	Common Name	IUCN/ECOS rating
Bivalvia	*Actinonaias*	*ligamentina (carinatus)*	Lamarck (Barnes)	–	–
	Cambarunio (Villosa)	*nebulosus (nebulosa)*	Conrad	–	–
	Cyclonaias	*tuberculata*	Rafinesque	Purple wartyback	IUCN: near threatened due to invasion by zebra mussels, but stable in Alabama
	Dromus	*dromas (dromus)*	Lea	Dromedary pearlymussel	–
	Elliptio	*crassidens*	Lamarck	Elephantear mussel	IUCN: least concern
	Epioblasma (Dysnomia)	*arcaeformis*	Lea	Arc-form pearly mussel	IUCN: extinct due to habitat modification and destruction by damming
	Epioblasma (Dysnomia)	*haysiana*	Lea	Acorn pearly mussel	IUCN: extinct, possibly due to pollution in catchment
	Epioblasma (Dysnomia)	*lewisii (lewisi)*	Walker	Lewis pearly mussel	IUCN: extinct, possibly due to pollution in catchment
	Epioblasma (Dysnomia)	*triquetra*	Rafinesque	Snuffbox	IUCN: endangered, 62% decline in area occupied, remaining populations threatened by siltation, pollution and invasive species
	Eurynia (Elliptio)	*dilatata (dilatatus)*	Rafinesque	–	–
	Lampsilis	*ovata*	Say	–	IUCN: least concern

[1] Species ID uncertain

[2] May be Campeloma decisum Say, an IUCN least concern species

Table 36 (continued). Aquatic mollusks documented by Clench (1974) that were reported by Hobbs (1994) as potentially occurring in Russell Cave. Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses. Notes reflect IUCN or Environmental Conservation Online System (ECOS) (USFWS 2018) conservation status when available.

Class	Genus	Species	Authority	Common Name	IUCN/ECOS rating
Bivalvia	*Obliquaria*	*reflexa*	Rafinesque	Threehorn wartyback	IUCN: least concern
	Pleurobema	*clava*	Lamarck	Club naiad	ECOS: endangered outside of Alabama
	Pleurobema	*cordatum (cordata)*	Rafinesque	Ohio pigtoe	–
	Ptychobranchus	*subtentum (subtentis)*	Say	Fluted kidneyshell	–
	Quadrula	*cylindrica*	Say	–	IUCN: near threatened, habitat decline almost 30% & populations in decline
	Toxolasma (Carunculina)	*parvum (parva)*	Barnes	Lilliput	–
	Strophitus	*undulatus*	Say	–	–
Gastropoda	*Anculosa*	*subglobosa*	Say	–	–
	Anculosa	*virgata*	Lea	–	[1]
	Campeloma	*regularis*	Lea	–	[2]
	Elimia (Goniobasis)	*laqueata*	Say	Panel elimia	–
	Goniobasis	*angulata*	Anthony	–	[1]
	Lithasia	*verrucosa*	Rafinesque	Varicose rocksnail	IUCN: least concern
	Pleurocera	*canaliculata*	Say	Silty hornsnail	–
	Pomatiopsis	*lapidaria*	Say	Slender walker	IUCN: least concern

[1] Species ID uncertain

[2] May be Campeloma decisum Say, an IUCN least concern species

Since the survey by Hobbs (1994), one study has been conducted on the fish assemblage within Russell Cave, but no other studies have been conducted to document the aquatic biota within caves at RUCA. Zimmerman (2007) surveyed fish in six pools in Russell Cave in October 2005 and June 2006. This survey was conducted by snorkeling with underwater spotlights, bankside observations, and using ten minnow traps (baited with canned dog food, boiled eggs, crickets, light sticks) set for 24 hours. Zimmerman (2007) collected a single banded sculpin (*Cottus carolinae* Gill) and no other fish during this survey, though he noted that additional sculpins were visible from the bankside, as well as crayfish and salamanders (unidentified). Concurrent to the cave pool survey, Zimmerman (2007) also surveyed the fish assemblage in the spring and stream entering Russell Cave using a backpack shocker over three surveys from summer 2005 to spring 2006. These surveys captured 145 individual fish from three species: 133 banded sculpin, 11 largescale stonerollers (*Campostoma oligolepis* Hubbs and Greene), and 1 Western blacknose dace (*Rhinichthys obtusus* Agassiz). Because these fish occur upstream of Russell Cave, potential exists that they may become part of the cave aquatic biota as a result of flood events, similar to the bluegill found in Russell Cave by Hobbs (1994). Similarly, Zimmerman (2007) considered the largescale stonerollers and the Western blacknose dace to be incidental occupants of the stream that originated from other parts of the watershed. Considering the surveys by Hobbs (1994) and Zimmerman (2007) together, it appears that the banded sculpin is the dominant fish in both the waterway flowing into Russell Cave and the aquatic habitats within caves at RUCA.

While no other surveys of aquatic biota have occurred within caves at RUCA, two additional studies have been conducted to evaluate the aquatic insect and amphibian/reptile assemblages in habitats directly upstream of the entrances to Russell Cave and Ridley Cave. Parker et al. (2015) surveyed aquatic insects over six sampling dates from June 2005 to March 2007 (five days at Russell Cave, one day at Ridley Cave), see Table 37. This survey targeted insect taxa that are indicative of water quality, including the insect orders Ephemeroptera (mayflies), Odonata (dragonflies and damselflies), Plecoptera (stoneflies), Megaloptera (alderflies), and Trichoptera (caddisflies). Sampling methods included hand sampling with D-frame nets and UV light trapping and sweep netting for emergent adults. A total of 21 aquatic insect taxa were recorded from the orders Ephemeroptera (5 taxa), Plecoptera (5 taxa) and Trichoptera (11 taxa); species of Odonota and Megaloptera were not found. Of the 21 taxa, 14 occurred at Russell Cave, nine occurred at Ridley Cave, and only two taxa were shared between the sampling sites (a saddle-case making caddisfly and the fine-net caddisfly). Moreover, non-target aquatic invertebrates were unintentionally sampled along with the target insects (Table 38). These taxa include aquatic snails, flies (that have an aquatic larval stage), amphipods, isopods and worms.

Table 37. Aquatic insects reported by Parker et al. (2015) outside the entrances to Russell Cave and Ridley Cave. Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018). Genus names provided in the original report are shown in parentheses.

Order	Family	Genus	Species	Authority	Common Name	Location
Ephemeroptera	Ephemerellidae	*Ephemerella*	–	–	Spiny crawler mayfly	Russell Cave
	Ephemerellidae	*Eurylophella*	–	–	Spiny crawler mayfly	Ridley Cave
	Heptageniidae	*Epeorus*	–	–	Flat-headed mayfly	Russell Cave
	Heptageniidae	*Maccaffertium*	–	–	Flat-headed mayfly	Ridley Cave
	Leptophlebiidae	*Paraleptophlebia*	–	–	Pronggill mayfly	Ridley Cave
Plecoptera	Capniidae	*Allocapnia*	–	–	Snowfly	Russell Cave
	Chloroperlidae	*Sweltsa*	–	–	Sallfly	Russell Cave
	Leuctridae	*Leuctra*	*sibleyi*	Claassen	Brook needlefly	Russell Cave
	Taeniopterygidae	*Strophopteryx*	–	–	Willowfly	Ridley Cave
	Taeniopterygidae	*Taeniopteryx*	–	–	Willowfly	Ridley Cave
Trichoptera	Brachycentridae	*Micrasema*	–	–	Short-horned caddisfly	Russell Cave
	Glossosomatidae	*Agapetus*	*vireo*	Ross	Saddle-case making caddisfly	Russell Cave
	Glossosomatidae	*Glossosoma*	*nigrior*	Banks	Saddle-case making caddisfly	Ridley & Russell Caves
	Hydropsychidae	*Ceratopsyche (Hydropsyche)*	*sparna*	Ross	Spurious retreat-maker caddisfly	Ridley Cave
	Hydropsychidae	*Cheumatopsyche*	*oxa*	Ross	Oxate little retreat-maker caddisfly	Russell Cave
	Hydropsychidae	*Cheumatopsyche*	*pasella*	Ross	Retreat-making caddisfly	Russell Cave
	Odontoceridae	*Psilotreta*	–	–	Sturdy case-maker caddisfly	Russell Cave
	Philopotamidae	*Chimarra*	*aterrima*	Hagen	Finger-net caddisfly	Ridley Cave
	Polycentropodidae	*Polycentropus*	–	–	Fine-net caddisfly	Ridley & Russell Caves
	Psychomyiidae	*Lype*	*diversa*	Banks	Diverse little caddis	Russell Cave
	Rhyacophilidae	*Rhyacophila*	*ledra*	Ross	Free-living caddisfly	Russell Cave

Table 38. Non-target aquatic invertebrates reported by Parker et al. (2015) outside the entrances to Russell Cave and Ridley Cave. Oligochaeta identification was not confirmed.

Class	**Order**	**Family**	**Genus**	**Common Name**	**Location**
Gastropoda	Basommatophora	Physidae	*Physa*	Aquatic snails	Russell Cave
Insecta	Diptera	Chironomidae	–	Non-biting midge	Ridley & Russell Caves
Insecta	Diptera	Limoniidae	–	Crane fly	Ridley & Russell Caves
Insecta	Diptera	Tipulidae	–	Crane fly	Russell Cave
Malacostraca	Amphipoda	Gammaridae	*Gammarus*	Amphipods	Russell Cave
Malacostraca	Isopoda	Asellidae	*Caecidotea*	Isopods	Ridley & Russell Caves
Oligochaeta	–	–	–	Segmented worms	Ridley & Russell Caves

Parker et al. (2015) used the surveys of aquatic invertebrates to calculate a sensitivity index and conservation scores for both cave sites and to compare these values with another site in RUCA and sites at Little River Canyon National Preserve. The sensitivity index is an indicator of water quality and human disturbance, whereas conservation scores indicate whether the insect assemblage is unique or common among sampling sites. Across locations, the RUCA cave sites had relatively low conservation scores, indicating that the species present at these sites are fairly widespread. However, the RUCA cave sites had sensitivity scores near average across sites, suggesting that the taxa that are present at RUCA are rather intolerant of disturbance. These values reflect that the waterways upstream of RUCA cave sites are relatively pristine but contain a very low number of taxa from the five target insect orders compared to other sites across the Cumberland Piedmont and Appalachian Highlands (Parker et al. 2012).

Amphibians and reptiles at RUCA were surveyed by Accipiter Biological Consultants (ABC) from 2003 to 2005 (ABC 2006). Areas containing aquatic habitats (springs, streams, ephemeral pools) directly outside the entrances to Russell and Ridley Caves comprised two of the sites included in this study. Sampling consisted of hand collections by turning and replacing ground cover, seining and dip netting, and visual observations, including spotlighting. Also, minnow traps and audio surveys of anuran calls were used at the Russell and Ridley Cave sites. A total of 12 amphibian and one reptile species that require aquatic habitats for some part of their life cycle were found at the two sites (Table 39), including eight anuran species (frogs and toads), four salamander species, and a species of water snake. Four of the amphibians (American toad, Southern leopard frog, cave salamander and Tennessee cave salamander) were also reported by Hobbs (1994), demonstrating that these species occur both outside and inside the cave systems. Amphibians not reported by Hobbs (1994) include two treefrog species, two toad species, two true frog species, and two salamander species. Both the Russell Cave and Ridley Cave sites were inhabited by seven amphibian species, but only three species were common between these sites. Midland water snakes were only observed at Ridley Cave.

The aquatic species found in habitats outside the entrances to caves at RUCA have great potential to become components of the cave aquatic biota, even if for a brief period of time. Moreover, the surveys show that the composition of the aquatic communities are different at the Ridley and Russell Cave sites. Overall, multiple cave systems contribute to maintaining the diversity of aquatic biota at RUCA.

Table 39. Aquatic amphibians and reptiles documented by Accipiter Biological Consultants (2006) outside the entrances to Russell Cave and Ridley Cave. Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses and notes indicate the sites where each species was observed.

Order	Family	Genus	Species	Authority	Common Name	Notes
Anura	Bufonidae	*Anaxyrus (Bufo)*	*americanus*	Holbrook	American toad	Russell Cave, terrestrial adults, larvae are aquatic
	Bufonidae	*Anaxyrus (Bufo)*	*fowleri (woodhousii fowleri)*	Hinckley	Fowler's toad	Russell Cave, terrestrial adults, larvae are aquatic
	Hylidae	*Dryophytes (Hyla)*	*chrysoscelis*	Cope	Cope's gray treefrog	Ridley Cave, terrestrial adults, larvae are aquatic
	Hylidae	*Dryophytes (Hyla)*	*gratiosus (gratiosa)*	LeConte	Barking treefrog	Ridley Cave, terrestrial adults, larvae are aquatic
	Microhylidae	*Gastrophryne*	*carolinensis*	Holbrook	Eastern narrowmouth toad	Russell Cave, terrestrial adults, larvae are aquatic
	Ranidae	*Lithobates (Rana)*	*clamitans melanota*	Latreille	Northern green frog	Ridley & Russell Caves, aquatic adults and larvae
	Ranidae	*Lithobates (Rana)*	*palustris*	LeConte	Pickerel frog	Ridley Cave, aquatic adults and larvae
	Ranidae	*Lithobates (Rana)*	*sphenocephalus (utricularia)*	Cope	Southern leopard frog	Ridley & Russell Caves, aquatic adults and larvae
Caudata	Plethodontidae	*Eurycea*	*cirrigera*	Green	Southern two-lined salamander	Ridley Cave, adults found in wet rock habitat, aquatic larvae require running water
	Plethodontidae	*Eurycea*	*longicauda*	Green	Longtail salamander	reported to occur but data are not present in the Appendices, aquatic larvae in running water which is primarily located at the two cave sites at RUCA

Table 39 (continued). Aquatic amphibians and reptiles documented by Accipiter Biological Consultants (2006) outside the entrances to Russell Cave and Ridley Cave. Taxonomy has been updated to reflect currently accepted names using the Catalogue of Life (2018) and the IUCN Red List of Threatened Species (2018). Genus and species names provided in the original report are shown in parentheses and notes indicate the sites where each species was observed.

Order	Family	Genus	Species	Authority	Common Name	Notes
Caudata	Plethodontidae	*Eurycea*	*lucifuga*	Rafinesque	Cave salamander	Ridley & Russell Caves, terrestrial adults, larvae are aquatic
	Plethodontidae	*Gyrinophilus*	*palleucus*	McCrady	Tennessee cave salamander	Russell Cave, aquatic adults and larvae, single adult found in small sinkhole
Squamata	Natricidae	*Nerodia*	*sipedon pleuralis*	Cope	Midland watersnake	Ridley Cave, consumes fish and amphibians

Threats and Stressors

Disturbances to the watersheds upstream of the cave systems at RUCA have the potential to threaten the community of cave aquatic biota. Timber harvest in the watershed could alter the hydrological regime flowing into the cave systems (Hobbs 1994). Stream channelization and other activities that cause soil disturbances alter water flows and sediment loads that enter caves, potentially covering cobble and gravel-floored habitats and restricting water passageways within the cave (Hobbs 1994). Pollutants entering the watershed, such as pesticides and other harmful chemicals, may also negatively impact cave biota (Hobbs 1994, ABC 2006).

