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Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Stones River National Battlefield

Natural Resource Report NPS/STRI/NRR—2016/1141

ON THIS PAGE
Native warm season grass, located south of Stones River National Battlefield visitor center
Photograph by: Jeremy Aber, MTSU Geospatial Research Center

ON THE COVER
Karst topography in the cedar forest at the "Slaughter Pen," Stones River National Battlefield
Photograph by: Jeremy Aber, MTSU Geospatial Research Center

Natural Resource Condition Assessment for Stones River National Battlefield

Natural Resource Report NPS/STRI/NRR—2016/1141

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Photograph by: Jeremy Aber, MTSU Geospatial Research Center

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Executive Summary

The Stones River National Battlefield (STRI) is an important national park as it commemorates the Battle of Stones River, one of the bloodiest conflicts of the Civil War and a critical moment in American history. Stones River National Battlefield is located along the Stones River, three miles northwest of downtown Murfreesboro, Rutherford County, Tennessee. The park's holdings consist of roughly 712 acres divided into six distinct units. The park is situated within a physiographic region known as the Inner Nashville Basin or Central Basin physiographic province. The Inner Basin occupies an area of about 600 square miles in the geographic center of Tennessee and is known for its flat to gently rolling landscape and karst topography.

In this Natural Resource Condition Assessment (NRCA) report, STRI natural resources and their indicators were evaluated based on existing studies to assess their current conditions and trends (whenever possible). The main objective of this report was to summarize data and generate information to support managers and decision makers by describing present conditions and trends and by identifying data/study gaps. The assessments and evaluations described herein were the result of collaborative efforts between stakeholders from Middle Tennessee State University (MTSU), the Cumberland Piedmont Inventory and Monitoring Network (CUPN), the National Park Service (NPS) Southeast Regional Office, and STRI.

The literature and datasets utilized were obtained through personal communication with CUPN and STRI personnel, publically available websites, published technical reports, and scientific manuscripts. No new datasets/studies were generated. Evaluation criteria were determined based on published documentation in the form of state regulations and technical reports.

Out of 23 components analyzed, three of them were assigned no condition, four were assigned good condition, nine were assigned moderate concern, and six were identified as significant concern. The components with no condition assigned, indicate either lack of data for performing an assessment or an indicator that an assessment was not applicable, such as weather and geology.

Amongst all components identified of significant concern, the invasive/exotic species are the most critical. Although STRI's staff has employed numerous management efforts to control invasive species, approximately 30% of the plants at STRI are introduced species and, therefore, continued efforts will be needed for full recovery of vegetation. Additionally, many of the fields were once planted in crops and have been converted to native grasslands, requiring continued management.

Landscape dynamics provide the means to evaluate the temporal change of land use/land cover within the park and around the vicinity of STRI. Preliminary studies have been shown a significant conversion of land cover/land use within and around the park, with urbanization around the park as the most noticeable driving factor of change. Additional studies should be performed to allow for more detailed analysis of other landscape changing factors as multiple scales.

Cedar glades are important natural features at STRI and were remarked on in letters written by Civil War soldiers. These features cover approximately 10% of the park's area and contain several state-listed rare plant species, an out-planted (for conservation purposes) federally-listed plant, and approximately 230 plant taxa recorded. Significant attention and efforts have been applied to protect this unique and biologically rich system.

Geographic Information Systems (GIS) resources are available at STRI, but are not being utilized to their full potential. While many GIS datasets exist, they are largely disconnected from each other and lack proper context that would allow for future use. One of the largest issues is the lack of metadata/standardization for the vast majority of the files, which means that the datasets do not comply with federal standards (FGDC) and limits the utilization of the data by anyone other than their creator. Implementation of GIS best practices would allow STRI to effectively produce, maintain, and make effective use of their geospatial infrastructure. Given that GIS technologies are an integral component of modern environmental monitoring and management, it is strongly recommended that STRI invest in this area, as it can have a positive impact on every other area of environmental concern.

The NPS began recording visitor use statistics for STRI in 1934. Since that time, visitation to the park has continuously increased. This continued support and interest from the public demonstrates the historical importance of the park. Understanding threats and stressors to natural resources at STRI along with identifying data gaps, supports the prioritization and efficient allocation of the limited monetary and infrastructural resources available to STRI. Overall, the outcome of this report will help protect and maintain the health of the STRI's natural resources.

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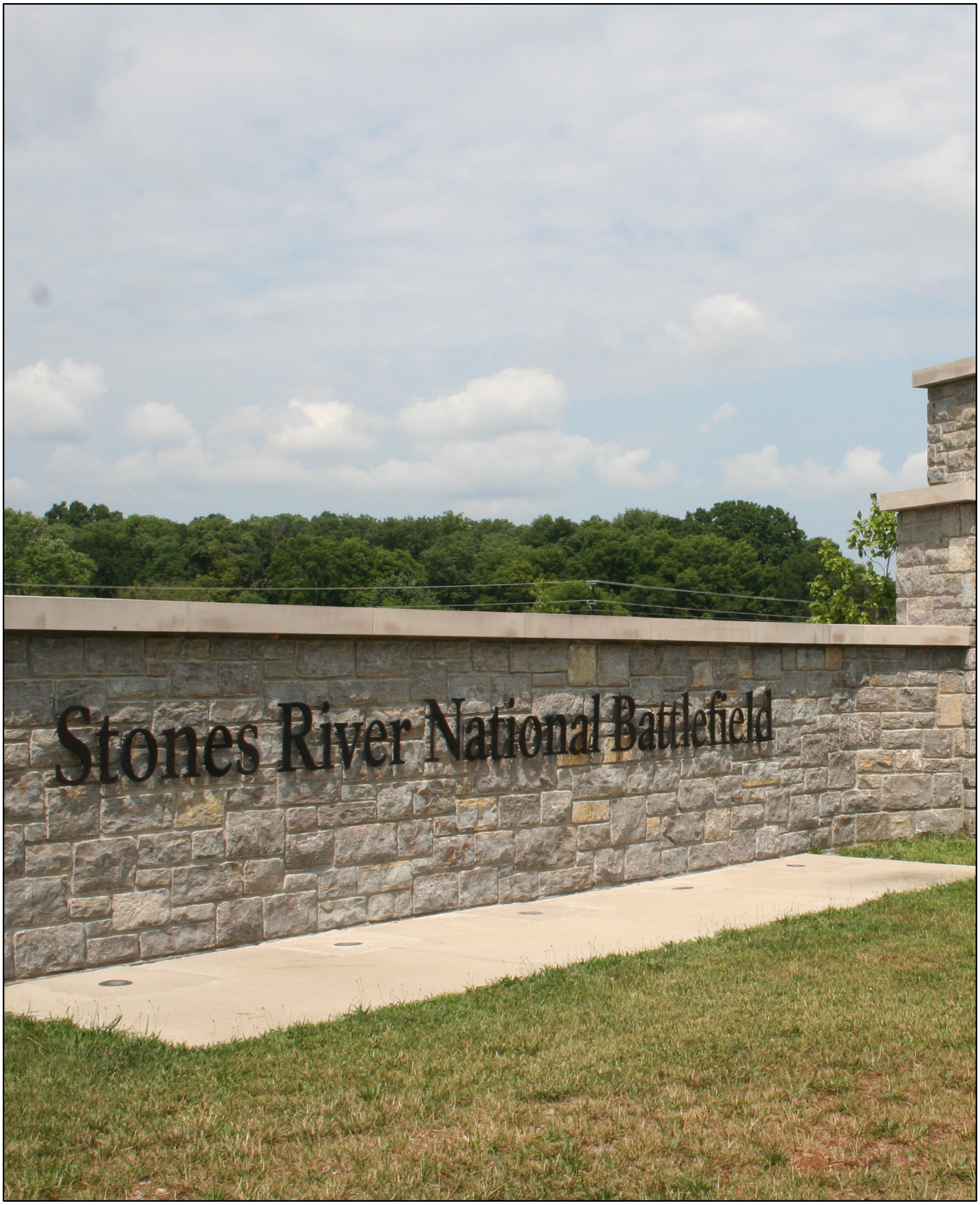

Stones River National Battlefield entrance gate on Thompson Lane
Photograph by: Jeremy Aber, MTSU Geospatial Research Center

Acronyms

ARD	Air Resources Division
BISO	Big South Fork National River and Recreation Area
BOD	Biochemical Oxygen Demand
BSBS	Battlefield Spring
CAA	Clean Air Act
COOP	Cooperative Observer Program
CRMS	Center for Remote Sensing and Mapping Science
CUPN	Cumberland Piedmont Network
DO	Dissolved Oxygen
EMF	Ecological Monitoring Framework
EPPC	Exotic Pest Plant Council
EPT	Ephemeroptera, Plecoptera, and Trichoptera index (insects)
FMU	Fire Management Unit
GIS	Geographic Information Systems
GPS	Global Positioning System
GRI	Geologic Resources Inventory
HGM	Hydrogeomorphic Classification for Wetlands
HUC	Hydrologic Unit Code
I&M	Inventory and Monitoring
KSKP	King Pond
LC	Lytle Creek
MFWF	West Fork at McFadden's Ford
MRLC	Multi-Resolution Land Characteristics Consortium
MTSU	Middle Tennessee State University
NAAQS	National Ambient Air Quality Standards
NLCD	National Land Cover Dataset
NPS	National Park Service
NRCA	Natural Resource Condition Assessment
NRR	Natural Resource Report

NVC	National Vegetation Classification
NWI	National Wetland Inventory
PEM	Palustrine Emergent
PFO	Palustrine Forested
POMS	Portable Ozone Monitoring Station
POW	Palustrine Open Water
PSS	Palustrine Scrub-Shrub
RBWF	West Fork at Redoubt Brannan
RSS	Resource Stewardship Strategy
SPC	Specific Conductance
STRI	Stones River National Battlefield
TDEC	Tennessee Department of Environment and Conservation
TMDL	Total Maximum Daily Load
TNHP	Tennessee Natural Heritage Program
TWRA	Tennessee Wildlife Resources Agency
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
UV	Ultraviolet
VOC	Volatile Organic Compound
WFSR	West Fork of the Stones River

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 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:

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

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

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

[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-on 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.

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 a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm

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

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

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

2. Chapter 2 Introduction and Resource Setting

2.1. Introduction

2.1.1. *Enabling Legislation*

Stones River National Battlefield (STRI) commemorates the Battle of Stones River, one of the bloodiest conflicts of the Civil War and a key moment in the struggle to control Middle Tennessee. On 3 March 1927, Congress authorized the creation of Stones River National Military Park and established a commission to recommend the portions of the battlefield to acquire.

> *It shall be the duty of the commission, acting under the direction of the Secretary of War, to inspect the battle field of Stones River, Tennessee, and to carefully study the available records and historical data with respect to the location and movement of all troops which engaged in the battle of Stones River, and the important events connected therewith, with a view of preserving and marking such field for historical and professional military study (44 Stat. 1399).*

In June of 1933, administration of the park was transferred from the Secretary of War to the National Park Service, expanding its size from 325 acres acquired in 1927 to 344 acres (Wiss et al., 2007). On 22 April 1960, the park was renamed to "Stones River National Battlefield" (74 Stat. 82). In 1987, Congress acted to expand the authorized boundaries of Stones River National Battlefield, including an agreement with the City of Murfreesboro, Tennessee to share management of an intact remnant of Fortress Rosecrans (Public Law 100-205). The authorized boundary was expanded once more in 1991 to 712 acres, 650 acres of which is currently administered by the NPS. The 1991 legislation also changed the management of Fortress Rosecrans and the Stones River Greenway (105 Stat. 1682; U.S. Department of the Interior, 1999).

2.1.2. *Geographic Setting*

Stones River National Battlefield is located along the Stones River, three miles northwest of downtown Murfreesboro, Rutherford County, Tennessee (Figure 1). The park's holdings consist of roughly 712 acres (Figure 2), which represents less than 20% of the original battlefield (Wiss et al., 2007). The park contains six distinct units: Nashville Pike Unit, which includes the tour loop and visitors center, Stones River National Cemetery (Figure 3a), and the Hazen Brigade Monument (Figure 3b) are part of the Nashville Pike Unit; the McFadden Farm Unit (Figure 3c); Rosecrans's Headquarters (Figure 3d) Bragg's Headquarters (Figure 3e), Fortress Rosecrans curtain wall and lunettes, and Redoubt Brannan (Figure 3f).

The park is located within a physiographic region known as the Inner Nashville Basin or Central Basin physiographic province. The Inner Basin occupies an area of about 600 square miles in the geographic center of Tennessee and is known for gently rolling hills and karst topography (Miller, 1974; Wiss et al., 2007).

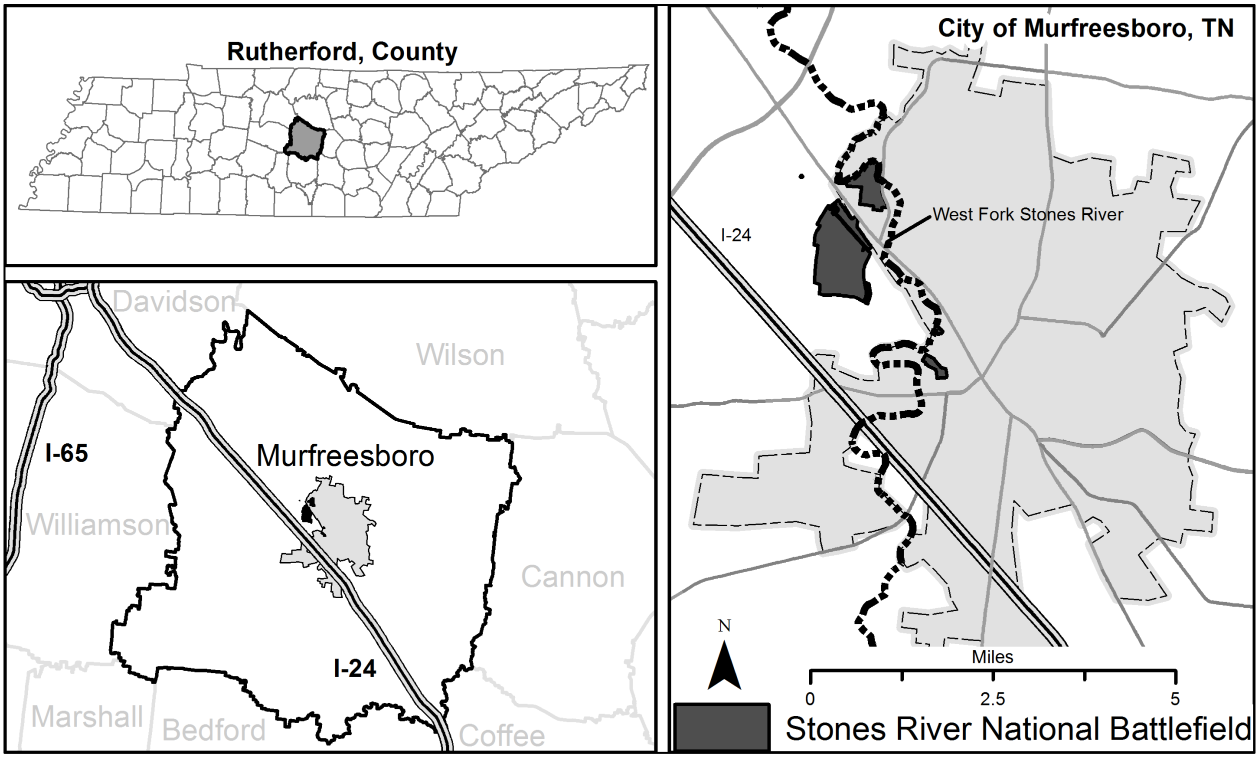


Figure 1. Geographical location of the Stones River National Battlefield.

The topography of the park is generally flat with an elevation ranging between 520-600 feet above sea level. However, portions of the riverbanks stand as high as forty feet above the water. The Union artillery position on high ground above the western side of the river during the third day of the battle provided a distinct advantage over Confederate soldiers approaching from the east (Wiss et al., 2007).

Stones River National Battlefield contains more than 600 species of plants and falls within Braun's Western Mesophytic Forest Region (Braun, 1950; Nordman, 2004). Efforts have been made by the NPS to maintain the vegetation communities similar to the composition prevalent during the 1862-1863 battle. However, invasive exotic plant species have penetrated the park and are now a major component of the park's vegetation composition (Wiss et al., 2007).

Land conditions in the park simulate conditions present during the time of the battle, providing more effective educational and interpretive opportunities for the public, while also supporting recreational activities, such as jogging, biking, and picnicking. Automobile traffic within the park circulates via a paved road, which begins and ends at the visitor center (Figure 2). Trails also run throughout the park to facilitate pedestrian access to various interpretive points and stops along the tour of the battlefield. These trails and roadways also allow recreational use for nature walks, jogging, and biking (Figure 2).

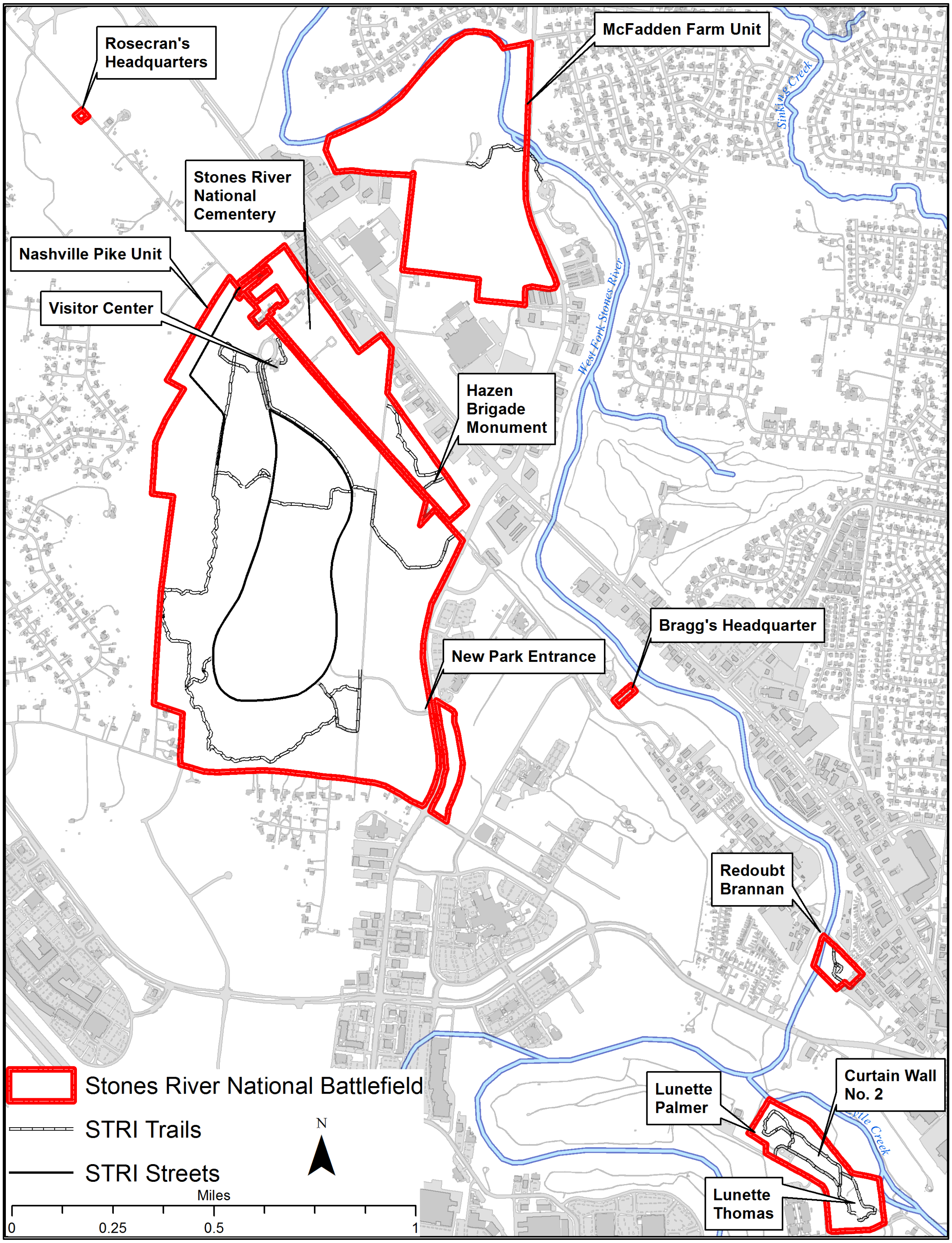


Figure 2. Parcels of the Stones River National Battlefield.

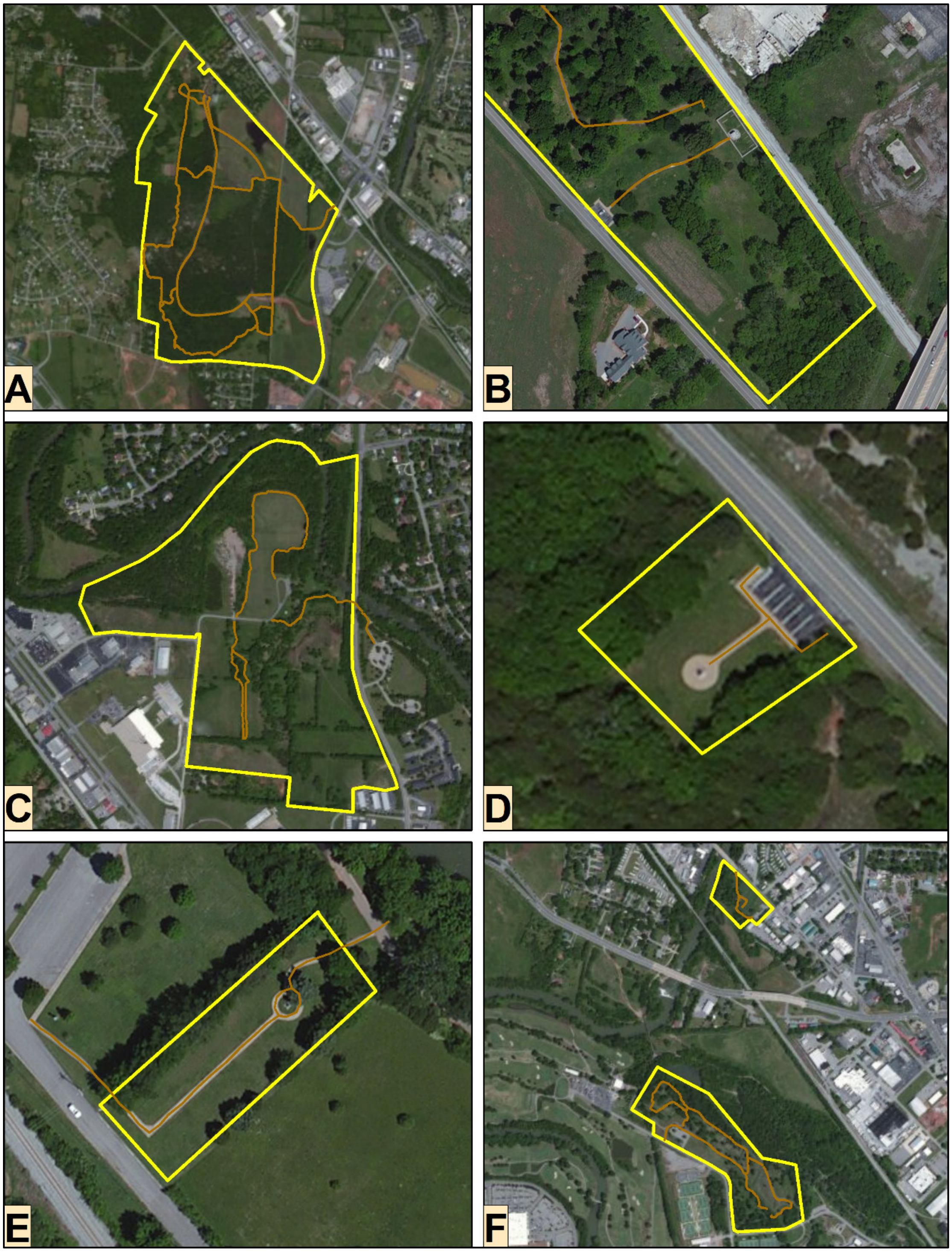


Figure 3. Aerial photographs of trails (orange) of the disparate parcels (yellow) of STRI.

Land use adjacent to the park consists of residential, commercial, industrial, and agricultural areas (Figure 2), which brings additional challenges to the management of the park. Unlike many other national parks that are in a more natural setting, the main unit STRI is directly adjacent to the city limits of Murfreesboro, TN and other units are within the city limits, and the entire park is slowly being surrounded by new development. Much of the land encompassing the original battlefield has been converted for other uses as noted above and the increasing development in this region will continue to stress the natural environment of the park. In 2011, the main park entrance was relocated from Old Nashville Highway to Thompson Lane to provide easier access from I-24 (Figure 4).

In 2012, Murfreesboro had an estimated population of 114,038. The 2010 census enumerated 41,077 households with 23.5% of the population being under the age of 18 and an average household size of 2.54. The median income per household was $49,450 with a median per capita income level of $25,256. 17.8% of Rutherford County's total population reported income at or below poverty level (U.S. Census Bureau, 2014).

2.1.3. *Visitation Statistics*

The NPS began recording visitor use statistics for Stones River National Battlefield in 1934. Since that time, visitation to the park has increased from under 2,000 to a recent peak of over 250,000 per annum during 2012 and 2013 (NPS 2014b; Figure 5), during which time the park opened a new entrance off of a major thoroughfare and celebrated the sesquicentennial of the battle. Average annual visitation since 2000 is 204,312. Visitation tends to peak during the summer months of May, June, and July, but decreases towards the colder months of December, January, and February. A significant increase in the number of visitors is noted in October that is comparable to values from the summer months (Figure 6).

Figure 4. New STRI entrance. Inaugurated in 2011, the entrance facilitates access from I-24.

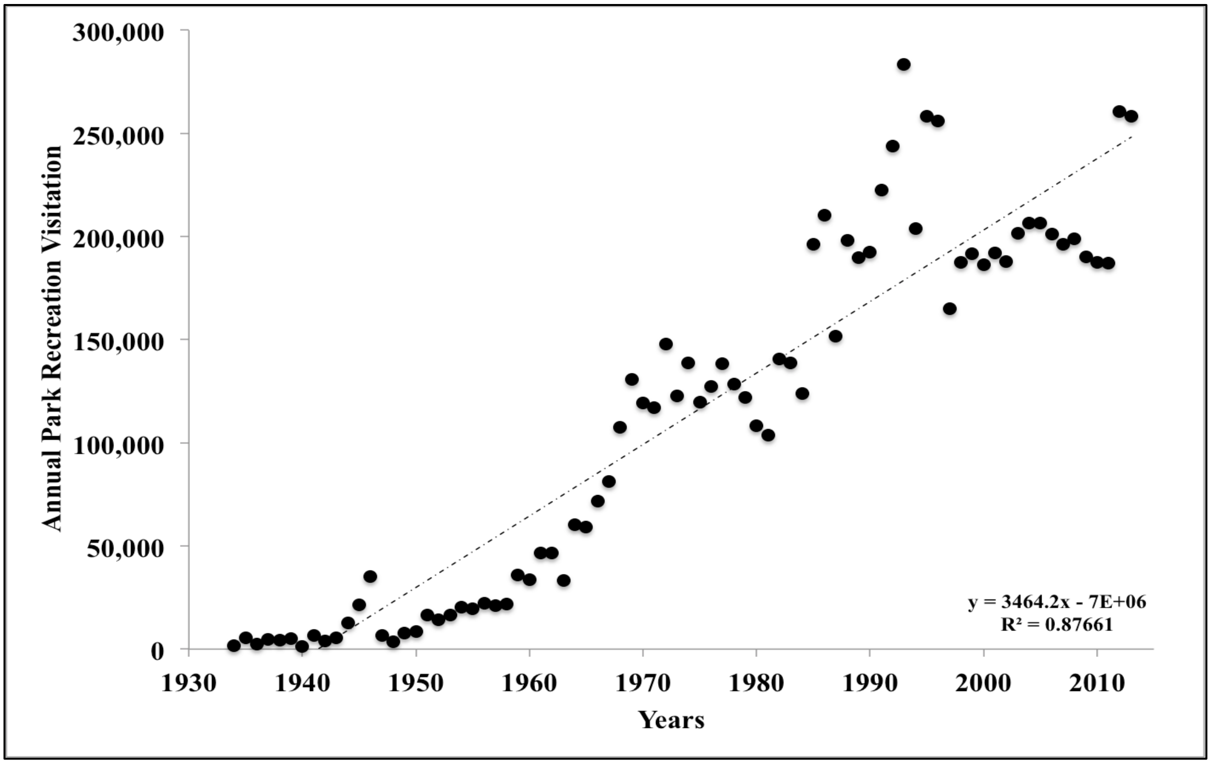


Figure 5. Annual recreation visitor numbers for Stones River National Battlefield, 1934 to 2013.

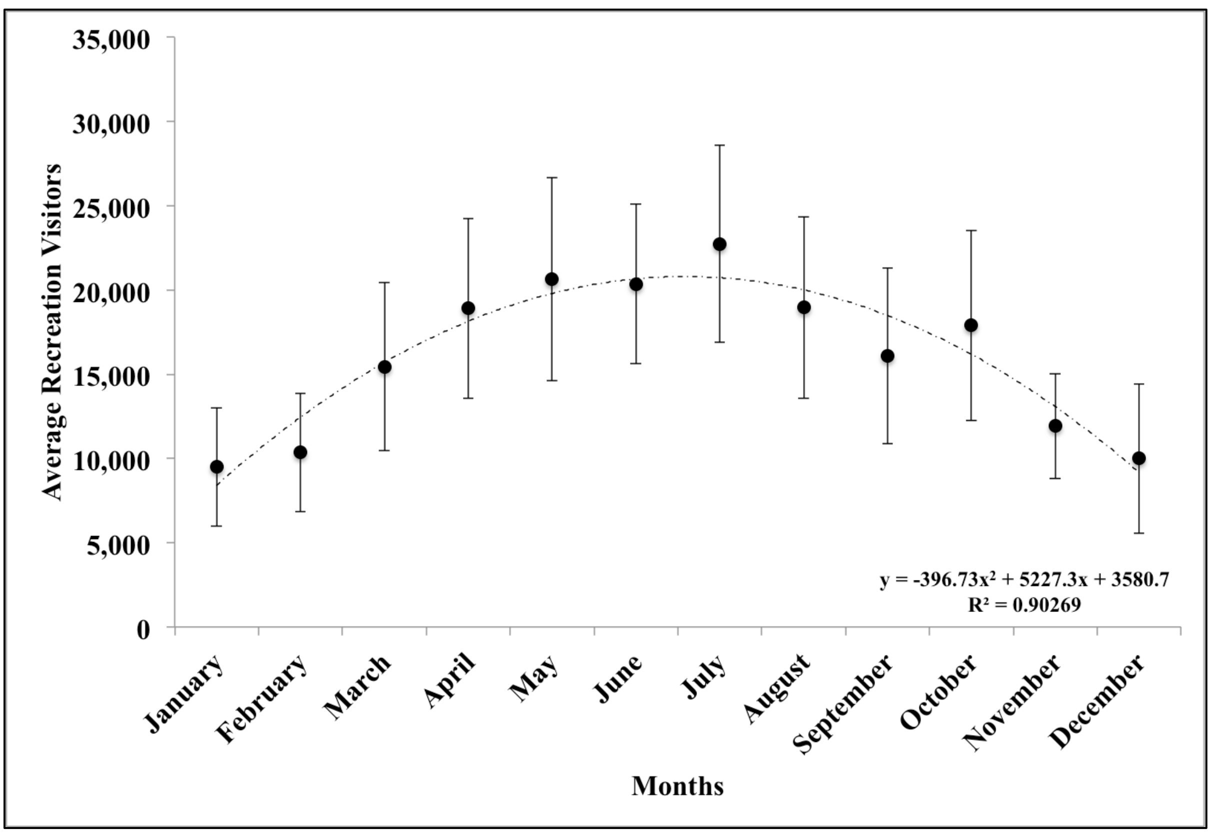


Figure 6. Monthly average of Stones River National Battlefield recreation visitor numbers,1979 to 2013.

2.2. Natural Resources

2.2.1. *Ecological Units and Watershed*

Stones River National Battlefield lies in the West Fork Stones River watershed (HUC 0513020302). At the northern edge of this watershed, the East Fork and West Fork of the Stones River meet before entering into Percy Priest Lake and subsequently the Cumberland River (Figure 7). The West Fork Stones River watershed is one of the two main watersheds that drain out of the city of Murfreesboro, in which STRI resides.