Condition Status

The aquatic community within the caves at RUCA deserves moderate concern, given the paucity of data and the presence of vulnerable and near threatened species. The Tennessee cave salamander is considered a vulnerable species due to its small range size, severely fragmented distribution, and the continuing decline in extent and quality of available habitat (IUCN 2018). The Southern cavefish is listed as near threatened because it is vulnerable to declining groundwater quality and little data is available to assess population trends (IUCN 2018). The other species of amphibians and fish are of least concern, as well as the crayfish species (IUCN 2018). Conservation assessments are unavailable for other invertebrates found at RUCA. However, there is potential for concern for the bivalve species that may occur at RUCA, which warrant further study. Of the 18 mussel species documented by shell remains, three are thought to have become extinct during the last century, three are endangered in some part of their range, and two are considered near threatened (USFWS 2018, IUCN 2018). Though these mollusk species may be unlikely to currently exist at RUCA, the presence of any one of these species would provide justification for further conservation measures. Moreover, cave ecosystems in the surrounding region are known to harbor cryptic species that are morphologically similar but evolutionarily distinct (Buhay et al. 2007, Buhay and Crandall 2008). Additional efforts are needed to determine whether cryptic species occur within the cave aquatic biota at RUCA and to understand their conservation status.

Trend in Condition

At this time, no trend in condition can be assigned for the cave aquatic biota. Only one study has attempted to document the entire aquatic community within caves at RUCA (Hobbs 1994). Subsequent studies have primarily assessed the ecological resources outside of the cave systems (ABC 2006, Zimmerman 2007, Parker et al. 2015); these surveys have provided useful information for the species that may potentially occur within the cave ecosystem. One additional study on the fish fauna in Russell Cave has been conducted (Zimmerman 2007), but too few data were collected to establish a trend for this component of the aquatic cave community.

Confidence in Assessment

The studies supporting this report were conducted by experts using standard protocols with documented sampling locations. Therefore, the thematic and spatial data collected by these studies are deemed good, though they are sparse (Table 40). Sampling was conducted over two general time periods: 1992-1993 (Hobbs 1994) and 2003-2007 (ABC 2006, Zimmerman 2007, Parker et al. 2015).

No studies have occurred within the last five years and temporal confidence is low. Overall, the confidence used to make an assessment for the cave aquatic biota is medium.

Table 40. The condition of RUCA cave aquatic biota.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Cave Aquatic Biota	Aquatic Biota Presence & Abundance		Moderate concern. A single study has been conducted to comprehensively evaluate the cave aquatic community at RUCA, though additional data from near cave entrances are also relevant. Data were collected from 1992-1993 (Hobbs 1994) and from 2003-2007 (ABC 2006, Zimmerman 2007, Parker et al. 2015). Temporal trends cannot be assessed because the data are too infrequent and not recent. Confidence in the existing thematic and spatial data are good, but additional sampling is needed within the cave systems.

4.4.7. Cave Bats

<u>Relevance and Context</u>

Bats perform many ecological services, such as pollination, seed dispersal, and insect suppression (Kunz et al. 2011). As important predators of nocturnal insects, bats also have a significant impact on agriculture and forestry (Boyles et al. 2011). Like most bats in North America, the bat species documented at Russell Cave National Monument follow an insectivorous diet (Thomas et al. 2016). Although bats are often associated with caves, only some species actually utilize them (Thomas et al. 2016). Of the eight species of bats documented at Russell Cave (Grow et al. 2010, Thomas et al. 2016), six regularly utilize caves (Thomas et al. 2016). Bats that regularly use caves make important contributions to the relatively limited amounts of nutrients available in cave ecosystems (Culver & Pipan 2009). Because of their important roles in both terrestrial and cave ecosystems, monitoring bat populations is important (Thomas et al. 2016).

<u>Resource Knowledge</u>

Grow et al. (2010) conducted a baseline survey of the mammals of Russell Cave National Monument during the fall and winter of 2006, the winter of 2008, and the summer and fall of 2009. Six species of bats were documented using standard mist-netting techniques: gray bat (*Myotis grisescens*), northern long-eared bat (*Myotis septentrionalis),* tri-colored bat (*Perimyotis subflavus*), big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), and evening bat (*Nycticeius humeralis*). Mist netting ceased in August 2009 following the capture of *M. grisescens*, which is a federally endangered species (Grow et al. 2010). The most plentiful bat species documented at RUCA was *E. fuscus,* most likely due to the presence of a nursery colony numbering between 25 – 50 bats located beneath a bridge near the main entrance (Grow et al. 2010). A large portion of Russell Cave was also surveyed for bats during the winter of 2008, with *M. septentrionalis*, *E. fuscus*, and *P. subflavus* found scattered throughout the cave with no large clusters observed (Grow et al. 2010). Subsequent bat use assessment of caves and bat population monitoring from 2012-2018 at Russell Cave National

Monument using summer emergence counts and winter bat counts documented two additional species: little brown bat (*Myotis lucifugus*) and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) (Thomas et al. 2016). A list of bats documented at Russell Cave National Monument is provided in Table 41.

Table 41. List of bat species documented at Russell Cave National Monument.

Common Name	Scientific Name	Federal Status
big brown bat*	*Eptesicus fuscus*	none
gray bat*	*Myotis grisescens*	endangered
little brown bat*	*Myotis lucifugus*	under evaluation
northern long-eared bat*	*Myotis septentrionalis*	threatened
tri-colored bat*	*Perimyotis subflavus*	under evaluation
Rafinesque's big-eared bat*	*Corynorhinus rafinesquii*	species of concern
evening bat	*Nycticeius humeralis*	none
eastern red bat	*Lasiurus borealis*	none

*Bat species known to regularly use caves. Table adapted from Thomas et al. (2016).

Threats and Stressors

Potential stressors for the bat populations at RUCA include forest fires, air and water pollution, human disturbance, cave-entrance collapse, flooding, and in-cave modifications (Thomas et al. 2016). One of the most significant threats to bat populations in RUCA is the fungal disease white-nose syndrome (WNS), which was confirmed in the Russell Cave complex in 2012 (Grow et al. 2010, Thomas et al. 2016). Caused by the fungal pathogen *Pseudogymnoascus destructans*, WNS has had a destructive impact on North American bat populations (Reynolds et al. 2015). Linked to increased mortality during hibernation, WNS has resulted in the deaths of more than six million bats (Thomas et al. 2016).

Condition Status

The condition of bat assemblages in RUCA warrants moderate concern. Among the documented bat species in the monument, one (*M. grisescens*) is federally endangered, one is listed as threatened (*M. septentrionalis*), another is listed as a species of concern (*C. rafinesquii*), and two more are under evaluation (*M. lucifugus* and *P. subflavus*) (Thomas et al. 2016). Of the remaining bat species, *E. fuscus* had a nursery colony located near the monument entrance and was found to be the most abundant bat species documented (Grow et al. 2010). The final two bat species (*N. humeralis* and *Lasiurus borealis*) are of Lowest Conservation Concern at the state level (Grow et al. 2010) and are not regularly associated with caves and are therefore not thought to be at risk from WNS. In fact, some research suggests that WNS may indirectly benefit from WNS by allowing for a restructuring of forest bat communities (Pettit and O'Keefe 2017, Thalken 2017). However, it is uncertain whether these shifts in relative species abundance are temporary or permanent.

Trend in Conditions

Because of limited data, no trend was assigned to the bat assemblages. However, ongoing efforts to monitor bat populations at RUCA should provide sufficient data to be analyzed for trends at a later date.

Confidence in Assessment

The confidence in the assessment was medium (Table 42). Standard mist-netting techniques, summer emergence counts, and winter bat counts were used to collect data throughout the monument in a variety of habitats by knowledgeable individuals with experience using these scientifically-sound methods for measuring bat populations (Grow et al. 2010, Thomas et al. 2016). Data were collected in the fall and winter of 2006, the winter of 2008, and the summer and fall of 2009 (Grow et al. 2010). Additional data were collected annually from 2012-2018 using a protocol developed to monitor bat populations in the Cumberland Piedmont Network (Thomas et al. 2016). Ongoing sampling using this protocol should allow for increased confidence over time.

Table 42. The condition of RUCA bat assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Bat assemblages	Bat assemblage condition		The condition of the bat assemblages at RUCA warrants moderate concern due to potential threats (e.g., impact to habitat, habitat loss) and the presence of WNS (Thomas et al. 2016). Among the bat species documented at RUCA, *M. grisescens* is federally endangered, *M. septentrionalis* is listed as threatened, *C. rafinesquii* is listed as a species of concern, and *M. lucifugus* and *P. subflavus* are under evaluation (Thomas et al. 2016). Because of limited data, no trend was established.

4.4.8. Mammal Assemblages

Relevance and Context

Mammals have many important ecological roles. They interact with other organisms at many trophic levels as carnivores, herbivores, insectivores, and omnivores. Mammals are also important agents in pollination (National Research Council 2007), seed dispersal (Willson 1993), and insect suppression (Grow et al. 2010). Hence, an understanding of their diversity and abundance plays an important role in successfully managing natural resources.

Resource Knowledge

Grow et al. (2010) conducted a survey of the mammals found at RUCA during the fall and winter of 2006, the winter of 2008, and the summer and fall of 2009. Twelve one-ha plots were randomly selected and surveyed using live traps, scent stations, baited camera stations, spotlight surveys, and regular observations (Grow et al. 2010). Additional plots incorporating habitat types not well represented in the random sample were added, while spotlight surveys were conducted along monument roadways (Grow et al. 2010).

Twenty-nine mammal species (including bats) were documented on the site, representing 8 orders and 14 families (see Table 43). Prior to the survey, 30 mammal species were deemed to have a high potential to occur at RUCA. Thus, 97% of the expected species were confirmed (Grow et al. 2010). Rodents represented the largest group of mammals at RUCA, with 10 species documented: eastern chipmunk (*Tamias striatus*); woodchuck (*Marmota monax*); eastern gray squirrel (*Sciurus carolinensis*); southern flying squirrel (*Glaucomys volans*); American beaver (*Castor canadensis*); white-footed deermouse (*Peromyscus leucopus*); cotton deermouse (*Peromyscus gossypinus*); hispid cotton rat (*Sigmodon hispidus*); Allegheny woodrat (*Neotoma magister*); and woodland vole (*Microtus pinetorum*) (Grow et al. 2010).

Table 43. Mammals documented at Russell Cave National Monument from 2006-2009 (excluding bat species). Abundance rankings: A = abundant; C = common; UC = uncommon; R = rare. Table adapted from Grow et al. (2010).

Scientific Name	Common Name	Abundance Ranking
Blarina brevicauda	northern short-tailed shrew	UC
Canis familiaris	domestic dog	C
Canis latrans	coyote	C
Castor Canadensis	American beaver	UC
Dasypus novemcinctus	nine-banded armadillo	UC
Didelphis virginiana	Virginia opossum	A
Felis catus	domestic cat	UC
Glaucomys volans	southern flying squirrel	UC
Lynx rufus	bobcat	UC
Marmota monax	woodchuck	UC
Mephitis	striped skunk	C
Microtus pinetorum	woodland vole	UC
Neotoma magister	Allegheny woodrat	UC
Odocoileus virginianus	white-tailed deer	C
Peromyscus gossypinus	cotton deermouse	A
Peromyscus leucopus	white-footed deer mouse	A
Procyon lotor	raccoon	C
Scalopus aquaticus	eastern mole	C
Sciurus carolinensis	eastern gray squirrel	C
Sigmodon hispidus	hispid cotton rat	UC
Sylvilagus floridanus	eastern cottontail	UC
Tamias striatus	eastern chipmunk	UC
Urocyon cinereoargenteus	gray fox	UC

Additional mammals confirmed at the site included Virginia opossum (*Didelphis virginiana*), northern short-tailed shrew (*Blarina brevicauda*), eastern mole (*Scalopus aquaticus*), nine-banded armadillo (*Dasypus novemcinctus*), eastern cottontail (*Sylvilagus floridanus*), domestic dog (*Canis familiaris*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), eastern striped skunk (*Mephitis mephitis*), bobcat (*Felis rufus*), feral cat (*Felis catus*), white-tailed deer (*Odocoileus virginianus*), and 6 species of bats (detailed in a separate section) (Grow et al. 2010). The only species of shrew documented at RUCA, *B. brevicauda*, has a conservation status of Moderate Conservation Concern in the state of Alabama (Grow et al. 2010).

Threats and Stressors

As noted earlier, 23 of the 24 non-bat species deemed likely present at RUCA were documented, indicating a relatively high level of mammalian biodiversity at the site (Grow et al. 2010). Because some mammal species have large home areas or utilize specific types of habitat occasionally, the relatively small size of RUCA may limit the number of resident species (Grow et al. 2010). Accordingly, the primary threats to mammal diversity in the monument include both modification and loss of habitat in nearby areas (Grow et al. 2010). Habitat fragmentation also represents a potential threat for some small mammal species at the site. Therefore, Grow et al. (2010) recommended small patches of habitat used by these species remain connected to promote gene flow and maintain populations. Although upland forest represents the most widely distributed habitat type at RUCA, Grow et al. (2010) noted the importance of other habitats at the site (e.g., rocky outcroppings, old fields, and field/forest edges) and recommended maintaining a mosaic of habitats to preserve species richness.

Condition Status

Apart from bats, which are discussed elsewhere, the mammal assemblages in RUCA were found to be in good condition. Of the 46 non-bat species of mammals that were thought to have some potential to occur in RUCA, 24 species were deemed likely to be present. Of those 24 species, 23 were documented by Grow et al. (2010), resulting in 96% of the expected species being found within the site. Four additional species of shrews were thought to possibly occur within RUCA: southern short-tailed shrew (*B. carolinensis*); southeastern shrew (*Sorex longirostris*); North American least shrew (*Cryptotis parva*); and pygmy shrew (*S. hoyi*). However, their small size limited the utility of the traps employed to census small mammals (Grow et al. 2010). Future studies will likely document additional species of shrews in RUCA, which all have a conservation status of either Moderate or Highest Concern in the state of Alabama (Grow et al. 2010).

Trend in Condition

Because a single baseline study was deemed insufficient to establish a trend, no trend was assigned to the mammal assemblages at RUCA.

Confidence in Assessment

The confidence used to make the assessment was medium (Table 44). Data on the mammal assemblages were collected using various scientifically-sound monitoring techniques (e.g., live traps, scent stations, baited camera stations, spotlight surveys, and regular observations) (Grow et al. 2010). In addition, the researchers collecting data on mammal species in RUCA had comprehensive experience in identifying and examining regional mammals. Yet the limited duration, periodic sampling of the surveys, and size/type of traps used may not have presented an accurate representation of the total mammal biodiversity supported at RUCA (Grow et al. 2010).

Table 44. The condition of RUCA mammal assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Mammal Assemblages (excluding bats)	Species Composition and Diversity		The RUCA mammal assemblages were found to be in good condition. Of the 24 non-bat species of mammals deemed likely to be present at RUCA, 23 were documented (Grow et al. 2010). Thus, 96% of the mammal species likely to be present at RUCA (excluding bats) were found at the site. The limited duration, periodic sampling of the surveys, and size/type of traps used may have resulted in a less accurate representation of the mammal biodiversity supported at RUCA. Continued sampling efforts may allow for increased confidence in the assessment. Because of limited data, no trend was established.

4.4.9. Bird Assemblages

Relevance and Context

Birds are important indicators of biodiversity and ecosystem health, due to their diversity, mobility, higher locations in food chains, and sensitivity to environmental disturbance (Gregory and Strien 2010). Although the size of RUCA limits the number of bird species expected to be found there, approximately 57% of the birds expected to be seen in northern Alabama were documented within the monument (Stedman and Stedman 2006). Although no particular species has been identified as having a high priority for conservation or as a management concern, several species that occur regularly within the monument's largely intact and high-quality forest habitat (e.g., Kentucky Warbler, Wood Thrush) have declining continental populations (Stedman and Stedman 2006).

Resource Knowledge

The avifauna at RUCA was inventoried beginning in April of 2003 and ending in May of 2005 (Stedman and Stedman 2006). Several techniques were used at RUCA to assess the bird assemblages: migration walks, point counts, night surveys, raptor surveys, and general inventories (birds seen throughout the day while visiting various sites within the monument) (Stedman and Stedman 2006). The authors compared the number of birds documented in RUCA to the 230 bird species known to occur in the region.

Stedman and Stedman (2006) documented 130 species of birds at the monument, which represents approximately 57% of the bird species expected in northern Alabama. The number of bird species documented was found to be consistent with the relatively small size of RUCA. Additionally, bird species adapted to the predominate deciduous woodland habitat of the monument were found to be more prominent as expected. Evidence of breeding was also documented for 79 species and divided into three categories: 43 confirmed breeders (54.4%), 20 probable breeders (25.3%), and 16 possible breeders (20.3%) (Stedman and Stedman 2006). None of the bird species documented at RUCA are listed as threatened or endangered by the United States Fish and Wildlife Service (USFWS). In addition, none of the bird species documented at RUCA are listed by the state of Alabama as protected species (Watson 2004). However, a number of species deemed high priority for the Southern Ridge and Valley physiographic areas by Partners in Flight were found to regularly occur in RUCA, including the Summer Tanager (*Piranga olivacea*), Acadian Flycatcher (*Empidonax virescens*), Field Sparrow (*Spizella pusilla*), Brown Thrasher (*Toxostoma rufum*), Wood Thrush (*Hylocichla mustelina*), Yellow-throated Warbler (*Dendroica dominica*), Louisiana Waterthrush (*Seiurus motacilla*), Kentucky Warbler (*Oporornis formosus*), Prairie Warbler (*Dendroica discolor*) and Worm-eating warbler (*Helmitheros vermivorum*) (Watson 2004).

Threats and Stressors

Threats to North American birds include competition from exotic species, habitat loss from residential development, and habitat alteration from cropland expansion (North American Bird Conservation Initiative and U.S. Committee 2014). Although Stedman and Stedman (2006) cited several factors that might have had a negative impact on bird diversity in RUCA (e.g., blowdown from a tornado, a prescribed burn by monument personnel, mild winters), Watson (2004) did not find any significant threats that might represent major issues for avifauna conservation at RUCA. Recommendations for mitigating potential threats included managing and monitoring exotic vegetation, removing existing towers within the monument, and working with local stakeholders to restore regional habitats and prevent further habitat fragmentation (Watson 2004).

However, several management recommendations to enhance and protect important bird habitats in RUCA were made following the bird species inventory. These include adjusting the frequency and timing of prescribed burns within the monument, allowing lower elevations and areas along creeks that are mowed to develop into shrub-scrub habitat, and planting native mast-bearing trees near the monument entrance and along fencerows (Stedman and Stedman 2006).

Condition Status

The condition of the avifauna assemblage at RUCA was good. Because of its small size and location away from major migration flyways, the number of bird species at RUCA was predicted to be fairly low (Stedman and Stedman 2006). Although only 57% of the birds expected to be seen in northern Alabama were documented at the monument, Stedman and Stedman (2006) reported that overall bird species richness found within the monument exceeded their expectations. Of the 230 species of birds known to occur in the region, 130 species were recorded at the monument (Stedman and Stedman 2006). However, some species of migrating raptors and neotropical migrant warblers were found in lower numbers than expected (Stedman and Stedman 2006). Evidence of breeding was found for 79 of the bird species found within the monument and the researchers documenting the bird species in RUCA noted that species richness surpassed their expectations (Stedman and Stedman 2006). Notably, several species of Neotropical migrants whose continental populations have been declining were found to have robust population numbers in RUCA due to its largely intact and high-quality forest habitat (Stedman and Stedman 2006). Also, several species deemed high priority for the Southern Ridge and Valley physiographic areas are found in RUCA (Watson 2004). Accordingly, both Stedman and Stedman (2006) and Watson (2004) recommend that conservation efforts within the monument should focus on these species.

Trend in Condition

Although a variety of techniques were used to document bird species in RUCA, the data collected comes from the short period between 2003 and 2005 (Stedman and Stedman 2006). The limited duration of the timeframe during which data was collected prevented trend assessment.

Confidence in Assessment

The confidence in the assessment was moderate (Table 45). Data on the avifauna assemblage were collected using various scientifically-sound bird monitoring techniques (e.g., migration walks, point counts, night surveys, raptor surveys, and general inventories) (Stedman and Stedman 2006). In addition, the researchers collecting data on bird species in RUCA had comprehensive experience in identifying and examining regional birds. Yet several factors might have negatively impacted the results of the bird surveys, such as a tornado event in 2004 and the subsequent cleanup efforts that involved the removal of downed trees and a prescribed burn (Stedman and Stedman 2006). Also, the lack of more recent data on the avifauna assemblage reduced confidence in the assessment.

Table 45. The condition of RUCA avifauna assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Bird Assemblages	Avifauna Assemblage Condition		Species diversity was as expected for a small unit yet exceeded the expectations of Stedman and Stedman (2006). Data quality was good, but confidence is medium due to the age of the data. No trend could be established due to only having one study.

4.4.10. Aquatic Insects

Relevance and Context

Aquatic macroinvertebrates are important indicators of not only stream water quality but also prevailing environmental conditions (Barbour et al. 1999). Macroinvertebrates respond to different tolerance levels of pollution which makes the presence or absence of these organisms useful indicators of healthy ecosystem functioning (United States Environmental Protection Agency 1996). More specifically, aquatic insects often have multiple developmental phases or multiple generations that occur at different timeframes or in various parts of a stream and streamside environments. Ease in sampling and decades of research that connects environmental stressors to insect orders with immature or early developmental stages in freshwater streams makes these orders appropriate indicator species (Kenney et al. 2009). The five water quality indicator taxa, represented by the acronym, EOPMT, are comprised of the Ephemeroptera (E: mayflies), Odentata (O: damselflies, dragonflies), Plecotpera (P: stoneflies), Megaloptera (M: alderflies, dobsonflies, fishflies), and Tricoptera (T: caddisflies). Although RUCA was established to protect historical archeological evidence of human activity, the limited water resources are connected to this history which makes understanding more about the ecology and composition of the aquatic insect community meaningful.

Resource Knowledge

The U.S. Geological survey sampled at five sites at RUCA based upon the presence of hydrologic features and recommendations from monument staff from 2005 to 2007 (Parker et al. 2009). The surface water resources at the monument are limited to Russell Cave spring that flows into Russell Cave and Dry Creek that flows several hundred meters north to south across the monument property. Sampling occurred at three seeps along Dry Creek and above ground at the entrances to Russell Cave and Ridley Cave. Although there are seasonal fluctuations in water flow the overall water quality is considered good by Meiman (2007).

Eight collections were conducted using approved methods, such as light trapping when warm enough for adult insect activity or hand sampling at all times of the year with nets. Aquatic stages required turning over rocks, sticks, logs and also the use of a D-frame net for microhabitats. The number of specimens collected totaled 226, with 152 EOPMT represented from 17 families, 25 genera, and 26 species; all are common with a G4 or G5 ranking (Table 46). Other taxa collected (Table 47) included Diptera (gnats), Isopoda (isopods), Amphipoda (amphipods), and Oligochaeta (worms).

Table 46. From Parker et al. (2009). Numbers of taxa and specimens of EOMPT species collected from RUCA. This represents specimens identified to species and seven genera for which species identification was not possible but these represent the only record of these genera at RUCA.

Order	Families	Genera	Species	Specimens
Ephemeroptera	3	5	5	33
Odonata	0	0	0	0
Megaloptera	0	0	0	0
Plecoptera	5	6	6	11
Trichoptera	9	14	15	108
Total	**17**	**25**	**26**	**152**

Table 47. From Parker et al. (2009). Numbers of taxa and specimens of non-EOMPT species collected from RUCA. Oligochaeta_order refers to worms not idenified to order.

Orders	Families	Genera	Specimens
Amphipoda	1	1	19
Basommatophora	1	1	6
Diptera	3	3	23
Ixodida	1	1	1
Isopoda	2	2	13
Oligochaeta	1	1	11
Psocoptera	1	1	1
Total	**10**	**10**	**74**

Russell Cave National Monument had the lowest number of EOMPT fauna collected from a survey of 18 parks of the Appalachian Highland and Cumberland monitoring network (Parker et al. 2012). This result can be attributed to the total land area available and sampling effort (Parker 2009). Not only does RUCA have a very small watershed but Parker et al. noted extremely dry conditions during the survey from 2005 to 2007. The one stream within the monument, Dry Creek, was reduced to disconnected pools which restricted sampling effort. Although five sites were initially selected for the survey only 3 retained sufficient water for sampling.

Site sensitivity index (SSI) values were generated from these three sites for EOMPT based upon accepted tolerance values used in biomonitoring. Conservation scores (CS) were calculated based upon a scoring system that considers unique habitats and rarity of a species, where 0=widespread, common, without unique habitat requirements to 4=endemic species, extremely rare or possible new species. Since conservation scores are additive based upon multiple species per site, the CS was summed for all species at one site to obtain a site level CS. The SSI ranged from 4.17 to 7.48 and the CS ranged from 3 to 7 (see Table 48). The sites all ranked the same, with Moonshine Still ranked the highest. A full list of the EOMPT species collected at RUCA can be seen in Table 49.

The records for non-target taxa from Russell Cave National Monument (RUCA) are presented in the Table 50, organized by location and collection event. All non-target specimens collected during this survey are listed, except those that remain unsorted and unidentified. Those reported here represent 3 Phyla, 5 Classes, 6 Orders, 8 Families, and 4 Genera. In addition, many taxa are included in catchall groups that represent specimens that the authors did not identify. These are indicated in the table by entries such as Oligochaeta_order, Diptera_family, and Coleoptera species. Most of the non-target taxa are aquatic species. However, terrestrial species also are represented.

Table 48. Site sensitivity index and site level conservation score for individual sites RUCA. (SSI, site sensitivity index; rSSI, rank of sites based on site sensitivity index; CS, conservation score; rCS, rank of sites based on conservation score). From Appendix 2, Table 2.2 by Parker et al. (2009).

Site	SSI	rSSI	CS	rCS
RUCA Moonshine Still	7.48	1	7	1
RUCA Ridley Cave	6.97	2	3	2
RUCA Cave Entrance	4.17	3	2	3

Table 49. The Ephemeroptera, Plecoptera, and Trichoptera collected in Russell Cave National Monument (RUCA). From Appendix 3, Table 2.3 from Parker et al. (2009).

Collection Location and Method	Order	Family	Taxon	Specimens
[AL, Alabama; Co., county; ♀, female; ♂, male]	Ephemeroptera	Ephemerellidae	*Ephemerella* species	1 larva
	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	4 pupae
AL:Jackson Co., RUCA Cave Entrance, 2 Nov 2006, by hand	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	1 male ♂
AL:Jackson Co., RUCA Cave Entrance, 23 Mar 2007, by hand	Plecoptera	Leuctridae	*Leuctra sibleyi* Claassen, 1923	1 male ♂
	Trichoptera	Brachycentridae	*Micrasema* species	1 larva
	Trichoptera	Glossosomatidae	*Agapetus vireo* Ross, 1941	2 male ♂♂
	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	4 male ♂♂
	Trichoptera	Hydropsychidae	*Cheumatopsyche oxa* Ross, 1938	4 pupae
	Trichoptera	Hydropsychidae	*Cheumatopsyche pasella* Ross, 1941	4 male ♂♂
	Trichoptera	Psychomyiidae	*Lype diversa* (Banks, 1914)	several male ♂♂
	Trichoptera	Rhyacophilidae	*Rhyacophila ledra* Ross, 1939	1 larva
AL:Jackson Co., RUCA Cave Entrance, 23 Nov 2005, by hand	Ephemeroptera	Heptageniidae	*Epeorus* species	1 immature
	Plecoptera	Capniidae	*Allocapnia* species	1 larva
	Plecoptera	Chloroperlidae	*Sweltsa* species	3 larvae
	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	2 pupae
	Trichoptera	Hydropsychidae	*Cheumatopsyche* species	29 larvae
	Trichoptera	Odontoceridae	*Psilotreta* species	1 larva
	Trichoptera	Polycentropodidae	*Polycentropus* species	2 larvae
AL:Jackson Co., RUCA Cave Entrance, 3 Mar 2006, by hand	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	2 male ♂
	Trichoptera	Hydropsychidae	*Cheumatopsyche oxa* Ross, 1938	1 male ♂
	Trichoptera	Psychomyiidae	*Lype diversa* (Banks, 1914)	5 male ♂♂
AL:Jackson Co., RUCA Moonshine Still, 23 Mar 2007, by hand	Plecoptera	Leuctridae	*Leuctra* species	1 female ♀
	Plecoptera	Nemouridae	*Ostrocerca truncata* (Claassen, 1923)	2 male ♂
	Trichoptera	Hydropsychidae	*Diplectrona metaqui* Ross, 1970	3 larvae

Table 49 (continued). The Ephemeroptera, Plecoptera, and Trichoptera collected in Russell Cave National Monument (RUCA). From Appendix 3, Table 2.3 from Parker et al. (2009).