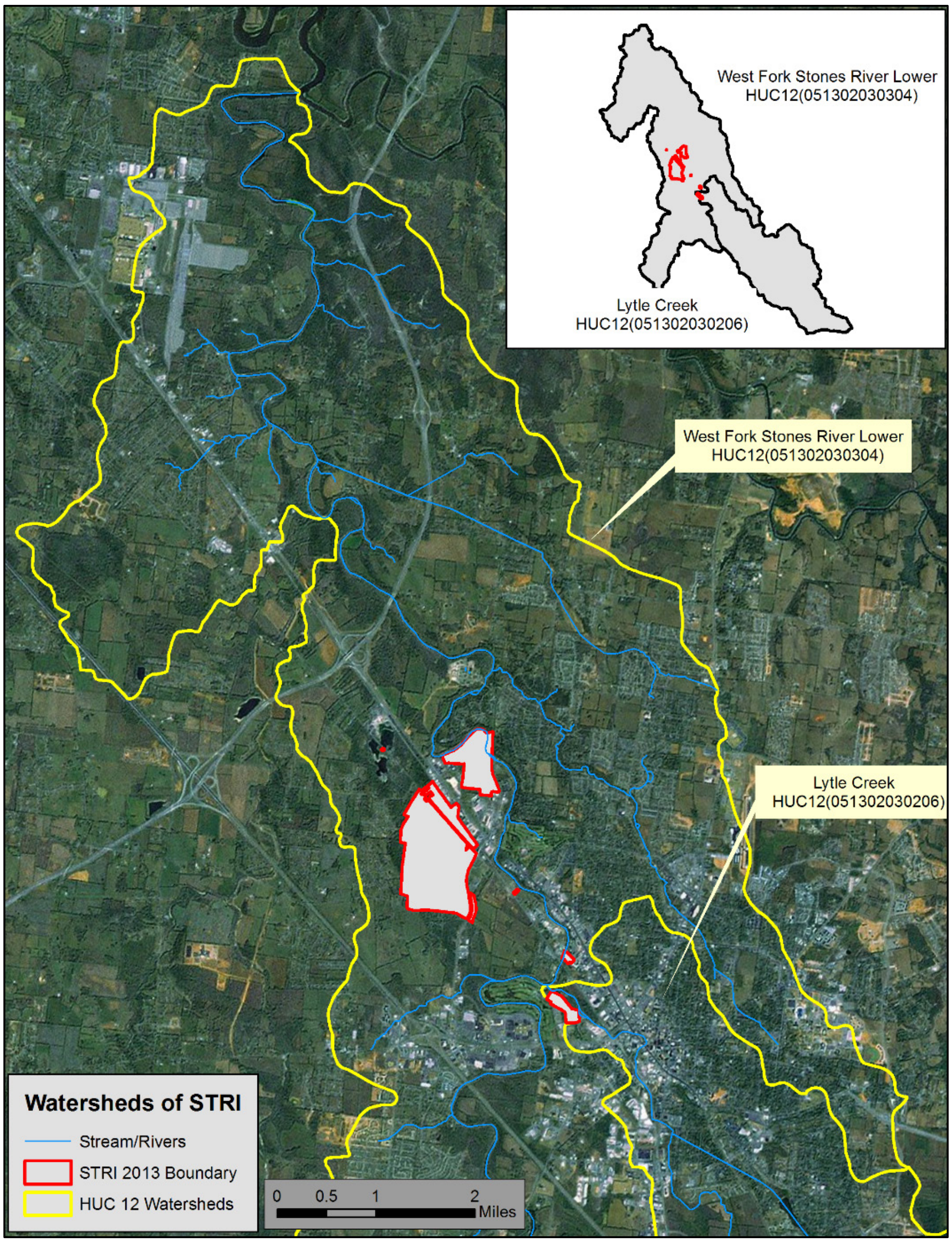


Figure 7. Location of Stones River National Battlefield within the Lytle Creek and West Fork Stones River watersheds.

According to the United States Environmental Protection Agency (USEPA), STRI resides in the level IV Ecoregion Inner Nashville Basin. According to Omernik (2009):

> *The Inner Nashville Basin is less hilly and lower than the Outer Nashville Basin (71h), outcrops of the Ordovician-age limestone are common, and the generally shallow soils are redder and lower in phosphorus than those of the outer basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the inner basin are a maple-oak-hickoryash [sic] association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest cedar glades vegetation type with many endemic species, are located primarily on the limestones of the Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species. Urban, suburban, and industrial land use in the region is increasing.*

Many of the features indicative of the Inner Nashville Basin can be found within the park, including notable examples of the limestone cedar glades (Figure 8).

Figure 8. Cedar Glades are an important natural resource of STRI.

2.2.2. *Resource Descriptions*

Stones River Cedar Glade and Barrens

Cedar glades are characterized by herbaceous communities growing on flat bedrock covered with a thin layer of soil (Anderson et al., 2007). In 2003, the State of Tennessee designated a 185-acre section of the Nashville Pike Unit of STRI as the Stones River Cedar Glades and Barrens Natural Area. The Stones River glades serve as a recovery site for Pyne's ground plum and the Tennessee purple coneflower (discussed below) and also harbor several other plants endemic to glade communities. The position of the glades within NPS boundaries provides a unique level of protection for these communities.

Sensitive Plant Species

Stones River National Battlefield supports a concentration of rare plant species, most of which are part of the Nashville Basin Limestone Glade ecological system. The glade rare plant species indigenous to the national battlefield include Tennessee milk-vetch (*Astragalus tennesseensis*), limestone fameflower (*Talinum calcaricum*), evolvulus (*Evolvulus nuttallianus*), and glade-cress (*Leavenworthia exigua* var. *exigua*) (Nordman, 2004).

In addition, Pyne's ground plum (*Astragalus bibullatus*), a federally listed endangered plant, occurs on the grounds of Stones River National Battlefield (Nordman, 2004). The Battlefield also hosts a population of the Tennessee purple coneflower (*Echinacea tennesseensis*), which was recently de-listed due to efforts of USFWS, NPS, and state and private conservation agencies (Bowen, 2011). Pyne's ground plum occurs at Stones River National Battlefield as the result of successful introduction to the glades from collaboration with United States Fish and Wildlife Service (USFWS), NPS, TDEC, and Missouri Botanical Gardens. Tennessee purple coneflower was introduced to the battlefield many years before Pyne's ground plum by Dr. Tom Hemmerly, formerly a professor at Middle Tennessee State University. The protection and management of rare plants at Stones River National Battlefield provides an important part of regional conservation efforts. Rutherford County is growing and developing very rapidly, so the relative importance of the rare plants at Stones River National Battlefield will continue to increase.

Fishes

Stones River National Battlefield has two waterways passing through two separate park units (Figure 2): Lytle Creek, which passes by the Fortress Rosecrans Unit and the West Fork of the Stones River (WFSR), which edges the McFadden Farm Unit and Redoubt Brannan. In addition, there are two small ponds in the park that occasionally sustain fish populations. A total of 46 species representing eight orders and 11 families have been identified in the park during inventorying of fish (Mullen, 2006). Based on the species documented and species richness estimates, Mullen (2006) concluded that 90% of species within the area were documented during the survey effort.

Birds

Stones River National Battlefield has a large bird assemblage, with a total of 152 species recorded in the park during the most recent bird inventory completed in 2005 (Stedman and Stedman, 2006). Park personnel have observed two additional bird species since the original inventory was taken for a total of 154 species, or 73% of the expected species. Urban development around the perimeter of the park may be a deterrent to some species utilizing the park, and associated noise may have somewhat limited the effectiveness of Stedman and Stedman's (2006) ability to detect some vocalizations during their inventory effort.

Mammals

The mammals found in the park are indicative of a regionally typical fauna. A recent park inventory (Kennedy et al., 2007) found 25 species of mammals. Park personnel have observed three additional mammal species since the original inventory was taken for a total of 28 species identified in the park. No state or federally endangered species were reported from the park during this inventory. The observed mammal species richness in the park was not high relative to the list of mammals potentially occurring in the region. However, the species richness was consistent with expectations for a small and relatively protected area. Additionally, the position of the park within the karst geological region provides potential habitats for two federally protected bat species, the grey bat (*Myotis grisescens*) and the Indiana bat, (*Myotis sodalis*), as well as one new candidate for federal listing, the northern long-eared bat (*Myotis septentrionalis*). Though none of the aforementioned bat species have been reported within the park, their potential presence has an impact on land management practices within the park (Kennedy et al., 2007).

Reptiles and Amphibians

A recent inventory of STRI herpetofauna reported 29 species (Miller et al., 2005). No state or federally listed species were observed. The park harbors a regionally typical fauna that includes around 50% of the species expected in the region. The authors concluded that while the expected species list was likely overly optimistic (including all species known to occur within Rutherford County), species diversity "…undoubtedly is greater than that documented in this report" (Miller et al., 2005).

Water Quality

In 2003, water quality sampling began at STRI as part of the Cumberland Piedmont Network (CUPN) Inventory and Management (I&M) program; an initiative from the NPS to facilitate and promote information sharing between national parks (Meiman, 2005). Water quality is measured at four sites: 1) West Fork Stones River at Redoubt Brannan, 2) West Fork Stones River at McFadden's Ford, 3) King's Pond Spring, and 4) Battlefield Spring near the river. These sites are measured on a "two years on-five years off" basis with each site being tested monthly during the two year time-frame.

2.2.3. *Resource Issues Overview*

In addition to the specific resources outlined above, there are other factors that actively affect natural resources at STRI and deserve continued monitoring and management attention. Prescribed burning, for example, is an effective management practice that can result in several ecological benefits. In addition, air quality is of particular concern due to the influence it can have on visitor experience and for its impact on vegetation health in the park unit. Changes in the overall landscape surrounding the park can also represent significant factors that may affect visitor experience. Because of these considerations at many NPS units, they are common targets for monitoring throughout the NPS.

Fire Management

The management of fire within STRI remains an important aspect of maintaining the park and contributing to the overall health of the ecosystem within. According to fire ecologist Dr. Cecil Frost (1998), "… fire once played a role in shaping all but the wettest, the most arid, or the most fire-sheltered plant communities of the United States." Although a natural fire regime no longer exists, prescribed fire and other methods can be used to simulate the effects of a natural fire regime. STRI has developed a fire management plan according to NPS Wildland Fire Management Guidelines (DO-18), which states, "all parks with vegetation that can sustain fire must have a fire management plan" (NPS, 1998). Resource management objectives in relation to the fire management program include: 1) preserving and protecting the historic battlefield landscape, 2) preserving the cedar glade habitat, which provides ideal habitat for the federally-listed endangered Pyne's ground plum 3) promoting exotic vegetation control and 4) preserving extant earthworks by removing invasive vegetation while promoting the establishment of native grass species to stabilize them (NPS, 2003b).

Currently, STRI is divided into two fire management units. The first unit is approximately 305 acres in size and is primarily comprised of open fields. The second unit contains approximately 407 acres of mixed hardwood forest and cedar glades (NPS, 2003a). As of their most current fire management plan (2014), the park's administration intends to conduct mechanical treatment and prescribed fire activities on approximately 244 of the 305 acres in Fire Management Unit (FMU) 1, and 365 of 407 acres in FMU 2. The goal is to treat 50 to 300 acres of the total 712 which has been designated for either mechanical or fire treatment annually as circumstances allow. Since initiation of their 2003 fire management plan, STRI has converted more than 40 acres of crop fields to native warm season grasses, and has removed substantial amounts of woody invasive species, as part of fire management (NPS, 2014).

Air Quality

The potential for creation of ozone is particularly a threat near industrialized areas, where nitrogen oxides (NOx) in the presence of volatile organic compounds (VOCs) can result in the creation of ground-level ozone. This ozone can be particularly harmful to human health and cause foliar injury in natural and agricultural vegetation. A 2007 assessment of ozone injury risk to plants in NPS units resulted in a high-risk classification at STRI (Kohut, 2007). In 2010, the CUPN began monitoring ozone and foliar injury at STRI (Jernigan et al., 2011).

In addition to ozone, other areas of area quality concern include wet and dry chemical deposition and atmospheric particulates. Nitrogen and sulfur oxides are released into the atmosphere from the use of fossil fuels, which once in the atmosphere, can form compounds that lead to acidic pollutants. Ecosystem components such as water, vegetation, and soil can be heavily affected by acidic pollutants. Monitoring the deposition of nitrogen and sulfur oxides can provide insight into the relative health of the ecosystems found within STRI. Particulate matter is a mixture of miniscule particles and liquids that may be found suspended throughout the atmosphere. These particles are one of the primary factors affecting visibility at STRI (USEPA, 2013). Visibility is negatively affected whenever light is scattered or absorbed by the suspended particles. Atmospheric moisture can further reduce visibility by causing the particulate matter to expand (USEPA, 2013). Aside from visibility deterioration, human health is another major consideration when examining the negative properties of particulate matter. When passing through the throat and nose, these particles may enter the lungs causing decreased capacity, fatigue, and a variety of other health issues (USEPA, 2008; USEPA, 2009; USEPA, 2013).

Landscape Dynamics

Many of the other vital signs established for STRI interact and respond to landscape changes within and surrounding the park, including invasive species introductions, water quality issues, and air quality problems. In some cases it is possible to link specific problems, like the reduction of a particular forest species, to particular landscape metrics, such as a decrease in the amount of core forested habitat, or an increase in levels of wildland-urban interface.

The NPS created a series of landscape dynamics data products called NPScape, which can be accessed at https://science.nature.nps.gov/im/monitor/npscape/, whose goal was to create an organized protocol for landscape-scale assessment for all park units in the US. To achieve that goal, NPScape divided the landscape assessment into five main categories: 1) landcover, 2) roads, 3) population and housing, 4) pattern, and 5) conservation status. Each of these categories has an associated data source and data products that provide the foundation for further analysis. For each section, the NPScape interpretative guide provides a literature review, including lists of thresholds that can serve as metric guidelines.

Invasive Plants

In the 2004 vegetation inventory conducted at STRI (Nordman, 2004), the author reported that exotic plant species represent "probably the biggest single threat to the overall ecological health of the park at this point in time." The inventory also showed that roughly 28% of species in the park are non-native and that a total of 44 species are considered invasive by the Tennessee Exotic Pest Plant Council (TN-EPPC, 2001). Eighteen of these are considered severe, 20 more are considered to be a significant threat, 12 more are considered a lesser threat, and four more are on the Watch List (TN-EPPC, 2001). Preliminary findings from a 2011-2012 plot survey taken within STRI has helped confirm prevalence of exotics in the park, with 32 exotics detected in 16 total test plots and comprising 17% of the species found within those plots (CUPN, 2013). Invasive plant management efforts are focused on removing and controlling invasive species that are found within the park in order to protect native flora, fauna, and the cultural landscape of the park (NPS, 2009).

2.3. Resource Stewardship

2.3.1. *Management Directives and Planning Guidance*

STRI has a General Management Plan that outlines the management objectives for the park unit (NPS, 1999). The following objectives come directly from the General Management Plan:

- Interpret the Battle of Stones River within the context of the Western Theater and Civil War.
- Provide visitors the opportunity to understand the objectives, strategies, and tactics of the battle.

- Provide an atmosphere at a series of vignettes/sites that allow the visitor to visualize the rural setting at the time of the battle, to understand the battle events, and to contemplate the sacredness of the ground.
- Preserve a core segment of the Stones River battlefield, representative of major battle action, in a way that allows visitors to visualize and imagine the influence of landscape features on the strategy and outcome of the battle.
- To the greatest extent practicable, preserve and restore to a general 1860s appearance the land within the authorized boundary of the national battlefield.
- Maintain the open space and mark the sites of Rosecrans's and Bragg's headquarters.
- Preserve the 1892 design of the national cemetery's landscape and the 1860s design of the Hazen Monument, and maintain a quiet, reflective, and reverent atmosphere.
- Preserve and stabilize remnants of Redoubt Brannan, Lunettes Palmer and Thomas, and Curtain Wall No. 2.
- Provide controlled access to earthworks to interpret the fort (Fortress Rosecrans) and allow visitors to understand the extent of the fortifications and their significance.
- Develop preservation/mitigation strategies with landowners and local governments to achieve the general appearance of an agricultural landscape as viewed from interpretive areas within the national battlefield.
- Encourage the creation of a park-like experience in corridors linking noncontiguous units.
- Encourage interpretation of the greater battlefield through cooperation with landowners and local government agencies.

In 2014, STRI completed a Foundation Document that updates the management objectives.

2.3.2. *Status of Supporting Science*

Through a series of workshops in 2002, CUPN identified key resources for each of its parks network-wide. The identified resources, called "Vital Signs" are used to determine the overall health of the parks. In 2005, CUPN completed and released a Vital Signs Monitoring Plan (Leibfreid et al., 2005). Table 1 shows the CUPN Vital Signs for the entire CUPN including STRI.

Table 1. CUPN high priority Vital Signs by park (revised from 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	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚

✚ Vital Signs for which the CUPN IM Program will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring programs.

Table 1 (continued). CUPN high priority Vital Signs by park (revised from 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
Water (continued)	Water Quality (continued)	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														

✚ Vital Signs for which the CUPN IM Program will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring programs.

Table 1 (continued). CUPN high priority Vital Signs by park (revised from 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
Biological Integrity (continued)	Focal Species or Communities (continued)	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														

✚ Vital Signs for which the CUPN IM Program will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring programs.

3. Study Scoping and Design

This NRCA is a collaborative project between the National Park Service (NPS) and Middle Tennessee State University (MTSU) to evaluate natural resource conditions within Stones River National Battlefield (STRI). Project stakeholders include the STRI resource management team, Cumberland Piedmont Network (CUPN) Inventory and Monitoring Program team, NPS Southeast Regional Office, and the MTSU team (faculty, graduate students, and staff from the Department of Geosciences and Department of Biology).

3.1. Preliminary Scoping

A pre-scoping conference call was held on November 19, 2013. Participants in the conference call included representatives from the MTSU team, the CUPN team, the STRI team, and the NPS Southeast Region NRCA coordinator. The NRCA coordinator described the overall goals of the NRCA program and how this assessment fits within the broader program objectives. Additionally, key characteristics of the NRCA project were described, multiple potential sources of data were shared with the stakeholders, and initial planning activities were initiated for the forthcoming scoping meeting.

The scoping meeting was held on January 7-8, 2014 at STRI (Table 2). On the first day, after brief introduction of all participants, the STRI team provided a detailed tour, highlighting key natural and cultural resources of the park. The meeting resumed on the next day with meetings designed to provide insight of the main scope of the NRCA report and also to identify potential sources of data. Important considerations emerged from the meeting:

- The NRCA represents a "snap-shot" in time of the park natural conditions.
- Only a subset of important resources identified by stakeholders as relevant to the park are included.
- The report should identify critical studies and data gaps pertinent to the park's mission and long term resource management operation.
- In the preparation of the NRCA report, condition assessments are performed utilizing existing data and information in the form of published reports and studies.
- The definition of the reference conditions are driven by the STRI resource management team.
- The NRCA report has a strong spatial component represented by the assimilation and organization of Geographic Information Systems (GIS) datasets describing STRI natural resources.
- When applicable, reference conditions are defined for individual resources. If multi-temporal information is available for a resource with reference condition, temporal trends are also defined.

Table 2. Agenda of the scoping meeting held at STRI during January 7-8, 2014.

Date	Topics
Tuesday, January 7, 2014 Start: 1:00 p.m. End: 4:15 p.m.	Welcome (STRI main visitor center) (5 min)
	Introductory comments (10 min)
	Resource management tour of the park (2.5 to 3.0 hours)
Wednesday, January 8, 2014 Start: 9:00 a.m. End: 12:15 p.m.	Welcome (STRI main visitor center) (5 min) Introductory comments (25 min)
	Description/demonstration of the available databases at the park (10 min)
	Description/ demonstration of the available databases in the Cumberland Piedmont Network (10 min)
	Break (10 min)
	Discussion of the hierarchical study framework, scoping table, and STRI's specific reference conditions
	Break (10 min)
	Development of draft master schedule based on the signed task agreement document
	Final remarks (5 min)

3.2. Study Design

3.2.1. *Indicator Framework, Focal Study Resources, and Indicators*

During the scoping meeting, the stakeholders selected the NPS ecological monitoring framework (EMF) introduced by Fancy and others (Fancy et al., 2009). This NPS EMF divides the resources monitoring into three hierarchical general levels representing different scale of analysis (Table 3). In the first level, the resources are divided into six categories that are then further subdivided into two levels. Level one represents individual resource items that will be aggregated to define level two, in which resources will be aggregated to describe the vital signs of level three categories.

The NPS EMF was utilized as the basis for the definition of the master plan defined as the scoping table (Table 4). The scoping table was generated based on an iterative procedure involving all stakeholders. Individual components, data sources, and reference conditions were generated based on STRI resource management team input on vital resource items, availability of data, and published reports. The scoping table has provided a common platform to the stakeholders serving as the directorial document in all steps of the report preparation.

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

Ecological Monitoring Framework		
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
	Subsurface Geologic Processes	Geothermal Features and 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

* Indicates areas of interest identified by stakeholders during the scoping meeting.

Table 4 (continued). Ecological Monitoring Framework selected for the STRI NRCA project (Fancy et al., 2009).

Ecological Monitoring Framework		
Level 1 Category	**Level 2 Category**	**Level 3 Category**
Biological Integrity *	Invasive Species *	Invasive/Exotic Plants *
		Invasive/Exotic Animals *
	Infestations and Disease *	Insect Pests
		Plant Diseases
		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 *

* Indicates areas of interest identified by stakeholders during the scoping meeting.

Table 5 (continued). Ecological Monitoring Framework selected for the STRI NRCA project (Fancy et al., 2009).

Ecological Monitoring Framework		
Level 1 Category	**Level 2 Category**	**Level 3 Category**
Biological Integrity * (continued)	Focal Species or Communities * (continued)	Mammals *
		Vegetation Complex (use sparingly) *
		Terrestrial Complex (use sparingly)
	At-risk Biota *	T&E Species and Communities *
Human Use *	Point Source Human Effects *	Point Source Human Effects
	Non-point Source Human Effects *	Non-point Source Human Effects
	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 areas of interest identified by stakeholders during the scoping meeting.

Table 6. Summary of resource components, standards, and data sources used in the Natural Resource Condition Assessment of Stones River National Battlefield.

Components	Primary Data Sources	Primary Reference Conditions	Primary Resources Stressors
Air and Climate- Air Quality			
Ozone	• Jernigan et al. 2010 • NPS Air Quality Division Report 2013	4th highest maximum 8-hour average ozone concentration greater than 0.075 ppm	Sulfur and Nitrogen deposition- caused in some areas by increased oil and gas production
Wet and Dry Deposition	NPS Air Quality Division Report 2013	Greater than 3 (kg/ha/yr) of Nitrogen or Sulfur	Non-regulated sources (i.e. agriculture)
Visibility and Particulate Matter	NPS Air Quality Division Report 2013	Visibility measurements (dv) of greater than 8 dv	Tailpipe emissions
Air and Climate -Weather			
Weather and Climate	• Davey CA and Others. 2007. CUPN Weather and Climate Inventory • Bruno C and Others. 2012. Effects of Climate Change on CUPN species • Monahan and Fischelli. 2014. Recent Climate Change Exposure of Stones River National Battlefield.	Deviation from Norm	Climate Change
Geology and Soils-Geomorphology			
Geology	Thornberry-Ehrlich STRI Geology Report 2012	N/A	N/A
Landscapes-Landscape Dynamics			
Land Use Land Cover	• STRI General Management Plan 1999 • STRI Cultural Landscape Report 2007	Land use conversion	Urbanization of surrounding areas and land use conversion within the park

Table 4 (continued). Summary of resource components, standards, and data sources used in the Natural Resource Condition Assessment of Stones River National Battlefield.

Components	Primary Data Sources	Primary Reference Conditions	Primary Resources Stressors
Water-Water Quality			
Water Quality	• Meiman 2005 CUPN Water Quality Report • Meiman 2010 CUPN Water Quality Report • Meiman 2014 CUPN Water Quality Report Natural Resource Condition Summary Table	• **Water Temperature** Not to exceed 86.9˚F/30.5˚C • **Dissolved Oxygen** Not to deceed 5.0 mg/l • **pH** Between 6.0 and 9.0 SU • ***Escherichia coli*** Not to exceed 487 MPN/100ml • **SpC** No Standard • **Nitrate** Not to exceed 90 mg/l	Surface Runoff, Increased Sedimentation, Industrial Contamination, Land Use Change
Biological Integrity- Invasive Species			
Invasive/Exotic Plants	• Nordman, 2004 STRI Vegetation Plant Inventory • Hogan and Weber, 1999 STRI Plant Inventory • Keefer, Helf, Leibfreid, and Kaye, 2012 Early Detection of Invasive Species • STRI Forest Vegetation Resource Brief, 2013 • STRI, 2009 Integrated Pest Management Plan	Control or eradicate of existing invasive species. Prevent introduction of new invasive species	
Biological Integrity-Focal Species or Communities			
Wetland Communities	• Roberts and Morgan, 2007 STRI Wetland Inventory	Wetland Quality	Past land-use practices, changes in hydrology from surrounding urbanized areas

Table 4 (continued). Summary of resource components, standards, and data sources used in the Natural Resource Condition Assessment of Stones River National Battlefield.

Components	Primary Data Sources	Primary Reference Conditions	Primary Resources Stressors
Biological Integrity-Focal Species or Communities (continued)			
Cedar Glades	• Cofer, Walck, and Hidayati, 2007 Species Richness and Exotic Species Invasion on Cedar Glades • Cartwright, 2014 Soil Ecology of Cedar Glades • Albrecht and McCue, 2010 Changes in Demographic Processes • Conard, 2011 The Changing Face of the Country • Hogan, Sutter, and Rudd, 1996 STRI Glades Final Report	Species Composition, Glade Quality	Past land-use practices, Exotic plants, Encroachment of woody plants, Changes in hydrology (and other climate aspects)
Vegetation Communities	• Nordman, 2004 STRI Plant Community Classification • Summer and Nordman, 2008 STRI Accuracy Assessment • Jordan and Madden, 2010 Digital Vegetation Maps • STRI Forest Vegetation Resource Brief, 2013 • Adams, Walck, Howard, and Milberg, 2012 Forest composition and structure	Community Classification	Exotic plants, Changes in climate, Past land-use practices (including fire incidence)
Fishes	Mullen, 2006 STRI Fish Inventory	Species Composition	Highly compromised water quality, Sedimentation and siltation
Amphibians and Reptiles	Miller, Speiss, and Niemiller, 2005 STRI Herp Inventory	Species Composition and Abundance	Past land-use practices, Highly fragmented nature of park
Birds	Stedman and Stedman, 2006 STRI Bird Inventory	Species Composition and Breeding Status	Exotic plants and animals, Highly fragmented nature of park

Table 4 (continued). Summary of resource components, standards, and data sources used in the Natural Resource Condition Assessment of Stones River National Battlefield.

Components	Primary Data Sources	Primary Reference Conditions	Primary Resources Stressors
Biological Integrity-Focal Species or Communities (continued)			
Mammals	Kennedy and LaMountain, 2007 STRI Mammal Inventory	Species Composition	Past land-use practices, Highly fragmented nature of park, Exotic animals
Freshwater Invertebrates	• CUPN Aquatic Insect Inventory, 2007 • Robinson, 2012 Aquatic Insect Diversity	Species Composition	Sedimentation and siltation

3.2.2. *Reporting Areas*

Although Stones River National Battlefield is composed of six parcels, it has typically been treated as a single reporting unit. This is justified by the small size of each parcel and the commonality of the land cover within the six park units and the surrounding areas. It is important to note, however, certain exceptions in which smaller reporting units were considered based on an individual resource's variability within the park boundaries. Natural resource indicators associated with or influenced by the cedar glades environment are an example of reporting areas smaller than the park boundaries.

3.2.3. *General Approach and Methods*

The main sources of information for this study were provided by existing published reports and data describing scientific/quantitative studies of individual resource components. No new data was neither collected nor new studies conducted. Where appropriate, existing data from multiple sources were merged and summarized and potential temporal trends evaluated. Condition, trend, and confidence levels were assigned by first 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 evaluated 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 STRI 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 6). 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.

Table 7. Standard NRCA symbol set for resource condition reporting.

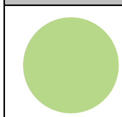
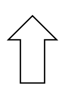
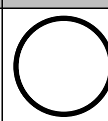
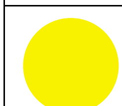
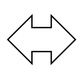
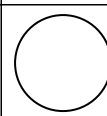
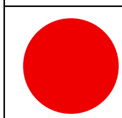
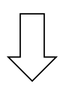
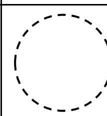
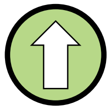
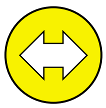
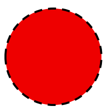
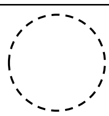
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Table 8. Examples of NRCA symbol interpretation.

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

4. Natural Resource Conditions

4.1. Air Quality

The Clean Air Act (CAA) of 1970 was established to provide federal protection to air quality and to ensure that quality levels do not diminish. Air quality levels are measured against the National Ambient Air Quality Standards (NAAQS), which cover six different types of airborne pollutants, among which ozone, particulate matter, and sulfur and nitrogen dioxides are of high concern for STRI (Kohut, 2007; USEPA, 2014). In a 2007 study of NPS units, R. Kohut observed a high risk of foliar injury at STRI. Because of the risk potential found by the study, air quality is of high concern to the future of natural resource management in the park. Under the Clean Air Act, STRI is considered a Class II park unit. As a Class II unit, air pollution levels at STRI must meet a moderate maximum standard of concentration, though less stringent than the air quality increment maximum of a Class I area. The Class II category is designed to allow for average development activities in the area while providing protection against rapid, significant deterioration of the environment.

Reference Condition Standards

The NPS Air Resources Division (ARD) developed a method for rating the overall condition of air quality throughout the NPS system. This method is based on NAAQS, visibility improvement goals, and ecosystem thresholds. Different air quality index values were used to assess air quality in national parks (Table 7). Ozone concentration condition levels are based on NAAQS of 75 parts per billion (ppb). When assessing the wet deposition of nitrogen or sulfur, rain and snow depositions are examined. Haze Index measures visibility condition. Haze index is calculated by light extinction and is representative of the minimum detectable change in visibility to the human eye (NPS, 2010).

Table 9. Condition standards for air quality resources at STRI (National Park Service, Air Resources Division, 2013.)

Condition	Ozone concentration (ppb)	Wet Deposition of Nitrogen or Sulfur (kg/ha/yr)	Visibility (dv*)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

4.1.1. *Ozone and Foliar Injury*

Relevance and Context

Due to the relationship between ozone and foliar injury, the National Ambient Air Quality Standards for ozone is important to an assessment of conditions at STRI. Ozone is a compound found in the atmosphere that can have both positive and negative influences on the environment. At high elevations, ozone aids in atmospheric absorption of ultra violet (UV) radiation, preventing the harmful rays from reaching the Earth's surface (USEPA, 2011). Conversely, when high concentrations are found within the troposphere, biota are negatively impacted. Instead, ozone found within the troposphere is formed when nitrogen oxides and organic compounds react with one another while receiving sunlight. Excessive concentrations of ozone are typically associated with urban and suburban areas due to the abundance of nitrogen oxide and organic compound emitting sources such as motor vehicles and industrial processes (USEPA, 2011). High concentrations of ozone have been linked to negative effects in both humans and foliage (USEPA, 2011). In humans, these negative effects can include a weakened respiratory and immune system. The negative effects typically manifest in the form of reduced net photosynthesis leading to a growth reduction of plant species found at STRI (Lefohn and Runeckles, 1987; Ollinger et al., 1997; NPS, 2012a).

In addition to ozone concentrations, soil moisture levels affect foliar injury. For vegetation and foliage, soil moisture affects the interaction between the plants and outside gasses. The leaf stomates on the plant close at low levels of moisture content, reducing the overall intake of ozone into foliage (Kohut, 2007). At high moisture levels, the opposite interaction between the plant and outside gasses occurs. As moisture levels increase, the leaf stomates begin to open and allow for greater gas exchange. In areas of high ozone concentrations, high moisture levels can have a significant impact on foliar injury due to greater interaction between foliage and the ozone-rich atmosphere (Kohut, 2007). Ozone creation is at a much higher level on hot and dry days. However, as these days typically have lower concentrations of soil moisture, leaf stomates intake lower amounts of ozone. Plants might intake greater concentrations of ozone on cooler days with more soil moisture even though overall concentrations of ozone in the atmosphere are lower (Kohut, 2007).

Methods and Data

On May 27, 2008, the USEPA lowered the NAAQS ozone concentrations from 0.080 parts per million (ppm) to 0.075 ppm. Whenever the fourth-highest daily maximum eight-hour average ozone concentration when averaged over three years (4^{th} HI Max 8-hr) rises above concentrations of 0.075 ppm over a three year period, the area's status is designated as nonattainment and remedial actions are recommended (Ray, 2013). The ozone concentration standards may be evaluated through a variety of methods. Two studies were conducted to evaluate the ozone concentrations at STRI: (i) one using field measurements based on Portable Ozone Monitoring Station (POMS), and (ii) one using interpolated predictions based on calculations using ozone models for the entire United States.

There are two POMS that rotate among park units in the CUPN on a six-year basis. The CUPN POMS most recently rotated to STRI during June through October of 2010 (Figure 10). Variations in ozone levels can be observed hourly (Figure 9) and daily (Figure 10). The POMS was on loan from the Gulf Coast Network and was not available to STRI for the entire growing season (Figure 11). The utilization of the POMS at STRI produced data from June 3rd, 2010, to October 31st, 2010. During this period, 8-hour average ozone concentrations did not exceed 0.075 ppm during any eight-hour monitoring period (Figure 12). According to USEPA standards, an ozone violation did not occur during the measuring period at STRI.

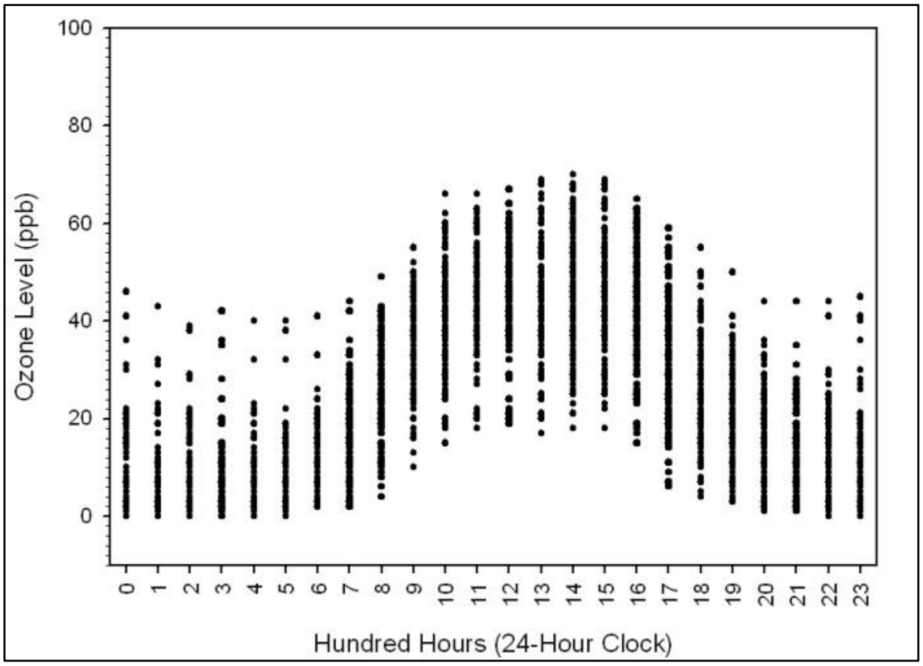


Figure 9. Measured daily ozone levels by the Portable Ozone Monitoring Station at STRI. Ozone levels vary with the time of day. (Source: Figure 8 in Jernigan, 2011).