Collection Location and Method	Order	Family	Taxon	Specimens
AL:Jackson Co., RUCA Moonshine Still, 23 Mar 2007, by hand (cont'd)	Philopotamidae	–	*Wormaldia moesta* (Banks, 1914)	3 male ♂♂
	Rhyacophilidae	–	*Rhyacophila glaberrima* Ulmer, 1907	2 larvae
	Rhyacophilidae	–	*Rhyacophila ledra* Ross, 1939	1 larva
	Rhyacophilidae	Thremmatidae	*Neophylax* species	3 larvae
AL:Jackson Co., RUCA Moonshine Still, 3 Mar 2006, by hand	Trichoptera	Hydropsychidae	*Diplectrona metaqui* Ross, 1970	4 larvae
	Trichoptera	Limnephilidae	*Pseudostenophylax uniformis* (Betten, 1934)	6 larvae
	Trichoptera	Rhyacophilidae	*Rhyacophila glaberrima* Ulmer, 1907	2 larvae
	Trichoptera	–	*Rhyacophila ledra* Ross, 1939	5 larvae
AL:Jackson Co., RUCA Ridley Cave, 23 Nov 2005, by hand	Ephemeroptera	Ephemerellidae	*Eurylophella* species	28 immatures
	Ephemeroptera	Heptageniidae	*Maccaffertium* species	2 immatures
	Ephemeroptera	Leptophlebiidae	*Paraleptophlebia* species	1 immature
	Plecoptera	Taeniopterygidae	*Strophopteryx* species	1 larva
	Plecoptera	–	*Taeniopteryx* species	2 larvae
	Trichoptera	Glossosomatidae	*Glossosoma nigrior* Banks, 1911	3 larvae
	Trichoptera	Hydropsychidae	*Hydropsyche sparna* Ross, 1938	1 larva
	Trichoptera	–	*Hydropsyche* species	1 larva
	Trichoptera	Philopotamidae	*Chimarra aterrima* Hagen, 1861	1 larva
	Trichoptera	Polycentropodidae	*Polycentropus* species	1 larva

Table 50. Non-target specimen data from Russell Cave National Monument (RUCA). AL = Alabama; Co.= County; indivs.: individuals; ♀ = female; ♂ = male.

Collection Location and Method	Order	Family	Taxon	Specimens
AL:Jackson Co., RUCA Cave Entrance, 23 Nov 2005, by hand, CRParker & MGeraghty	Oligochaeta	Oligochaeta	Oligochaeta species	8 indivs.
	Ixodida	Ixodidae	*Ixodes dentatus* Neumann, 1899	1 female ♀
	Diptera	Chironomidae	Chironomidae species	7 larvae
	Limoniidae	–	Limoniidae species	1 larva
	Tipulidae	–	Tipulidae species	6 larvae
	Amphipoda	Gammaridae	*Gammarus* species	19 indivs.
	Isopoda	Asellidae	*Caecidotea* species	7 indivs.
	Basommatophora	Physidae	*Physa* species	6 indivs.
AL:Jackson Co., RUCA Ridley Cave, 23 Nov 2005, by hand, CRParker & MGeraghty	Oligochaeta	Oligochaeta	Oligochaeta species	2 indivs.
	Diptera	Chironomidae	Chironomidae species	3 larvae
	Limoniidae	–	Limoniidae species	2 larvae
	Psocoptera	Psocoptera	Psocoptera species	1 adult
	Isopoda	Asellidae	*Caecidotea* species	5 indivs.
	Isopoda	–	*Isopoda* species	1 indiv.

Threats and Stressors

Habitat alteration poses a large threat to aquatic insects. The hydrologic features in RUCA experience fluctuations in flow seasonally. Fed by a spring with less than 40 m of flow above the ground, the mouth of Russell Cave can fill during flood stage and have minimal flow during summer. Dry Creek and other springs in RUCA have seasonal intermittent flow. Although more than 100 species have beeen identified by Parker et al. (2009) as occuring in Jackson County, most have not been confirmed at the monument. Although the watershed for RUCA is small, the springs and creek are also subject to other stressors such as agicultural run-off, solid waste accumulating in the cave entrance, and human activity, in addition to seasonal fluctuations.

Condition Status

The condition warrants moderate concern. More than 100 species of aquatic insects (EOMPT) have been identified as occurring in Jackson County but only 24.5% have been confirmed at the monument. Parker et al. (2009) indicates much additional collecting is needed to know more about the RUCA aquatic species and associated life stages.

Trend in Condition

No trend was assigned to the aquatic insect community, since single baseline studies or inventories are inadequate to establish a trend. Only a single study conducted from 2005 to 2007 of the aquatic insects in the surface waters at RUCA is known to be reported.

Confidence in Assessment

The thematic quality of the data to make the assessment is good (Table 51). Sampling was conducted by representatives from USGS and specialists from other institutions with an expertise in aquatic insect monitoring (Parker et al. 2009). Data were collected using a variety of scientifically-sound methods, collection points were identified by GPS units at five sites representative of the hydrologic features of RUCA, therefore, the spatial data is deemed good. Sampling occurred from 2005 to 2007 which was not within five years of this report; therefore, temporal data quality is insufficient. Confidence in the assessment is medium.

Table 51. The condition of RUCA aquatic insect assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Aquatic Insect Assemblages	Aquatic Insect Population Quality		Condition warrants moderate concern based upon a single study conducted 2005 to 2007 (Parker et al. 2009) with 24.5% of species known to occur in Jackson County. No trend can be assigned based upon a single study. Confidence in thematic and spatial quality of data is good, in that sites where documented and survey conducted by experts. Survey was conducted more than 5 years ago, which makes temporal data insufficient, therefore confidence in the assessment is medium.

4.4.11. Fish

Relevance and Context

The hydrologic surface features at RUCA include an intermittent creek, Dry Creek, which flows across the monument property, small seeps and springs, several smaller cave entrances, and the large Russell Cave entrance spring. Within the cave system monument boundaries are several accessible cave pools. Distinct ecological zones occur between the cave entrance (threshold) where light can penetrate and temperatures fluctuate, and the dark area with constant temperatures (Poulson and White 1969). Besides darkness, one of the significant aspects of a cave is the lack of food. Although wide variations occur in the physiochemical features of the cave threshold, this area is the most biologically diverse (Hobbs 1994). For this reason, knowledge about seasonal variations in fish assemblages can provide resource managers with important information about water quality that can inform if changes in habitat are caused by anthropogenic or natural causes (Schlosser 1990).

Resource Knowledge

An ichthyofaunal survey of the cave entrance spring and six pools was conducted October 2005 to June 2006 by Zimmerman (2007). Sampling included snorkeling with underwater spotlights, bankside observations and minnow traps set for 24 hours. The Russell Cave entrance spring was sampled three times (2005 summer and fall, 2006 spring). Banded sculpin (Cottus caronlinae), a troglophile that can complete life histories within caves but can also occur in suitable epigean habitats, dominated the fish assemblages all seasons. Two species considered to be incidental because the stream doesn't allow for immigration/emigration from other tributaries, was a small population of largescale stonerollers (Campostoma oligolepis) and a single western blacknose dace (*Rhinichthys obtusus*). Weather patterns and the RUCA landscape result in flash floods that bring in species from other areas. Species richness stayed relatively the same across all seasons (Table 52). Cave pools were only sampled twice, October 2005 and June 2006, due to difficulty in accessing. Only one banded sculpin was collected in a cave pool in fall 2005.

Table 52. Abundance, species richness, and species diversity of Russell Cave Entrance Spring (RUCA) for Summer/Fall 2005 and Spring 2006 from Zimmerman (2007).

Species	Common Name	Summer Species #	Fall Species #	Spring Species #
Campostoma oligolepis	Largescale stoneroller	5	3	3
Rhinichthys obtusus	Western blacknose dace	0	1	0
Cottus carolinae	Banded sculpin	52	41	40
Total	–	**57**	**45**	**43**
Species Richness	–	**2**	**3**	**3**
Species Diversity	–	**0.30**	**0.35**	**0.25**

An earlier cave ecological assessment by Hobbs (1994) from August 1992 to December 1993 included 12 sampling stations. The purpose of the Hobbs survey at Russell Cave was to access the ecological resources including distribution and abundance of species, in addition to establishing a baseline for physiochemical properties of the cave system. In reference to fish species, he observed small populations of southern cavefish (*Typhlichthys subterraneus*) in a deep cave pool and collected banded sculpin (*Cottus caronlinae*) and bluegill (*Lepomis macrochirus*), which is occasionally washed into caves.

The lack of variation in the fish assemblages can be attributed to stream isolation and seasonal habitat stability (Zimmerman 2007). Zimmerman (2007) also noted the sampling difficulty associated with cavefishes due to their acute sensory responses to vibration and light, and the presence of multiple escape routes among cave pool floors.

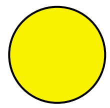
<u>Threats and Stressors</u>
Hobbs (1994) reported concerns about clear cutting and the introduction of chip mills in property surrounding and in the recharge area of RUCA. He also noted that Dry Creek was stablilized by the National Park Service in 1992 and in the process of channelizing the stream, created a high velocity pathway for silt, sand, gravel, and vegetation to be transported into Russell Cave. Shute et al. (1997) states concerns about how the multifacted ecological relationships among species makes it difficult to pinpoint threats.

<u>Condition Status</u>
The condition of RUCA fish community warrants moderate concern. The current global and state ranking for the southern blind cavefish (*Typhlichthys subterraneus*) is G4 and S3, respectively. This species is listed as state protected (Alabama Natural Heritage Program 2007). A 2005 to 2006 study of similar cave pools did not document the southern cavefish.

<u>Trend in Condition</u>
No trend was assigned to the fish community, since the two studies conducted were 14 years apart and although documented, used several different sampling sites, which makes it inadequate to establish a trend.

<u>Confidence in Assessment</u>
The confidence used to make the assessment was medium (Table 53). The thematic and spatial data is deemed good in that sampling points were established and monitored according to standard protocols; both studies were documented by individuals with a high level of expertise. A comprehensive cave ecological assessment was conducted August 1992 to December 1993, which included ichthyofauna in addition to other species (Hobbs 1994). Another survey was conducted from October 2005 to June 2006 to determine changes in fish assemblages seasonally (Zimmerman 2007). Since the studies have not occurred within the last five years, the temporal data confidence is low.

Table 53. The condition of RUCA fish assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Fish Assemblages	Fish Population Quality		Condition warrants moderate concern based upon two studies. No trend can be assigned based upon these two separate studies. Confidence in thematic and spatial quality of data is good, in that sites where documented and surveys conducted by experts. Surveys were conducted more than 5 years ago and 14 years apart which makes temporal data insufficient, therefore confidence in the assessment is medium.

4.4.12. Amphibian and Reptile Assemblages

Relevance and Context

Reptiles and amphibians represent a substantial component of vertebrate biodiversity in nearly every freshwater and terrestrial habitat in the southeastern United States (Tuberville et al. 2005). Close to half of the herpetofauna species native to North America can be found in the region, with approximately 20 percent of those species endemic to the area (Russell et al. 2004). Unfortunately, reptile and amphibian species are declining globally due to threats such as habitat destruction, pollution, and disease (Gibbon et al. 2000). Accordingly, developing an understanding of the status of herpetofauna assemblages represents an important step in evaluating the overall condition of the ecosystems where they are found.

Resource Knowledge

A baseline monument-wide inventory of amphibian and reptile species was conducted at RUCA during 2003-2005 (ABC 2006). Among the goals of the study were to determine the herpetofauna species present in the monument, document at least 90% of the species thought likely to occur there, and describe their relative abundance and distribution (ABC 2006). Twelve random 1-ha plots were surveyed using several standard methods for sampling herpetofauna: minnow traps, coverboards, audio frog breeding surveys, general observation and collection, and drift fences with funnel type live traps (ABC 2006).

Of the 32 species deemed likely to occur in RUCA, 30 (94%) were documented during the course of the study (ABC 2006) (See Table 54): ten species of frogs and toads, seven species of salamanders, three species of lizards, nine species of snakes, and one species of turtle. Four more species were documented by monument staff after the inventory was carried out: green salamander (*Aneides aeneus),* marbled salamander (*Ambystoma opacum*), Dekay's snake (*Storeria dekayi*), and broadhead skink (*Plestiodon laticeps*). The documented list of herpetofauna species at RUCA exceeded the study goal of 90% of the species thought likely to occur at the site. None of the species reported in the monument are listed as rare, threatened, or endangered by the USFWS. However, the green salamander (*A. aeneus*) is listed as a protected species by the State of Alabama Department of Conservation and Natural Resources (ADCNR) (ADCNR 2014).

Table 54. Herpetofauna documented at Russell Cave National Monument from 2003-2005. Abundance rankings: A = abundant; C = common; U = uncommon; R = rare. Table adapted from ABC (2006).

Species	Common Name	Abundance Ranking
Plethodon dorsalis	zigzag salamander	C
Plethodon glutinosus	northern slimy salamander	C
Gyrinophilus palleucus	Tennessee cave salamander	U
Eurycea cirrigera	southern two-lined salamander	U
Eurycea longicauda	longtail salamander	U
Eurycea lucifuga	cave salamander	C
Bufo americanus	American toad	C
Bufo woodhousii fowleri	Fowler's toad	A
Hyla gratiosa	barking treefrog	U
Hyla chrysoscelis	Cope's gray treefrog	C
Pseudacris crucifer	spring peeper	C
Pseudacris triseriata	upland chorus frog	C
Gastrophryne carolinensis	eastern narrowmouth toad	U
Rana clamitans melanota	green frog	A
Rana utricularia	southern leopard frog	C
Rana palustris	pickerel frog	U
Terrapene carolina	eastern box turtle	C
Sceloporus undulatus	eastern fence lizard	A
Scincella lateralis	ground skink	U
Plestiodon fasciatus	five-lined skink	C
Nerodia sipedon pleuralis	midland watersnake	U
Thamnophis sirtalis	eastern garter snake	C
Virginia valeriae	smooth earth snake	U
Diadophis punctatus	ringneck snake	C
Carphophis amoenus	eastern worm snake	U
Elaphe obsoleta	rat snake	U
Lampropeltis getula nigra	black kingsnake	U
Agkistrodon contortrix	copperhead	U
Crotalus horridus	timber rattlesnake	U

Threats and Stressors

Representing 94% of the expected species, 30 of the 32 reptile and amphibian species deemed likely to be present at RUCA were documented, indicating a relatively high level of herpetofauna biodiversity at the site. However, there are potential threats and stressors to the herpetofauna assemblages at RUCA. Habitat degradation and destruction in adjacent properties likely pose the greatest threat to reptile and amphibian populations at the site. For Tennessee Cave Salamander populations, urbanization and agricultural and silvicultural practices in adjacent properties likely represent the greatest and most immediate threat by increasing pesticide, herbicide, and silt load in storm water runoff (Miller and Niemiller 2008). During the course of the herpetofauna inventory, eastern box turtles (*Terrapene carolina*) were also found dead or with profound injuries as the result of being struck by vehicles and mowers (ABC 2006). Accordingly, the researchers conducting the inventory recommended mowers in monument areas be set to cut at a minimum height of eight inches to prevent box turtle injury or mortality (ABC 2006).