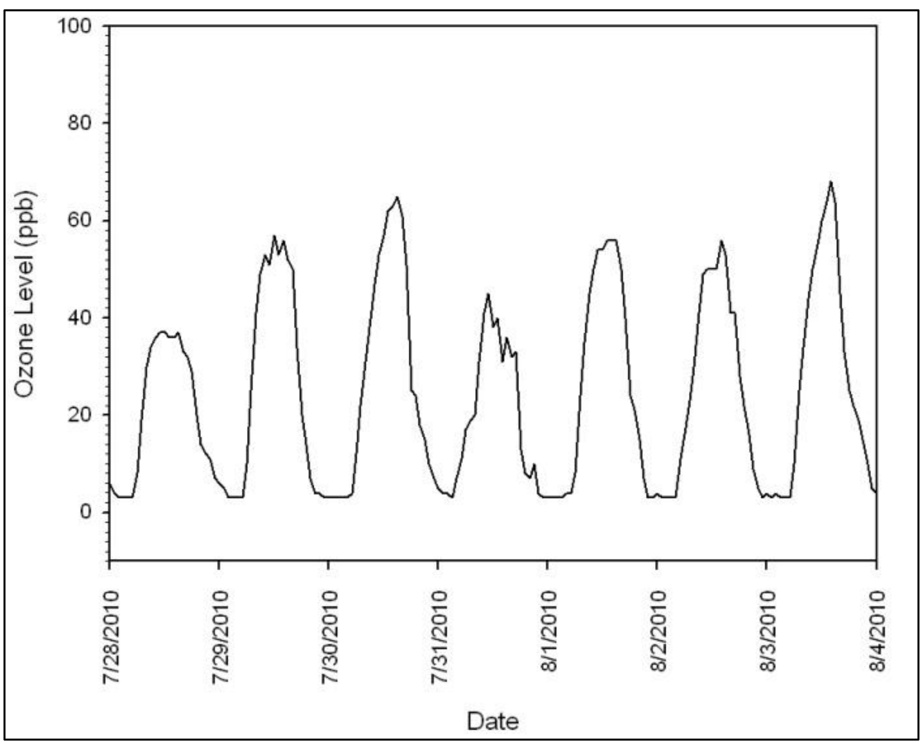


Figure 10. Measured ozone levels by the Portable Ozone Monitoring Station at STRI. Daily variance in ozone levels at STRI. (Source: Figure 8 in Jernigan, 2011).

The NPS ARD performed a second ozone concentration study. The study estimated 4th Hi Max 8-hr metrics based on national interpolation datasets over five-year periods. They were: 0.0832 ppm

(1999-2003), 0.0774 ppm (2001-2005), 0.0766 ppm (2003-2007), 0.0750 ppm (2004-2008), 0.0748 ppm (2005-2009), and 0.0737 ppm (2006-2010) (NPS 2012b). All of the data points from STRI indicate that ozone concentrations are slowly declining (Figure 12). Although concentrations are declining, other factors such as soil moisture can be instrumental in overall ozone injury. For this reason, ozone injury is still a significant risk at STRI.

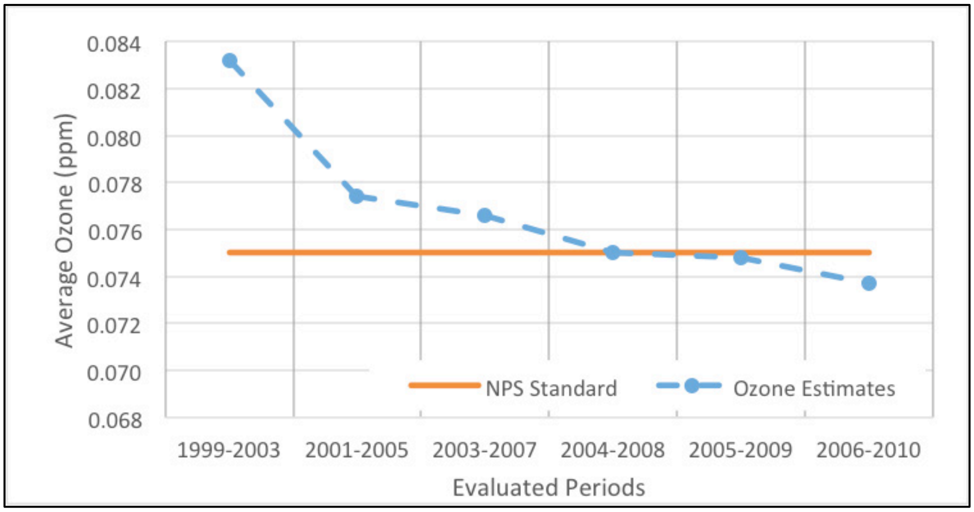


Figure 9. Ozone averages at STRI based on interpolated models. (Data source: NPS, 2012b).

Two biological indices were also used to estimate the effect of ozone levels on foliar injury: SUM06 and W126. The SUM06 index represents a cumulative 90-day maximum of the ozone concentrations above 0.060 ppm between 8:00AM and 8:00PM (Kohut, 2004). The second biological index, W126, is defined as a cumulative index; which is calculated using the maximum 90-day sum of average daily ozone concentration. The daily average is calculated using hourly ozone concentration values between 8:00AM and 8:00PM and weighted by a sigmoidal curve with values between 0 and 1. The sigmoidal weight curve is designed to increase the significance of ozone concentrations greater than 0.04 ppm and to diminish the significance of ozone concentrations smaller than 0.04 ppm (Ray, 2004). Other authors define the W126 index as a monthly value rather than the maximum 90-day sum (Kohut, 2004). The Sum06 and W126 indices at STRI both met the standards stated by Ray (2004) with respective values of 3.3 ppm-hours and 3.5 ppm-hrs (Table 8).

Table 10. SUM06 and W126 air quality indices at STRI. (Data source: Kohut, 2004).

Air Quality Index	1995	1996	1997	1998	1999
SUM06	24	25	21	25	37
W126	31.9	34.8	36.7	41	54.2

Soil moisture levels were measured using the Palmer Z index. The Palmer Z index provides a value which is used to assess and measure drought and wetness by examining soil moisture levels, temperature, and precipitation (Palmer, 1965). A number in the range of -4.0 to +4.0 is assigned and used to describe variance in moisture levels when compared to long-term monthly averages. Typically, values within the range of -0.9 to +0.9 are representative of normal soil moisture levels (NPS, 2004). Analysis of Palmer Z index for the three months in which the SUM06 were investigated indicates that the majority of the values were within the range representing normal soil moisture levels (Table 9). Similarly, when applying the Palmer index to the seven months in which the W126 index were evaluated, 21 out 30 values were outside the suggested -0.9 to 0.9 range (Table 10).

Table 11. Palmer Z Index data for 3-month SUM06 period at STRI. (Data source: Kohut, 2004).

Months Considered	1995	1996	1997	1998	1999
Month 1	0.98	0.49	-1.5	3.31	1.61
Month 2	0.14	3.03	0.61	-0.93	-1.23
Month 3	0.59	-0.02	1.74	-2.5	-2.01

Table 12. Palmer Z Index data for the 7-month W126 period at STRI. (Data source: Kohut, 2004).

Month	1995	1996	1997	1998	1999
April	0.25	0.8	-0.8	3.42	-1.35
May	2.39	0.31	1.51	0.15	-0.35
June	0.98	0.49	4.61	5.86	1.61
July	0.14	3.03	-1.5	3.31	-1.23
August	0.59	-0.02	0.61	-0.93	-2.01
September	0.96	4.2	1.74	-2.5	-1.97
October	2.81	1.09	0.43	-0.88	-0.87

Condition and Trend

The average ozone concentrations for each of the 5-year interpolation periods show a trend toward general air quality improvement (Figure 12). Ozone concentrations were found to be above the USEPA standard of 0.075 ppm from 2000-2005, but have slowly decreased to compliant concentrations at 0.0737 ppm in the 2006-2010 interpolation period (NPS, 2012b; Figure 12). Although the data gathered by the POMS unit cannot be compared to all the interpolated values, the POMS data at STRI further reinforces the estimations for 2006-2010. The POMS data provided a 4th Hi 8-hr Max value of 0.062 ppm and, as with the estimations, the results did not show any periods with ozone concentrations of greater than 0.075 ppm. However, the POMS unit needs to gather data for several more seasons for the information to be solely relied upon. All of the data suggests that while ozone concentrations have recently fallen below the NAAQS, there is still a severe risk of negative effects to human health and vegetation at STRI. For these reasons, ozone condition status at STRI receives a ranking of fair/warranting moderate concern.

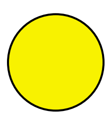
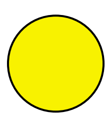
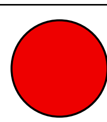
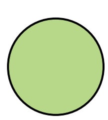
In 2010, an on-the-ground foliar injury assessment was conducted at three sites in STRI, wherein 62 plants of 3 species were inspected for ozone damage (Table 11; Jernigan et al., 2011). Of the selected specimens, only 8 were observed to have possible ozone damage. However, a regional expert from the United States Forestry Service (USFS) examined the 8 plants and determined that foliar injury had not occurred.

Table 13. Plant species tested for foliar injury in various locations in STRI. (Data source: Jernigan, 2011).

Site Name	Species	Number of Plants Inspected	Confirmed Injury?
Beasley Field - Site 1	Blackberry	30	No
Beasley Field - Site 2	Black Cherry	2	No
Beasley Field - Site 2	Common Milkweed	30	No

As onsite POMS data is only available for the summer of 2010, data quality could be improved through further use of the POMS. Doing so would allow for the collection of data showing local trends and changes in ozone concentrations and provide a more complete and thorough analysis of the potential effects of ozone on the park's natural resources. However, as ozone concentration data is largely interpolated with little onsite analysis, no trend is assigned (Table 12).

Table 14. Visual condition assessment for ozone and foliar injury at STRI. (Data source: Jernigan, 2014).

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Ozone	5-Year Average of the Annual 4th-Highest 8-Hour Concentration		The estimated ozone concentration for 2006–2010 at the park was 73.7 parts per billion (ppb) (NPS 2012b), which warrants moderate concern based on NPS Air Resource Division benchmarks (NPS ARD 2013). No trend information is available because there are not sufficient on-site or nearby ozone monitor data (NPS ARD 2013).
Foliar Injury	3 month 8-to-8 W126 Statistic Below the 7 – 15 ppm-hr range		The estimated average W126 statistic for 2006-2010 at the park was 12.8 ppm-hrs (NPS 2012b). A CUPN ozone monitor reported a W126 value of 3.5 in 2010 (Jernigan et al., 2011).
Foliar Injury	Risk based upon Kohut Assessment		Twenty-two ozone-sensitive plant species are found in the park and the park is at high risk for ozone injury to vegetation (Jernigan et al., 2012; Kohut 2007).
Foliar Injury	Number of Species with Injury		No species with injury found in 2010 CUPN sampling (Jernigan et al., 2014). However, those results should not be expected to be typical since ozone concentrations in the region are generally high enough to cause injury.

4.1.2. *Deposition of Nitrogen and Sulfur*

<u>Relevance and Context</u>

Nitrogen and sulfur oxides are released into the atmosphere in several different manners and result in both wet and dry forms of acidic pollution. Typically, these oxides are released from the use of fossil fuels or as byproducts of industrial waste (USEPA, 2011). For example, coal burning power plants, smelting plants, and various types of factories are all associated with excessive levels of nitrogen and sulfur oxides. After being emitted into the atmosphere, the nitrogen and sulfur form compounds that become acidic pollutants. The pollution typically takes the form of particulate matter that is dissolvable by moisture (USEPA, 2008). Polluted moisture carrying these nitrogen and sulfur compounds is spread throughout the world through the various weather and climate processes. A well-known example of polluted moisture is acid rain. Depending on location and proximity to nitrogen and sulfur oxide producing sources, acid rain can be up to 100 times more acidic than natural precipitation (USEPA, 2008). When not dissolved by moisture, dry forms of the acidic pollutants are capable of being carried and spread by the wind (USEPA, 2008). The pollutant compounds are significant factors in assessing ecosystem health and stability. Pollutants most heavily affect an ecosystem's water, vegetation, and soil (NPS, 2008). In lakes, streams, and other water sources, acidic deposition is harmful to both the aquatic life and vegetation reliant on the water source. While vegetation can be harmed through direct contact with these acidic pollutants, most of the damage occurs through negative changes to the nutrients and physical characteristics of the soil (USEPA, 2008).

<u>Methods and Data</u>

As with the ozone, the NPS ARD also created several deposition estimates over multiple 5-year periods from individual parks. By spatially interpolating data from 5-year periods, annual fluctuations in precipitation were filtered out and only the general trend retained. The NPS designated three possible conditions for deposition measurements: significant concern, moderate condition, and good condition (Table 13).

<u>Condition and Trend</u>

Wet deposition of either nitrogen or sulfur of concentrations of greater than 3 kg/ha/yr warrants significant concern (Table 13). The most recent 5-year (2006-2010) estimates total wet deposition of nitrogen in STRI at 4.8 kg/ha/yr, while total wet deposition of sulfur is 5.0 kg/ha/yr (NPS, 2012b). Both nitrogen and sulfur levels are well above the minimum levels indicating "Significant Concern." However, by examining the trends from the estimates of the 5-year averages, deposition of both nitrogen and s0ulfur seem to be slightly improving (Figure 13). For these reasons, the deposition condition warrants significant concern but is assigned an improving trend. Due to the lack of wet deposition data gathered at STRI and the entirety of applicable data being interpolated 5-year estimates, confidence is given a low value (Table 13).

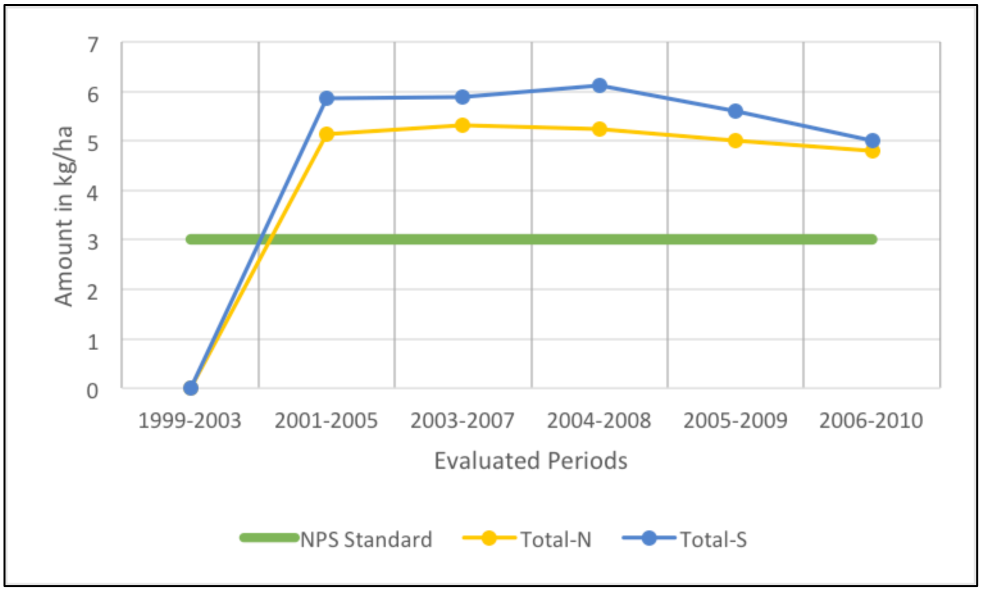
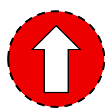


Figure 13. Five-year average wet deposition estimates. (Data source: NPS, 2012b).

Table 15. Visual condition assessment for deposition of nitrogen and sulfur at STRI (NPS, 2012B).

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Deposition of Nitrogen or Sulfur	Nitrogen or sulfur concentrations		Total wet deposition for nitrogen and sulfur at STRI is 4.8 kg/ha/yr and 5.0 kg/ha/yr, respectively. Both values are above the "significant concern" threshold of 3.0 kg/ha/yr. Due to slightly decreasing nitrogen and sulfur concentrations, a positive trend is assigned. However, as data for STRI was largely interpolated, confidence in nitrogen and sulfur concentration values are low.

4.1.3. *Particulate Matter and Visibility*

<u>Relevance and Context</u>

Particulate matter is a mixture of miniscule particles and liquids that may be found suspended throughout the atmosphere. Its makeup varies, but typically it consists of metals, acids, and/or dust particles. These particles are assigned different grades, with those smaller than 2.5 micrometers in diameter known as fine particles ($PM_{2.5}$; USEPA, 2009). These fine particles are one of the primary causes of reduced visibility, or haze, which may be seen throughout the NPS system (USEPA, 2013). A characteristic associated with particulate matter is the scattering or absorption of light, which may affect distance and clarity of vision. Moisture in the atmosphere may cause a further decrease in visibility through the swelling of nitrate and sulfate particles. This swelling or expansion of particle size increases the levels of light scattering associated with particulate matter (USEPA, 2013). In the eastern United States, visibility ranges of 15 to 30 miles are typical. Without man-made pollution affecting visibility, visual ranges of 45 to 90 miles would be expected (USEPA, 2008). Aside from visibility deterioration, human health is another major consideration when examining the negative properties of $PM_{2.5}$. These particles may easily pass through the throat and nose and enter the lungs causing decreased capacity, fatigue, increased occurrence of respiratory illnesses, and a myriad of health issues ranging from coughing and other respiratory problems to cancer (USEPA, 2008; USEPA, 2009; USEPA, 2013).

Methods and Data

The NPS measures visibility in deciviews (dv) using the Haze Index. As Haze Index values increase, visibility conditions worsen. In simple terms, the visibility condition can be estimated by subtracting the estimated average natural visibility from the average current visibility (NPS, 2013). A dv value less than 2 indicates good visibility conditions. Parks with visibility ranging from 2-8 dv above natural conditions are considered to be in the "moderate concern" category. Values greater than 8 dv places parks into the "significant concern" category (Table 14).

Due to lack of onsite testing of visibility data, STRI conditions are best estimated using the interpolated data from 5-year periods of national averages. They were: 11.6 dv for 2001-2005, 14.7 dv for 2003-2007, 14.31 dv for 2004-2008, 13.8 dv for 2005-2009, and 13.1 dv for 2006-2010 (NPS, 2012b; Figure 14).

Condition and Trend

Visibility condition values of greater than 8 dv warrant significant concern (Table 14). For all five-year periods, the dv values at STRI were greater than 8. Comparing the 2001-2005 and 2003-2007 periods shows a significant increase in dv values. However, from the 2003-2007 period on, dv values slowly dropped. Although these values are decreasing, at their lowest value of 13.1 dv in the 2006-2010 period, they are still well above the NPS standard of 8. For these reasons, particulate matter and visibility conditions warrant significant concern but are assigned an improving trend due to the decrease in estimated dv (Table 14).

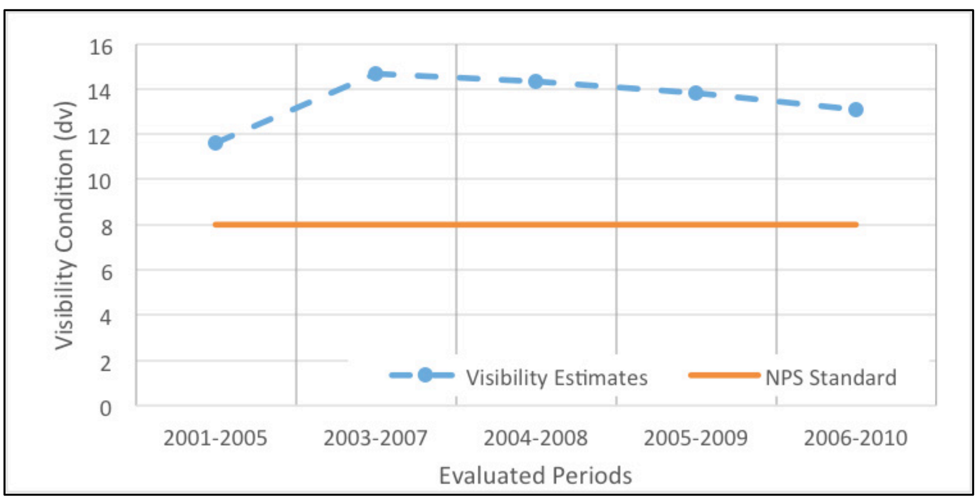
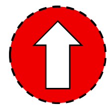


Figure 14. Five-year average of visibility estimates. (Data source: NPS, 2012b)

Table 16. Visual condition assessment for particle matter and visibility at STRI. (Source: NPS, 2012b).

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Particulate Matter and Visibility	Haze Index		All 5-year periods show haze index values of greater than 8 dv. For this reason, a condition of “significant concern” was assigned. However, haze index and visibility conditions values are decreasing. Due to the lowering haze index values, a positive trend is assigned. However, as data for STRI was largely interpolated, confidence in haze index values is low.

<u>Data Needs</u>

Air quality data for STRI is deficient. While useful data on ozone concentrations was gathered using POMS equipment for several months during 2010, the other air quality conditions lack specific, long-term data. Particulate matter, nitrogen and sulfur deposition, and visibility condition assessments were completed using interpolated data from around the country. While this provides useful estimations, exact data gathered from within STRI boundaries are necessary for a more accurate condition assessment. Ozone data gathered from the POMS is exact, but is nearly four years old. The POMS equipment for the CUPN travels on a rotation so an ozone assessment would be most relevant directly after the upcoming monitoring cycle.

4.2. Weather and Climate

The National Park Service attempts to monitor weather and climate data within the various park networks through the Air Resources Division (ARD) and use of the Inventory and Monitoring Program (I&M). In 2007, the I&M Program identified the most reliable and pertinent stations for each park network by tracking the various applicable weather stations. Once appropriate stations are identified, weather and climate data are gathered and analyzed for any patterns or trends (Davey et al., 2007).

When examining weather and climate data trends, it is important to note the distinction between "weather" and "climate". Typically, "weather" refers to the immediate and present meteorological conditions. Trends are not applicable, as "weather" is concerned with day-to-day conditions. The term "climate", however, refers to the statistical measures of spatial and temporal changes that occur within the atmosphere over time (Davey et al., 2007). These statistical measures are of great significance due to the major impact of climate on ecological processes. Certain climate characteristics are noted for increasing the spread of invasive plant and animal species as well as affecting the levels of pollutants in the area (Davey et al., 2007). As a result, the National Park Service desires close monitoring of weather and climate for the various park networks to better prepare for and counteract the negative effects of the changing climate characteristics (Davey et al., 2007).

During the 2007 inventory, the I&M Program identified multiple weather stations within or nearby STRI, including one of the two POMS rotated among the parks within the CUPN on a seven-year basis. Another station type is a Cooperative Observation Station (COOP). However, as this station is shared with other parks within the CUPN, weather and climate data are missing from the dates when both of the POMS were in use by other parks. Although several COOP stations were located near STRI, all but one were disregarded due to poor and/or missing datasets. "Murfreesboro 5 N" is the name of the COOP station with the longest and most complete dataset and is located approximately 3 miles east of the park (Davey et al., 2007). Although active since 1890, the first 10 years of data from "Murfreesboro 5 N" were discarded due to missing data. Precipitation and temperature averages were determined through examination of the COOP station's datasets beginning in 1900. "Smyrna 6 S" is another nearby COOP station (located 7 miles northwest of STRI) and was established in 1941 (Davey et al., 2007). This COOP station was not operational from the 1950s to the 1990s, however, and thus is missing data from these years (Davey et al., 2007). It is also worth noting that a COOP station exists at STRI, but due to the data coverage's short time span and varying quality, these measurements were disregarded.

4.2.1. *Precipitation*

Precipitation is one of the major influencing factors on ecosystem structure and health. The amount of precipitation experienced by an ecosystem can affect a variety of functions such as foliage growth and spread, wet deposition of pollutants, nutrient dispersion, etc. (Davey et al., 2007). For STRI, precipitation amounts vary depending on time of year with fall being the driest season (Davey et al., 2007). Using data from the COOP station "Murfreesboro 5 N" for the years 1900 to 2013, the average precipitation amount for the area is 4.2 inches per month. Precipitation amounts reported from this station ranged from the lowest average of 2.9 inches per month to the largest amount at 6.1 inches per month (Figure 15). The data points from the early 1900s show much less variability in precipitation amounts compared to the later years. For instance, in the early 1990s, average monthly precipitation increased by almost 2.5 inches per month. Radical changes in precipitation were uncommon in the early data points from "Murfreesboro 5 N" (National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

The largest monthly average precipitation amount of 5.4 inches is seen in March, while the lowest average precipitation of 2.9 inches occurs in October (Figure 16). Typically, the wettest seasons for STRI are winter and spring with the driest seasons occurring in summer and fall (National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

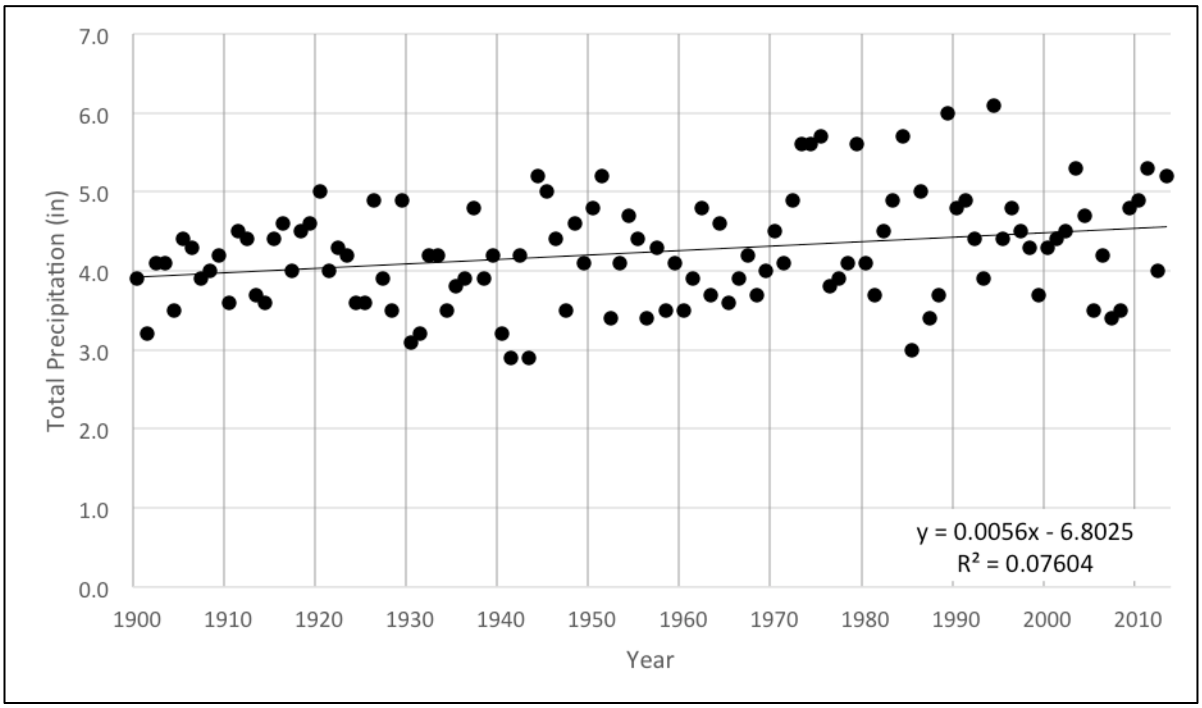


Figure 10. Monthly average precipitation in inches measured in the vicinities of STRI from 1900 to 2013. (Data source: National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

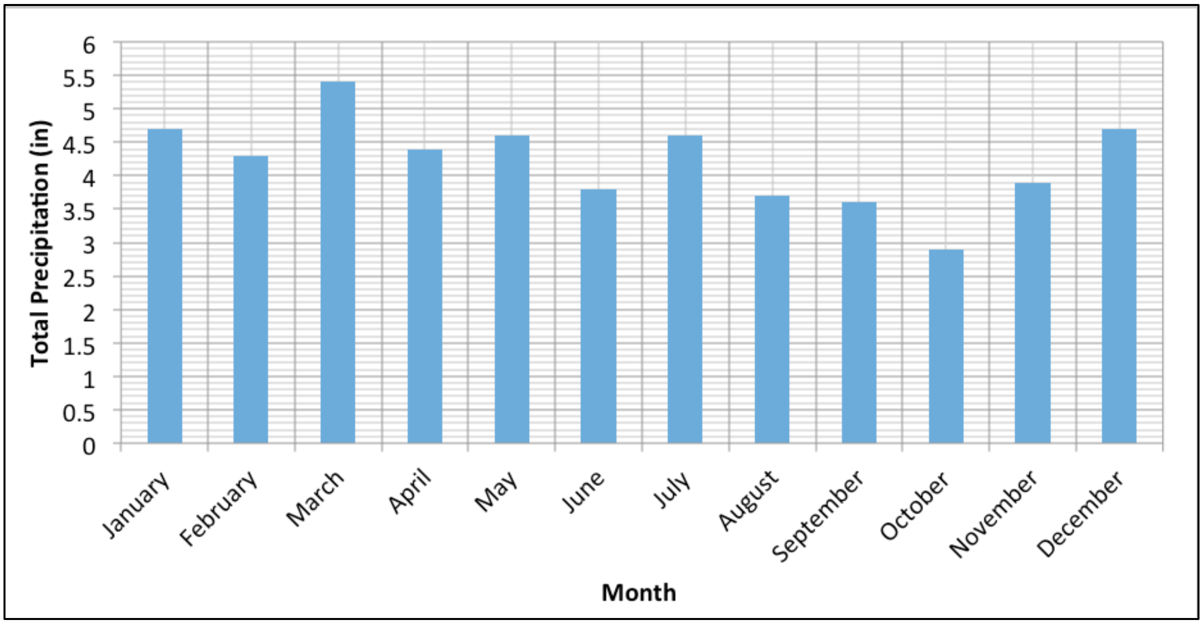


Figure 11. Average precipitation for individual months from 1900-2013. (Data source: National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

4.2.2. *Temperature*

Data from "Murfreesboro 5 N" shows distinct patterns in temperature change over the past century. The I&M Program hypothesized that the major changes in annual mean temperature could be a result of global climate change (Davey et al., 2007). According to the USEPA, climate change may negatively impact ecosystems in a variety of ways. Disruption of the food web due to migration and dwindling populations of ecosystem species is becoming much more commonplace. Increases in major weather events like droughts are leading to drier ecosystems that are at higher risk for dangerous wildfires (USEPA, 2014). For the CUPN and STRI, the warmest years were in the 1940s and 1950s. In the 1960s, there was a significant drop in temperature. Since then, however, temperatures have been rising steadily until present day (Davey et al., 2007; National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

The datasets gathered from the National Climatic Data Center show that 1956 posted the highest average temperature of 63.6 degrees Fahrenheit (17.6^{0}C) (Figure 17). However, in two years the temperature dropped to an average of 58.3 degrees Fahrenheit (14.6^{0}C). Since the mid 1970's, the temperature has continued to rise. It is expected that more extreme temperature changes could happen in the future (Davey et al., 2007).

The average temperatures per month are typical for the southeastern United States. Temperatures are at low points in the winter months of January (38.7^{0}F/3.7^{0}C) and December (40.8^{0}F/4.9^{0}C). Temperatures peak in the summer months of July (78.9^{0}F/26.0^{0}C) and August (77.5^{0}F/25.3^{0}C) (Figure 18).

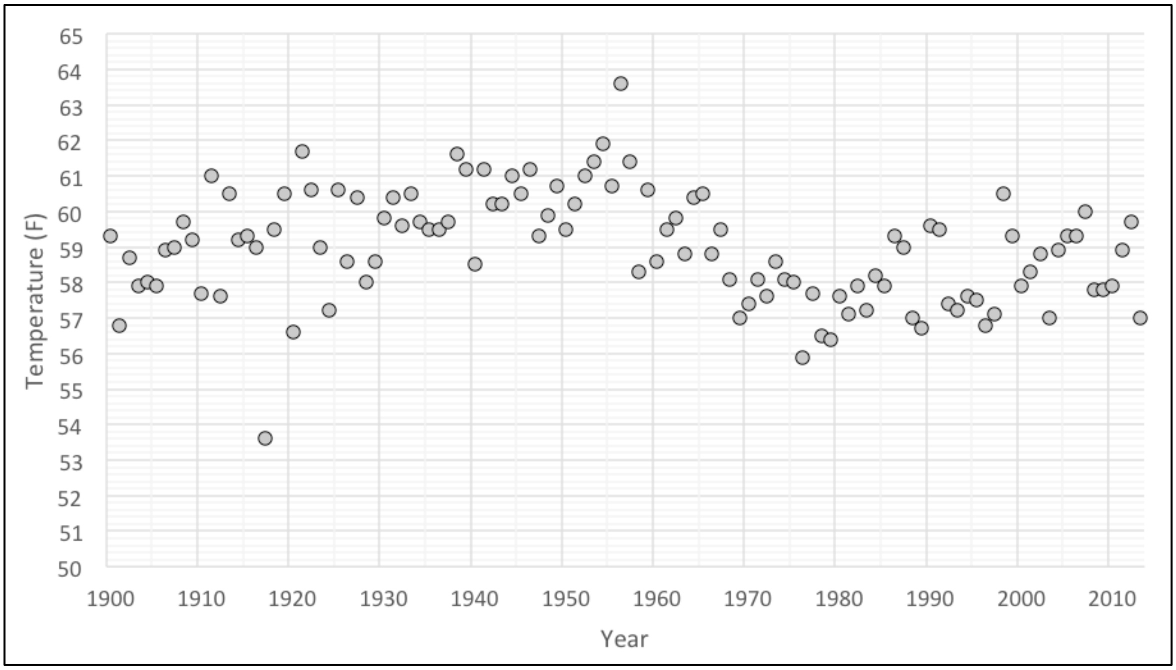


Figure 12. Average temperature per year at STRI from 1900-2013. (Data source: National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

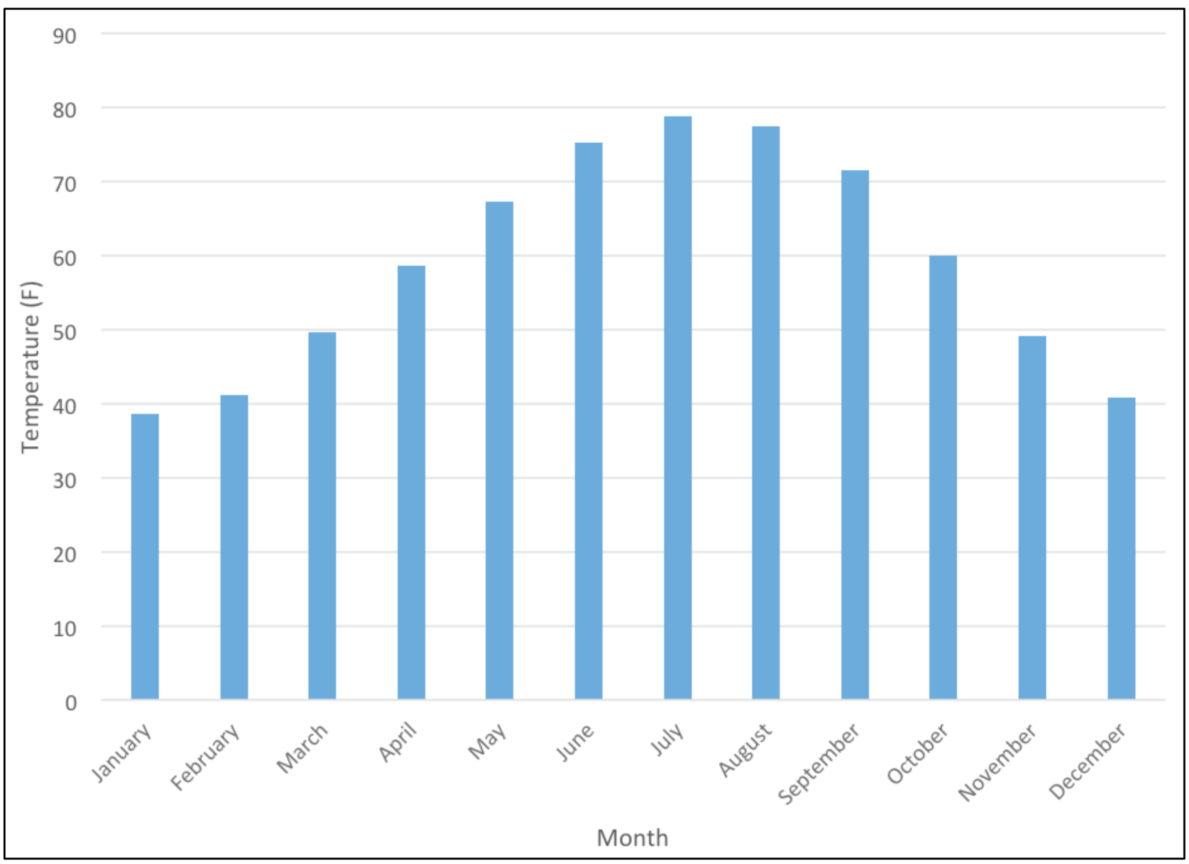
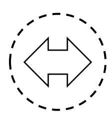


Figure 13. Average temperature for individual months from 1900-2013 at STRI (Data source: National Oceanic and Atmospheric Administration, National Climatic Data Center, 2014).

Conditions and Trends

Overall, the selection of data sources with reliable monitoring periods to make observations on weather and climate at STRI are limited. While the COOP station at "Murfreesboro 5 N" is a reliable source, there are no other nearby monitoring stations with an equivalent level of data longevity and quality to make comparisons with. As mentioned previously, a COOP station is currently in use at STRI, but the limited time period represented by the data restricts long-term analyses. For a more thorough and effective condition assessment of weather and climate, more high quality data from the surrounding area is needed. While there is a trend toward increasing temperatures, it seems to be effectively minor. Average precipitation seems largely unchanging. However, there does seem to be a larger amount of variance in precipitation year to year in recent years compared to decades of the past. As a result, the condition status for weather and climate at STRI is assigned a “stable” trend. The assignment of a condition status is not suited to this attribute as assessing the health of the weather and climate at STRI is beyond the scope of this report (Table 15). Weather and climate at STRI are part of the greater weather patterns found throughout the CUPN. For this reason, this condition cannot be reliable evaluated at STRI in particular. For further study, an analysis on the effects of climate change at STRI could be used to examine temperature and precipitation changes.

Table 17. Visual condition assessment for weather and climate at STRI.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Weather and Climate	Precipitation and Temperature Measurements		Due to the nature of weather and climate, a condition assessment is not suitable. The periods measured in both the precipitation and temperature datasets showed a steady and unchanging trend.

4.3. Geology and Soil

The geology of Stones River National Battlefield is especially relevant to (1) interpretation, (2) cedar glade ecology, and (3) the hydrogeology of the area. Thornberry-Ehrlich (2012) completed a geologic resources inventory (GRI) for Stones River National Battlefield. The GRI report provides a brief description of geologic units, issues related to geology, geologic features and processes, and geologic history, and the report includes a geologic map. The report includes a paleontological resources section, and information about paleontological resources can also be found in Hunt-Foster et al. (2009). The report also includes a section on Geologic Connections to Park Stories.

All of the park is located on Ordovician marine carbonate, silty carbonate, and shale of the Stones River Group, and almost all of the park is on Ordovician Ridley Limestone (Galloway, 1919; Wilson, 1964; Wilson, 1965; Farmer and Hollyday, 1999; Thornberry-Ehrlich, 2012). Relatively pure carbonate is found throughout much of this formation, and fissures (joints widened by dissolution) have developed within this carbonate in many places. Geomorphically, the fissures result in areas characterized by carbonate pinnacles and intervening karren (furrows). The Slaughter Pen, an important historical site, developed on relatively pure carbonate of the Ridley limestone and contains spectacular examples of pinnacles and karren.

In addition to limestone, the formation also contains dolomite, chert nodules, silty carbonate, and shale. The hydrogeology of the area reflects both the flow of groundwater through fissured carbonate aquifers and the relative lack of flow through silty carbonate and shale aquitards. For example, central Tennessee springs are often found at the contact between an aquifer and an underlying aquitard.

Although the GRI report is on the whole a good summary of previous geologic investigations, the geologic map included with the report is problematic because the map is based solely on Wilson (1964) and Wilson (1965). Subsurface (Farmer and Hollyday, 1999) and surface (Abolins, 2014) geologic investigations in areas east and south of the park have shown that in many areas the Wilson maps are grossly inaccurate in their depiction of the Murfreesboro-Pierce and Pierce-Ridley contacts. A straightforward interpretation of the low geologic map accuracy is that the Ridley, Murfreesboro, and Pierce Limestones cannot be differentiated at 1:24,000 scale and should instead be lumped into a single unit at this scale. Note that, these inaccuracies notwithstanding, there is no data suggesting that anything other than the Ridley Limestone underlies most of the park. Rather, the point is that the Murfreesboro-Pierce and Pierce-Ridley contacts depicted on the GRI geologic map cannot be assumed to have anywhere near the same accuracy as other contacts depicted on central Tennessee geologic maps.

The GRI report mentions soils in several places. In particular, the report mentions the inclusion of a former topsoil mine within the park and the use of soil to fill depressions at the National Cemetery during the 1970s. Detailed soil data can be obtained through the United States Department of Agriculture (USDA) Web Soil Survey site (http://websoilsurvey.sc.egov.usda.gov). One soil type (Gladeville-Rock outcrop-Talbott association or GRC) covers 28% of the park and five soil types (GRC, Cumberland silt loam or CuB, Bradyville-Rock outcrop complex or BtA and BtC, and

Harpeth silt loam or HCA) cover 67% of the park (Figure 19). Soils are generally described as thin or absent except on the floodplain of the Stones River or where soil fills bedrock fissures.

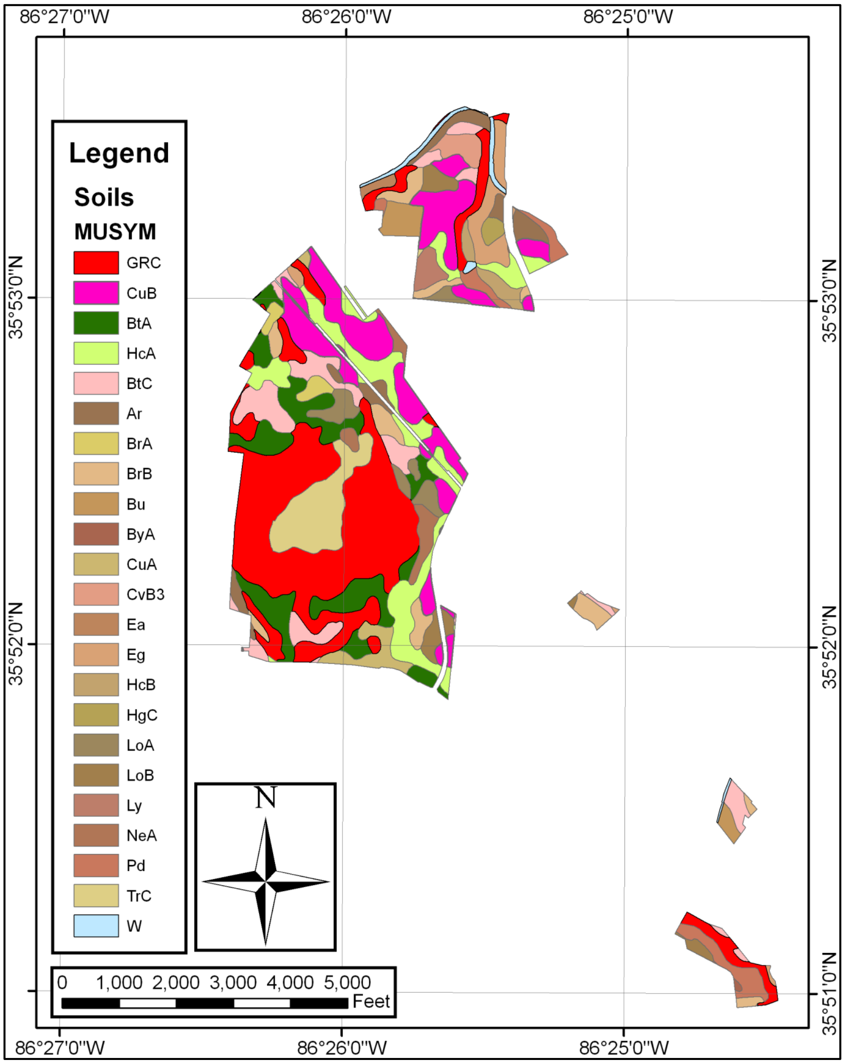


Figure 14. USDA soils of Stones River National Battlefield, Tennessee. The five most common are at the top in order of decreasing abundance, and the rest of the soil types are in alphabetical order. See text for the names of the five most abundant soils and visit the web soil survey site for the names of the less abundant soils.

4.4. Water Quality

4.4.1. *Description*

Beginning in 2003, STRI began a water quality monitoring effort, as part of a CUPN initiative to better understand water quality within network parks. Water Quality is a CUPN Vital Sign for park health and the studying of water quality has many park benefits, as listed by CUPN I&M Monitoring Objectives:

1. Fundamentally, the data from this program will form a backdrop to compare changes in the aquatic biologic communities.
2. Violations of state designated use water quality standards will be detected.
3. Stressors, such as land uses and land-use change within the watershed, will be monitored.
4. Regional effects of atmospheric contaminants (acid precipitation) can be determined.
5. Potential pollutant sources can be determined (non-point source contaminants versus point-sources).
6. Impacts to water quality by in-park activities within selected watersheds will be assessed.

4.4.2. *Data and Methods*

Water quality is measured monthly for two years, with a five-year break between measurement periods. Water quality is measured at 4 testing sites: West Fork at McFadden's Ford (MFWF), Battlefield Spring (BSBS), West Fork at Redoubt Brannan (RBWF), and King Pond (KSKP) (Figure 20). These sites were selected by CUPN and STRI staff based on multiple criteria. The selected sites have been used for water quality measurement programs before with United States Geological Survey (USGS) water quality inventory, so this allows for a longer-term understanding of water quality when combined with the USGS monitoring history. Two of the four sites (KSKP and BSBS) are within the boundaries of the park, with the other two being just outside the disparate park parcel boundaries (Table 16). There are no test sites in the main park unit, National Cemetery, Hazen Brigade Monument, or either headquarters site. Three of the sites are within or proximal to the McFadden Farm unit, with the other site being proximal to Fortress Rosecrans. Samples are taken from each of the 4 sites and lab analyzed for the various water quality parameters that are studied.

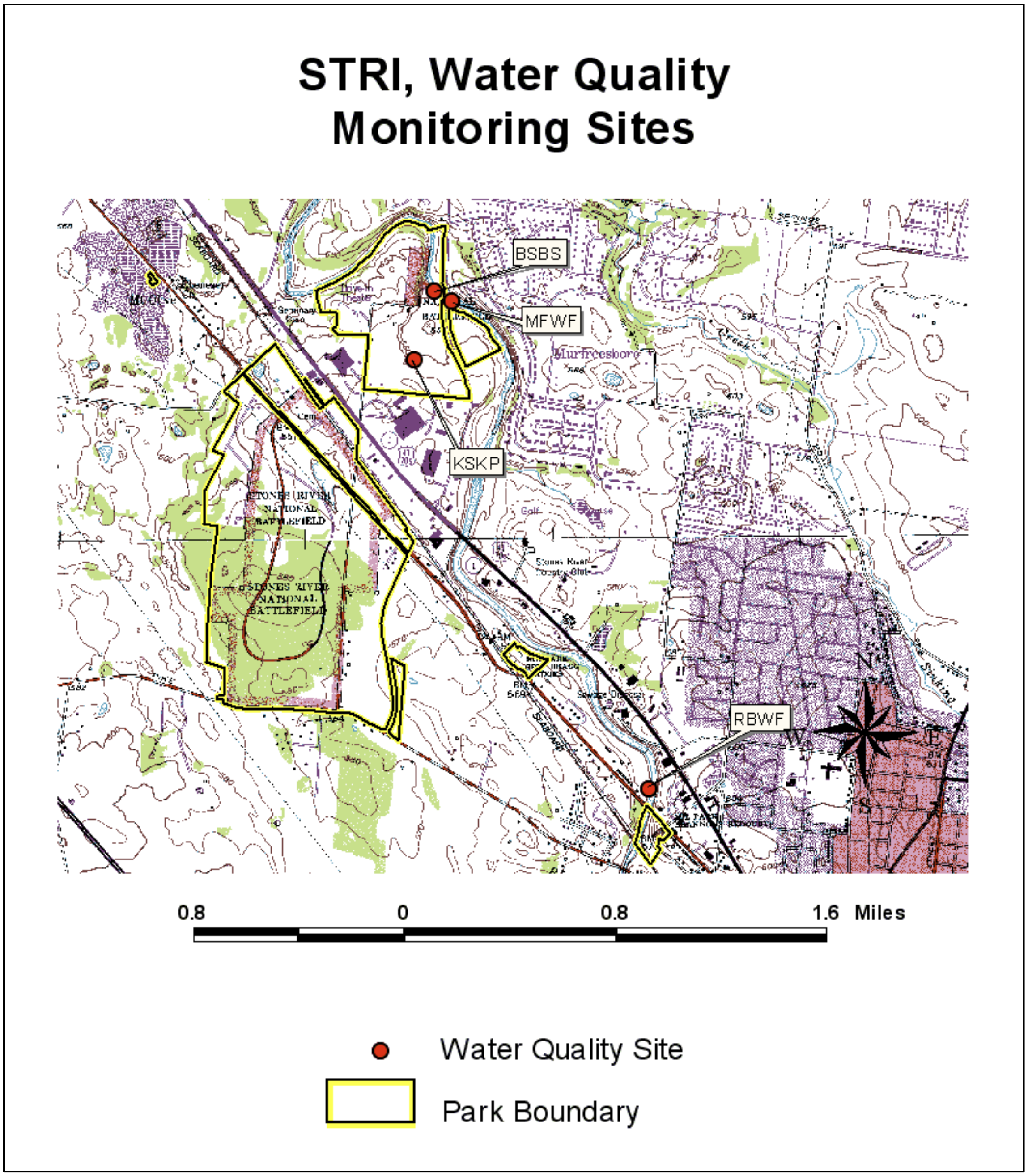


Figure 15. Locations of water quality testing sites within STRI (Meiman, 2005)

CUPN staff laid out four core field parameters for water quality, which are: temperature, pH, specific conductance, and dissolved oxygen. After the first round of water quality measurement and analysis, which was done across a spectrum of parameters, two other parameters were recommended for further study in subsequent water monitoring, nitrate and *E. coli*/total coliform.

Reference conditions for water quality follow state or national level standards for water quality where at all possible. The state of Tennessee classifies waterbodies into one or more use categories that dictate the water quality criteria for that body. If more than one designated use is listed for one waterbody, the highest standard should be used. Only the West Fork Stones River has state-designated uses, while uses for other waterbodies were determined during the water quality sampling according to state criteria (Meiman, 2005).

Table 18. Water quality testing site at STRI. (Source: Meiman, 2005)

Park	Code	Site	State	Designated Use
STRI	MFWF	West Fork Stones River At McFadden's Ford	TN	• Domestic Water Supply • Fish & Aquatic Life Industrial Water Supply Irrigation • Livestock Watering & Wildlife • Recreation
STRI	BSBS	Battlefield Spring	TN	Fish & Aquatic Life
STRI	RBWF	West Fork Stones River At Redoubt Brannan	TN	• Domestic Water Supply • Fish & Aquatic Life Industrial Water Supply Irrigation • Livestock Watering & Wildlife • Recreation
STRI	KSKP	Kings Pond	TN	Fish & Aquatic Life

The state of Tennessee has water quality criteria for several of the parameters: temperature, pH, dissolved oxygen and *E. coli*, with no set standards for either nitrate or specific conductance (Table 17). The USEPA uses a measure for nitrates allowed in water classified for domestic water supply. There are no set standards for specific conductance, but it is a good indicator of the amount and types of dissolved solids that are in water.

Measurements of water and air temperatures at the field site are essential for water-data collection. Determinations of dissolved-oxygen concentrations, conductivity, pH, rate and equilibrium of chemical reactions, biological activity, and fluid properties rely on accurate temperature measurements. Accurate water- and air-temperature data are essential for documenting thermal alterations to the environment caused by natural phenomena and by human activities. Tennessee specifies a limit of 86.9˚F/30.5˚C for fish and aquatic life, industrial water supply, and recreation waters.

Electrical conductance is a measure of the capacity of water (or other media) to conduct an electrical current. Specific conductance (SPC) is a quick and reliable estimation of the dissolved solids in the water. Although there is no state standard for this parameter, the USEPA (1997) sampling methods manual identifies an ideal range of 150 to 500 µS/cm for "inland fresh waters…supporting good mixed fisheries," and furthermore suggests that "conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates."

Table 19. Water quality criteria for Tennessee (Source: TDEC, 2011)

Parameter	Use Classification *					
	FAQ	IWS	IRR	LWW	REC	DOM
Nitrates as NO3 (mg/L) #	--	--	--	--	--	45
Dissolved Oxygen (mg/L)	≥ 4.0	--	--	--	--	--
Temperature (˚F/˚C)	86.9/30.5	86.9/30.5	--	--	86.9/30.5	86.9/30.5
Specific Conductance (μS/cm)	--	--	--	--	--	--
Escherichia coli (colonies/100mL)	2,880 †	--	--	--	487/941 §	1000
pH (SU)	6.0/6.0–9.0 ‡	6.0–9.0	6.0-9.0	6.0–9.0	6.0-9.0	6.0-9.0

* FAQ: Fish and Aquatic Life; IWS: Industrial Water Supply; IRR: Irrigation; LWW: Livestock Watering & Wildlife; REC: Recreation: EPA: Environmental Protection Agency; DOM: Drinking Water Supply

EPA Standards for Nitrates in drinking water

† For single samples

‡ pH for FAQ is 6.0 – 9.0 in Wadeable streams and 6.5 – 9.0 in large rivers, lakes, reservoirs, and wetlands

§ 487 colonies/100mL for a single sample taken from a lake, reservoir, or exceptional state water; 941 for other classifications

The pH of an aqueous solution is controlled by interrelated chemical reactions that produce or consume hydrogen ions. Water pH is a useful index of the status of equilibrium reactions in which water participates. The pH of water directly affects physiological functions of plants and animals, and it is, therefore, an important indicator of the health of a water system. Low pH and high pH can be toxic to many aquatic species and also may increase the mobility and uptake of toxicants (USEPA, 1997). Tennessee requires pH measurements between 6 and 9 standard units for all uses at STRI, with the exception of freshwater and aquatic life, which has a higher minimum of 6.5 in lakes, reservoirs, large rivers, and wetlands (TDEC, 2011).

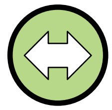
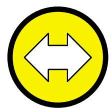
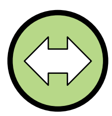
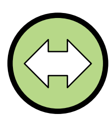
Coliform bacteria are a group of bacteria that live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated viruses and pathogens. Fecal indicator bacteria, *E. coli*, are used to assess the quality of water because they are not typically disease-causing, but are correlated to the presence of several waterborne disease-causing organisms (pathogens). The concentration of indicator bacteria (the term "indicator bacteria" is used synonymously with fecal indicator bacteria in this section) is a measure of water safety for body-contact recreation or for consumption (Meiman, 2005).

Accurate data on concentrations of dissolved oxygen (DO) in water are essential for documenting changes to the environment caused by natural phenomena and human activities. Sources of DO in water include atmospheric reaeration and photosynthetic activities of aquatic plants. Many chemical and biological reactions in ground water and surface water depend directly or indirectly on the amount of oxygen present. Dissolved oxygen is necessary in aquatic systems for the survival and growth of many aquatic organisms. Several sources of runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from 41 microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (USEPA, 1997).

4.4.3. *Conditions and Trends*

During both monitoring periods of 2004-2005 and 2009-2010, there were measurements that exceeded the state standards for several of the parameters at multiple sites. Overall, water quality measurements at STRI fall well within the state limits. In some instances, natural causes explain measurements found to exceed the state standard, such as the low amount of dissolved oxygen at KSKP and BSBS caused by their epikarst nature. However, there are some issues with water quality in STRI which may be caused by human activity in the area. Meiman notes in his 2005 report that STRI has the most compromised water quality of any park in the CUPN, due largely to its proximity to large-scale development. Based on the water quality reports from STRI and in conjunction with Meiman's analysis of water quality at STRI, water quality at STRI is assigned a condition of "moderate concern", with a trend of "no change" (Table 18).

Table 20. Cumberland Piedmont Network water quality summary. (Source: Meiman, 2014).

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water Quality	Water Chemistry	pH		0% of pH measurements fell below the TN lower standard for Fish and Wildlife of 6.0 SU. (1) N=176	Meet TN Fish and Wildlife standard of between 6.0 and 9.0 SU. (A)	
Water Quality	Water Chemistry	Dissolved Oxygen		20% of measurements fell below the TN standard for Fish and Wildlife of 4.0 mg/l for Subecoregion 71i. Nearly all low readings are from a natural condition of park springs (1) N=175	Meet TN standard of 4.0 mg/l. (A)	
Water Quality	Water Chemistry	Water Temperature		0% of temperature measurements were above the TN standard for Fish and Wildlife of 86.9˚F/30.5˚C (1) N=176	Meet TN standard of 86.9˚F/30.5˚C (A)	
Water Quality	Water Chemistry	Specific Conductivity		There is no TN standard for specific conductivity. STRI waters reflect the geology of limestone watersheds. (1) N=176	Not to exceed one standard deviation above the maximum value (as of 1-1-14) per site.	

Water Quality: Green 0%-5% did not meet WQ criteria, Yellow 5%-25%, Red >25%.

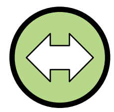
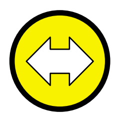
References and Data Sources:

(1) CUPN: 11/2002-9/2010

(A) Tennessee: Rules 1200-4-3-01, Tennessee Department of Environment and Conservation.

(B) USEPA 440/5-86-001

Table 21 (continued). Cumberland Piedmont Network water quality summary. (Source: Meiman, 2014).

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water Quality	Water Chemistry	Nitrate		0% exceeded the USEPA recommendation for freshwater life (90 mg/l) or the USEPA drinking water standard of (45 mg/l). (1) N=176165	Not to exceed USEPA recommended levels. (B)	
Water Quality	Water Chemistry	*Escherichia coli*		9% exceeded the TN recreational standard for Fish and Wildlife *E. coli* standard. High bacteria are always associated with runoff events. (1) N=4592	Not to exceed TN standard of 487 CFU/100ml. (A)	Non-point source

Water Quality: Green 0%-5% did not meet WQ criteria, Yellow 5%-25%, Red >25%.

References and Data Sources:

(1) CUPN: 11/2002-9/2010

(A) Tennessee: Rules 1200-4-3-01, Tennessee Department of Environment and Conservation.

(B) USEPA 440/5-86-001

4.5. Biological Integrity

4.5.1. *Invasive/Exotic Plants*

Relevance and Context

Species richness of a habitat can be influenced by the invasion of species, especially exotic ones (Cofer et al., 2008). National parks are susceptible to invasions, which may negatively impact park resources and visitor enjoyment. Accidentally or deliberately introduced plant species can influence the native ecosystems at any scale. The invasiveness and persistence of species may influence biodiversity through competition effects, by reducing nutrient resources to native plants and by altering fundamental properties such as geomorphological processes, allelopathy, nutrient cycles, and fire regimes (Gordon, 1998; Dukes and Mooney, 1999).

Resource Knowledge

Nordman (2004) conducted a comprehensive inventory of STRI vegetation in the summer 2002 and spring 2003. He established sixteen permanent plots throughout the park, documented ecological communities using United States National Vegetation Classifications, and collected any species found in the plots that were not previously recorded, placing them into a herbarium. Altogether, Nordman recorded 611 plant species within STRI. This is higher than previously documented by Hogan and Weber (1999) who identified 507 species in the park, and found that 141 or 28% of them were cultivars or introduced species. In his inventory, Nordman (2004) reported 54 species that were considered invasive by the Tennessee Exotic Pest Plant Council (TN-EPPC, 2001).

Based on their invasive characteristics, exotic species have been ranked into four levels: severe threat, significant threat, lesser threat, and alert (TN-EPPC, 2009). Based on the 2001 TN-EPPC list, 18, 20, 12, and 4 of the exotic species at STRI were considered a severe threat (EPPC-1), a significant threat (EPPC-2), a lesser threat (EPPC-3), or placed on the alert list (EPPC-A), respectively (Table 19). An updated list by TN-EPPC (2009) has 13, 12, 15, and 11 species listed as severe threat, significant threat, lesser threat, and alert, respectively. The severe threat is dominated shrubs, forbs/herbs, and grasses, with tree of heaven (*Ailanthus altissima*), silktree (*Albizia julibrissin*), and princess tree (*Pauwlonia tomentosa*) being the only trees listed. No tree species are found in the other ranks of invasiveness. Forb/herb is the dominant type of growth form in all three categories (Nordman, 2004). STRI manages 40 of the park's documented exotic species as invasive (Table 20; STRI, 2009).

Nordman also identified 20 unique vegetation communities within the park boundary. Out of 20 distinct vegetation associations identified in the park, four associations are considered successional with three of them being dominated by exotic species (Chinese Privet Upland Shrubland - CEGL003807, Chinese Privet Temporarily Flooded Shrubland - CEGL003837, Cultivated Meadow - CEGL004048).

Threats and Stressors

Invasions by exotic species result in significant change in biodiversity. An Integrated Pest Management Plan has been implemented in the park and has been successful, for instance the control of kudzu (*Pueraria montana* var. *lobata*) at Fortress Rosecrans (Nordman, 2004). However, the understory in the interior parts of forests at STRI has been colonized by shrubs such as Chinese privet (*Ligustrum sinense*) and amur honeysuckle (*Lonicera maackii*), and by vines such as climbing euonymus (*Euonymus fortunei*). After many years of successful control (and almost eradication) of these shrubs in the forest of the Nashville Pike unit, an April 2009 tornado cut a path through the forest, partially destroying the canopy and allowing invasive shrub growth to increase dramatically. Following the tornado, the park intensified management efforts in this area. Chinese privet (*Ligustrum sinense*) along with Chinese yam (*Dioscorea oppositifolia*) dominates much of the floodplain of the West Fork of the Stones River, whereas Johnson grass (*Sorghum halapense*) and Japanese lespedeza (*Lespedeza cuneata*) can be found in fields and/or newly cleared areas. Species listed as "alert" such as sacred bamboo (*Nandina domestica*), crown vetch (*Coronilla varia*), and white sweet clover (*Melilotus alba*) may also need monitoring attention at STRI to make certain that their populations do not expand. Between Nordman (2004) and Keefer et al. (2012), six species were added to the list of exotics occurring at STRI: bull thistle (*Cirsium vulgare*), goatweed (*Hypericum perforatum*), creeping jenny (*Lysimachia nummularia*), Japanese knotweed (*Polygonum cuspidatum*), callery pear (*Pryus calleryana*), and greater periwinkle (*Vinca major*). It is unknown whether these species have recently invaded the park or were not originally detected and recorded.

<u>Condition and Trend</u>

Condition Status

The condition of STRI invasive/exotic plants warrants significant concern (Table 21). The presence of exotic species at STRI poses a major threat to native plant communities in STRI. Based on CUPN 2011-13 forest vegetation monitoring, 100% of plots (i.e., 20 of 20 plots) contained multiple exotic species (mean = 7.4 exotic species/400 m^2 plot) with the most commonly occurring being classified as a severe or significant threat by the Tennessee Exotic Pest Plant Council. The proportion of species which are exotic across all plots in the 1 m^2 sampling frames was nearly 18%. To provide some context, the proportion of exotic species in the 1 m^2 sampling frames ranged from <1% to nearly 20% across CUPN parks. Cofer et al. (2008) mentioned that disturbed glades contained higher number of exotic species than non-disturbed ones; thus, minimizing the disturbance in the glade communities will reduce invasion of exotic species. Although management practices have been effective in removing or reducing the abundance of some exotic species such as kudzu (*Pueraria montana* var. *lobata*), Chinese yam (*Dioscorea oppositifolia*), Chinese privet (*Ligustrum sinense*) and Amur honeysuckle (*Lonicera maackii*) in the park, continued efforts will be needed for full recovery of vegetation (Walck, 2006).

Trend in Condition

No trend was assigned to the exotic plants, since single baseline studies or inventories are insufficient to establish a trend (Table 21). The level of threat categories has changed between 2001 and 2009 by Tennessee Exotic Pest Plant Council due to a re-evaluation of the invasibility and danger posed by the exotic species (TN-EPPC, 2009).

Confidence in Assessment

The confidence used to make the assessment was high (Table 21). Data were collected throughout the park covering all habitats using a variety of scientifically-sound methods. Permanent plots were established and determined by GPS units, and vegetation monitoring data collected. In addition, information on the presence/abundance of exotic species as well as on pest management has been recorded and well documented over many years. The researchers conducting the study had extensive experience sampling the vegetation (and exotic species) of the region.

Table 22. List of exotic species and their growth form documented at STRI (Nordman, 2004; Keefer et al., 2012) and listed by the Tennessee Exotic Pest Plant Council (2009).

No.	Scientific name	Common name	Growth form	TN-EPPC
1	*Ailanthus altissima*	Tree-of-heaven	Tree	Severe threat
2	*Albizia julibrissin*	Silktree	Tree	Severe threat
3	*Bromus tectorum*	Cheatgrass	Grass	Severe threat
4	*Dioscorea oppositifolia*	Chinese yam	Vine	Severe threat
5	*Hypericum perforatum*	Bull thistle	Forb/Herb	Severe threat
6	*Kummerowia stipulacea*	Korean clover	Forb/Herb	Severe threat
7	*Lespedeza cuneata*	Japanese lespedeza	Forb/Herb	Severe threat
8	*Ligustrum sinense*	Chinese privet	Shrub	Severe threat
9	*Ligustrum vulgare*	European privet	Shrub	Severe threat
10	*Microstegium vimineum*	Japanese stiltgrass	Grass	Severe threat
11	*Paulownia tomentosa*	Princess tree	Tree	Severe threat
12	*Polygonum cuspidatum*	Japanese knotweed	Forb/Herb	Severe threat
13	*Pueraria montana*	Kudzu	Vine	Severe threat
14	*Rosa multiflora*	Mutiflora rose	Shrub	Severe threat
15	*Sorghum halapense*	Johnson grass	Grass	Severe threat
16	*Alliaria petiolata*	Garlic mustard	Forb/Herb	Significant threat
17	*Allium vineale*	Field garlic	Forb/Herb	Significant threat
18	*Carduus nutans*	Nodding thistle	Forb/Herb	Significant threat
19	*Cirsium vulgare*	Bull thistle	Forb/Herb	Significant threat
20	*Eleagnus pungens*	Thorny olive	Shrub	Significant threat

Table 19 (continued). List of exotic species and their growth form documented at STRI (Nordman, 2004; Keefer et al., 2012) and listed by the Tennessee Exotic Pest Plant Council (2009).