Finally, another potential threat to herpetological life is the presence of snake fungal disease (SFD). SNF is a potentially lethal skin infection caused by the fungus *Ophidiomyces ophiodiicola* that may contribute to the extirpation of localized snake populations (Lorch et al. 2016). SFD has been positively identified in a specimen within the monument, and other living snakes have been suspected of having SFD but have not been confirmed (Shew 2018).

Condition Status

The condition of the herpetofauna assemblages at RUCA was found to be good. 94% of expected species were documented at the site, indicating a high level of herpetofauna diversity (ABC 2006). Importantly, the most recent data available indicated no management plan in place at the monument for herpetofauna (ABC 2006).

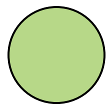
Trend in Condition

Although two previous studies had documented a small number of reptile and amphibian species in RUCA (Godwin 2000, Hobbs 1994), all the species noted were again documented during the study by ABC (2006). As a single baseline study was deemed insufficient to establish a trend, no trend was assigned to the amphibian and reptile assemblages at RUCA.

Confidence in Assessment

The confidence used to make the assessment was medium (Table 55). Data on the herpetofauna assemblages were collected using various scientifically-sound sampling techniques (e.g. minnow traps, coverboards, audio frog breeding surveys, general observation and collection, drift fences with funnel type live traps) (ABC 2006). In addition, the researchers collecting data on reptile and amphibian species in RUCA had comprehensive experience in identifying and examining regional herpetofauna. Yet the authors of the herpetofauna survey list several factors that might have impacted their results, such as a tornado event in 2004 and a prescribed burn in 2005 (ABC 2006). Also, the lack of more recent data on the herpetofauna assemblages reduced confidence in the assessment.

Table 55. The condition of RUCA herpetofauna assemblages.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Herpetofauna assemblages	Species Composition and Diversity		Data reviewed for this condition assessment indicated the RUCA herpetofauna assemblages are in good condition. Of the 32 species deemed likely to be present at RUCA, 30 were documented in the monument (ABC 2006). Thus, 94% of the reptile and amphibian species likely to be present at RUCA were found at the site, indicating a high level of herpetofauna diversity (ABC 2006). However, the presence of snake fungal disease has been documented by monument staff and has been recognized as a concern. Because of the limited data, no trend was established. Also, the confidence in the condition assessment was medium due to the lack of more recent data.

4.5. Landscapes and Human Use

Landscape dynamics represent a broad group of primarily anthropogenic processes that affect the monument's integrity and use. At RUCA, stakeholders have identified five areas warranting investigation: cultural landscape, land cover and use, night sky conditions, fire and fuel dynamics, and visitor use. Visitor use, fire and fuel dynamics, and dark night sky conditions are addressed in sections 2.1.3 and 2.2.3 of this report, but discussion of the other categories follows.

4.5.1. Cultural Landscape

<u>Relevance and Context</u>

Through multiple prehistoric sites, RUCA offers a rare window into the lives of America's prehistoric past. Previously excavated by other archaeological concerns prior to the NPS' ownership of the land, the NPS has conducted the majority of excavations at RUCA. Understandable for a monument of RUCA's size, research and recognition of in situ problems within the monument are made difficult by a dearth of published data and reports discussing RUCA. In addition to the specific resources previously outlined in this report, there are other factors that actively affect both natural and cultural resources at RUCA that need increased and continued monitoring from management. In particular, the rock shelter is undergoing potentially site-threatening structural changes, the current causes of which are not entirely understood (Shew 2017).

In 1994, with the cooperation of the Tennessee National Guard, bulwarks made of geotextiles and rock were installed to halt the collapse of the slopes around RUCA. Though an admirable effort, there remains some concern to be had regarding the overall structural stability of the cave itself given its karst topography (Shew 2017). While discussed in more detail in section 4.3, the karst topography is worth revisiting here because of its significant, specific risk to the cultural deposits in the primary sites of RUCA. Karst is commonly understood to not be one of most enduring of formations, and it is hard to predict when a given area will enter into a structurally critical period preceding the collapse of a cave.

The artifacts within RUCA do not appear to be in any danger at this time due to NPS' diligence. In particular, the rock shelter is protected from illegal looting as best can be reasonably managed via electronic monitoring and ranger presence on tours. Despite past and present efforts, there still exists some danger to the cultural landscape of RUCA. Some of the sites in the monument are at significant risk of deteriorating conditions due to a confluence of factors: location of these sites, limited staff present at RUCA, large quantities of public traffic these areas receive, and a risk of looting. While there are no documented cases of looting, the sensitive nature of known and potential cultural remains on RUCA means that the risk of looting should always be considered a concern.

4.5.2. Land Cover and Land Use

Relevance and Context

Naturally, RUCA staff have little if any influence on land cover use and changes outside the boundaries of the monument. Unfortunately, those changes have the potential to strongly influence environmental factors within the monument, particularly those impacted by increased development of the surrounding land. RUCA is relatively distant from major population centers, but there are urban and industrial activities in the region that may affect the monument. In order to assist with these issues, the NPS created NPScape, a combination of tools and datasets to help support management of natural resources, assist with long-term planning, and help interpret landscape-scale information (NPS 2016).

One component of the NPScape program is the use of National Landcover Dataset (NLCD) raster information to understand change in land cover in the areas around the monument. The NLCD is a Landsat-based raster dataset produced by the Multi-Resolution Land Characteristics Consortium that is classified into different land cover types. The NPScape program reclassifies these into a smaller set of classes, primarily concerned with natural and converted land cover types (Gross et al. 2009). Table 56 shows the different classes and whether or not they are considered to have been converted from a natural state.

Table 56. NLCD landcover classes aggregated into generalized categories of converted and natural land types (Gross et al. 2009).

General Category	NLCD Classes
Converted	Low intensity developed, Medium intensity developed, High intensity developed, Open space developed, Pasture/hay, Cultivated crops
Natural	Grassland/herbaceous, Shrub/scrub, Mixed forest, Evergreen forest, Deciduous forest, Barren land, Perennial ice/snow, Woody wetlands, Emergent herbaceous wetlands, Open water

For this report, NPScape-classified raster data is visualized at three scales, one showing the land cover within the monument and its immediate surroundings (Figure 13), a three-kilometer buffer around the monument boundaries (Figure 14), and a 30-km buffer to provide a broader context to the land cover in the area (Figures 15-17). These figures also show the data at three timesteps, 2001, 2006, and 2011, in order to highlight changes in land cover over time. Locally, there is little to no change within the monument and the immediate area across the ten-year time scale, and the vast majority of the monument itself is natural land cover. Looking more broadly though, some changes occur within the three- and 30- km buffers.

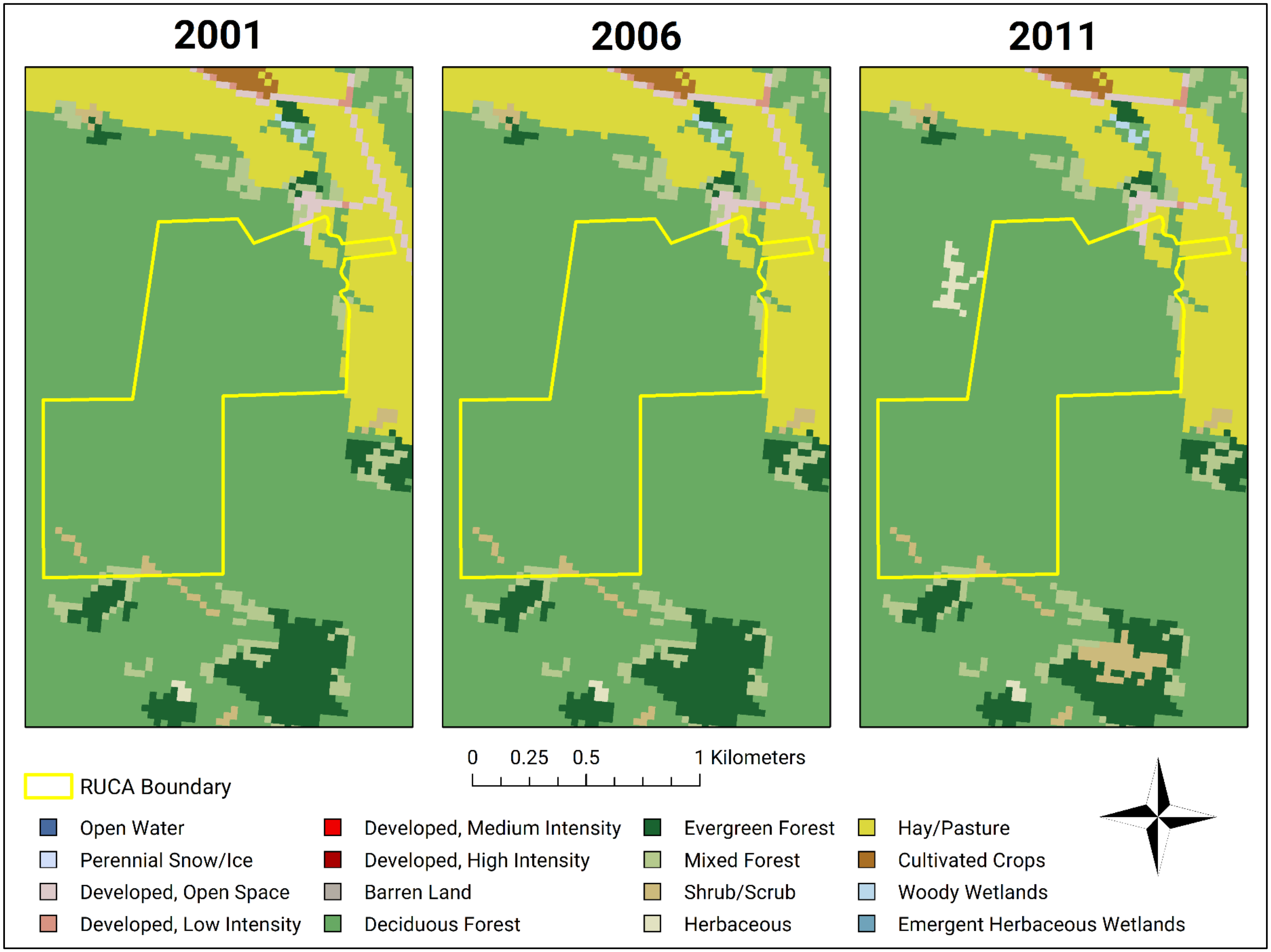


Figure 13. Land cover within the monument in 2001, 2006, and 2011 (NPS 2018).

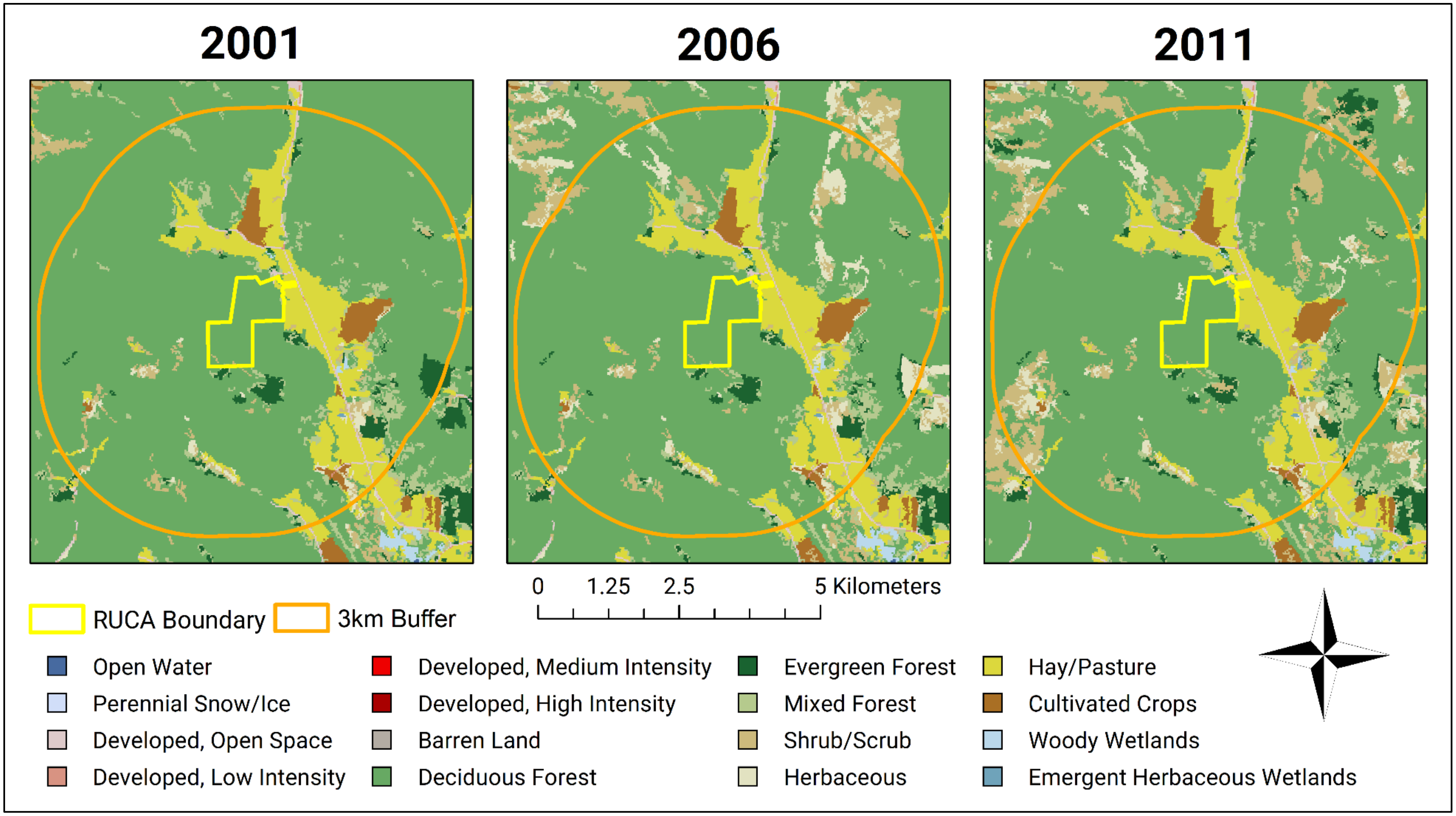


Figure 14. Land cover within a three-kilometer buffer of the monument boundaries in 2001, 2006, and 2011 (NPS 2018).