No.	Scientific name	Common name	Growth form	TN-EPPC
21	*Eragrostis curvula*	Weeping lovegrass	Grass	Significant threat
22	*Festuca arundinacea*	Tall fescue	Grass	Significant threat
23	*Glechoma hederacea*	Ground ivy	Vine	Significant threat
24	*Lonicera maackii*	Amur honeysuckle	Shrub	Significant threat
25	*Lysimachia nummularia*	Creeping jenny	Forb/Herb	Significant threat
26	*Polygonum caespitosum* var. *longisetum*	Bristly lady's thumb	Forb/Herb	Significant threat
27	*Polygonum persicaria*	Spotted lady's thumb	Forb/Herb	Significant threat
28	*Setaria faberi*	Nodding foxtail-grass	Grass	Significant threat
29	*Setaria viridis*	Green foxtail	Grass	Significant threat
30	*Verbascum thapsus*	Common mullein	Forb/Herb	Significant threat
31	*Vinca major*	Common periwinkle	Vine	Significant threat
32	*Boglossoides arvense*	Corn-gromwell	Forb/Herb	Lesser threat
33	*Bromus sterilis*	Poverty brome	Grass	Lesser threat
34	*Buplureum rotundifolium*	Hound's ear	Forb/Herb	Lesser threat
35	*Cardiospermum halicabacum*	Balloon vine	Vine	Lesser threat
36	*Centaurea cyanus*	Bachelor button	Forb/Herb	Lesser threat
37	*Clematis terniflora*	Sweet autumn clematis	Vine	Lesser threat
38	*Conium maculatum*	Poison hemlock	Forb/Herb	Lesser threat
39	*Dipsacus fullonum*	Fuller's teasel	Forb/Herb	Lesser threat
40	*Euonymus alatus*	Burning bush	Shrub	Lesser threat
41	*Euonymus fortunei*	Winter creeper	Vine	Lesser threat
42	*Hedera helix*	English ivy	Vine	Lesser threat
43	*Hibiscus syriacus*	Rose of Sharon	Shrub	Lesser threat

Table 19 (continued). List of exotic species and their growth form documented at STRI (Nordman, 2004; Keefer et al., 2012) and listed by the Tennessee Exotic Pest Plant Council (2009).

No.	Scientific name	Common name	Growth form	TN-EPPC
44	*Muscari neglectum*	Grape hyacinth	Forb/Herb	Lesser threat
45	*Ornithogalum umbellatum*	Star of Bethlehem	Forb/Herb	Lesser threat
46	*Tragopogon dubius*	Yellow goat's-beard	Forb/Herb	Lesser threat
47	*Bromus japonicus*	Japanese brome	Grass	Alert
48	*Coronilla varia*	Crown vetch	Vine	Alert
49	*Daucus carota*	Queen Anne's-lace	Forb/Herb	Alert
50	*Kummerowia striata*	Japanese clover	Forb/Herb	Alert
51	*Lepidium campestre*	Field pepperweed	Forb/Herb	Alert
52	*Leucanthemum vulgare*	Ox-eye daisy	Forb/Herb	Alert
53	*Lonicera fragrantissima*	January jasmine	Shrub	Alert
54	*Lonicera japonica*	Japanese honeysuckle	Vine	Alert
55	*Mahonia bealei*	Letherleaf mahonia	Shrub	Alert
56	*Melilotus alba*	White sweet clover	Forb/Herb	Alert
57	*Melilotus officinalis*	Yellow sweet clover	Forb/Herb	Alert
58	*Nandina domestica*	Sacred bamboo	Shrub	Alert
59	*Pyrus calleryana*	Callery pear	Tree	Alert
60	*Rubus bifrons*	Himalayan berry	Shrub	Alert

Table 23. List of exotic plant species managed by the natural resources staff at STRI (STRI, 2009).

No	Scientific name	Common name	Location *	Zone †	Methods
1	*Ailanthus altissima*	Tree-of-heaven	NP, MF, FR, RB	1, 2, 5	Foliar Spray, Basal Bark Spray, Girdle & Spray, Cut & Stump Treat
2	*Albizia julibrissin*	Silktree	NP, MF, FR, RB	1, 2, 4, 5, 6	Hand Pulling, Foliar Spray, Basal Bark Spray, Cut Stump, Hand Cutting, Hand Pulling
3	*Alliaria petiolata*	Garlic mustard	NP, MF, FR, RB	1, 5, 7	Foliar Spray, Hand Cutting
4	*Bromus commutatus*	Meadow brome	NP, MF, FR, RB	1, 2, 3, 4, 5, 7	Foliar Spray, Hand Pulling Hand Cutting
5	*Bromus japonicas*	Japanese brome	NP, MF, FR, RB	1, 2, 3, 4, 5, 7	Foliar Spray, Hand Cutting Hand Pulling
6	*Bromus tectorum*	Cheatgrass	NP, MF, FR, RB	1, 2, 3, 4, 5, 7	Foliar Spray, Hand Cutting & Bag Flowers
7	*Carduus nutans*	Nodding thistle	NP, MF, FR, RB	2, 3, 4, 5, 7	Hand Pulling, Foliar Spray, Hand Cutting & Bag Flowers
8	*Cirsium vulgare*	Bull thistle	NP, MF	2, 3, 4, 7	Hand Pulling, Foliar Spray, Grubbing, Hand Cutting
9	*Conium maculatum*	Poison hemlock	NP, MF, FR, RB	1, 2, 4, 5, 7	Grubbing, Hand Pulling, Mowing, Foliar Spray, Tilling
10	*Cynodon dactylon*	Bermudagrass	NP, MF, FR, RB	2, 4, 5, 6, 7	Grubbing, Foliar Spray
11	*Dioscorea oppositifolia*	Chinese yam	NP, MF, FR, RB	1, 5, 6, 7	Grubbing, Hand Pulling

* Locations: NP= Nashville Pike; MF = McFadden Farm; FR = Fortress Rosecrans; RB = Redoubt Brannan.

† Zones: 1 = Natural (forest, cedar glades and associated plants communities, wetland); 2 = Native grass field (including fields established for native seed production); 2 = Crop field; 4 = Non-native grass field (to be converted to native grass); 5 = Earthwork and surrounding cultural landscape; 6 = Highly maintained; 7 = Other managed cultural landscapes.

Table 20 (continued). List of exotic plant species managed by the natural resources staff at STRI (STRI, 2009).

No	Scientific name	Common name	Location *	Zone †	Methods
12	*Eragrostis curvula*	Weeping lovegrass	FR, RB	5	Foliar Spray is not effective as Mech. Removal, Grubbing, Foliar Spray
13	*Euonymus alatus*	Winged burning bush	NP, MF	1	Basal Bark Spray, Cut & Stump Spray, Grubbing, Hand Pulling
14	*Euonymus fortunei*	Climbing euonymus Winter creeper	NP, MF, FR, RB	1, 5, 6, 7	Foliar Spray, Cut Stump, Burning, Foliar Spray
15	*Festuca arundinacea*	Tall fescue	NP, MF, FR, RB	1, 2, 4, 5, 6, 7	Mowing, Grubbing, Hand Pulling
16	*Hedera helix*	English ivy	NP, MF, FR, RB	1, 5, 7	Mulching, Foliar Spray, Basal Bark, Cut & Stump Treat, Hand Cutting, Foliar Spray
17	*Lespedeza cuneata*	Lespedeza	NP, MF, FR, RB	All zones	Grubbing, Hand Pulling
18	*Ligustrum sinense*	Chinese privet	NP, MF, FR, RB	All zones	Foliar Spray, Cut Stump, Grubbing, Hand Pulling
19	*Lonicera japonica*	Japanese - honeysuckle	NP, MF, FR, RB	All zones	Foliar Spray, Cut Stump, Grubbing, Hand Cutting
20	*Lonicera maackii*	Bush honeysuckle	NP, MF, FR, RB	All zones	Hand Pulling, Foliar Spray, Basal Bark Spray, Cut & Stump Spray, Grubbing, Hand Cutting

* Locations: NP= Nashville Pike; MF = McFadden Farm; FR = Fortress Rosecrans; RB = Redoubt Brannan.

† Zones: 1 = Natural (forest, cedar glades and associated plants communities, wetland); 2 = Native grass field (including fields established for native seed production); 2 = Crop field; 4 = Non-native grass field (to be converted to native grass); 5 = Earthwork and surrounding cultural landscape; 6 = Highly maintained; 7 = Other managed cultural landscapes.

Table 20 (continued). List of exotic plant species managed by the natural resources staff at STRI (STRI, 2009).

No	Scientific name	Common name	Location *	Zone †	Methods
21	*Lonicera standishiii*	Standish honeysuckle	NP, MF	1	Hand Pulling, Hand Cutting, Foliar Spray, Cut & Stump Treat, Grubbing
22	*Mahonia bealei*	Beale's barberry	NP, MF	1	Foliar Spray, Cut & Stump Treat, Hand Cutting
23	*Melilotus alba*	White sweet clover	NP, MF, RB	1, 4, 5	Mowing, Burning, Hand Cutting, Hand Pulling
24	*Melilotus officinalis*	Yellow sweet clover	NP, MF, RB	1, 4, 5	Mowing, Burning, Hand Cutting, Hand Pulling
25	*Microstegium vimineum*	Microstegium	NP, MF, FR, RB	1, 2, 4, 5, 6, 7	Foliar Spray, Grubbing, Hand Pulling
26	*Nandina domestica*	Sacred bamboo	NP, MF, FR	1, 5	Foliar Spray, Cut & Stump Treat, Hand Pulling, Basal Bark Spray
27	*Paulownia tomentosa*	Princess tree	RB	5	Girdle & Spray, Cut & Stump Treat, Hand Pulling, Mowing
28	*Perilla frutescens*	Beefsteak plant or perilla mint	NP, MF, FR, RB	All zones	Foliar Spray, Hand Cutting, Cut & Stump Treat
29	*Pueraria montana*	Kudzu	RB	5	Root Crown, Grubbing, Hand Pulling
30	*Pyrus calleryana*	bradford pear or callery pear	NP, MF, FR, RB	Alll zones	Burning, Foliar Spray, Basal Bark Spray, Girdle & Spray, Cut & Stump treat, Hand Pulling, Mowing

* Locations: NP= Nashville Pike; MF = McFadden Farm; FR = Fortress Rosecrans; RB = Redoubt Brannan.

† Zones: 1 = Natural (forest, cedar glades and associated plants communities, wetland); 2 = Native grass field (including fields established for native seed production); 2 = Crop field; 4 = Non-native grass field (to be converted to native grass); 5 = Earthwork and surrounding cultural landscape; 6 = Highly maintained; 7 = Other managed cultural landscapes.

Table 20 (continued). List of exotic plant species managed by the natural resources staff at STRI (STRI, 2009).

No	Scientific name	Common name	Location *	Zone †	Methods
31	*Rosa multiflora*	Multiflora rose	NP, MF, FR, RB	1, 2, 4, 5, 7	Burning, Foliar Spray, Cut & Stump Treat, Hand Cutting, Hand Pulling
32	*Setaria viridis*	Foxtail	NP, MF, FR, RB	2, 3, 4, 5, 7	Mowing, Burning, Foliar Spray, Hand Cutting, Hand Pulling
33	*Sorghum halapense*	Johnson grass	NP, MF, FR, RB	2, 3, 4, 5, 6, 7	Grubbing, Hand Pulling
34	*Tragopogon dubius*	Fistulus goatsbeard	NP, MF, FR, RB	2, 4, 5, 7	Tilling, Foliar Spray, Grubbing, Hand Cutting
35	*Verbascum thapsus*	Common mullein	NP, MF, FR, RB	1, 2, 4, 5, 7	Hand Pulling, Mowing, Foliar Spray, Grubbing, Hand Cutting
36	*Verbascum blattaria*	Moth mullein	NP, MF, FR, RB	1, 2, 4, 5, 7	Hand Pulling, Mowing, Foliar Spray, Grubbing, Hand Pulling
37	*Vinca minor*	Common periwinkle	NP, MF, FR	1, 2, 4, 5	Mowing, Foliar Spray, Cut & Stump Treat, Grubbing, Hand Pulling
38	*Vinca major*	Bigleaf periwinkle	NP, MF, FR	1, 2, 4, 5	Mowing, Foliar Spray, Cut & Stump Treat

* Locations: NP= Nashville Pike; MF = McFadden Farm; FR = Fortress Rosecrans; RB = Redoubt Brannan.

† Zones: 1 = Natural (forest, cedar glades and associated plants communities, wetland); 2 = Native grass field (including fields established for native seed production); 2 = Crop field; 4 = Non-native grass field (to be converted to native grass); 5 = Earthwork and surrounding cultural landscape; 6 = Highly maintained; 7 = Other managed cultural landscapes.

Table 24. The condition of STRI invasive plant species.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Invasive Plants	Invasive (Exotic) Plant Species Threat		The condition of STRI invasive/exotic plants warrants significant concern. Invasive plants occur in relatively high abundance at STRI, except in some areas where they have been controlled by intensive management. They are a high threat to native biodiversity. Continued management will probably always be needed to keep them under control; complete eradication is not possible given the surrounding urbanized areas where these exotics are prevalent and management is usually not done. A trend cannot be established at this time, since only baseline studies have been conducted. Confidence in our assessment was high due to extensive, scientifically sound data maintained over many years.

4.5.2. *Wetland Communities*

Resource Knowledge

A wetland is an area of land that is saturated with water, either permanently or seasonally. It is a highly productive community and provides habitat and food resources for a wide range of species. Based on the National Wetland Inventory (NWI) map for the Murfreesboro quadrangle, four wetlands were present at STRI. However, this system for detecting wetlands has limitations. Roberts and Morgan (2006) conducted an inventory to collect baseline information on wetlands at STRI during summer 2004. Based on the Wetland Delineation Manual by U.S. Army Corps of Engineers (1987), Roberts and Morgan (2006) identified and characterized 15 wetlands in the park, totaling 1.70 acres with the largest being ~0.77 acres and the smallest 0.002 acres (Figure 21) using two wetland classification systems: Hydrogeomorphic Classification for Wetlands (HGM) (Brinson, 1993) and Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979). Based on HGM classification, Roberts and Morgan (2006) identified nine depression, four slope, and two riverine wetlands. Using the Cowardin system, they recognized seven PFO wetlands subclasses, seven PEM, and one POW (Table 22). Roberts and Morgan (2006) reported that wetlands at STRI are in good condition and could be used in model development projects. Twenty eight dominant plant species in the wetlands at STRI were identified (Table 23) and their indicator status determined from Reed (1988). Common species included sugarberry (*Celtis laevigata*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), fox sedge (*Carex vulpinoidea*) and cutgrass (*Leersia virginica*). In addition, Roberts and Morgan (2006) identified two plant species not previously documented at STRI, lizard tail (*Saururus cernuus*) and duckweed (*Lemna* sp.) found in wetlands adjacent to Stones River. Furthermore, several wetlands in the park that hold water for relatively long periods are used as breeding habitat by amphibians (Miller et al., 2005).

Threats and Stressors

The NWI listed four wetlands and Roberts and Morgan (2006) discovered 15 wetlands at STRI. The difference between these reports is due to the landscape, size of wetlands, and source of hydrology.

The average wetland size at STRI is smaller than 1 acre, which could be missed by remote sensed imagery used in NWI mapping. Although small in size, the wetlands at STRI are an important component of the plant and animal communities. For example, most of the wetland communities at STRI support unique woody and herbaceous vegetation and are used as breeding habitat by amphibians. However, the survey was too short in duration to document the use of wetlands by other animals. The addition of two herbaceous species not previously recorded in the park might indicate that a longer survey and future research could greatly enhance understanding of wetlands in maintaining plant and animal communities at STRI. Moreover, wetlands at STRI occur as unique patches within a mostly upland landscape. Therefore, while wetlands at STRI have not been as severely impacted as many wetlands on private lands, managing the landscape through the minimization of drainage, ditching, and landscape alterations would impede wetlands loss.

Condition and Trend

Condition Status

The condition of wetlands at STRI warrants moderate concern (Table 24). Although Roberts and Morgan (2006) reported that wetlands at STRI are in good condition, it is likely that all wetlands at STRI have been impacted by land-use history within the park and the surrounding areas. In particular, changes in hydrology of the surrounding urbanized areas potentially could have adverse effects on STRI wetlands. On the other hand, STRI contains 15 wetlands, higher than the four wetlands identified on the NWI map probably due to their small size, which are relatively undisturbed.

Trend in Condition

No trend was assigned to the wetland communities, since a single baseline study is insufficient to establish a trend (Table 24).

Confidence in Assessment

The confidence used to make the assessment was medium (Table 24). Data were collected using a variety of scientifically-sound methods, and were collected throughout the park covering all habitats. Location of each wetland was determined by GPS units. The study was conducted during the summer of 2004. The researchers conducting the study had extensive experience identifying and sampling wetlands of the region. Although the intensive effort to identify and map wetlands was successful, the condition of and potential threats (both within and outside the park) to each wetland were not part of the study.

Table 25. Classes and subsclasses of wetlands [based on Cowardin et al.'s (1979) classification] at STRI (Roberts and Morgan, 2006). Number of wetlands is indicated before each class or subclass acronym.

Class	Subclass	Characters
7 - PFO	4 - PFO1A	Palustrine forested, deciduous, temporarily flooded
	2 - PFO1C	Palustrine forested, deciduous, seasonally flooded
	1 - PFO1E	Palustrine forested, deciduous, seasonally flooded/saturated
7 – PEM	6 - PEM1A	Palustrine emergent, persistent vegetation, temporarily floode
	1 - PEM1C + PSS1C	Mix between Palustrine emergent, scrub-shrub broad-leaved deciduous, seasonally flooded and Palustrine scrub-shrub broad-leaved deciduous, seasonally flooded.
1 – PSS	1 - PSS1C	Palustrine open water, palustrine scrub-shrub broad-leaved deciduous, seasonally flooded.

Table 26. List of wetland plants and indicator status at STRI (Roberts and Morgan, 2006).

Scientific name	Common name	Indicator status *
Acer rubrum	Red maple	FAC
Acer saccharinum	Silver maple	FACW
Boehmeria cylindrica	False nettle	FACW
Campsis radicans	Trumpet creeper	FAC
Carex sp.	Unknown	Unknown
Carex vulpinoidea	Fox sedge	FACW
Celtis laevigata	Sugarberry	FACW
Cyperus strigosis	False nut sedge	FACW
Diodea teres	Buttonweed	FAC
Eleocharis obtusa	Spike grass	OBL
Festuca arundinacea	Fescue	FAC
Fraxinus pennsylvanica	Green ash	FACW
Hibiscus moscheutos	Rose mallow	FACW
Iva annua	Rough marsh-elder	FAC
Juncus effusus	Soft rush	FACW
Justicia americana	Water willow	OBL
Leersia virginica	White grass	FACW
Lemna sp.	Duckweed	OBL

Table 23 (continued). List of wetland plants and indicator status at STRI (Roberts and Morgan, 2006).

Scientific name	Common name	Indicator status *
Ligustrum vulgare	Common privet	FAC
Lonicera japonica	Japanese honeysuckle	FAC
Toxicodendron radicans	Poison ivy	FAC
Typha latifolia	Cattail	OBL
Ulmus americana	American elm	FACW
Ulmus rubra	Slippery elm	FAC

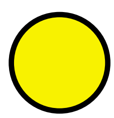
* Wetland indicator definitions according to Reed (1988):

OBL: Obligate wetland; occur almost always (estimated probability >99%) in wetlands under natural conditions.

FACW: Facultative wetland; usually occur in wetlands (estimated probability 67-99%), but occasionally found in non-wetlands.

FAC: Facultative; equally likely to occur in wetlands or non-wetlands.

Table 27. The condition of STRI wetland communities.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Wetland Community	Quality of Wetland Areas		The condition of the wetlands at STRI warrants moderate concern, considering that all of the wetlands in the park have been impacted by land-use history. In particular, changes in hydrology from the surrounding urbanized area could adversely affect STRI wetlands. No trend was assigned due to the lack of data beyond the baseline study. The confidence in the assessment was medium. Although all wetlands have been identified and mapped in STRI, more information is needed on the condition and threats to them.

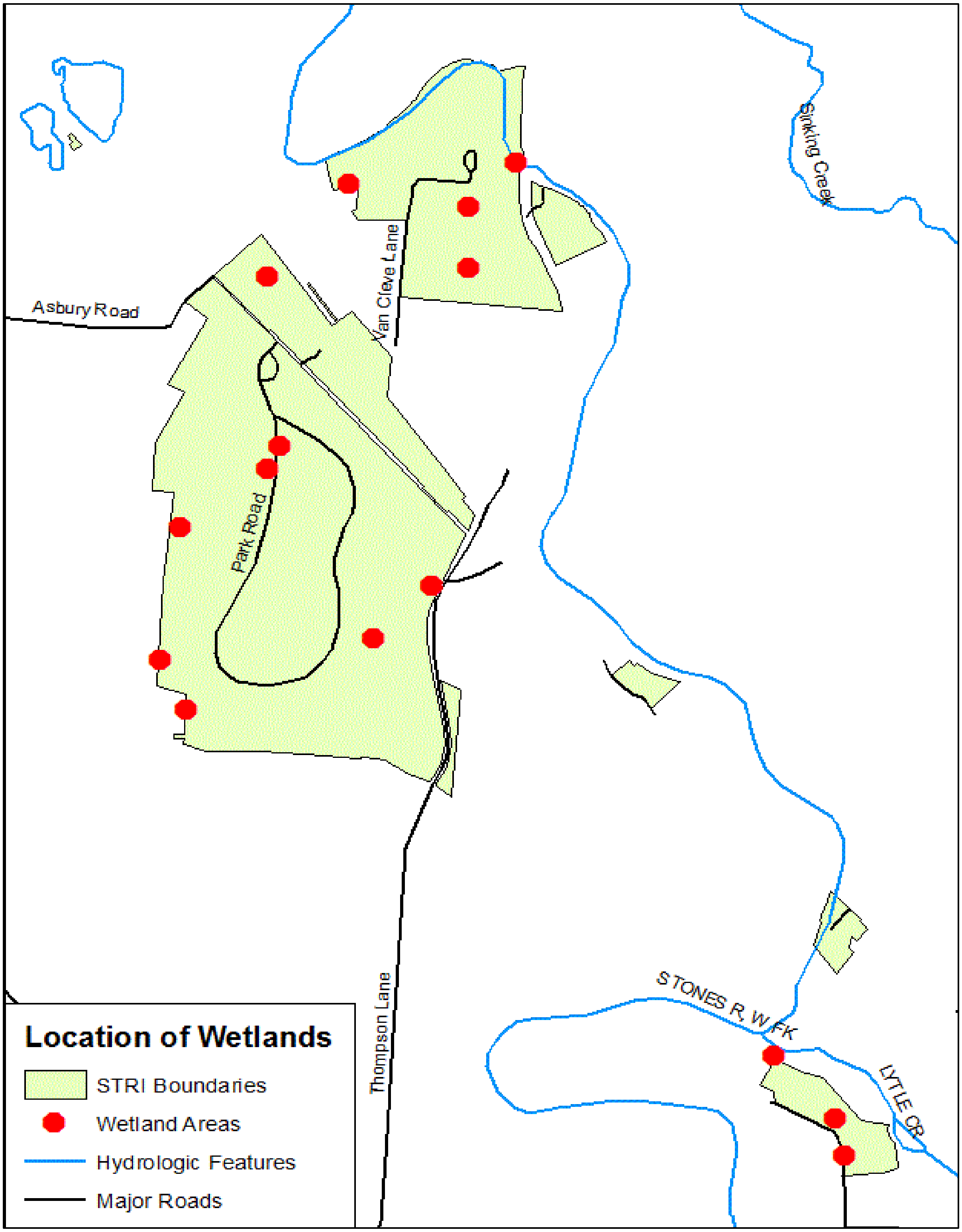


Figure 16. Location of wetlands at STRI. Modified from Roberts and Morgan 2006 (Figure 2).

4.5.3. ***Freshwater Aquatic Insects***

Relevance and Context

Freshwater river system quality is assessed through not only physiochemical analysis but also biological measures which can provide a more comprehensive view of the health of the river (USEPA, 1996). Biological indicators in lotic systems can be measured at the community level ranging from upper trophic levels composed of fish to lower levels which include algae and macroinvertebrates (Kenney et al., 2009). Since macroinvertebrates tend to be more localized than fish, their environmental sensitivity due to multiple life stages and ease with which they can be sampled makes these organisms a suitable indicator of water quality (Barbour et al., 1999). STRI borders a section of the West Fork of the Stones River (WFSR) at McFadden's Ford (location of Artillery Monument) and a section of Lytle Creek (LC) adjacent to Fortress Rosecrans, which is why aquatic insects are included in this report.

Resource Knowledge

There has been one documented aquatic insect sampling event at STRI by Geraghty and Parker 29 and 30 June 2006 at the WFSR at McFadden's Ford and LC at Fortress Rosecrans. Water was characterized as slightly turbid with the macroinvertebrate habitat composed of 2% snag, 20% undercut bank, and 20% detritus. Collection methods included hand collection, sweeping, and a light trap. Additional information included GPS locational data, methods of preserving voucher specimens, and weather conditions. A second sampling date 1 July 2005 conducted by Robinson and Parker was noted on an excel spreadsheet provided to STRI.

The STRI aquatic insects collected from samples taken 1 July 2005 and 29-30 June 2006, total more than 7,400 individuals from several sites, with 50 distinct taxa identified to the species level. One reported species of stonefly, *Neoperla coosa* (Smith and Stark, 1998), is state and federally listed rank 2 as a benthic species with an unclear distribution (Withers, 2009). Robinson (2012) compiled samples of aquatic insect's collected from17 national parks from 2005 to 2011 and noted that areas with high values of aquatic species richness are not more populated with rare species. According to Robinson, this would be expected because some of the parks sampled were historical or battlegrounds and not noted for water resources. This is the situation for STRI which lacks a significant portion of river, in comparison to other parks such as Great Smoky Mountains National Park with numerous, high quality rivers. Due to insufficient Ephemeroptera, Plecoptera, and Tricoptera (EPT) data, which represents common benthic invertebrate orders that determine water quality, STRI was omitted from several analyses in the Robinson dissertation.

Threats and Stressors

Threats to aquatic insects can be triggered by alterations to naturally occurring stream debris or the riparian zone. Other threats and stressors which can negatively impact aquatic insect populations include changes in water parameters such as temperature, pH, and oxygen, or increases in turbidity or nutrients (Wallace et al., 1996). A CUPN water quality report by Meiman (2005) generated from two years of water quality data indicated STRI had the most compromised water quality of any park in the network due to the high level of urbanization surrounding the Stones River system. The USEPA 2010 Water Body Report lists the WFSR and LC as impaired for fish and aquatic life due to excessive sedimentation and siltation as a consequence of an alteration in streamside coverage or littoral zone vegetation. Lytle Creek is also listed as impaired for recreation due to a high Total Maximum Daily Load (TMDL) for pathogens of *E. coli* due to cattle grazing near the river (USEPA Water Body Report, 2010). The Tennessee Department of Environment and Conservation 2012 303(D) List for the Stones River Watershed identifies WFSR as a category 5 (impaired for one or more uses) and LC as a category 4a (impaired but with USEPA approved siltation/habitat alteration and pathogen TMDLs that address the known pollutants).

<u>Condition and Trend</u>

Condition Status

The condition of the aquatic insects at STRI warrants moderate concern (Table 25). The patterns of occurrence for the 22 aquatic insect species sampled in segments of WFSR and LC ranked G5 in categories of imperilment in national parks (Robinson, 2012). There are some inconsistencies in data in that 50 species are reported in *CUPN Aquatic Insect Species from 18 National Parks* report, and one was listed as S2 and G2; however, this Plecopteran species was not reported in Robinson's study (2012). Given the discrepancy in the data, we have opted to use Robinson's EPT richness value of 22 for STRI. Using EPT richness value ranges as determined by Parker (2003), STRI ranks fair/good (range 19-27). Following Parker's recommendation to report fair/good narratives as fair, EPT species richness is reported as fair.

Trend in Condition

Data analyses for aquatic insects sampled in 17 national parks were reported by Robinson (2012). Due to the absence of Plecoptera, STRI was omitted from pairwise distance analysis for occurrence or absence of species in parks and states. Therefore, a trend cannot be reported (Table 25).

Confidence in Assessment

The confidence used to make the assessment was medium (Table 25). The aquatic insect sampling at STRI was conducted by aquatic ecology professionals with aquatic insect life history expertise. Sampling occurred at two separate sites, WFSR and LC, which represent river sections that border STRI. According to data quality parameters established in the Big South Fork National River and Recreation Area (Worsham et al., 2013), it was determined by the number of sites sampled within an area, with two or more sites sampled as good and one site sampled as fair. STRI was sampled twice which rates as good spatial data quality. An Event Record and excel spreadsheet provided to STRI document and catalog insects collected by location, taxa and number of individuals. Based on available records, sampling occurred 1 July 2005 and 29-30 June 2006.

Table 28. The condition of STRI aquatic insect assemblages.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Source for Resource Condition
Aquatic Insect Assemblages	Freshwater Aquatic Insect Condition		Robinson (2012) reported an EPT richness value of 22 for STRI. Based on Parker (2003) this value falls near the lower limit of a fair/good assessment (i.e., 19-27). As a result a condition of moderate concern was assigned to STRI. No trend data is available for the aquatic insect population at this time. The confidence in the assessment was medium. Although sampling was conducted by aquatic ecology professionals and met sampling criteria established as good (BISO NRCA, 2013), the data is older than five years.

4.5.4. *Bird Assemblages*

Relevance and Context

Being relatively easy to monitor, birds are valuable indicators of ecosystem quality and function (Furness and Greenwood, 1993). Grassland, aridland, and eastern-forest-obligate bird species declined, whereas urban-suburban species increased over the interval 1968–2008 (Sauer and Link, 2011). STRI provides diverse habitat – from forests and cedar glades to grasslands – for breeding as well as migratory birds, even though urban and agricultural lands surround it. Moreover, several habitats at STRI (e.g., cedar glades and grasslands) are important for priority birds in the Interior Low Plateaus Physiographic Area (Ford et al., 2000).

Resource Knowledge

The avifauna at STRI was inventoried from 2003 to 2005 (Stedman and Stedman, 2006). Several techniques were used during the inventory at STRI: point counts, migration walks, raptor surveys, night surveys, and general (less regimented) visits to all types of habitats during the course of a day to keep track of all species sighted. A checklist was compiled that indicates the status and abundance of species for each season of the year. The authors compared their list to a list of species recorded in the Nashville area, including Rutherford County and eight other counties around Nashville (Parmer, 1985). The Nashville list consists of about 310 species recorded over 90 years. Removing species from Parmer's list that are associated with habitats not found at STRI (i.e., large lakes and wetland habitat), then the list of potential species can be pared down to 210 species.

The STRI avifauna consisted of 152 species, of which 21 (14%) were possible breeders, 25 (16%) were probable breeders, and 34 (22%) were confirmed breeders (Stedman and Stedman, 2006). The largest units of STRI tended to support the greatest number of species. Species richness was determined to be "moderately good." Species that use grassland ([e.g., Grasshopper Sparrow (*Ammodramus savannarum*)] and shrub-scrub habitats (e.g., several breeding and overwintering songbirds) were well represented, and may further increase with the conversion of all additional agricultural fields to native grasslands. The total number of species represented about 72% of the 210 species that might be expected to occur at STRI. None of the species reported from the park are listed as threatened or endangered by the United States Fish and Wildlife Service. At the state level, Lark

Sparrow (*Chondestes grammacus*) is listed as threatened and Bewick's Wren (*Thryomanes bewickii*) as endangered by Tennessee Wildlife Resources Agency; both species are possible breeders at STRI. Several species are listed as special concern on the Tennessee Natural Heritage Program list (Table 26). In addition, Bewick's Wren, Prairie Warbler (Dendroica discolor), another possible breeder at STRI, and Dickcissel (*Spiza americana*), a summer resident at STRI, are listed as priority birds by Partners in Flight (Ford et al., 2000); four transient birds at STRI also are listed. Four species observed at STRI are non-native: Rock Pigeon (*Columba livia*), Eurasian Collared Dove (*Streptopelia decaocto*), European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*).

Table 29. Rare birds observed at STRI. Status at STRI (Stedman and Stedman, 2006): TR = transient (migrant), UN = uncertain status, VR = visitor (irregularly present), WR = winter resident. State status on TWRA list or on TNHP list (Withers, 2009): E = endangered, SC= special concern, T = threatened, R = rare (listed by TNHP without designation and considered rare by the DNA, NatureServe, or other agencies).

Scientific name	Common name	Status at STRI	State status
Haliaeetus leucocephalus	Bald Eagle	VR	SC
Circus cyaneus	Northern Harrier	TR	SC
Accipiter striatus	Sharp-shinned Hawk	TR	SC
Sphyrapicus varius	Yellow-bellied Sapsucker	WR	SC
Lanius ludovicianus	Loggerhead Shrike	VR	SC
Thryomanes bewickii	Bewick's Wren	UN (possible breeder)	E
Dendroica cerulea	Cerulean Warbler	TR	SC
Chondestes grammacus	Lark Sparrow	UN (possible breeder)	T
Passerculus sandwichensis	Savannah Sparrow	WR	R

Threats and Stressors

North American birds face a number of threats, such as land conversion, development, and exotic species (North American Bird Conservation Initiative, 2009). There are a number of possible threats to birds at STRI listed by Stedman and Stedman (2006). The habitats in STRI are highly fragmented and have been highly invaded by exotic organisms, particularly plants (STRI, 2009). STRI also is located within a largely urban environment, making the park an isolated block of habitat. Birds in fragmented forests (Faaborg, 1995) and in highly invaded forests (Borgmann and Rodewald, 2004) have reduced nesting success due to high levels of nest parasitism and nest predation. Moreover, feral and free-roaming cats (which have been recorded at STRI) and dogs can pose a threat to nesting birds (Loss et al., 2013).

The difference between the expected list (based on the Nashville area and surrounding counties) and documented list of birds at STRI is due to the general lack of certain habitats. Additionally some species, such as Barred Owls and many warblers, were present in smaller numbers than expected as breeders or as transients due to the isolated nature and relatively small size of the park. During the survey, no boreal irruptives and no "fall-out" events occurred (Stedman and Stedman, 2006). Below are a few other considerations mentioned by Stedman and Stedman (2006) that may impact the abundance of birds at STRI:

- Barred Owls (*Strix varia*), Pileated Woodpeckers (*Dryocopus pileatus*), and breeding warblers were detected at lesser density than initially expected but suitable habitat was limited to absent for them. It is likely additional survey efforts could detect more species within park boundaries – particularly rare or incidental migrants and possibly boreal species – during particularly severe winter conditions.
- Timing for management of grasslands (e.g., controlled burns) is critical so as not to overlap with breeding season of grassland birds.
- Maintaining shrub-scrub habitat is critical for several songbird species, whose populations are declining.
- Removing dead snags or wood debris piles may impact cavity-nesting birds and impact Bewick's Wrens.

Condition and Trend

Condition Status
The condition of the avifauna at STRI (Table 27). Although STRI contains 152 species of birds, only 22% of them were confirmed breeders and four of them are non-native (Stedman and Stedman, 2006). The species richness at STRI was judged to be "moderately good" given the size and land-use history of STRI and the surrounding environs. The total number of species represented about 72% of the 210 species that might be expected to occur at STRI. The birds that have not been seen in the park probably do not occur due to limited suitable habitat (e.g., lack of large blocks of forest). One species observed at STRI is listed as endangered in TN and another species as threatened; both are possible breeders. Confirmation of breeding for these rare birds at STRI is needed and then management (mostly to maintain grassland habitat) should be implemented.

Trend in Condition
Although point counts were done every year between 2003 and 2005 (Stedman and Stedman, 2006), this timeframe is too short for assessing trend (Table 27).

Confidence in Assessment
The confidence used to make the assessment was medium (Table 27). Data were collected using a variety of scientifically-sound methods, and were collected throughout the park covering all habitats. Locations (GPS information as well as tagged tree information and directions) are provided for point-count plots. The study was conducted from 2003-2005. The researchers conducting the study had extensive experience identifying and studying birds of the region. However, additional information is vitally needed on confirming breeding status of species and on the population status of species, particularly those that are rare or of special concern.

Table 30. The condition of STRI avifauna assemblages.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Bird Assemblages	Avifauna Assemblage Condition		The condition of bird assemblages at STRI warrants moderate concern due the relatively low number of confirmed breeders, presence of non-native species, and lack of certain species due to land-use history and suitable habitat. Moreover, confirmation of breeding for rare species is needed along with habitat management. No trend was assigned at this time. Point count data is available for the years 2003-2005, but has yet to be analyzed. Confidence in our assessment was medium. Although bird surveys have been conducted over a few years, there is a lack of detailed information on breeding status and on the population status of rare or special concern species.

4.5.5. *Cedar Glades*

Resource Knowledge

The Nashville Pike unit of STRI consists of forests interspersed with many cedar glades (Shea et al., 2008). About 40 cedar glades are located in a circular pattern around a slightly elevated hill in the park and are connected by a network of trails. Of the acreage at STRI (654 acres), cedar glades and barrens vegetation complex (including Nashville Basin Limestone Glade, Nashville Basin Limestone Glade Margin Shrubland, and Eastern Redcedar Successional Forest) occupy approximately 10% (Jordan and Madden, 2010).

For the cedar glades at STRI, Hogan et al. (1995) began photo point monitoring, recorded population counts of rare species, inventoried vascular plants, and established baseline transects for vegetation surveys. The photos have been retaken (probably twice) and some of the glades have been re-sampled since 1995 (T. Hogan, pers. comm.). As part of a vascular flora survey at STRI, Hogan and Weber (1999) paid particular attention to cedar glades and their rare plants. Shea et al. (2008) examined the relationship between environmental parameters and species richness on glades and the influence of native species richness on exotic invasion. Soil biochemical processes and the ecology of soil microbial communities in limestone cedar glades at STRI were examined by Cartwright (2014).

Mention of cedar glades is made in personal letters by soldiers and in official correspondence (Hogan et al., 1995; Conrad, 2011). Before and after the battle, until the establishment of the park (late 1920s–early 1930s), the land was used for farming, as wood lots, grazing lands, or home sites. Aerial and ground photographs during the 1920s and 1930s show large cleared tracts. Fence rows, unpaved roads and glades are apparent. Since the 1930s, much of the land surrounding the glades has become densely forested but signs of disturbances still remain (e.g., a network of trails).

A total of 232 taxa were found by Shea et al. (2008) on the cedar glades at STRI with broomsedge bluestem (*Andropogon virginicus*), prairie tea (*Croton monanthogynus*), eastern redcedar (*Juniperus virginiana*), wiry panicgrass (*Panicum flexile*), and winged elm (*Ulmus alata*) present on all glades. The exotics Chinese privet (*Ligustrum sinense*), oxeye daisy (*Leucanthemum vulgare*), and common dandelion (*Taraxacum officinale*) occurred on the majority of glades. Gattinger's lobelia (*Lobelia appendiculata* var. *gattingeri*), cedar gladecress (*Leavenworthia stylosa*), and Nashville breadroot (*Pediomelum subacaule*) were the most frequent endemics. Richness of native, exotic, and endemic species increased with increasing area and perimeter and decreased with increasing isolation of the glade. Disturbed glades contained a higher number of exotic and native species than nondisturbed ones, but they were larger. Invasion of exotic species was unrelated to native species richness when glade size was statistically controlled. Most endemics occurred over a broad range of glade sizes emphasizing the point that glades of all sizes are worthy of protection.

Cartwright (2014) found that several soil properties (e.g., soil depth, organic matter levels, pH, and particle size distribution) were spatially correlated to ecological structures and functions such as vegetation patterns, soil respiration, the density of culturable heterotrophic microbes in soil and metabolic diversity of soil microbial community profiles. Zones within the cedar glades (characterized by relatively shallow soil, alkaline pH, low levels of organic matter and high levels of silt) tended to have depressed rates of soil respiration and reduced densities and metabolic diversity of culturable heterotrophic soil microbes.

The cedar glades at STRI contain populations of several state listed rare plant species (as special concern), such as Tennessee milk-vetch (*Astragalus tennesseensis*), limestone fame-flower (*Phemeranthus calcaricus*), and evolvulus (*Evolvulus nuttalianus*) (Crabtree, 2014). One federally listed endangered plant, Pyne's ground-plum (*Astragalus bibulatus*), and one previously listed plant, Tennessee coneflower (*Echinacea tennesseensis*), have been introduced into the park. Pyne's ground-plum is listed as endangered in Tennessee, and the Tennessee coneflower as threatened (Crabtree, 2014). The Tennessee coneflower population is now thriving in Tennessee, and the species was delisted from the endangered species list in 2011 (Bowen, 2011). Establishment and persistence of Pyne's ground-plum, however, has been more problematic (Albrecht and McCue, 2010).

Threats and Stressors

STRI has taken a number of steps to protect the cedar glades (e.g., reducing foot traffic, re-routing the tour road) and their associated plants (e.g., controlling exotic species). Although shallow soil areas on cedar glades are relatively stable over the long term, deeper soil areas supporting grassland- or barren-like habitats that are usually associated with cedar glades need to be monitored closely for woody plant encroachment. Management of woody plants (e.g., by burning or cutting) may need to be considered. Other environmental impacts (e.g., climate change) will also need to be assessed in the future.

Condition and Trend

Condition Status

The condition of STRI cedar glades warrants moderate concern (Table 28). STRI has devoted much time and effort to protect the cedar glades (e.g., reducing foot traffic, re-routing the tour road) and their associated plants (e.g., by controlling exotic species) and to monitor their long-term viability. However, the impact of reduced traffic and removal of exotic species have not been assessed. Cedar glades are relatively stable, but encroachment of woody plants (e.g., along edges of glades and in areas with relatively deep soil) is a potential concern for glade closure especially so for relatively small glades at STRI. Additional work is needed at STRI to better understand impacts from other environmental pressures (e.g., climate change and hydrology) on glades.

Trend in Condition
No trend was assigned to the cedar glades because single baseline studies or inventories are insufficient to establish a trend (Table 28). Although photos of the glades have been retaken and some of the glades re-sampled since 1995, to the best of our knowledge this data has not been analyzed.

Confidence in Assessment
The confidence used to make the assessment was medium (Table 28). Data were collected using a variety of scientifically-sound methods. Permanent transects and photo points have been established and determined by GPS units. Although work has been conducted on the cedar glades at STRI more recently, the original vegetation survey and photo point monitoring was conducted in 1995. To the best of our knowledge, no trend analyses have been conducted to compare the original data with the re-sampled data. This is a major drawback in our confidence in understanding the long-term stability of glades at STRI. The researchers conducting the study were very familiar with cedar glades and their associated plants.

Table 31. The condition of STRI cedar glades.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Cedar Glades	Cedar Glade Health		The condition of STRI cedar glades warrants moderate concern. Although much effort has been devoted by STRI in preserving and in reducing impacts (e.g., foot traffic) to glades in the park, little is known about the long-term viability/stability of them. No trend was assigned at this time, as only a baseline study has been conducted. Photographs of the glades and resampling data since 1995 have yet to be analyzed. Mostly due to the lack of trend analyses, our confidence in the assessment was medium.

4.5.6. *Fish Assemblages*

Relevance and Context

The aquatic habitats of Tennessee are rich in ichthyofauna, with nearly 300 native species reported and five species unique to the Nashville Basin (Etnier and Starnes, 1993). STRI boundaries include sections of the West Fork of the Stones River (WFSR) at Redoubt Brannan and McFadden's Ford and a small section of Lytle Creek (LC) adjacent to Fortress Rosecrans. Although STRI only includes segments of WFSR and LC, these riverine sections exhibit diverse habitats representative of the Stones River ranging from deep limestone bedrock runs to gravel/pebble pools to shallow riffle (Mullen, 2006).

Resource Knowledge

The only documented STRI survey of ichthyofauna was conducted between October 2004 and August 2006 at riverine sites of the WFSR at McFadden's Ford at the Artillery Monument, the east bank of WFSR at Redoubt Brannan, LC at Fortress Rosecrans, and two ponds (Mullen, 2006). Each site was sampled once per season using appropriate methods for aquatic habitat type such as 10 m bag seine, hand held dip nets, hoop nets, and a backpack electrofisher. Additionally, water quality (temperature, pH, dissolved oxygen, conductivity), aquatic plants, and habitat type were characterized at each site. A digital voucher photograph was taken of each species captured. Prior to sampling, a potential fish list for STRI aquatic habitats was generated from 1997 Tennessee Wildlife records, Etnier and Starnes (1993) distribution list of fishes in Tennessee, an MTSU thesis (McKee, 1986) surveying fish communities of the Stones River System, and personal observation or communication with other scientists (Mullen, 2006).

The list of fishes potentially occurring in aquatic habitats in and around STRI consists of 10 orders, 14 families, and 60 species. Mullen (2006) reported seven orders, nine families, and 41 species which accounts for 73% of the potential list; species richness estimates indicate the survey identified 90% of STRI ichthyofauna. Mullen (2006) indicates that species not reported can be attributed to sampling times not coinciding with spawning cycles in larger mobile species that reside in large rivers or reservoirs or headwaters of clear streams. Other species not detected may be (1) present but not at any of the sampling sites on the sampling dates, (2) not present at all, or (3) present but not detected. A case in point is every sampling event for the Mullen survey added new species to the cumulative catch list for at least one of the sites. No federal or state-listed endangered or threatened species were captured although five species are reported to occur in the Stones River watershed (Withers, 2009).

Threats and Stressors

The Tennessee Department of Environment and Conservation (TDEC) identified nearly 30% of native Tennessee fish (93 species) as state and/or federally listed (Withers, 2009). Two years of water quality data indicate STRI has highly compromised water quality due to the proximity of Murfreesboro City, Rutherford County developments, and increased population growth in both of these areas (Meiman, 2005). As a consequence of alteration in the riparian zone such as the removal of vegetation or streamside cover, the USEPA 2010 Water Body Report lists the WFSR and LC as impaired for fish due to excessive sedimentation and siltation. The TDEC 2012 303(D) List for the Stones River Watershed identified WFSR as a category 5 (impaired for one or more uses) and LC as a category 4a (impaired but with USEPA approved siltation/habitat alteration and pathogen TMDLs that address the know pollutants). Management of the riparian zone upstream of WFSR is beyond the control of STRI but efforts to maintain the STRI sections of riparian habitat in conjunction with the city of Murfreesboro's Greenway system could reduce siltation in this section of the river.

Condition and Trend

Condition Status

The condition of the fish assemblage at riverine sites for STRI warrants moderate concern (Table 29). Forty-six species have been recorded at STRI, comprising 73% of the potential species known to occur in this system. The Index for Biotic Integrity for fish communities ranks McFadden's Ford and

Lytle Creek between fair and good and Redoubt Brannan as fair (Mullen, 2006). Although all six pollution intolerant species known to occur in the Stones River were captured (bigeye shiner, *Notropis boops*; spotted sucker, *Minytrema melanops*; large rockbass, *Ambloplites rupestris*; slender madtom, *Notorus exilis*; fantail darter, *Etheostoma flabellare*; speckled darter, *Etheostoma stigmaeum*), half of these were small benthic dwellers that need clean substrate for spawning and were few in number (Etnier and Starnes, 1993; Mullen, 2006). No state or federally listed species were documented in the Mullen study (2006); however STRI property comprises approximately 570 m of habitat out of 4,700 m from LC to WFSR at McFadden's Ford, which makes underestimates likely.

Trend in Condition
No trend was assigned to fish assemblages because only one study was conducted; there is insufficient data to establish a trend (Table 29).

Confidence in Assessment
The confidence used to make the assessment was medium (Table 29). The researcher conducting the study had professional expertise in ichthyology and experience sampling fishes in Middle Tennessee. Sampling was conducted seasonally in diverse aquatic habitats that border or occur at STRI using scientifically appropriate methods (Barbour et al., 1999). Geospatial data and catch lists by aquatic habitat location were maintained. The study was conducted from 2004 – 2006.

Table 32. The condition of STRI fish assemblages.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Fish Assemblages	Fish Population Quality		The quality of the fish assemblage at STRI warrants moderate concern. Although about a quarter of the fish species known to occur in riverine systems associated with STRI were recorded, some pollution intolerant species were few in number and excessive siltation is a major problem. Moreover, the Index for Biotic Integrity ranked STRI's riverine system mostly as fair. Studies are needed to assign a trend to the fish populations. The confidence in the assessment was moderate. Although an expert did sampling effort over a 2-year period, additional sampling over time would allow for increased confidence.

4.5.7. *Amphibian and Reptile Assemblages*

<u>Relevance and Context</u>
The southeastern United States contains the highest diversity of herpetofauna in North America, with approximately half of the total 450 US species occurring there (Gibbons and Buhlmann, 2001; Tuberville et al., 2005). Amphibians and reptiles are vital components of southeastern ecosystems, and serve as important indicators of environmental integrity (Gibbons et al., 2000). However, global declines in amphibians and reptiles have been noted and the multiple causes for these declines studied (Gibbons et al., 2000; Stuart et al., 2004). Thus, herpetofauna has increasingly become a focus of management concern and effort.

Resource Knowledge

Miller et al. (2005) conducted a comprehensive inventory of STRI herpetofauna from 15 April 2003 to 12 July 2004. Several collecting techniques were used during the inventory at STRI: coverboard arrays, drift-fencing and funnel box traps, drift-fencing-pitfall traps, aural surveys, visual encounter surveys, road surveys, minnow traps, and aquatic turtle trap surveys. In addition, measurements and sex, GPS locational data and habitat types, and voucher species were obtained from captured or observed animals. The authors compared their list to an expected list of the herpetofauna of Rutherford County (Conant and Collins, 1991; Redmond and Scott, 1996), which consists of 59 species including 12 frogs, 15 salamanders, seven lizards, 17 snakes, and eight turtles.

The STRI herpetofauna consisted of 29 species: seven species of frogs, four species of salamanders, four species of lizards, eight species of snakes, and six species of turtles. Fourteen species were considered common (Table 30). The composition of the herpetofauna varied among the four isolated units of STRI due to the size and habitat diversity of the units. The most abundant species in each order/suborder of herpetofauna found at STRI were the American bullfrog (*Rana catesbeiana*), northern zigzag salamander (*Plethodon dorsalis*), eastern fence lizard (*Sceloporus undulatus*), eastern racer (*Coluber constrictor*) snake, and red-eared slider (*Trachemys scripta elegans*) turtle. Turtles were the highest (75% of expected) represented taxon of herpetofauna followed by frogs (58%), lizards (57%), and snakes (47%), whereas salamanders (27%) were not well represented at STRI. The documented list of species at STRI was lower than the expected list of species that can be found in Rutherford County by 30 species. None of the species reported from the park are listed as rare, threatened, or endangered by the Tennessee Wildlife Resources Agency or by the United States Fish and Wildlife Service.

Threats and Stressors

The difference between the expected list (based on all species in Rutherford County) and documented list of species at STRI may be due to the lack (or scarcity) of particular habitats and/or historic land use practices at STRI, such as agriculture, that eliminated suitable habitats (Miller et al., 2005; see also Niemiller et al., 2011). Some of the species on the expected list have specific habitat requirements and/or limited distributions in the county that do not occur at STRI. Other factors that may contribute or limit the number of documented species at STRI include:

- The duration of the Miller et al. (2005) survey was too short to document all species at STRI.
- The length of time that ephemeral wetlands are flooded at STRI is not long enough to allow for egg and larval development of certain species.
- The urban and agricultural development of the surrounding environs has isolated STRI and may prevent recolonization of some species that may have once occurred at STRI and are relatively common in similar habitats in Rutherford County.

Habitat fragmentation (resulting in isolation of STRI) and direct historical land use practice at STRI are the most obvious reason that many species common in the region were not detected at STRI (Miller et al., 2005). Several other impacts (e.g., diseases, climate change) threaten the herpetofauna of southeastern United States (Gibbons et al., 2000) and possibly STRI.

Table 33. Most common herpetofauna species (≥2% of all observations) from all units at STRI (Table 1 from Miller et al., 2005). Inventory was conducted from April 2003 to July 2004. Percentages indicate number of times that a species was observed out of the total number of observations (n = 810).

Scientific name	Common name	% Observations
Rana catesbeiana	American bullfrog	28
Trachemys scripta	Red-eared slider	24
Sternotherus odoratus	Stinkpot	12
Rana sphenocephala	Southern leopard frog	4
Sceloporus undulates	Eastern fence lizard	4
Plethodon dorsalis	Northern zigzag salamander	3
Eumeces fasciatus	Common five-lined skink	2
Eumeces laticeps	Broad-headed skink	2
Coluber constrictor	Northern black racer	2
Lampropeltis getula	Eastern kingsnake	2
Regina septemvittata	Queen snake	2
Thamnophis sirtalis	Eastern gartersnake	2
Chelydra serpentine	Eastern snapping turtle	2
Terrepene carolina	Eastern box turtle	2

Condition and Trend

Condition Status

The condition of STRI herpetofauna warrants significant concern (Table 31). STRI contains 29 species of amphibians and reptiles, a richness consistent with expectations for a protected area of its size in Tennessee (Sundin et al., 2013). The low ratio (49%) of documented species at STRI to expected species in Rutherford County is explained mostly by the absence (or sparsity) of particular habitats at STRI. However, seven species that are conspicuous or relatively easy to locate at Flat Rock Cedar Glades and Barrens State Natural Area, located less than 12 km from STRI, are absent at STRI, probably due to land-use history at STRI and the environs.

Trend in Condition

No trend was assigned to the herpetofauna because a single baseline study is insufficient to establish a trend (Table 31).

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 throughout the park covering all habitats. Location of each amphibian or reptile captured or observed was determined using GPS units. The study was conducted from 2003-2004. The researchers conducting the study have expertise and extensive experience sampling the reptiles and amphibians of the region.

Table 34. The condition of STRI herpetofauna assemblages.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Herpetofauna Assemblages	Reptile/ Amphibian Species Abundance		The condition of STRI herpetofauna warrants significant concern. STRI contains 29 species of amphibians and reptiles. However, certain expected species were absent probably due to land-use history at STRI and the environs. No trend is established at this time without more than a baseline study. Although experts did sampling effort over a 1-year period, additional sampling over time would allow for increased confidence.

4.5.8. *Mammal Assemblages*

Relevance and Context

The distribution of species varies across geographical areas. Hence, the distribution of animals and plants vary on local, regional, and national scales (Meffe et al., 1997). Van Dyke (2003) mentioned that habitat reduction and/or modification almost always resulted in habitat fragmentation, which in the long run affects populations of organisms and may cause species to be lost. Mammals, as components of an ecosystem, play roles at multiple trophic levels. Therefore, successful management of natural resources is an important aspect of mammal populations.

Resource Knowledge

Kennedy and LaMountain (2007) completed a comprehensive inventory of mammalian biodiversity at STRI from summer 2004 to autumn 2006. They randomly established plots throughout STRI, and also sampled in areas not sufficiently represented in the random plots. In their inventory, they utilized Sherman live traps and pitfall traps for small mammals (other than bats), bait/camera stations, mist nets, scent stations, and spotlight surveys, and made incidental observations. Additionally, size, sex, GPS locational data, habitat association, abundance, and voucher species were obtained from captured or observed animals. Then they compared their list to the potential list of species occurring at STRI from the literature (Kellogg, 1939; Hall; 1981; Kennedy 1991; Choate et al., 1994) and from their discussions with personnel of STRI.

Altogether, the list of relatively high potential species occurring at STRI consisted of 27 species of mammals (Kennedy and LaMountain, 2007). Kennedy and LaMountain (2007) reported seven orders, 13 families and 25 species from STRI, 93% of the high potential list. They ranked species within families based on their abundances during the surveys. The documented species of mammals at STRI varies across habitat types with the most common and abundant small mammals on the site being white-footed mouse (*Peromyscus leucopus*) and gray squirrels (*Sciurus* carolinensis) (Table 32). In addition, Virginia opossum (*Didelphis viginiana*), eastern mole (*Scalopus aquaticus*), red bat (*Lasiurus borealis*), eastern cotton tail rabbits (*Sylvigalus floridanus*), wood chuck (*Marmota monax*), coyote (*Canis latrans*), and raccoons (*Procyon lotor*) were among the common mammals in the park. Northern short-tailed shrew (*Blarina brevicauda*), eastern pipistrelle (*Pipistrellus subflavus*), red fox (*Vulpes vulpes*), eastern harvest mouse (*Reithrdontomys humulis*), and deer mouse (*Peromyscus maniculatus*) were considered uncommon. The nine-banded armadillo (*Dasypus novemcinctus*) and beaver (*Castor canadensis*) were not reported from the documented list although they are known in the region and in urban habitats (Bolen and Robinson, 2003). No federal or state listed endangered or threatened species were reported from the park. One species, however, the southeastern shrew (*Sorex longirostris*), is listed at the state level as special concern.

Table 35. Mammal species reported from summer 2004 to autumn 2006 during an inventory at STRI (Table 2 from Kennedy and LaMountain, 2007). Letter abbreviations refer to abundance rankings: A = abundant; C = common; UC = uncommon; R = rare.

No.	Scientific Name	Common Name	Status
1	*Didelphis virginiana*	Virginia opossum	C
2	*Sorex longirostris*	Southeastern shrew	R
3	*Blarina brevicauda*	Northern short-tailed shrew	UC
4	*Cryptotis parva*	Least shrew	R
5	*Scalopus aquaticus*	Eastern mole	C
6	*Pipistrellus subflavus*	Eastern pipistrelle	UC
7	*Lasiurus borealis*	Red bat	C
8	*Sylvilagus floridanus*	Eastern cottontail	C
9	*Marmota monax*	Woodchuck	C
10	*Sciurus carolinensis*	Eastern gray squirrel	A
11	*Reithrodontomys humulis*	Eastern harvest mouse	UC
12	*Peromyscus maniculatus*	Deer mouse	UC
13	*Peromyscus leucopus*	White-footed mouse	A
14	*Microtus ochrogaster*	Prairie vole	C
15	*Ondatra zibethicus*	Muskrat	R
16	*Mus musculus*	House mouse	A
17	*Canis familiaris*	Domestic dog	UC
18	*Canis latrans*	Coyote	C
19	*Vulpes vulpes*	Red fox	UC
20	*Procyon lotor*	Raccoon	A
21	*Mustela vison*	Mink	R
22	*Lontra canadensis*	River otter	R

Table 32 (continued). Mammal species reported from summer 2004 to autumn 2006 during an inventory at STRI (Table 2 from Kennedy and LaMountain, 2007). Letter abbreviations refer to abundance rankings: A = abundant; C = common; UC = uncommon; R = rare.

No.	Scientific Name	Common Name	Status
23	*Mephitis mephitis*	Stripe skunk	C
24	*Felis catus*	Feral cat	UC
25	*Odocoileus virginianus*	White-tailed deer	UC

Threats and Stressors

There is a small discrepancy between the potential species list and the documented list from the park. Much of the discrepancy between the lists resulted from the small numbers of species of bats, shrews and rodents at STRI. The differences may be due to limited food resources and roosting sites in the park. Miller et al. (2005) reported that the lower number of documented amphibians and reptiles at STRI (as compared to an expected list) could have been due to extirpation from the park a long time ago by historic land use practices. Such practices resulted in habitat isolation that now prevents recolonization of the species. Habitat alteration, attributed to habitat loss or fragmentation, can decrease the abundance of species or cause their extirpation (Andren, 1994). Other aspects contributing to the differences may be lack of specific habitat requirements at STRI. However, the mosaic habitat types present at STRI are supportive of a wide diversity of mammals. Therefore, in the future, additional species may be added to the list of mammals occurring at STRI. The exotic species in the park such as: house mouse (*Mus musculus*), domestic dog (*Canis familiaris*) and feral cat (*Felis catus*) can cause problems for native mammal populations. Their presence can potentially affect mammal communities through predation, resource competition, or habitat alteration. Yet, the impacts of non-native species have not been reported at STRI. Several other impacts (e.g., diseases, parasites, exploitation, pollution, climate change) threaten the mammals of southeastern United States and possibly STRI. However, Kennedy and LaMountain (2007) did not report on them.

Condition and Trend

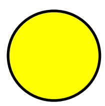
Condition Status

The condition of STRI mammals warrants moderate concern (Table 33). STRI contains 25 species of mammals, which make up 93% of the expected species to occur in the area. However, two species, the nine-banded armadillo (*Dasypus novemcinctus*) and beaver (*Castor canadensis*) were absent at STRI during the inventory even though they are known in the region (Bolen and Robinson, 2003). Since the inventory, nine-banded armadillo, bobcat (*Lynx rufus*), and southern flying squirrel (*Glaucomys volans*) have been recorded. In addition, gray bat (*Myotis grisescens*) has been recorded nearby STRI (G. Backlund, pers. comm.). The reason that some species known to occur in the region were not found at the park was due to land use prior to park establishment and the lack of adequate corridors for recolonization by extirpated species. Kennedy and LaMountain (2007) noted this is particularly shown by the few species of bats, shrews and rodents found at STRI. The authors noted the possible negative impact on animal populations as a result of the highly fragmented habitat at the park.

Trend
No trend was assigned to the mammals because a single baseline study is insufficient to establish a trend (Table 33).

Data Quality
The confidence used to make the assessment was medium (Table 33). Data were collected using a variety of scientifically-sound methods, and were obtained throughout the park covering all habitats. Location of each mammal captured or observed was determined by GPS units. The study was conducted from 2004-2006. The researchers conducting the study had extensive experience sampling the mammals of the region.

Table 36. The condition of STRI mammal assemblages.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Mammal Assemblages	Mammal Species Quality		The condition of STRI mammals warrants moderate concern. STRI contains 25 species of mammals, which make up 93% of the expected species to occur in the area. Since the inventory, 3 additional species have been recorded. The reason that some species known to occur in the region were not found at the park was due to land use prior to park establishment, the highly fragmented habitat at the park, and the lack of adequate corridors for re-colonization by extirpated species. Not enough data is yet available to establish a trend. Although experts did sampling effort over a 2-year period, additional sampling over time would allow for increased confidence.

4.5.9. *Vegetation Communities*

<u>Resource Knowledge</u>
The vegetation communities at STRI were mapped by the University of Georgia Center for Remote Sensing and Mapping Science (Jordan and Madden, 2010), in collaboration with NatureServe (Nordman, 2004). As part of this effort, sixteen permanent plots were established by NatureServe and GPS location data were recorded. Using a modified Braun Blanquet cover class scale to determine overall cover value, the park vegetation classifications were produced in accordance with the National Vegetation Classification (NVC) (Anderson et al., 1998; Grossman et al., 1998). Four ecological systems and 20 distinct vegetation associations at STRI were identified (Nordman, 2004; see also Summer and Nordman, 2008). Of the community types, 12 were classified as natural, four as successional, one as a man-made pond, and three as dominated by exotic plant species (Table 34). Comparing the mapped vegetation type to the field verified vegetation type at randomized evaluation points assessed the map accuracy; the overall accuracy of the final map was 83% (Summer and Nordman, 2008).

Nordman (2004) concluded that over 90% of the predicted vascular plants at STRI have been documented, consisting of 615 species, varieties, or subspecies (611 species) and including several rare or endemic cedar glade plants. Nordman (2004) added 34 species to the previous list produced by Hogan and Webber (1999). Of the regional parks in which forest monitoring plots have been established by CUPN, STRI has the highest plant diversity at the 1 x 1 m scale but not at the 20 x 20 m scale (CUPN, 2013).

Nine of 16 forest monitoring plots at STRI (established 2011-12) were classified as Successional Eastern redcedar (*Juniperus virginiana*) forest, and four of the remaining seven as Interior Plateau Chinquapin oak (*Quercus muehlenbergii*)/Shumard oak (*Quercus shumardii*) forest. Tree basal area measures from the established plots validate these community determinations in that red cedar comprises just over 50% and oak and hickory species together comprised about 20% (CUPN, 2013). Adams et al. (2012) sampled the canopy and understory of six forest stands in middle Tennessee on cedar glade–forming limestones (Lebanon, Ridley); one stand was at STRI on Ridley Limestone. Within this stand at STRI, *J. virginiana*, shagbark hickory (*Carya ovata*), and *Q. muehlenbergii* were primary canopy components, and American ash (*Fraxinus americana*), hackberry (*Celtis* spp.), and redbud (*Cercis canadensis*) were primary understory components. In addition, no *Carya* spp. was found in the understory of the STRI stand. Across all stands in middle Tennessee, they predicted that (1) mesophytes and/or fire-sensitive species will increase and (2) xerophytes and/or fire-adapted species will decrease. As compared to forests in eastern United States where maples are increasing, this does not appear to be the case on STRI where maple in forest plots comprised <1% of the understory (CUPN, 2013).

As part of Nashville Basin Limestone Glade ecological system, STRI is home for several rare plant species (listed as special concern in Tennessee) such as the Tennessee milk-vetch (*Astragalus tennesseensis*), limestone fame-flower (*Phemeranthus calcaricus*), and evolvulus (*Evolvulus nuttalianus*) (Crabtree, 2014). One federally listed endangered plant, Pyne's ground-plum (*Astragalus bibulatus*), and one previously listed plant, Tennessee coneflower (*Echinacea tennesseensis*), have been introduced in the park. Pyne's ground-plum is listed as endangered in Tennessee, and Tennessee coneflower as threatened (Crabtree, 2014). Prior to the introduction, these two species were not known to occur at STRI. The Tennessee coneflower population is thriving in Tennessee, and the species was delisted from the endangered species list in 2011 (Bowen, 2011). As for Pyne's ground-plum, which was planted recently, establishment and persistence of the introduced plants have been problematic.

Invasive plants can be found throughout the Main Park, and dominated three community types. A total of 32 exotics were recorded within plots at STRI (CUPN, 2013). The most commonly occurring include Chinese privet (*Ligustrum sinense*) (100% of the 16 plots), Amur bush honeysuckle (*Lonicera maackii*) (88%), and Japanese honeysuckle (*Lonicera japonica*) (81%). The existence of exotic plants at STRI is believed to be a threat to native species since the exotic species found in the park are considered aggressive or potentially aggressive. Many of the exotic plants are actively managed by STRI, and successful eradication has occurred in some areas of the park. The April 2009 tornado did extensive damage to the forests in the Main Park and by opening the canopy of the forests allowed exotic shrubs to increase in presence. As compared to other parks in the region, forest monitoring plots at STRI contained a higher number of exotic species and exotics are generally prevalent throughout the forested landscape (CUPN, 2013).

Many of the fields that were once planted in crops have been converted to native grasslands. In addition, native grasses have been planted on the earthen works at Fortress Rosecrans. These grasslands will need continued management (e.g., by prescribed burns, periodic cutting, and chemical treatment).

Threats and Stressors

STRI contains numerous plants, including some that are rare and endangered. However, the presence of exotic plants, some of which are listed as severe threats, is a large concern for the native plant communities. Management of fields (e.g., by prescribed burns) that have been planted with native grasses will need to be continued. Out of the 20 associations in the park, 12 are representative of natural ecosystems (Nordman, 2004). These are areas that may have been heavily disturbed in the past but no longer show signs of substantial disturbance, and should have high priority for preservation and restoration (e.g., exotic plant removal) as compared to successional and exotic plant dominated associations. Other threats and stressors to vegetation (e.g., climate change) have not been thoroughly considered in previous studies.

Condition and Trend

Condition Status

The condition STRI vegetation communities warrants significant concern (Table 35), primarily due to the prevalence of exotic species, the highly disturbed land-use history of the park, and the high proportion of urban interface surrounding the park. Although management practices have been effective in removing or reducing the abundance of some exotic species in the park, continued efforts will be needed for full recovery of vegetation.

Trend in Condition

No trend was assigned to the vegetation communities, since single baseline studies or inventories are insufficient to establish a trend (Table 35). Adams et al. (2012) compared the understory versus canopy tree species, and found that the composition and structure may change in the future, which potentially points to a negative trend but one which needs more analyses before drawing firm conclusions.

Confidence in Assessment

The confidence used to make the assessment was medium (Table 35). Data were collected using a variety of scientifically-sound methods, and were collected from plots in the park. Permanent plots were established and determined by GPS units. The original vegetation survey was conducted from 2002 to 2003 (Nordman, 2004). Additional plots were established and surveyed in 2011-2012 by CUPN (2013). The researchers conducting the study had extensive experience sampling the vegetation of the region.