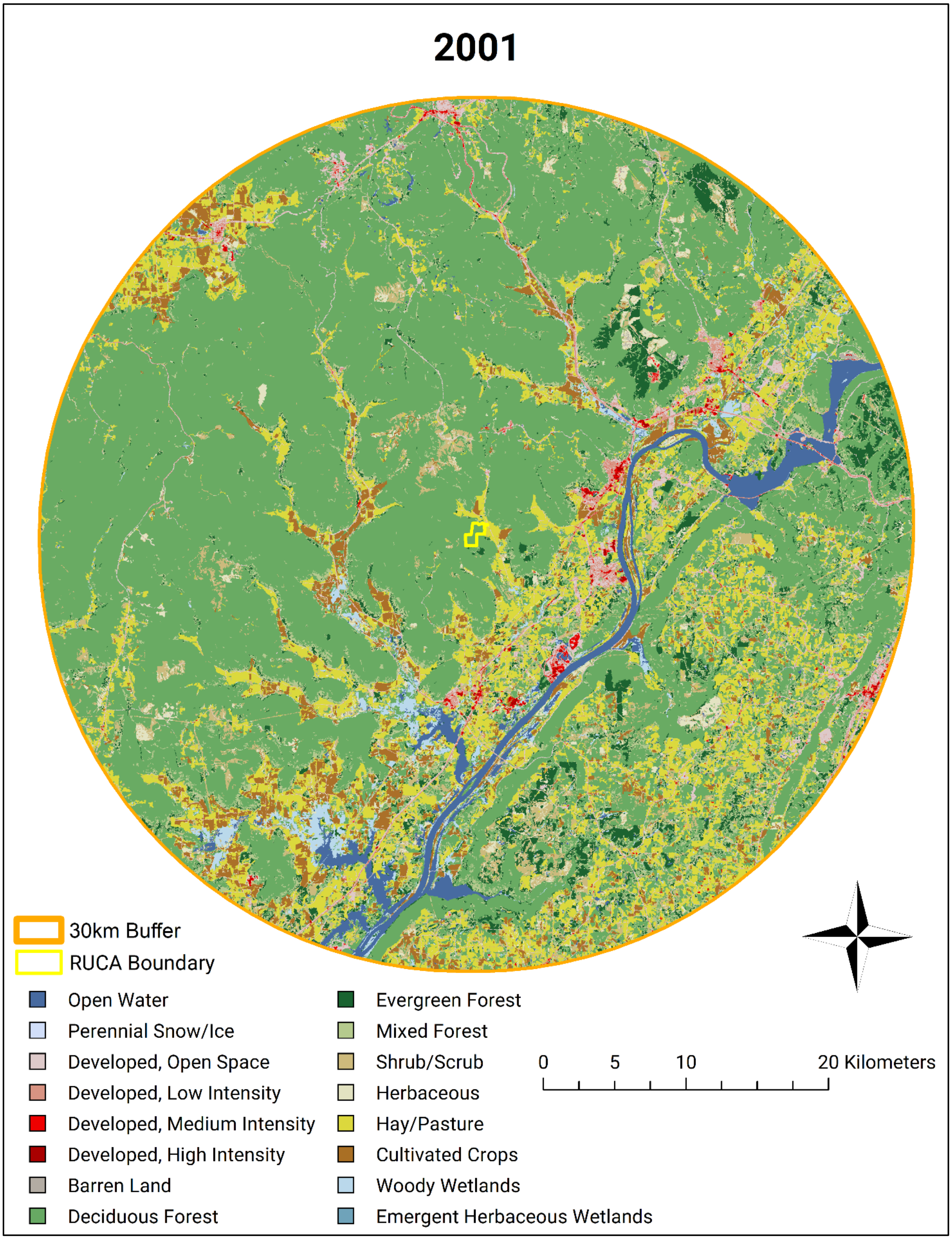


Figure 15. Land Cover within a 30 km buffer of the monument boundary in 2001 (NPS 2018).

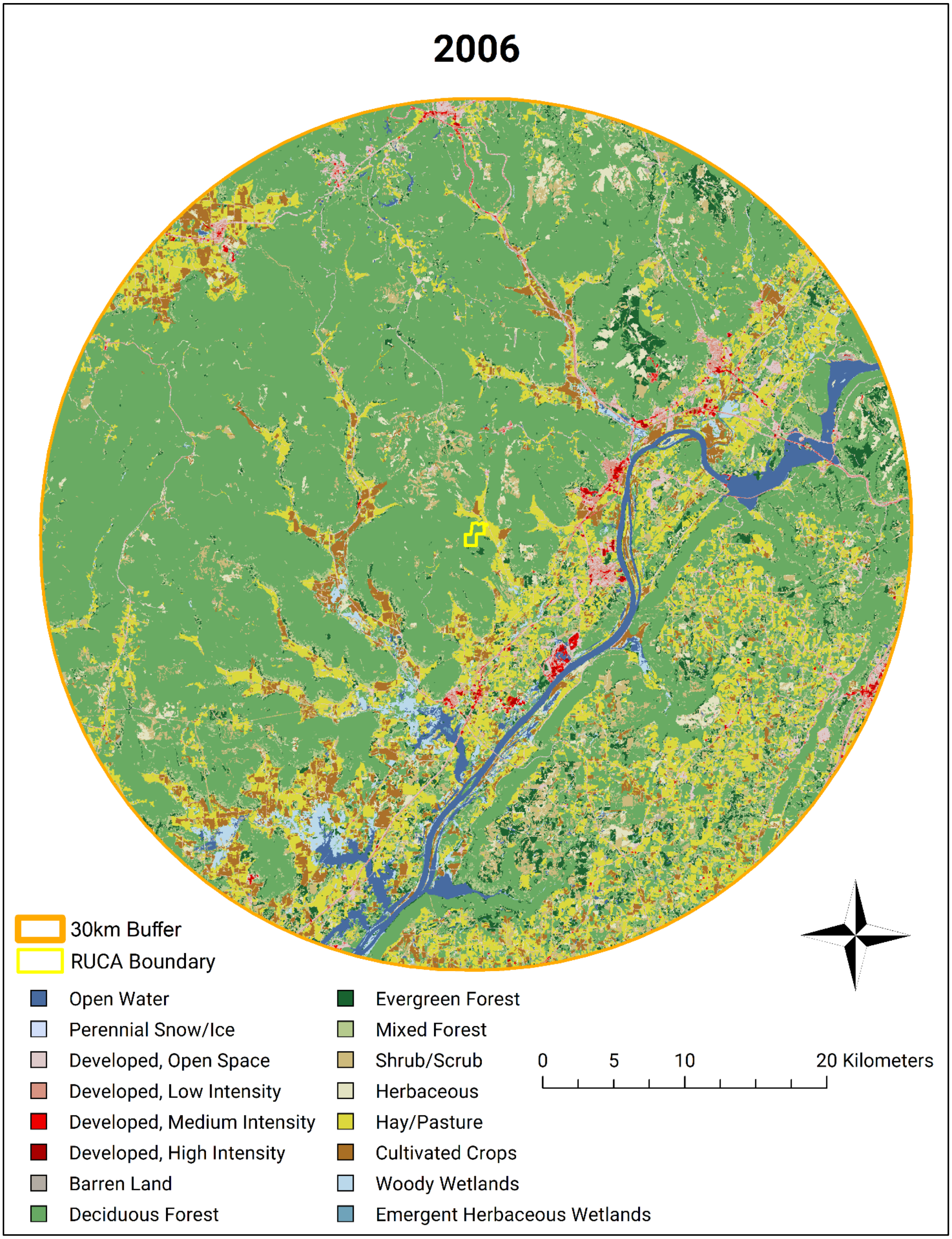


Figure 16. Land Cover within a 30 km buffer of the monument boundary in 2006 (NPS 2018).

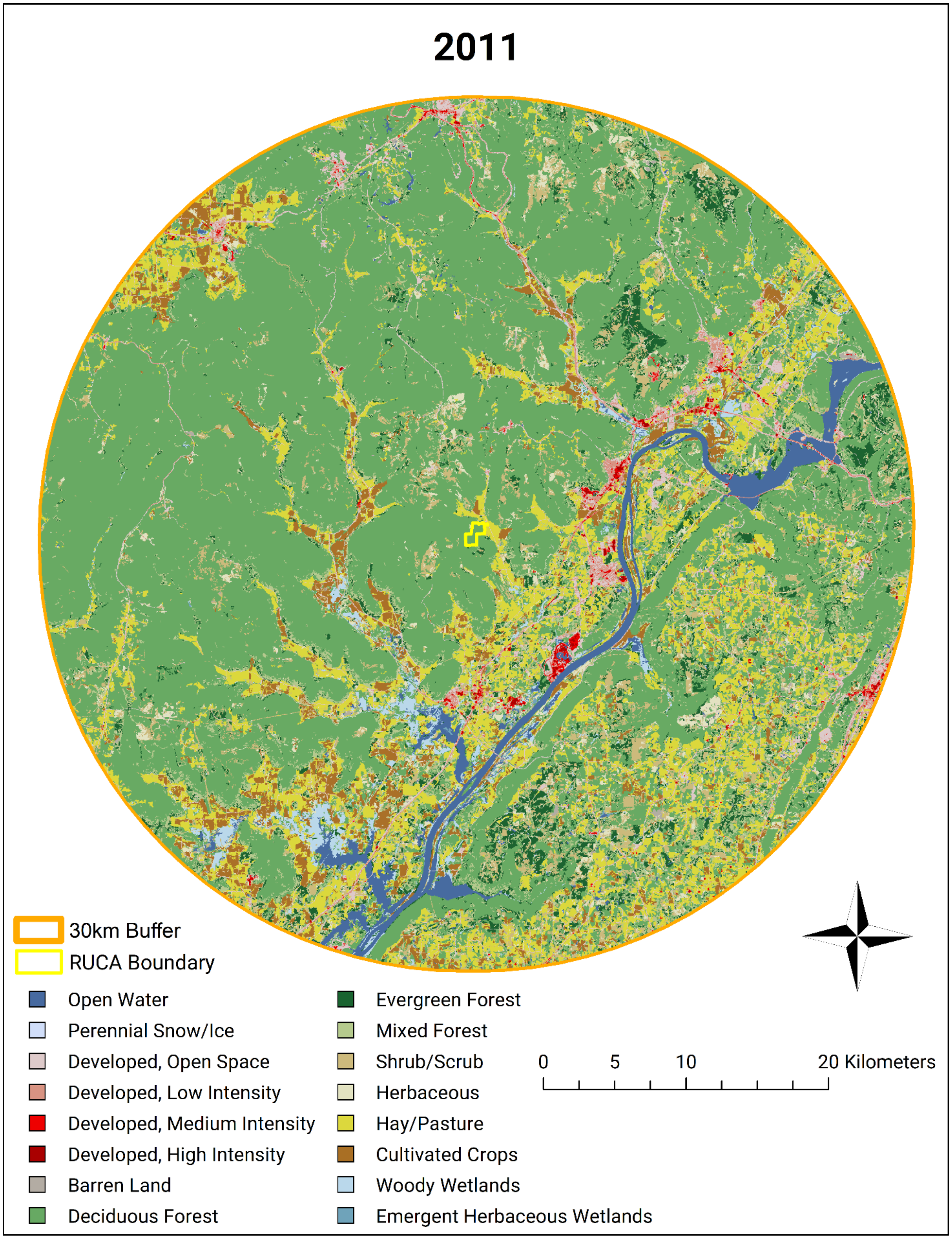


Figure 17. Land Cover within a 30 km buffer of the monument boundary in 2011 (NPS 2018).

Condition Status

Land cover within the monument is largely natural and the surrounding area has not undergone much if any change, warranting no concern. However, the existing and potential external changes within the region of the monument are worth noting. Staff of the monument may not have control over land cover changes that occur outside the boundaries of RUCA itself, but it is important to be aware of these changes and plan accordingly, as they have the potential to affect the monument's environmental health.

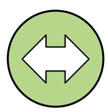
Trend in Condition

A trend of no change has been assigned to the category, since the few changes that have occurred in the immediate proximity to the monument remain natural land covers, as opposed to the transition from natural to converted land.

Confidence in Assessment

The data quality is good, as it is provided by the NPScape project which is supported by scientifically sound methods (Table 57). However, the most recent data from 2011 is more than five years old, so it is possible that changes have occurred since that are not reflected in the latest information available.

Table 57. The condition of RUCA land cover.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Land Cover	Converted land use		Condition warrants no concern and no trend, as the land cover within and immediately surrounding the monument is largely natural and has undergone little change in the timescale represented by the data. Because the data is more than five years old, the confidence level is medium.

Chapter 5. Discussion

5.1. Component Data Gaps

The quality and volume of data varied from one component resource to the next, although the general trend is that most categories had little available data. The overall lack of data indicates that further studies are necessary in order to get a handle on current conditions and trends in condition. Specific gaps are described below in Table 58. Each of the categories listed in this table are discussed in more detail in Chapter 4.

Table 58. Identified study and data gaps for resource conditions in RUCA.

Component	Data Gaps
Atmosphere	Ozone concentrations, Sulfur and Nitrogen deposition, and visibility information is generated from interpolated data, observations within the monument would improve data quality.
	There is no permanent weather station within the monument, and the nearest reliable weather data comes from almost 30 km away and at a much higher elevation. Local weather and climate data collection would improve understanding of atmospheric factors.
Water Quality	Water quality data exists going back a couple of decades, but the most recent data is more than five years old and should be updated. Monthly water sampling is scheduled for FY19-20.
Biological Integrity	Inventories on most of the biological components are needed, as most are more than five years old and some are more than ten years old.
	Establishing a monitoring and inventory rotation would be valuable, as most categories have only one or two major data points. Trends cannot be established or analyzed without regular, repeated studies.
Landscapes and Human Use	While NPScape provides a large volume of data, there are no reports or assessments focusing on the land cover or landscape dynamics within and near the monument. This kind of information would help inform many aspects of the environmental management of RUCA.
Geospatial Data	Geographic Information Systems data is Available at: RUCA, but a lack of metadata severely limits its use.
	The implementation of GIS best practices would let RUCA staff produce and maintain geospatial data more effectively. This is a central component of modern environmental monitoring and management and would improve the understanding of conditions and trends within the monument.

5.2. Natural Resource Component Conditions

5.2.1. Ozone

The NPS Air Resources Division (NPS-ARD) interpolation method is used to assess ozone concentrations at RUCA. These interpolated values warrant moderate concern, but the trend is positive, as the concentrations have been dropping in the 2009-2015 time period of available data.

Data Quality

The methods employed are appropriate and rigorous. However, ozone concentration confidence is medium, as the data is interpolated from air quality stations not located on-site.

5.2.2. Ozone-Caused Foliar Injury

Direct observation of foliar injury is a method of monitoring the impact of ozone on plant life. The indices used to assess the impact of ozone in the atmosphere on plant life measure the sum of hourly concentrations greater than 60ppb (SUM06) and the sum of hourly concentrations weighted by a sigmoidal function (W126). Direct observations at the monument in 2011 put SUM06 and W126 observations well below the critical thresholds. NPS-ARD also interpolates data to estimate ozone concentrations as measured by the W126 scale and finds that concentrations have been dropping yearly from 2009 to 2015. However, the interpolated values for 2011 are significantly higher than the direct observations on-site.

Visual inspection of plants for injury has also been carried out, with four plants exhibiting the signs of ozone injury identified in 2011. A 2017 report found no evidence of foliar injury.

Data Quality

The methods employed are appropriate and rigorous. However, the confidence is medium, as there are few on-site data points, the interpolated data does not match the on-site observations well, and the only on-site measurements of ozone concentrations are more than five years old.

5.2.3. Sulfur and Nitrogen Deposition

Sulfur and nitrogen pollutants in the atmosphere can lead to acidification of water systems, including streams, lakes, and soils, leading to negative environmental outcomes for plant and animal life at the monument. RUCA is not alone in the risk of this occurring, as all of the parks in the CUPN have high levels of atmospheric sulfur (S) and nitrogen (N) deposition (Sullivan 2016). Nitrogen deposition can also lead to an unnatural and undesirable nutrient enrichment of an ecosystem, which can affect the diversity of plant species and disrupt natural soil nutrient cycling. Both NPS-ARD and Schwede and Lear (2014) use models to estimate S and N deposition at RUCA, and both find decreases in deposition for the time periods they examine.

Data Quality

The confidence used to make the assessment is medium. Data was collected and processed using scientifically-sound methods and involved multiple agencies. However, having only two time points to compare and using an interpolation approach rather than measuring at the site reduces confidence in the assessment. The ARD numbers are more recent, with the latest figures coming from 2015, but other values are more than five years old.

5.2.4. Visibility

Particulate matter in the atmosphere absorbs and scatters light, shortening the length of visual range, and affecting the color and feel of the land. In the eastern part of the US, air pollution has reduced the visual range from around 145 km to 25-40 km, and in the west, the range has been reduced from 225 km to 55-145 km (EPA 2017). NPS-ARD has interpolated estimates of visibility based on the IMPROVE network. In all years estimated by NPS-ARD, the haze index warrants significant concern, although values have improved from each year to the next.

Data Quality

The confidence used to make the assessment is medium. Data was collected and processed using scientifically-sound methods, but values are based on an interpolation approach. Visibility values have been improving but remain in the significant concern category.

5.2.5. Weather and Climate

There is a lack of published reporting on weather and climate conditions at RUCA, but Monahan and Fisichelli (2014) did look for climate factors that reached an extreme (greater than 95% of the 1901-2012 average range). They identified high temperatures as the only climate factor that reached this extreme threshold. This is not surprising as rising temperatures are a part of the broader climate pattern in much of the world due to climate change. There is no permanent weather monitoring station at the monument, and only one station has a current and unbroken climate record within 30 km of the monument.

Data Quality

Monahan and Fisichelli (2014) is the only report to actually discuss climate variables at RUCA, and they do so broadly. As Davey et al. (2007) discuss, RUCA has spotty historic climate records, and other than the one-time deployment of the ozone-monitoring POMS equipment, has no atmospheric instrumentation on-site. Weather monitoring in the region is not complete, and the most complete and current record of data sits 27 km away and roughly 230 m higher in elevation from the monument leading to a low confidence in the specifics of RUCA weather and climate information.

5.2.6. Water Chemistry

Russell Cave National Monument is home to both surface and groundwater systems due to the local karst geology. Because of this geology, swallets, sinkholes, karst windows, seeps, and springs allowing water to move between surface and groundwater conditions at many points (The Center for Cave and Karst Studies 2008). The NPS Water Resources Division (WRD) has identified four core field parameters to monitor for assessing water quality: water temperature, pH, specific conductance, and dissolved oxygen. Beyond those four categories, the acid neutralizing capacity (alkalinity) and presence of fecal coliform bacteria are also commonly tested in RUCA reporting. Testing from the early 1990s to 2013 in and at sites around RUCA show that water chemistry values have not changed much over time, and the four important categories hold relatively steady (Hobbs 1994, NPS WRD 1999, Meiman 2007, CUPN 2012, CUPN 2013a).

Data Quality

Reporting was carried out using appropriate scientific methods by individuals with the proper training. However, the confidence is medium, as the most recent data is more than five years old at this point. Water quality values are good, with little change over time.

5.2.7. Bacteria

The presence of fecal indicator bacteria may indicate the presence of waterborne disease-causing organisms, and their measurement is used as a proxy for these pathogens (Meiman 2007). The state of Alabama's threshold for *E. coli* concentrations is no higher than 235 MPN/100 ml, which is a more stringent threshold than the EPA's 298 MPN/100 ml. Bacteria levels are typically below the state's threshold at RUCA, but they spike following precipitation and flooding events, as animal waste is washed into the cave system. Animal waste is essentially held in storage on the surface, and when rainfall events occur, this waste is washed into karst features or the stream channel that feeds RUCA.

Data Quality

Reporting was carried out using appropriate scientific methods by individuals with the proper training. However, the confidence is medium, as the most recent data is more than five years old at this point. Bacteria levels spike following rainfall events due to runoff entering streams, but otherwise the concentrations are in good condition.

5.2.8. Freshwater Wetland Communities

Three small wetlands are located at RUCA with a total size of 0.07 ac and an average size of 0.02 ac. The HGM classification system categorized two sites as depression wetlands and one as a slope/seep wetland. All of the RUCA wetlands maintain woody and herbaceous vegetation with common species including: red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), and clearweed (*Pilea pumila*). Two of the wetlands maintain dominant woody vegetation and are temporarily flooded and one maintains herbaceous vegetation and is seasonally flooded. One had the suggestion of breeding habitat for amphibians.

Data Quality

Data were collected throughout RUCA by experts using a variety of scientifically-sound methods and were geo-referenced. However, the survey was over 5 years old. The condition of the wetlands at RUCA warrants moderate concern, considering the small size. No trend was assigned due to the lack of data beyond the baseline study. The confidence in the assessment was medium.

5.2.9. Forest Vegetation Communities

Developing an understanding of the forest vegetation communities at RUCA can be a useful tool for monument managers and their partners in their efforts to make informed decisions about resource management (Schotz et al. 2006). A total of 10 different vegetative communities were identified at RUCA, indicating a relatively high level of forest biodiversity at the site. Although most of the forest communities found at RUCA are fairly common and relatively secure, the Shumard Oak - Chinquapin Oak Mesic Limestone Forest is considered uncommon or rare (Schotz et al. 2006). The presence of several highly invasive exotic plant species (e.g., multiflora rose, Japanese honeysuckle, and Japanese stiltgrass) represent the primary threats and stressors to the forest vegetation communities at RUCA.

In addition to this initial baseline study, twenty permanent monitoring plots have been established at RUCA as part of a broader long-term effort to monitor forest vegetation communities within CUPN parks (Bledsoe 2017). The plots measure 20 meters x 20 meters, with data collected grouped into several broad categories (e.g., species presence, canopy cover, plot characteristics, tree growth and health, forest community classification, and evidence of pests) (Bledsoe 2017).

Data Quality

Data were collected on forest vegetation communities in RUCA throughout the monument from 2003-2004 (Schotz et al. 2006) and from 2011-2015 (Bledsoe 2017). Using scientifically-sound sampling techniques, the data were collected by experienced researchers with wide-ranging experience in identifying and examining regional vegetative communities. Data collected on forest vegetation communities was insufficient to establish a trend. Confidence in the condition assessment was high.

5.2.10. Vascular Plants

Two ecological systems and ten distinct vegetation associations at RUCA have been identified. Of the community types, eight were classified as natural, one as semi natural, and another one as exotic-dominated community. Most plant species were considered widespread and/or abundant; and no species were on the list of federally endangered, threatened, or rare. Some species are imperiled in the state of Alabama due to scarcity, such as: Goldenseal (*Hydrastis canadensis*). American smoketree (*Cotinus obovatus*), American beakgrass (*Diarrhea americana*), cream avens (*Geum virginiatum*), white bergamot (*Monarda clinopodia*), and Indian-pipe (*Monotropa hypopithys*). Invasive species/exotic plants can be found in six vegetation communities, although most of them do not pose as serious threat. An Integrated Pest Management should be implemented more to prevent/reduce effect of invasive species/exotic plants to native plants communities.

Data Quality

Data were collected throughout RUCA by experts. Methods they used were scientifically –sound and geo-referenced. The condition of RUCA vascular plants warrants moderate concern. No trend data can be assigned for vascular plants at this time. The confidence in the assessment was medium.

5.2.11. Non-Vascular Plants

Data for non-vascular plants were collected throughout RUCA: Cave sites, dry Creek, Lower Slope, Upper Slope, and Caprock Sandstone. Three surveys were conducted on June 1993 – December 1994, resulted in 159 taxa of mosses and liverworts. Based on this study, we found that RUCA has a relatively high species richness of bryophytes. Some species abundant in moist areas, others are restricted in specific/critical areas. Bryophytes are naturally sensitive to changing environment and/or climate. Minimizing habitat disturbance will ensure their survival within the monument.

Data Quality

Data were collected by experts using scientifically sound methods. However, this is the only study in bryophytes and is older than 5 years. The condition of non-vascular plants at RUCA warrant moderate concern, considering some species have restricted or scattered distribution and some others have critical habitat within the monument. No trend was assigned due to lack of data beyond the baseline study. The confidence in the assessment was medium.

5.2.12. Invasive/Exotic Plants

Approximately 12% of the plants at RUCA are introduced species. Of the exotic plants occurring at the monument, three species are listed as Alabama's worst 10 and seven species as extensive and dense infestation in Alabama. Only four out of ten vegetation communities at RUCA are without invasive species/exotic plants at this time. Treatments to some invasive species has been ongoing over the years, yet continued efforts will be needed for full recovery of vegetation and prevention of natural vegetation communities.

Data Quality

Data were collected throughout RUCA by experts using a variety of scientifically sound methods. The condition of invasive species/exotic plants at RUCA warrant significant concern. A negative trend was assigned based on increasing numbers of non-native/invasive plants within the monument. The confidence in the assessment was high.

5.2.13. Cave Aquatic Biota

As the cave is the primary natural feature at the monument, the condition of the aquatic life within the cave is important. A few species are considered vulnerable or near-threatened, including the Tennessee cave salamander and the Southern cavefish. The small number of studies looking at aquatic biota in the cave and the vulnerable status of some species leads to a condition of moderate concern. Future monitoring of cave aquatic biota will be conducted by CUPN, starting in 2019.

Data Quality

The studies supporting this report were conducted by experts using standard protocols with documented sampling locations. Therefore, the thematic and spatial data collected by these studies are deemed good, though they are sparse. Sampling was conducted over two general time periods: 1992-1993 (Hobbs 1994) and 2003-2007 (ABC 2006, Zimmerman 2007, Parker et al. 2015). No trend can be assigned as the data is too infrequent; however, upcoming monitoring of cave aquatic biota by CUPN should address this need in the future. Overall, the confidence used to make an assessment for the cave aquatic biota is medium.

5.2.14. Cave Bats

Because of the many ecological services performed by bats in both terrestrial and cave ecosystems, monitoring bat populations is a critical component of evaluating ecosystem health (Thomas et al. 2016). There were eight species of bats documented in RUCA using mist-netting, summer emergence counts, and winter bat counts: gray bat (Myotis grisescens), northern long-eared bat (Myotis septentrionalis), tri-colored bat (Perimyotis subflavus), big brown bat (Eptesicus fuscus), eastern red bat (Lasiurus borealis), and evening bat (Nycticeius humeralis) (Grow et al. 2010, Thomas et al. 2016). In addition to potential stressors such as habitat loss and habitat impact (e.g., in cave modifications, land use changes, and human disturbance), WNS represents the most significant threat to bat populations at RUCA (Grow et al. 2010, Thomas et al. 2016). The condition of bat assemblages in RUCA warrants moderate concern, with one species listed as federally endangered (M. grisescens), one listed as threatened (M. septentrionalis), another listed as a species of concern (C. rafinesquii), and two more under evaluation (M. lucifugus and P. subflavus) (Thomas et al. 2016). Although no trend was assigned to the bat assemblages, ongoing monitoring of cave-dwelling bats will likely provide sufficient data for assessing trend of bat species at RUCA at a later date.

Data Quality

Data were collected in RUCA by experienced researchers throughout the monument in a variety of habitats using an assortment of scientifically-sound procedures such as standard mist-netting techniques, summer emergence counts, and winter bat counts (Grow et al. 2010, Thomas et al. 2016). Data were collected at various times from the fall of 2006 until the fall of 2009 (Grow et al. 2010), with additional data on cave-dwelling bats collected from 2012-2018 that has yet to be analyzed. However, available data on bat assemblages were not enough to establish a trend. Confidence in the condition assessment is medium.

5.2.15. Mammal Assemblages

Mammals interact with other organisms at many trophic levels as carnivores, herbivores, insectivores, and omnivores. They are also import agents in seed dispersal, pollination, and seed dispersal (Grow et al. 2010, NRC 2007, Willson 1993). Therefore, developing an understanding of their diversity and abundance is critical to successfully managing natural resources. A total of 23 non-bat species of mammals were documented at RUCA, using live traps, scent stations, baited camera stations, spotlight surveys, and regular observations: eastern chipmunk (*Tamias striatus*); woodchuck (*Marmota monax*); eastern gray squirrel (*Sciurus carolinensis*); southern flying squirrel (*Glaucomys volans*); American beaver (*Castor canadensis*); white-footed deermouse (*Peromyscus leucopus*); cotton deermouse (*Peromyscus gossypinus*); hispid cotton rat (*Sigmodon hispidus*); Allegheny woodrat (*Neotoma magister*); woodland vole (*Microtus pinetorum*), Virginia opossum (*Didelphis virginiana*), northern short-tailed shrew (*Blarina brevicauda*), eastern mole (*Scalopus aquaticus*), nine-banded armadillo (*Dasypus novemcinctus*), eastern cottontail (*Sylvilagus floridanus*), domestic dog (*Canis familiaris*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), eastern striped skunk (*Mephitis mephitis*), bobcat (*Felis rufus*), feral cat (*Felis catus*), and white-tailed deer (*Odocoileus virginianus*) (Grow et al. 2010). The primary threats and stressors for mammal diversity within the monument include both modification and loss of habitat in nearby areas (Grow et al. 2010). Habitat fragmentation also represents a potential threat for some small mammal species at the site. Excluding bats, the condition of the mammal assemblages at RUCA is good. Of the 24 non-bat species of mammals deemed likely to occur at the site, 23 (96%) were documented. Although no trend for other mammal assemblages was assigned, future monitoring of mammal populations may provide data for assessing trend.

Data Quality

Data were collected on mammal assemblages in RUCA by experienced researchers throughout the monument in a variety of habitats using an assortment of scientifically-sound procedures such as using live traps, scent stations, baited camera stations, spotlight surveys, and regular observations (Grow et al. 2010). Data were collected during the fall and winter of 2006, the winter of 2008, and the summer and fall of 2009. However, data collected on other mammal assemblages were not enough to establish a trend. Confidence in the condition assessment is medium.