Table 37. Ecological system and association of vegetation identified at STRI (Table 5 from Nordman, 2004) based on the National Vegetation Classification (NVC) system.

Ecological system	NVC association (Scientific name)	NVC association (Common name)	Global Rank *
Southern Interior Low Plateau Dry Forest	*Quercus imbricaria – Q. shumardii – Q. muehlenbergii/ Celtis occidentalis/Urtica chamaedryoides* Forest	Shingle oak – Shumard oak – Chinquapin oak/Northern hackberry/Heart-leaf nettle forest **CEGL003876**	G3
	Q. muehlenbergii – Q. (*falcata, shumardii, stellata*)/*Cercis canadensis*/*Viburnum rufidulum* Forest	Chinquapin oak – (Southern red oak, shumard oak, post oak)/Redbud/ Rusty blackhaw Forest **CEGL007699**	G3
	Q. muehlenbergii – Q. shumardii – Carya (*carolinae-septentrionalis*, *ovata*) Forest	Chinquapin oak – Shumard oak – (Carolina shagbark hickory, Shagbark hickory) Forest **CEGL007808**	G3
South – Central Interior Small Stream and Riparian	*Acer negundo* – (*Platanus occidentalis*, *Populus deltoides*) Forest	Box-elder – (Sycamore, Eastern cottonwood) Forest **CEGL004690**	G4
	Justicia americana Herbaceous Vegetation	Common water-willow Herbaceous Vegetation **CEGL004286**	G4G5

* Definitions for interpreting NatureServe global conservation status ranks (G-ranks):

G1 (Critically Imperiled)—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors;

G2 (Imperiled)—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors;

G3 (Vulnerable)—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors;

G4 (Apparently Secure)—Uncommon but not rare, some cause for long-term concern due to declines or other factors;

G5 (Secure)—Common, widespread and abundant;

G#G# (Range Rank)—A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4);

GW (Ruderal)—It is not of conservation value as a vegetation association, but management to control exotic species is needed;

GD—Does not receive a conservation status rank because this forest represents early successional, modified, or silviculturally managed vegetation.

† Not a unit in NatureServe's Classification of Ecological System (NatureServe, 2004).

Table 34 (continued). Ecological system and association of vegetation identified at STRI (Table 5 from Nordman, 2004) based on the National Vegetation Classification (NVC) system.

Ecological system	**NVC association (Scientific name)**	**NVC association (Common name)**	**Global Rank ***
South-Central Interior Large Floodplain	*Fraxinus pennsylvanica – Ulmus americana – Celtis laevigata/Ilex decidua* Forest	Green ash – American elm – Sugarberry/Possum-haw Forest **CEGL002427**	G4G5
	Salix nigra Forest	Black willow Forest **CEGL002103**	G4
	Salix caroliniana Temporary Flooded Shrubland	Carolina willow Temporary Flooded Shrubland **CEGL003899**	G4
Nashville Basin Limestone Glade	*Juniperus virginiana* var. *virginiana – Forestiera ligustrina – Rhus aromatica – Hypericum frondosum* Shrubland	Eastern redcedar – Glade privet – Fragrant sumac – Golden St. John's wort Shrubland **CEGL003938**	G3G4
	Quercus muehlenbergii – Juniperus virginiana/Schizachyrium scoparium – Manfreda virginica Wooded Herbaceous Vegetation	Chinquapin oak – Eastern redcedar/Little bluestem – Eastern agave Wooded Herbaceous Vegetation **CEGL005131**	G2G3

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G2 (Imperiled)—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors;

G3 (Vulnerable)—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors;

G4 (Apparently Secure)—Uncommon but not rare, some cause for long-term concern due to declines or other factors;

G5 (Secure)—Common, widespread and abundant;

G#G# (Range Rank)—A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4);

GW (Ruderal)—It is not of conservation value as a vegetation association, but management to control exotic species is needed;

GD—Does not receive a conservation status rank because this forest represents early successional, modified, or silviculturally managed vegetation.

† Not a unit in NatureServe's Classification of Ecological System (NatureServe, 2004).

Table 34 (continued). Ecological system and association of vegetation identified at STRI (Table 5 from Nordman, 2004) based on the National Vegetation Classification (NVC) system.

Ecological system	**NVC association (Scientific name)**	**NVC association (Common name)**	**Global Rank ***
Nashville Basin Limestone Glade (continued)	*Sporobolus* (*neglectus, vaginiflorus*) – *Aristida longispica* – *Panicum flexile* – *Panicum capillare* Herbaceous Vegetation	(Barren dropseed, Poverty dropseed) – Slimpike three-awn-wiry panicgrass – Common panicgrass Herbaceous Vegetation **CEGL004340**	G3
	Sedum pulchellum – *Talinum calcaricum* – *Leavenworthia* spp./ *Nostoc commune* Herbaceous Vegetation	Widow's cross – Limestone fameflower – Gladecress species/Common nostoc Herbaceous Vegetation **CEGL004346**	G3
Early Successional †	*Juniperus virginiana* var. *virginiana* – (*Quercus* spp.) Forest	Eastern redcedar – (Oak species) Forest **CEGL007124**	GD
	Celtis (*laevigata, occidentalis*) – *Juglans nigra* – (*Aesculus glabra*) Forest	(Sugarberry, Northern hackberry) – Black walnut – (Ohio buckeye) Forest **CEGL004697**	GD

* Definitions for interpreting NatureServe global conservation status ranks (G-ranks):

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G2 (Imperiled)—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors;

G3 (Vulnerable)—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors;

G4 (Apparently Secure)—Uncommon but not rare, some cause for long-term concern due to declines or other factors;

G5 (Secure)—Common, widespread and abundant;

G#G# (Range Rank)—A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4);

GW (Ruderal)—It is not of conservation value as a vegetation association, but management to control exotic species is needed;

GD—Does not receive a conservation status rank because this forest represents early successional, modified, or silviculturally managed vegetation.

† Not a unit in NatureServe's Classification of Ecological System (NatureServe, 2004).

Table 34 (continued). Ecological system and association of vegetation identified at STRI (Table 5 from Nordman, 2004) based on the National Vegetation Classification (NVC) system.

Ecological system	**NVC association (Scientific name)**	**NVC association (Common name)**	**Global Rank ***
Early Successional † (continued)	*Rubus* (*argutus, trivialis*) – *Smilax* (*glauca, rotundifolia*) Shrubland	(Southern blackberry, Southern dewberry) – (Whiteleaf greenbrier, Common greenbrier) Shrubland **CEGL004732**	GD
	Andropogon virginicus var. *virginicus* Herbaceous Vegetation	Common broomsedge Herbaceous Vegetation **CEGL004049**	GD
Exotic Species Dominated †	*Lolium* (*arundinaceum, pretense*) Herbaceous Vegetation	(Tall fescue, Meadow fescue) Herbaceous Vegetation **CEGL004048**	GW
	Ligustrum sinense Upland Shrubland	Chinese privet Upland Shrubland **CEGL003807**	GW
	Ligustrum sinense Temporary Flooded Shrubland	Chinese privet Temporary Flooded Shrubland **CEGL003837**	GW
Impoundment Pond (Human created) †	*Ludwigia peploides* Herbaceous Vegetation	Floating water primrose Herbaceous Vegetation **CEGL007835**	G4G5

* Definitions for interpreting NatureServe global conservation status ranks (G-ranks):

G1 (Critically Imperiled)—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors;

G2 (Imperiled)—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors;

G3 (Vulnerable)—At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors;

G4 (Apparently Secure)—Uncommon but not rare, some cause for long-term concern due to declines or other factors;

G5 (Secure)—Common, widespread and abundant;

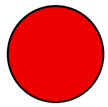
G#G# (Range Rank)—A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4);

GW (Ruderal)—It is not of conservation value as a vegetation association, but management to control exotic species is needed;

GD—Does not receive a conservation status rank because this forest represents early successional, modified, or silviculturally managed vegetation.

† Not a unit in NatureServe's Classification of Ecological System (NatureServe, 2004).

Table 38. The condition of STRI vegetation communities.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Vegetation Communities	Vegetation Community Quality		The condition STRI vegetation communities warrants significant concern, primarily due to the prevalence of exotic species, the highly disturbed land-use history of the park, and the high proportion of urban interface surrounding the park. No data are available to evaluate trends. Although experts did adequate sampling, additional work over time would allow for increased confidence.

4.6. Landscape and Landcover

4.6.1. *Landscape Dynamics*

Description

Landscape dynamics is a broad group of processes that include ecological, geomorphological, and anthropogenic types that occur across a range of spatial scales. This has been assigned as one of the vital signs for parks in CUPN, with several issues being most relevant to the integrity and health of the park. The four categories of landscape dynamics critical to the park include: habitat fragmentation, increased pollution sources, increasing avenues for the transmission of exotic pests, and changes in the viewshed and soundscape of the park (NPS, 2007). Despite effective resource management being implemented within parks (Monohan, 2012), external landscape stressors from population, housing and roads have increased over time (Davis and Hansen, 2011) and is projected to increase for the foreseeable future (Radeloff et al., 2010).

As STRI is located in a developed region, proximal to Murfreesboro, TN and the greater Nashville Metropolitan Area, the park and surrounding areas are prone to alteration due to the continued population expansion taking place near the park. Therefore, it is necessary that these changes be monitored in order for park staff to make more informed choices about conservation in the park.

Data and Methods

In order to effectively document and analyze changes in the landscape surrounding the park, the NPS created several GIS-based datasets and tools called NPScape (http://science.nature.nps.gov/im/monitor/npscape/). NPScape was created in order to support parks management of natural resources, help with long term planning, and to interpret results from landscape-scale information (NPS, 1999). According to the NPScape Interpretive Guide, the objectives of NPScape are: to provide a clear framework for analyzing and evaluating landscape scale data, to support decisions at a park level, to form a credible, well documented set of methods, found on strong science, that can be readily repeated and performed with local data, provide parks with data and products that are not usually found at the park level, and to provide assistance in interpreting the results from these datasets (Monahan et al., 2012). Three scales were used to evaluate the landscape dynamics of the park. These 3 scales include the area immediately within the park boundaries, a buffer of 3km around the boundary of the park, and a buffer of 30km around the boundary of the park (Table 36). This allows for analysis of the area immediately surrounding the park at several different scales to look at how landscape can affect the park's ecological immediate to the park, as well as the larger local area that surrounds the park, as ecological processes can operate on scales from 15-40km (Clark, 1985; Wiens, 1989). The six major measures of landscape dynamics which are evaluated in the NPScape data are: population, housing, roads, landcover, pattern, and conservation status.

Table 39. Shows the defined areas of interest and relevance for NPS Products (Source: Gross et al., 2009).

Areas of Interest	Relavance
Park	The scale at which park units have maximum management control.
Park + 3 km buffer	Captures the effects of human drivers that are most proximate and direct to the park.
Park + 30 km buffer	A local park landscape that tends to integrate the combined effects of human drivers, natural systems, and conservation

4.6.2. *Landcover*

The NPScape program provides several datasets and tools for the analysis of landscape-scale land cover. These datasets can be used to document land use change both within and outside the park boundaries. Several types of land cover datasets are available from NPScape for analysis, including: North American Landscape Characterization (NALC), National Landcover Dataset (NLCD), and Coastal Change Analysis Program (CCAP). The NCLD dataset was selected for analysis, as it allowed for use with the greatest number of NPScape tools, and was available over multiple time periods to measure change over time.

NLCD

The NLCD is a 30m x 30m resolution raster dataset produced by the Multi-Resolution Land Characteristics Consortium (MRLC) which is used to analyze several different changes in landscape, mainly due to anthropogenic influence. Datasets were available for 2001 to 2006 and 2006 to 2011 for some measures, with 2001 to 2006 being available for all NPScape Tools. The raster imagery is run through a classification scheme, where each pixel of the image is assigned to a unique land-cover class. As part of the NPScape product, Gross et al. (2009) reclassified the change product to include two main classes: natural and converted areas. The classified images are sorted into the two main classes (Table 37). The ratio of the converted area versus the natural area is called the "U-index" (O'Neill et al., 1988), and is intended as a direct representation of anthropogenic disturbance of a landscape. Various NLCD classes can be assigned to a landcover and whether or not that class is considered either a converted or natural type of landcover (Table 38 and Table 39).

Table 40. Aggregation of NLCD landcover classes into general categories of converted and natural land (Source: 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

The park itself has a relatively high percentage of converted versus natural area, 55% to 45%. This can be attributed to several factors, such as the tour road that goes through the park, the fields which were at one time used for agriculture (now converted to native grasses), Old Nashville Highway passing between the main park area and cemetery, and the cemetery itself which is classified entirely as developed open space. Changes between the two timeframes can be seen in Figure 22 and Figure 23, which indicate that not much change happened within the park, except those noted earlier. This ratio worsens at the 3km buffer zone, where almost 88% of the landcover was converted, showing a large degree of encroachment from development in the area directly proximate to the park. The percent area of forest drops to below 10% from almost 50% directly within the park, while developed land makes up almost 67% of the land cover at the 3km buffer (Figure 24, Figure 25, and Figure 26). It is interesting to note that there was not a significant change in landcover between the two time periods, indicating that conversion in the area in the vicinity of the park seems to have slowed at this point. Whether this trend continues remains to be seen, as the Murfreesboro area is continuing to grow at a high rate. Unlike the 3km buffer, as the range extends outs to the 30km buffer, the percent land cover of forest is similar to that within park boundaries, while there is a sharp decrease in developed land, and an increase in cultivated land (Figure 26 and Figure 27). The U-indices of both the park boundary area and within 30km are very similar showing the rural nature of the land that surrounds Murfreesboro, while the very high U-Index of the 3km buffer is an indication of how much the development of the city of Murfreesboro has begun to encroach upon the region surrounding the park. There were no significant changes in land cover between the 2006 and 2011 data, though there is a slight trend towards intensification of developed area.

Table 41. Landcover area and proportions of STRI for each buffer class based on two separate NLCD classifications and change product, as aggregated by Gross et al. (2011).

Classification	30 km Buffer		3 km Buffer		No Buffer	
	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area
NLCD 2006						
Open Water	48.33	1.50	0.56	0.75	0.05	1.66
Developed Open Space	254.23	7.89	17.32	23.16	0.66	23.12
Developed Low Intensity	162.89	5.05	21.26	28.43	0.18	6.23
Developed Medium Intensity	53.58	1.66	7.66	10.24	0.05	1.57
Developed High Intensity	19.15	0.59	4.28	5.72	0.02	0.75
Barren Land	8.56	0.27	0.08	0.11	0.00	0.00
Deciduous Forest	755.36	23.44	3.91	5.22	0.27	9.34
Evergreen Forest	316.49	9.82	2.02	2.70	0.70	24.47
Mixed Forest	194.27	6.03	1.06	1.42	0.14	4.98
Scrub/Shrub	114.01	3.54	1.13	1.50	0.07	2.51
Herbaceous	66.11	2.05	0.36	0.48	0.02	0.85
Pasture/Hay	1,084.77	33.66	12.55	16.79	0.58	20.18
Cultivated Agriculture	135.18	4.19	2.09	2.80	0.09	3.26
Woody Wetlands	8.15	0.25	0.40	0.53	0.03	1.07
Emergent Herbaceous Wetlands	1.42	0.04	0.11	0.14	< .01	0.03
NLCD 2006 Converted	**1,709.82**	**53.06**	**65.16**	**87.15**	**1.58**	**55.11**
NLCD 2006 Natural	**1,512.68**	**46.94**	**9.61**	**12.85**	**1.29**	**44.89**
NLCD 2011						
Open Water	48.28	1.50	0.54	0.73	0.05	1.66
Developed Open Space	260.03	8.07	17.46	23.36	0.66	23.12
Developed Low Intensity	171.36	5.32	21.66	28.97	0.18	6.23
Developed Medium Intensity	61.06	1.89	9.09	12.16	0.05	1.57
Developed High Intensity	22.05	0.68	4.93	6.59	0.02	0.75
Barren Land	10.94	0.34	0.07	0.09	0.00	0.00

Table 38 (continued). Landcover area and proportions of STRI for each buffer class based on two separate NLCD classifications and change product, as aggregated by Gross et al. (2011).

Classification	30 km Buffer		3 km Buffer		No Buffer	
	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area
NLCD 2011 (continued)						
Evergreen Forest	334.93	10.39	1.98	2.65	0.65	22.59
Mixed Forest	189.96	5.89	0.97	1.29	0.15	5.20
Scrub/Shrub	85.66	2.66	0.86	1.14	0.11	3.92
Grassland/Herbaceous	76.71	2.38	0.38	0.51	0.03	1.13
Pasture/Hay	1,070.97	33.23	10.70	14.31	0.58	20.18
Cultivated Agriculture	135.28	4.20	1.90	2.54	0.09	3.26
Woody Wetlands	8.17	0.25	0.36	0.49	0.03	1.07
Emergent Herbaceous Wetlands	1.54	0.05	0.11	0.14	< .01	0.03
NLCD 2011 Converted	**1,720.76**	**53.74**	**65.75**	**87.94**	**1.58**	**55.11**
NLCD 2011 Natural	**1,501.74**	**46.26**	**9.02**	**12.06**	**1.29**	**44.89**
NLCD 2011 U-Index		**1.16**		**7.29**		**1.23**

Table 42. NLCD land cover classes used in analyses of Natural/Converted and pattern analyses. (Source: Monahan, 2012).

Anderson Level I	Anderson Level II	Natural/Converted	Forest or Grassland Pattern
Open Water	11 Open Water	Natural	
	12 Perennial Ice/Snow		
2 Developed	21 Developed Open Space	Converted	
	22 Developed Low Intensity		
	23 Developed Medium		
	24 Developed High Intensity		
3 Barren/Quarries/Transitional	31 Barren Land	Natural	
	32 Unconsolidated Shore		

Table 39 (continued). NLCD land cover classes used in analyses of Natural/Converted and pattern analyses. (Source: Monahan, 2012).

Anderson Level I	Anderson Level II	Natural/Converted	Forest or Grassland Pattern
4 Forest	41 Deciduous Forest 42 Evergreen Forest 43 Mixed Forest	Natural	Forest
5 Shrub/Scrub	51 Dwarf Scrub 52 Shrub/Scrub	Natural	
7 Grassland/Herbaceous	71 Grassland/Herbaceous 72 Sedge/Herbaceous 73 Lichens 74 Moss	Natural	Grassland
8 Agriculture	81 Pasture/Hay 82 Cultivated Agriculture	Converted	
9 Wetlands	90 Woody Wetlands 95 Emergent Herbaceous Wetlands	Natural	Forest

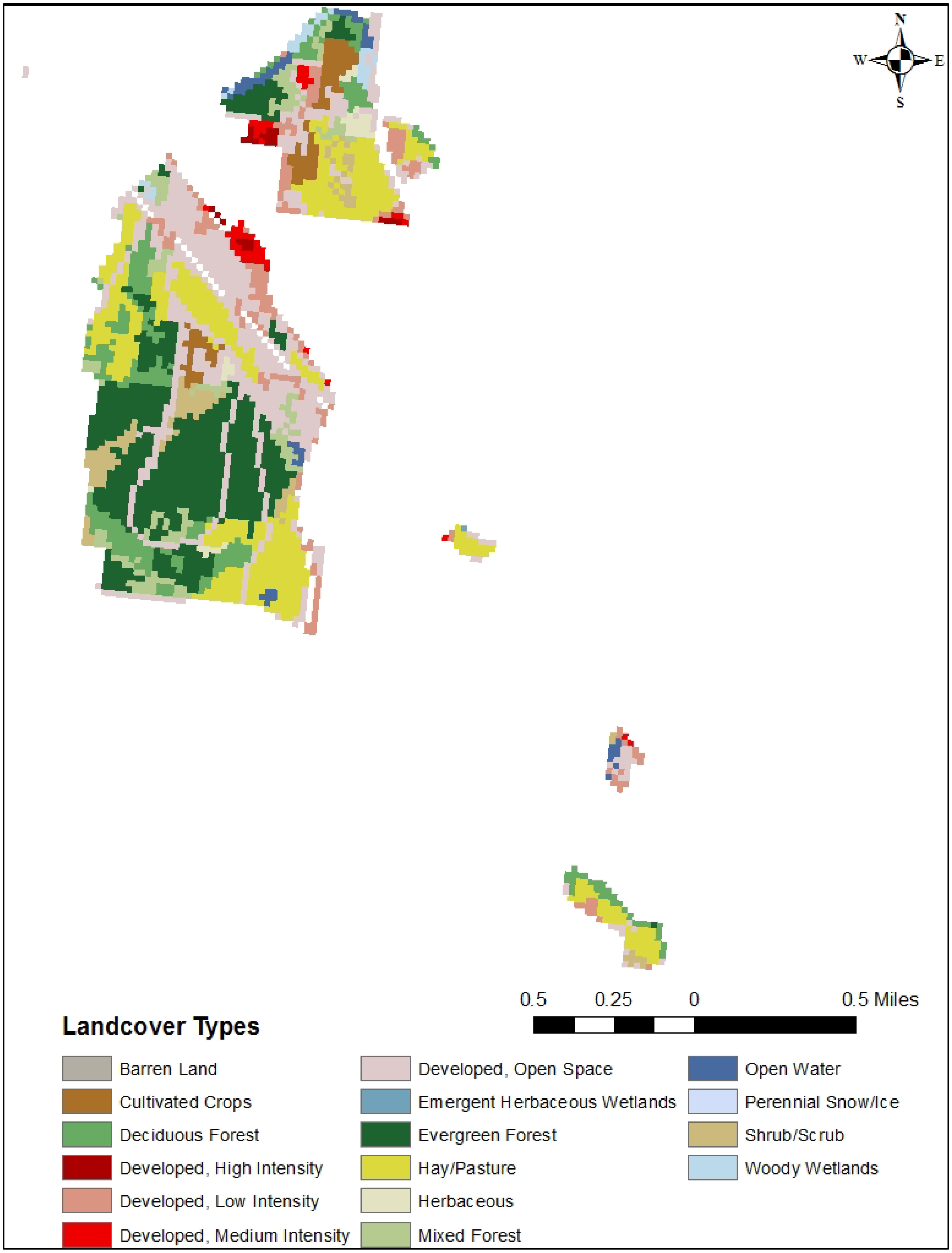


Figure 17. NLCD Landcover Classes within STRI Park Boundaries, 2006.

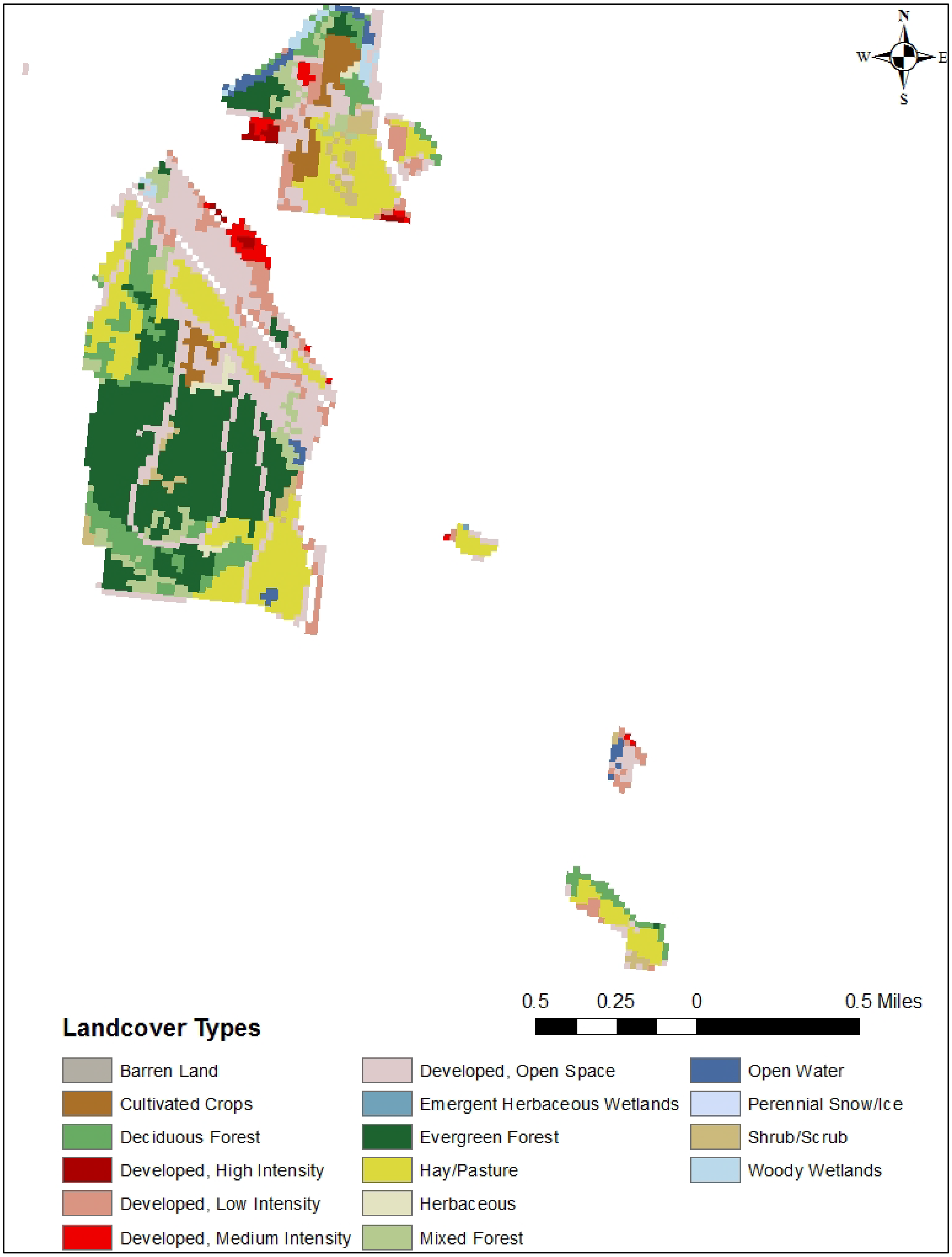


Figure 18. NLCD Landcover Classes within STRI Park Boundaries, 2011.

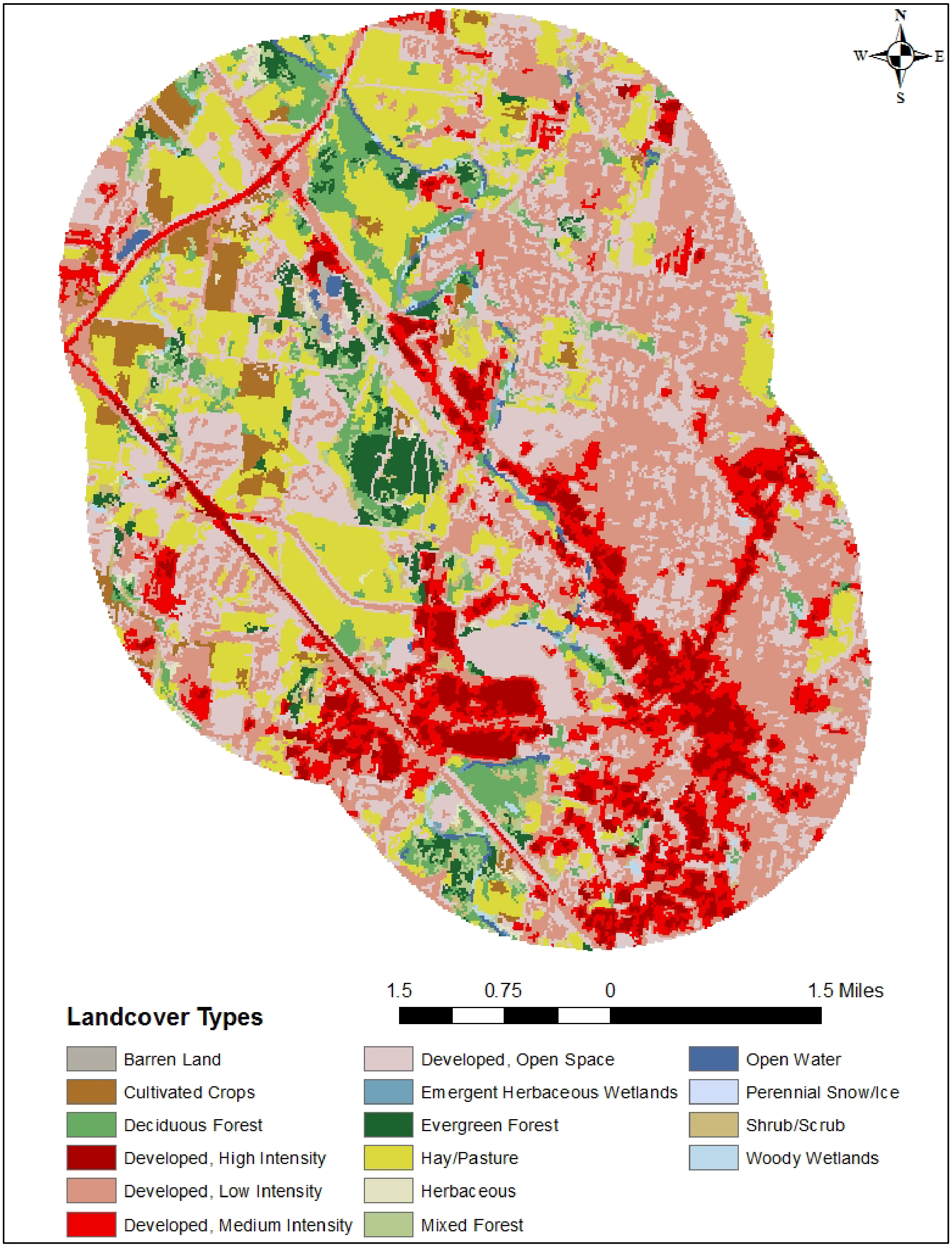


Figure 19. NLCD Landcover Classes within 3km of STRI, 2006.

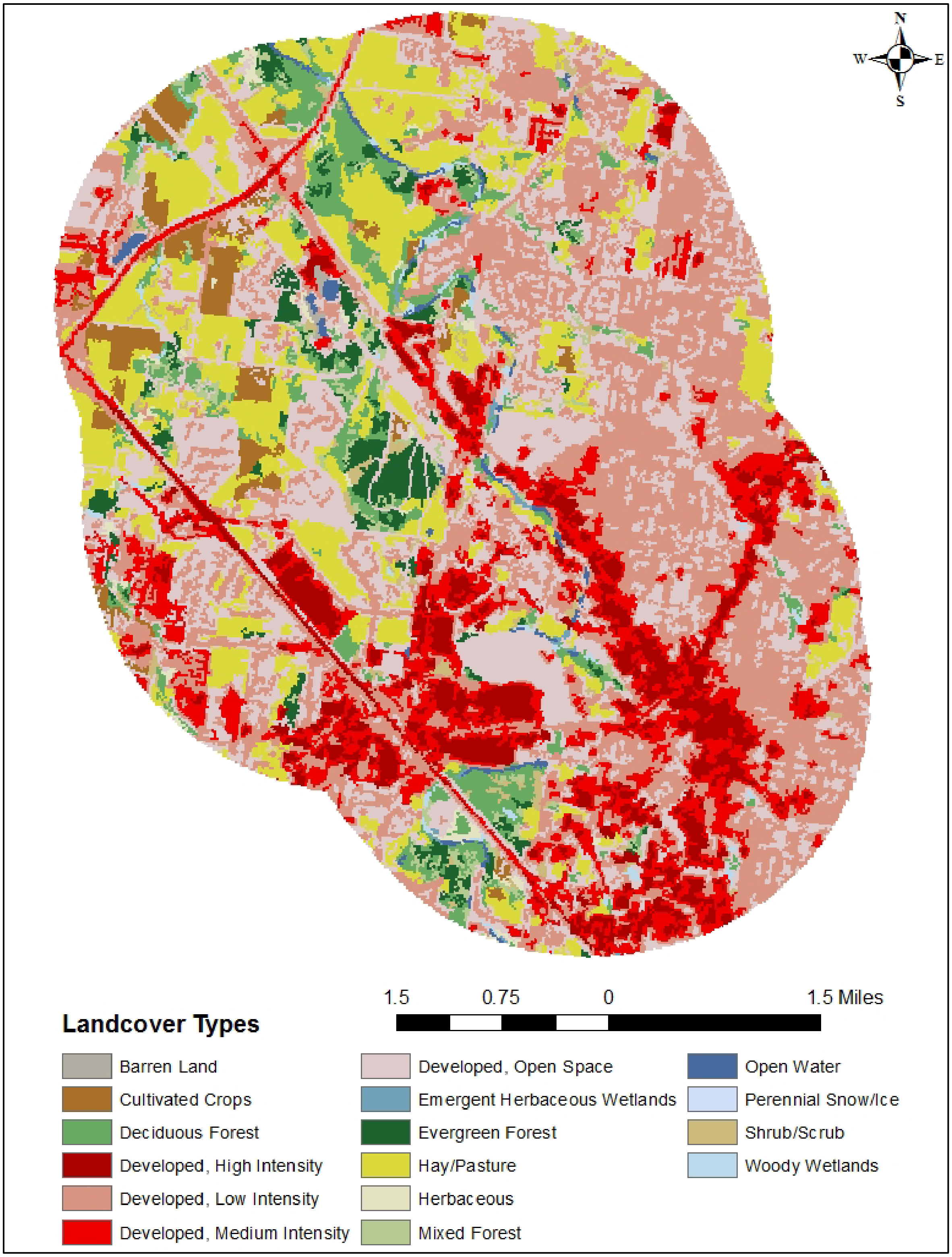


Figure 20. NLCD Landcover Classes within 3km of STRI, 2011.