5.2.16. Bird Assemblages

There were 130 species of birds documented in RUCA, with breeding evidence noted in 79 of those species: 43 confirmed breeders (54.4%), 20 probable breeders (25.3%), and 16 possible breeders

(20.3%) (Stedman and Stedman 2006). The number of bird species documented was found to be consistent with the relatively small size of RUCA. Additionally, bird species adapted to the predominate deciduous woodland habitat of the monument were found to be more prominent as expected. None of the bird species documented at RUCA are listed as threatened or endangered by the USFWS or listed by the state of Alabama as protected species (Watson 2004). However, several species deemed high priority for the Southern Ridge and Valley physiographic areas by Partners in Flight occur in RUCA, including the summer tanager (*Piranga olivacea*), Acadian flycatcher (*Empidonax virescens*), field sparrow (*Spizella pusilla*), brown thrasher (*Toxostoma rufum*), wood thrush (*Hylocichla mustelina*), yellow-throated warbler (*Dendroica dominica*), Louisiana waterthrush (*Seiurus motacilla*), Kentucky warbler (*Oporornis formosus*), prairie warbler (*Dendroica discolor*) and worm-eating warbler (*Helmitheros vermivorum*) (Watson 2004).

Data Quality

The condition of the avifauna assemblage at RUCA is good. Data were collected in RUCA by experienced researchers using an assortment of scientifically-sound procedures. However, the data collected is more than 10 years old. Although data were collected from 2003-2005, the data were not enough to establish a trend. Confidence in the condition assessment is medium.

5.2.17. Aquatic Insects

No federal or stated listed species were reported from the monument. More than 100 species of aquatic insects (EOMPT) have been identified as occurring in Jackson County but slightly less than one-fourth has been confirmed at the monument.

Data Quality

Data were collected throughout RUCA at significant hydrologic locations by experts using a variety of scientifically supported methods and were geo-referenced. However, sampling was not within five years of this report. The condition of the aquatic insects at RUCA warrants moderate concern. No trend data is available for the aquatic insect population at this time. The confidence in the assessment was medium.

5.2.18. Fish

Two ichthyofaunal surveys of RUCA cave entrance spring and sites within the cave reported five fish species: largescale stonerollers (*Campostoma oligolepis*), western blacknose dace (*Rhinichthys obtusus*), banded sculpin (*Cottus caronlinae*), bluegill (*Lepomis macrochirus*), and the southern blind cavefish (*Typhlichthys subterraneus*). The blind cavefish is listed as state protected (Alabama Natural Heritage Program 2007) and the current global and state ranking is G4 and S3, respectively. Lack of diversity in the fish community may be attributed to seasonal habitat changes and stream isolation. Another factor may be attributed to difficulty in sampling and access to cave pools as reported by Zimmerman (2007).

Data Quality

Data were collected throughout RUCA by experts using a variety of scientifically-sound methods and were geo-referenced. However, the study was over five years old. The quality of the fish assemblage at RUCA warrants moderate concern. Further study is needed to assign a trend to the fish population. Confidence in the assessment was medium.

5.2.19. Amphibian and Reptile Assemblages

Reptiles and amphibians represent a substantial component of vertebrate biodiversity in nearly every freshwater and terrestrial habitat in the southeastern United States (Tuberville et al. 2005). Accordingly, developing an understanding of the status of herpetofauna assemblages represents an important step in evaluating the overall condition of the ecosystems where they are found. A total of 30 reptile and amphibian species were documented at RUCA: ten species of frogs and toads, seven species of salamanders, three species of lizards, nine species of snakes, and one species of turtle. The documented list of herpetofauna species at RUCA exceeded the study goal of 90% of the species thought likely to occur at the site. None of the species reported within the monument are listed as rare, threatened, or endangered by the USFWS. However, the green salamander (*A. aeneus)* is listed as a protected species by the State of Alabama. Habitat degradation and destruction in adjacent properties, surrounding agricultural and silvicultural practices, stream modification, and mower and automobile injuries represent the primary threats and stressors for the herpetofauna assemblages in RUCA. Snake fungal disease has been positively identified with the monument, although only in one specimen. The condition of the herpetofauna assemblages at RUCA warrant moderate concern.

<u>Data Quality</u>

Data were collected on herpetofauna assemblages in RUCA by experienced researchers throughout the monument in a variety of habitats using an assortment of scientifically-sound sampling techniques (e.g., minnow traps, coverboards, audio frog breeding surveys, general observation and collection, drift fences with funnel type live traps) (ABC 2006). Data were collected from 2003-2005 by researchers with comprehensive experience in identifying and examining regional herpetofauna. However, data collected on herpetofauna assemblages were not enough to establish a trend. Confidence in the condition assessment is medium.

5.2.20. Land Cover and Land Use

Land cover has the potential to dramatically influence environmental conditions within RUCA, even if those changes occur outside the boundaries of the monument. Data from the NPScape service shows that no changes to land cover have occurred within the monument, and not much change has occurred in the surrounding three kilometers. Looking at a 30 km buffer, changes exist, but they are not dramatic. The possibility of increased development in the region does pose a potential thread to the monument, but there is little RUCA can do beyond responding to changes.

<u>Data Quality</u>

The data quality is good, as it is provided by the NPScape project which is supported by scientifically sound methods. However, the most recent data from 2011 is more than five years old, so it is possible that changes have occurred since that are not reflected in the latest information available.

5.2.21. Indicator level summary tables

Tables 59-62 list of the indicator summaries in one place, organized by their major resource categories.

Table 59. Indicator level summary table for atmospheric conditions.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Ozone	Ozone concentrations in ppb ≤70		Condition warrants moderate concern. The trend is positive with concentrations falling each year. The interpolated data used to reach this assessment is of a medium confidence, as it is based on air quality stations not on-site.
Foliar Injury	Number of injured plants observed and observed SUM06 and W126 values		Condition is good, as ozone concentrations on-site were low and few plants presented evidence of foliar injury. A positive trend is assigned due to the improvement in the ARD estimated values over time. Confidence is medium because of the nature of interpolated data and the small number of on-site observations.
Atmospheric Sulfur and Nitrogen deposition	Total S deposition		The data was collected and processed in an appropriate scientific manner and shows that total deposition of sulfur compounds has dropped significantly over the reported time period. The deposition rates are still well above the recommend rates, and the data being interpolated leads to significant concern and a medium confidence.
Atmospheric Sulfur and Nitrogen deposition	Total N deposition		The data was collected and processed in an appropriate scientific manner and shows that total deposition of nitrogen compounds has dropped significantly over the reported time period. The deposition rates are still much higher than the recommend rates, and deposition of NH_3 compounds have increased leading to an assessment of significant concern. The data being interpolated leads to a medium confidence.
Visibility	Haze index in deciviews (dv) > 8		The data was collected and processed in an appropriate scientific manner and shows that haze has decreased during the observation period. The visibility values are still well above the recommend rates, and the data being interpolated leads to significant concern and a medium confidence.
Weather and Climate	Temperature and other atmospheric measurements		Due to the nature of weather and climate, a condition assessment is not suitable. The little data available suggests that most atmospheric conditions beyond average temperatures are remaining steady. Due to the small amount of published reports on the monument, the confidence is low.
Atmosphere Overall			–

Table 60. Indicator level summary table for water quality.

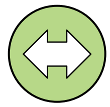
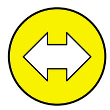
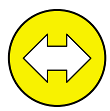
Resource	**Indicator**	**Status and Trend**	**Rationale and Reference Conditions**
Water Quality	Water Chemistry		Condition is good based upon measured water chemistry values. Trend is unchanging, as studies beginning in the early 1990s to as recently as 2013 show no major shifts in observed values. Confidence in data quality is medium; proper procedures in sampling methodology were employed, but the most recent information is more than five years old.
Water Quality	Bacterial Presence		Condition warrants moderate concern based upon measured bacterial volume in water. The volume of bacteria measured regularly fluctuates along with precipitation events. Trend is unchanging, as studies beginning in the mid-2000s to as recently as 2013 show no major shifts in observed values. Confidence in data quality is good due to evidence of proper procedure in sampling methodology.
Water Quality Overall			–

Table 61. Indicator level summary table for biological integrity.

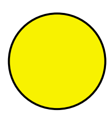
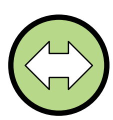
Resource	**Indicator**	**Status and Trend**	**Rationale and Reference Conditions**
Wetlands	Wetland Communities		Condition warrants moderate concern based upon the small isolated nature of the three wetlands. No trend can be assigned based upon a single study. Confidence in thematic and spatial quality of data is good, in that sites where documented and survey conducted by experts (Roberts and Morgan 2007). Survey was conducted more than 5 years ago, which makes temporal data insufficient, therefore confidence in the assessment is medium.
Forest Vegetation Communities	Forest Vegetation Communities Composition and Diversity		The condition of the RUCA forest vegetation communities is good. 10 distinct vegetative communities were identified, indicating a relatively high level of forest biodiversity. Data collected from 2003 – 2004 (Schotz et al. 2006) and also from 2011 – 2015 (Bledsoe 2017, CUPN 2013b) indicated the condition of the forest vegetation communities is largely unchanged. Confidence in the assessment was high.

Table 61 (continued). Indicator level summary table for biological integrity.

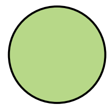
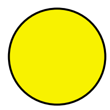
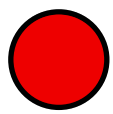
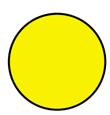
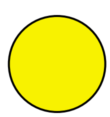
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Vascular Plants	Vascular Plant Diversity		The condition of RUCA vascular plants is good, due to the high vascular plant diversity and low exotic invasive plant prevalence. No data were available to evaluate trends. Although data were adequately collected, analyses of additional data currently being collected over time would increase confidence.
Non-vascular Plants	Non-vascular Plant Community Quality		The condition of non-vascular plants/bryophytes in RUCA warrants moderate concern. No trend was assigned at this time without more than a baseline study. Data quality fair, adequately collected and spatially explicit. The confidence in the assessment was medium. Although experts in their fields conducted sampling, the data were older than five years.
Invasive /Exotic Plants	Invasive/Exotic Plant Species Threat		The condition of RUCA invasive exotic plants warrants significant concern, primarily due to the occurrence of ten of Alabama's listed exotic species. They are a high threat to native biodiversity. Rapid treatment to the early detection candidate pest and plant species would reduce the invasions. Continued management probably will always be needed to keep them under control. Confidence in the assessment was high due to scientifically sound data available.
Cave Aquatic Biota	Aquatic Biota Presence & Abundance		Moderate concern. A single study has been conducted to comprehensively evaluate the cave aquatic community at RUCA, though additional data from near cave entrances are also relevant. Data were collected from 1992-1993 (Hobbs 1994) and from 2003-2007 (ABC 2006, Zimmerman 2007, Parker et al. 2015). Temporal trends cannot be assessed because the data are too infrequent and not recent. Confidence in the existing thematic and spatial data are good, but additional sampling is needed within the cave systems.
Bat Assemblages	Bat Assemblage Condition		The condition of the bat assemblages at RUCA warrants moderate concern due to potential threats (e.g., impact to habitat, habitat loss) and the presence of WNS (Thomas et al. 2016). Among the bat species documented at RUCA, *M. grisescens* is federally endangered, *M. septentrionalis* is listed as threatened, *C. rafinesquii* is listed as a species of concern, and *M. lucifugus* and *P. subflavus* are under evaluation (Thomas et al. 2016). Because of limited data, no trend was established.

Table 61 (continued). Indicator level summary table for biological integrity.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Mammal Assemblages (excluding bats)	Species Composition and Diversity		The RUCA mammal assemblages were found to be in good condition. Of the 24 non-bat species of mammals deemed likely to be present at RUCA, 23 were documented (Grow et al. 2010). Thus, 96% of the mammal species likely to be present at RUCA (excluding bats) were found at the site. The limited duration, periodic sampling of the surveys, and size/type of traps used may have resulted in a less accurate representation of the mammal biodiversity supported at RUCA. Continued sampling efforts may allow for increased confidence in the assessment. Because of limited data, no trend was established.
Bird Assemblages	Avifauna Assemblage Condition		Species diversity was as expected for a small unit yet exceeded the expectations of Stedman and Stedman (2006). Data quality was good, but confidence is medium due to the age of the data. No trend could be established due to only having one study.
Aquatic Insect Assemblages	Aquatic Insect Population Quality		Condition warrants moderate concern based upon a single study conducted 2005 to 2007 (Parker et al. 2009) with 24.5% of species known to occur in Jackson County. No trend can be assigned based upon a single study. Confidence in thematic and spatial quality of data is good, in that sites where documented and survey conducted by experts. Survey was conducted more than 5 years ago, which makes temporal data insufficient, therefore confidence in the assessment is medium.
Fish Assemblages	Fish Population Quality		Condition warrants moderate concern based upon two studies. No trend can be assigned based upon these two separate studies. Confidence in thematic and spatial quality of data is good, in that sites where documented and surveys conducted by experts. Surveys were conducted more than 5 years ago and 14 years apart which makes temporal data insufficient, therefore confidence in the assessment is medium.
Herpetofauna assemblages	Species Composition and Diversity		Data reviewed for this condition assessment indicated the RUCA herpetofauna assemblages are in good condition. Of the 32 species deemed likely to be present at RUCA, 30 were documented in the monument (ABC 2006). Thus, 94% of the reptile and amphibian species likely to be present at RUCA were found at the site, indicating a high level of herpetofauna diversity (ABC 2006). However, the presence of snake fungal disease has been documented by monument staff and has been recognized as a concern. Because of the limited data, no trend was established. Also, the confidence in the condition assessment was medium due to the lack of more recent data.

Table 61 (continued). Indicator level summary table for biological integrity.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Biological Integrity			–

Table 62. Indicator level summary table for landscapes and human use.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Land Cover	Converted Land Use		Condition warrants no concern and no trend, as the land cover within and immediately surrounding the monument is largely natural and has undergone little change in the timescale represented by the data. Because the data is more than five years old, the confidence level is medium.
Landscapes and Human Use Overall			**–**

5.3 Geospatial Data

Geographic Information Systems resources are Available at: RUCA but are not being utilized to their full potential. While some GIS datasets exist, they are largely drawn from outside sources and clipped to the monument boundary or local region. This provides a good base of data to work with, but there is little data collected from within the monument itself that is represented in a geospatial format.

One of the biggest issues of concern is the lack of metadata in many of the existing files. GIS data that is missing metadata does not comply with Federal Geographic Data Committee (FGDC) standards and is therefore unusable for official purposes. A lack of data documentation and standardization across some of the available datasets means that users beyond the original creators may find it difficult or impossible to interpret the information, also potentially rendering the data unusable.

Implementation of better GIS practices at RUCA would allow for more efficient tracking and management of the natural resources Available at: the monument. Although the monument does not cover a large amount of surface area when compared to some other units in the NPS, it can still be difficult to manage environmental trends without a geospatial perspective. Given that GIS technology is an integral component of modern environmental monitoring and management, it is strongly recommended that RUCA invest in this area, as it can have a positive impact on the understanding and protection of environmental factors within the monument and the surrounding region.

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Appendix: RUCA NRCA Collaborators

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