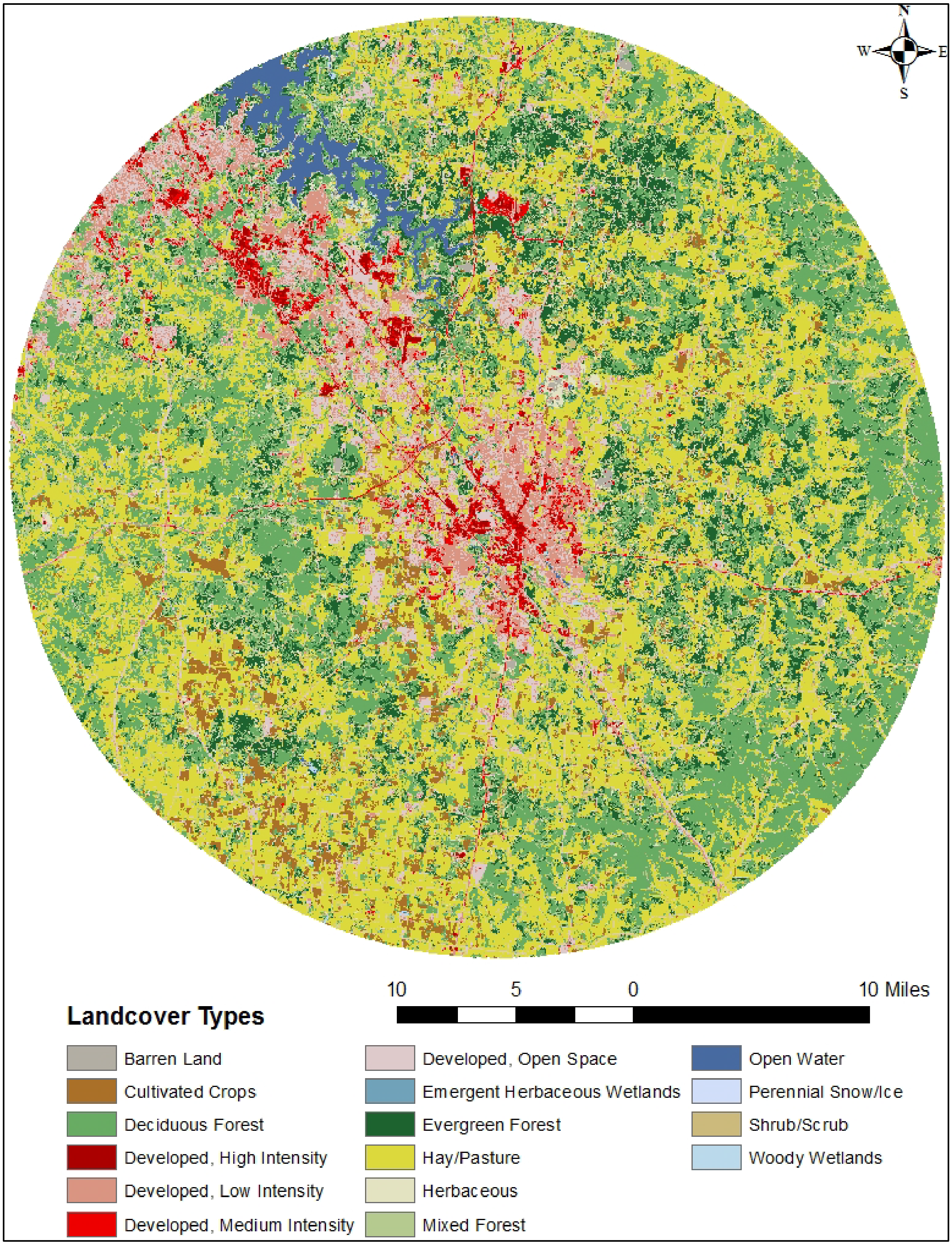


Figure 21. NLCD Landcover Classes within 30km of STRI, 2006.

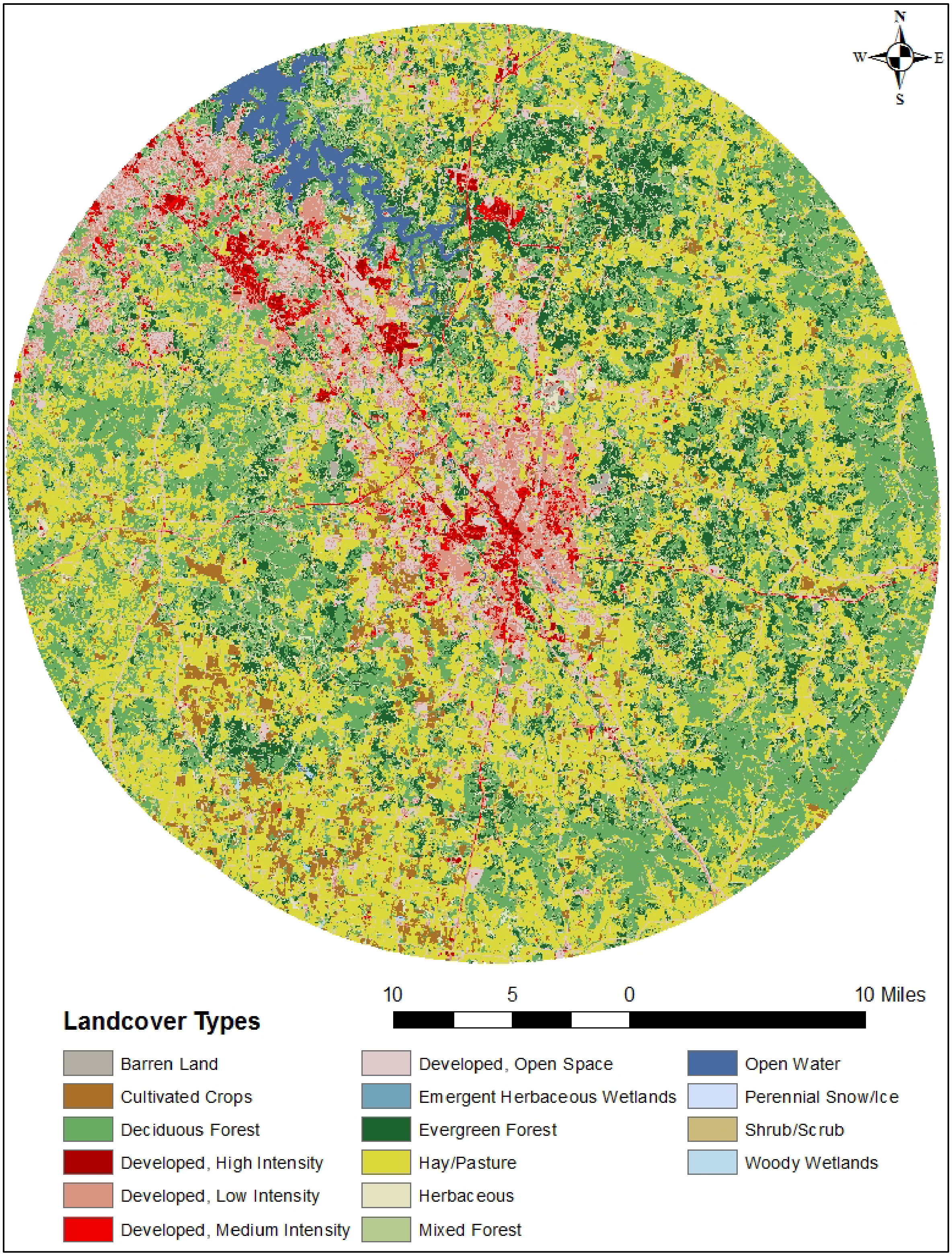


Figure 22. NLCD Landcover Classes within 30km of STRI, 2011.

Condition and Trend

Condition

We ranked the quality of STRI landscape dynamics as warranting significant concern (Table 40), due primarily to the high percentage of converted land use in all three scales, and the high U-Index values associated with them. Although park management can do little to affect landscape dynamics of the area outside of the park itself, it is helpful to be aware of changes in conditions outside the park and to acknowledge that the park is becoming an island of natural habitat surrounded by growing development and plan accordingly.

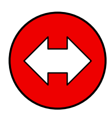
Trend

A trend of no change was assigned to the landscape dynamics, since comparisons between the data from the 2006 and 2011 show little change in the composition of the area surrounding the park during those periods at any of the three scales (Table 40).

Data Quality

The quality of the data used to make the assessment was good (Table 40). Data tools for analysis were provided by the NPScape, which was supported by a variety of scientifically sound methods. Landcover data was geographically referenced, and specific to the park area. Imagery available for analysis was available for two time periods 2001-2006 and 2007-2011. With the most recent data being less than 5 years old, the data is the most current available.

Table 43. The condition of STRI Landscape Dynamics.

Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition
Landscape Dynamics	Landscape dynamics and converted land use		Because STRI is surrounded by converted land, landscape dynamics is ranked as warranting significant concern. At this time, there is no change in the trend.

5. Chapter 5 Discussion

5.1. Component Data Gaps

The quality and amount of data varied with each of the component resources examined for STRI. Several of the key resource indicators used in this NRCA require further study to fully assess the conditions and trends for STRI. Specific gaps where more data is needed are noted in Table 41. Each of these is discussed in greater detail in Chapter 4.

Table 44. Identified data and study gaps for assessment components at STRI.

Component	Data Gaps
Air Quality	Specific, long-term data collection is needed at STRI. POMS equipment rotates through the CUPN on a six year cycle, which means a trend cannot be established at this time for ozone and foliar injury.
	Data used for the assessments of the deposition of nitrogen and sulfur and particulate matter is based on interpolated data from across the country. More specific data will allow for more specific assessments and allow the park to more effectively manage their resources
Weather and Climate	Despite the existence of COOP stations in the area, the quality and longevity of the data for temperature and precipitation is inconsistent.
	An assessment of higher quality data available from the surrounding area would provide a more complete condition assessment of this component at STRI.
Biological Integrity	Inventories on all components of biological integrity are needed, since much of the data used in this report is based on work conducted more than 5 years ago.
	While some for monitoring biological integrity have been established, regular inventorying at set intervals of time, along with data analyses, needs to be done for all components of biological integrity.
	Population trends and breeding status need to be assessed for faunal components.
	Effects of management (e.g., control burns, exotic plant removals) on population and community attributes need to be studied.
Landscape Dynamics	While there is ample data available through the NPScape program, a Landscape Report or Assessment has not been done for STRI. A completed study would help park managers recognize potential factors affecting the landscape of the park and shape future policies regarding the parks future.
	An assessment of higher quality data available from the surrounding area would provide a more complete condition assessment of this component at STRI.
Geospatial Data	Geographic Information Systems resources are available at STRI, but lack of metadata/standardization limits their utilization.
	Implementation of GIS best practices would allow STRI to effectively produce and maintain their geospatial infrastructure and better support modern environmental monitoring and management.

5.2. Natural Resource Component Conditions

The Natural Resource Condition Assessments (NRCAs) report on the current conditions of natural resources and resource indicators as a method to establish trends (if possible), report any gaps in data collection, and assign a level of confidence in the findings of the study for STRI. Key findings are summarized below by component condition (Tables 42- 47).

5.2.1. *Ozone and Foliar Injury*

Data for ozone readings is based on readings from two sources: two POMS which rotate through the CUPN on a six year rotational cycle, and also from a study conducted by the NPS Air Resource Division (ARD). The NPS ARD study used ozone models, which produced interpolated ozone predictions for STRI. Foliar injury was assessed using two methods. In the first method, the biological indices SUM06 and W126 use ozone data to estimate the effect ozone readings will have on foliage. Secondly, the Palmer Z index value, which measures drought and wetness from soil moisture content was also used in the assessment.

Data Quality

Estimated ozone readings warrant moderate concern based on NPS Air Resource Division benchmarks, but in order to establish a trend, more data from on-site or nearby monitoring sites is needed. The majority of the ozone data used was extrapolated, and not directly measured at STRI. The most recent foliar injury assessment was conducted in 2010. The area surrounding the park has undergone several changes since the study; therefore, for the foliar assessment to be accurate, more recent data is required.

5.2.2. *Deposition of Nitrogen and Sulfur*

Estimates for the wet deposition of nitrogen and sulfur were calculated based on data from a study by the NPS ARD. A general trend was established that indicates an overall lowing (improvement) in the deposition of nitrogen and sulfur at STRI. A condition of “significant concern” was still assigned due to the high concentrations still interpolated.

Data Quality

The condition and trend assessments for the deposition of nitrogen and sulfur were interpolated using NPS ARD data with five year averages. Confidence in the results of the wet deposition data can be increased with the direct collection of data at STRI rather than only interpolated data.

5.2.3. *Particulate Matter and Visibility*

The values for particulate matter and visibility reported for STRI are based on the NPS ARD interpolated data using national averages for every five years. The park consistently had values above the NPS recommended values for the Haze Index. However, even though “significant concern” is assigned to STRI, the interpolated data shows a slowly decreasing value in the Haze Index.

Data Quality

As with the other air quality indicators at STRI, particulate and matter visibility requires specific, onsite data to accurately capture conditions at the park. The confidence in the Haze Index for this component is low, due to the fact that this also used interpolated data from the NPS ARD.

5.2.4. ***Precipitation and Temperature***

Both the precipitation and temperature data were collected primarily from the Cooperative Observation Stations (COOP) located in or near STRI. Additional data was also gathered from the National Climatic Data Center. With the data collected, a "stable" trend was assigned to the park, but the variation in precipitation between each year seems to be increasing, and temperatures appear to be steadily rising.

Data Quality

The COOP stations near STRI contain gaps in data for some time periods. The Murfreesboro 5 N station provided the most reliable data for conditions at STRI, but needs further comparison with other stations in the area or a regional study to fully understand any climate effects at the park. STRI now has a COOP station within the park boundary, but the short time span of the collected data means it was not helpful in determining a trend at this time.

5.2.5. ***Water Quality***

Data for water quality is collected at four sites at STRI; West Fork at McFadden's Ford, Battlefield Spring, West Fork at Redoubt Brannan, and King Pond. Measurements are taken on a rotating 2 year on 5 year off cycle, based on USGS long term water quality monitoring policies. Based on data from the two monitoring periods that have taken place, we assign a condition of "fair" to water quality with no trend. No data gaps are present in this resource.

Data Quality

Data was collected and analyzed using scientifically sound means and is of high quality. Data will continue to be measured on the current trend of 2 years on 5 years off and is scheduled to resume in FY2016.

5.2.6. ***Invasive/Exotic Plants***

Approximately 30% of the plants at STRI are introduced species. Of the exotic plants occurring at STRI, they are listed as severe threat (15 species), significant threat (16 species), lesser threat (15 species), and alert (14 species). Three vegetation associations are dominated by exotic species (Chinese Privet Upland Shrubland, Chinese Privet Temporarily Flooded Shrubland, Cultivated Meadow). Out of all exotic species in the park, STRI manages about 40 of them by various methods. An Integrated Pest Management Plan has been implemented in the park, and effective control has occurred for some of exotic species. Overall, it is clear that exotic species presence pose a major threat to native plant communities in STRI. Although management practices have been effective in removing or reducing the abundance of some exotic species, continued efforts will be needed for full recovery of vegetation.

Data quality

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and geo-referenced. Some data was obtained within the past 5 years. The condition of STRI invasive/exotic plants warrants significant concern. A trend cannot be established at this time, since only baseline studies have been conducted. Confidence in our assessment was high.

5.2.7. *Wetlands Communities*
Four wetlands are present at STRI based on the National Wetland Inventory. However, a wetland survey done at STRI identified and characterized 15 wetlands, totaling 1.70 acres with the largest wetland being ~0.77 acres and the smallest 0.002 acres. These wetlands were of the following types: depression (nine wetlands), slope (four), and riverine (two). Twenty-eight dominant plant species in the wetlands at STRI were identified. Common species included sugarberry (*Celtis laevigata*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), fox sedge (*Carex vulpinoidea*) and cutgrass (*Leersia virginica*). Furthermore, several wetlands in the park that hold water for relatively long periods are used as breeding habitat by amphibians.

Data Quality
Data were collected throughout STRI 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 STRI warrants moderate concern, considering that all of them have been impacted by land-use history. No trend was assigned due to the lack of data beyond the baseline study. The confidence in the assessment was medium.

5.2.8. *Freshwater Aquatic Insects*
Fifty distinct taxa from 7,400 individuals collected have been reported from STRI. Forty-two distinct Ephemeroptera and Tricoptera taxa, 7 Odonata, and 1 Plecoptera order were reported. The EPT (Ephemeropter-Tricoptera-Plecoptera) species richness is fair. One species, the Coosa stonefly (*Neoperla coosa*), is listed S2 and G2; no other federal or stated listed species were reported from the park.

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

5.2.9. *Bird Assemblages*
The STRI avifauna consisted of 152 species, of which 14% were possible breeders, 16% were probable breeders, and 22% were confirmed breeders. Species that use grassland [e.g., Grassland Sparrows (*Ammodramus savannarum*)] and shrub-scrub habitats were well represented. The total number of species represented about 72% of the 210 species that might be expected to occur at STRI. None of the species reported from the park are listed as threatened or endangered by the US Fish and Wildlife Service. At the state level, Lark Sparrow (*Chondestes grammacus*) is listed as threatened and Bewick's Wren (*Thryomanes bewickii*) as endangered; both species are possible breeders at STRI. In addition, Bewick's Wren, Prairie Warbler (*Dendroica discolor*), another possible breeder at STRI, and Dickcissel (*Spiza americana*), a summer resident at STRI, are listed as priority birds by Partners in Flight. Four species observed at STRI are non-native: Rock Pigeon (*Columba livia*), Eurasian Collared-dove (*Streptopelia decaocto*), European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*).

Data Quality

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and were geo-referenced. However, the data were over 5 years old. The condition of bird assemblages at STRI warrants moderate concern. Although point counts were done every year between 2003 and 2005, these data have not been analyzed for trends. Confidence in our assessment was medium.

5.2.10. *Cedar Glades*

About 40 cedar glades are located at STRI, occupying approximately 10% of STRI's total acreage. Mention of cedar glades is made in personal letters by solders, and the land at STRI containing cedar glades has been heavily impacted and was once more open than it is today. Approximately 230 taxa have been recorded from the cedar glades at STRI. The cedar glades at STRI contain populations of several state listed rare plant species (as special concern): Tennessee milk-vetch (*Astragalus tennesseensis*), limestone fame-flower (*Phemeranthus calcaricus*), and evolvulus (*Evolvulus nuttalianus*). In addition, Pyne's ground-plum (*Astragalus bibulatus*) and Tennessee coneflower (*Echinacea tennesseensis*) have been planted there. STRI has taken a number of steps to protect the cedar glades and their associated plants, but management (e.g., to maintain viable populations of the rare species or openness of the habitat) may need to be considered in the future.

Data Quality

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and were geo-referenced. The condition of STRI cedar glades warrants moderate concern. No trend was assigned at this time, as only a baseline study has been conducted. Photographs of the glades and resampling data since 1995 have yet to be analyzed. Mostly due to the lack of trend analyses, our confidence in the assessment was medium.

5.2.11. *Fish Assemblages*

Riverine habitat at STRI totals 570 m out of 4,700 m to include the West Fork of the Stones River (WFSR) at Redoubt Brannon and Lytle Creek (LC) at Fortress Rosecrans and upstream WFSR at McFadden's Ford. This system is composed of nine habitat types ranging from deep bedrock runs to shallow gravel/pebble pool to pebble/cobble riffle. Habitat quality based on fish community metrics show LC and WFSR at McFadden's Ford as fair to good and WFSR at Redoubt Brannon as fair quality riverine habitat. All pollution intolerant species potentially occurring at STRI were reported (bigeye shiner, *Notropis boops*: spotted sucker, *Minytrema melanops;* large rockbass, *Ambloplites rupestris;* slender madtom, *Notorus exilis*; fantail darter, *Etheostoma flabellare*; speckled darter, *Etheostoma stigmaeum*), but half of these species (benthic dwellers with clean substrate requirements) were rare which indicates environmental stress. The USEPA 2010 Water Body Report lists the WFSR and LC as impaired for fish due to excessive sedimentation and siltation. None of the species reported from the park are listed as rare, threatened, or endangered by the Tennessee Wildlife Resources Agency or by the US Fish and Wildlife Service. Forty-six fish species or 73% out of 60 potentially occurring species have been reported indicating a relatively rich fish community.

Data Quality

Data were collected throughout STRI by an expert 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 STRI warrants moderate concern. Studies are needed to assign a trend to the fish populations. Our confidence in the assessment was medium.

5.2.12. *Amphibian and Reptile Assemblages*

STRI contains 29 species of amphibians and reptiles. The most abundant species in each order/suborder of herpetofauna found at STRI were the American bullfrog (*Rana catesbeiana*), northern zigzag salamander (*Plethodon dorsalis*), eastern fence lizard (*Sceloporus undulatus*), eastern racer (*Coluber constrictor*) snake, and red-eared slider (*Trachemys scripta elegans*) turtle. None of the species reported from the park are listed as rare, threatened, or endangered by the Tennessee Wildlife Resources Agency or by the United States Fish and Wildlife Service. A low ratio of documented species at STRI to expected species in Rutherford County was explained mostly by the absence (or sparsity) of particular habitats at STRI. However, seven species that are conspicuous or relatively easy to locate at a nearby state natural area are absent at STRI probably due to land-use history at STRI and the surrounding environs. On the other hand, these species might not have been detected and follow-up surveys would be helpful to clarify the presence/absence of them.

<u>Data Quality</u>

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and were geo-referenced. However, the data were over 5 years old. The condition of STRI herpetofauna warrants significant concern. No trend is established at this time without more than a baseline study. Our confidence in the assessment was medium.

5.2.13. *Mammal Assemblages*

Twenty-five species of mammals have been reported from STRI, which represents 93% of the expected mammals. The most common and abundant small mammals at STRI was white-footed mice (*Peromyscus leucopus*) and gray squirrel (*Sciurus carolinensis*). Virginia opossum (*Didelphis viginiana*), eastern mole (*Scalopus aquaticus*), red bat (*Lasiurus borealis*), eastern cotton tail (*Sylviiagus floridanus*) rabbit, wood chuck (*Marmota monax*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*) were among common mammals in the park. The nine-banded armadillo (*Dasypus novemcinctus*) and beaver (*Castor canadensis*) were not reported from STRI although they are known in the region. No federal or state listed endangered or threatened species were reported from the park, and the southeastern shrew (*Sorex longirostris*) is listed at the state level as special concern.

<u>Data Quality</u>

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and were geo-referenced. However, the data were over 5 years old. The condition of STRI mammals warrants moderate concern. Not enough data is yet available to establish a trend. Our confidence in the assessment was medium.

5.2.14. *Vegetation*

Four ecological systems and 20 distinct vegetation associations at STRI have been identified. Of the community types, 12 were classified as natural, four as successional, one as a man-made pond, and three as dominated by exotic plant species. The most commonly occurring exotic plants include Chinese privet (*Ligustrum sinense*), Amur bush honeysuckle (*Lonicera maackii*), and Japanese honeysuckle (*Lonicera japonica*). Of the regional parks in which forest monitoring plots have been established, STRI has the highest plant diversity at the 1 x 1 m scale but not at the 20 x 20 m scale. Nine of 16 forest monitoring plots at STRI (established 2011-12) were classified as successional eastern redcedar (*Juniperus virginiana*) forest, and four of the remaining seven as Interior Plateau chinquapin oak (*Quercus muehlenbergii*)/shumard oak (*Quercus shumardii*) forest. Within one stand at STRI, *J. virginiana*, shagbark hickory (*Carya ovata*), and *Q. muehlenbergii* were primary canopy components, and American ash (*Fraxinus americana*), hackberry (*Celtis* spp.), and redbud (*Cercis canadensis*) were primary understory components. In addition, no *Carya* spp. was found in the understory of this stand. Many of the fields that were once planted in crops have been converted to native grasslands, which will need to have continued management.

Data Quality

Data were collected throughout STRI by experts using a variety of scientifically-sound methods and were geo-referenced. Vegetation was surveyed less than 5 years ago. The condition STRI vegetation communities warrants significant concern. No data are available to evaluate trends. Our confidence in the assessment was medium.

5.2.15. *Landscape Dynamics*

The NPScape program provides landscape analysis tools and data for measuring the change of landcover/landuse within and around the vicinity of STRI. Landcover data consisted of NLCD raster data for years 2001-2006 and 2007-2011, which identifies landcover and then classifies it into several categories. Landcover data shown significant amount of converted area at all spatial scales, most alarmingly at 3km buffer. A condition of poor was assigned for the large amounts of converted landscape vs natural landscape, with a stable trend due to a lack of fluctuation in values between the two time periods.

Data Quality

Data was provided by NPS and was of the quality recommended for standardized landscape studies for all parks. However, a landscape report for the park has not been completed based on the NPScape program and should be completed to allow for analysis of more landscape factors. Also, while the data is consistent with the NPScape program and of good quality, STRI is significantly smaller than many of the parks within the NPS system and due to its smaller size, would benefit from the use of higher resolution data for analysis landcover. This would reflect a more thorough understanding of landcover/landuse with less room for error due to the improved resolution.

Table 45. Indicator-level summary table - Air Quality.

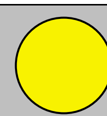
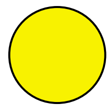
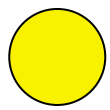
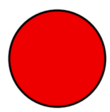
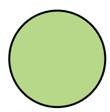
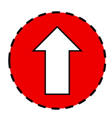
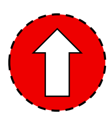
Air Quality			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Ozone	5-Year Average of the Annual 4th-Highest 8-Hour Concentration		The estimated ozone concentration for 2006–2010 at the park was 73.7 parts per billion (ppb), which warrants moderate concern based on NPS Air Resource Division benchmarks.
Foliar Injury	3 month 8-to-8 W126 Statistic Below the 7 – 15 ppm-hr range		The estimated average W126 statistic for 2006-2010 at the park was 12.8 ppm-hrs. A CUPN ozone monitor reported a W126 value of 3.5 in 2010.
Foliar Injury	Risk based upon Kohut Assessment		Twenty-two ozone-sensitive plant species are found in the park and the park is at high risk for ozone injury to vegetation.
Foliar Injury	Number of Species with Injury		No species with injury found in 2010 CUPN sampling. However, those results should not be expected to be typical since ozone concentrations in the region are generally high enough to cause injury.
Deposition of Nitrogen or Sulfur	Nitrogen or sulfur concentrations		Total wet deposition for nitrogen and sulfur at STRI is 4.8 kg/ha/yr and 5.0 kg/ha/yr, respectively. Both values are above the “significant concern” threshold of 3.0 kg/ha/yr. Due to slightly decreasing nitrogen and sulfur concentrations, a positive trend is assigned. However, as data for STRI was largely interpolated, confidence in nitrogen and sulfur concentration values are low.
Particulate Matter and Visibility	Haze Index		All 5-year periods show haze index values of greater than 8 dv. For this reason, a condition of “significant concern” was assigned. However, haze index and visibility conditions values are decreasing. Due to the lowering haze index values, a positive trend is assigned. However, as data for STRI was largely interpolated, confidence in haze index values is low.

Table 46. Indicator-level summary table – Weather and Climate.

Weather and Climate			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Weather and Climate	Precipitation and Temperature Measurements		Due to the nature of weather and climate, a condition assessment is not suitable. The periods measured in both the precipitation and temperature datasets showed a steady and unchanging trend.

Table 47. Indicator-level summary table - Geology.

Geology			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
None	None		None

Table 48. Indicator-level summary table – Surface Water.

Surface Water			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
pH	Meet TN Fish and Wildlife standard		0% of pH measurements fell below the TN lower standard for Fish and Wildlife of 6.0 SU
Dissolved Oxygen	TN standard		20% of measurements fell below the TN standard for Fish and Wildlife of 4.0 mg/l for Subecoregion 71i. Nearly all low readings are from a natural condition of park springs
Water Temperature	TN standard		0% of temperature measurements were above the TN standard for Fish and Wildlife of 86.9˚F/30.5˚C

Table 45 (continued). Indicator-level summary table – Surface Water.

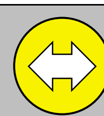
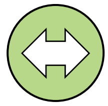
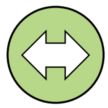
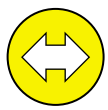
Surface Water			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Specific Conductivity	Not to exceed one standard deviation above the maximum value (as of 1-1-14) per site		There is no TN standard for specific conductivity. STRI waters reflect the geology of limestone watersheds.
Nitrate	Not to exceed USEPA recommended levels. (B)		0% exceeded the USEPA recommendation for freshwater life (90 mg/l) or the USEPA drinking water standard of (45 mg/l).
Escherichia coli	Not to exceed TN standard of 487 CFU/100ml. (A)		9% exceeded the TN recreational standard for Fish and Wildlife *E. coli* standard. High bacteria are always associated with runoff events.

Table 49. Indicator-level summary table – Biological Integrity.

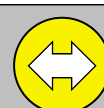
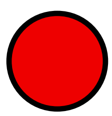
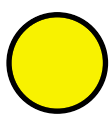
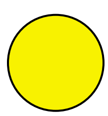
Biological Integrity			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Invasive Plants	Invasive (Exotic) Plant Species Threat		The condition of STRI invasive/exotic plants warrants significant concern. Confidence in our assessment was high due to extensive, scientifically sound data maintained over many years.
Wetland Community	Quality of Wetland Areas		The condition of the wetlands at STRI warrants moderate concern, considering that all of the wetlands in the park have been impacted by land-use history.
Aquatic Insect Assemblages	Freshwater Aquatic Insect Condition		Robinson (2012) reported an EPT richness value of 22 for STRI. Based on Parker (2003) this value falls near the lower limit of a fair/good assessment (i.e., 19-27). As a result a condition of moderate concern was assigned to STRI. No trend data is available for the aquatic insect population at this time. The confidence in the assessment was medium.

Table 46 (continued). Indicator-level summary table – Biological Integrity.

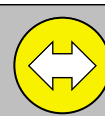
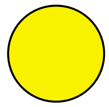
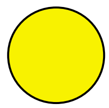
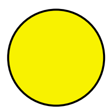
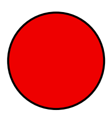
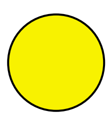
Biological Integrity			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Bird Assemblages	Avifauna Assemblage Condition		The condition of bird assemblages at STRI warrants moderate concern due the relatively low number of confirmed breeders, presence of non-native species, and lack of certain species due to land-use history and suitable habitat. Moreover, confirmation of breeding for rare species is needed along with habitat management. No trend was assigned at this time. Confidence in our assessment was medium.
Cedar Glades	Cedar Glade Health		The condition of STRI cedar glades warrants moderate concern. Although much effort has been devoted by STRI in preserving and in reducing impacts (e.g., foot traffic) to glades in the park, little is known about the long-term viability/stability of them. No trend was assigned at this time, as only a baseline study has been conducted.
Fish Assemblages	Fish Population Quality		The quality of the fish assemblage at STRI warrants moderate concern. Although about a quarter of the fish species known to occur in riverine systems associated with STRI were recorded, some pollution intolerant species were few in number and excessive siltation is a major problem. Moreover, the Index for Biotic Integrity ranked STRI's riverine system mostly as fair. The confidence in the assessment was moderate.
Herpetofauna Assemblages	Reptile/ Amphibian Species Abundance		The condition of STRI herpetofauna warrants significant concern. STRI contains 29 species of amphibians and reptiles. However, certain expected species were absent probably due to land-use history at STRI and the environs. No trend is established at this time without more than a baseline study.
Mammal Assemblages	Mammal Species Quality		The condition of STRI mammals warrants moderate concern. STRI contains 25 species of mammals, which make up 93% of the expected species to occur in the area. Since the inventory, 3 additional species have been recorded. The reason that some species known to occur in the region were not found at the park was due to land use prior to park establishment, the highly fragmented habitat at the park, and the lack of adequate corridors for re-colonization by extirpated species. Not enough data is yet available to establish a trend.

Table 46 (continued). Indicator-level summary table – Biological Integrity.

Biological Integrity			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Vegetation Communities	Vegetation Community Quality		The condition STRI vegetation communities warrants significant concern, primarily due to the prevalence of exotic species, the highly disturbed land-use history of the park, and the high proportion of urban interface surrounding the park. No data are available to evaluate trends. Although experts did adequate sampling, additional work over time would allow for increased confidence.

Table 50. Indicator-level summary table – Landscape Dynamics.

Landscape Dynamics			
Indicator of Condition	**Specific Measure**	**Condition Status/Trend**	**Rationale**
Landscape Dynamics	Landscape dynamics and		Because STRI is surrounded by converted land, landscape dynamics is ranked as warranting significant concern. At this time, there is no change in the trend.

5.3. Geospatial Data

Geographic Information Systems (GIS) resources are available at STRI, but are not being utilized to their full potential. While many GIS datasets exist, they are largely disconnected from each other and lack proper context that would allow for future use. One of the largest issues is the lack of metadata/standardization for the vast majority of the files, which means that the datasets do not comply with federal standards (FGDC) and limits the utilization of the data by anyone other than their creator. Implementation of GIS best practices would allow STRI to effectively produce, maintain, and make effective use of their geospatial infrastructure. Given that GIS technologies are an integral component of modern environmental monitoring and management, it is strongly recommended that STRI invest in this area, as it can have a positive impact on every other area of environmental concern.

6. Literature Cited

Abolins, M.J. 2014. Undergraduates discovering folds in flat strata: an unusual undergraduate geology field methods course. *Journal of Geoscience Education* 62: 264–277.

Adams, D.A., J.L. Walck, R.S. Howard, and P. Milberg. 2012. Forest composition and structure on glade-forming limestones in middle Tennessee. *Castanea* 77: 335-347.

Albrecht, M.A., and McCue, K.A. 2010. Changes in demographic processes over long time scales reveal the challenge of restoring an endangered plant. *Restoration Ecology* 18: 235-243.

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson. M. Pyne, M. Reid, L. Sneddon, and A.S. Weakley. 1998. International classification of ecological communities: terrestrial; vegetation of the United Stated. Volume II. The National Vegetation Classification System: list of types. The Nature Conservancy, Arlington, VA.

Anderson, R.C., J.M. Baskin, and J.S. Fralish. 2007. Savannas, Barrens, and Rock Outcrop Plant Communities of North America. Cambridge University Press, Cambridge, UK.

Andren, H. 1994. Effects of habitat fragmentation on bird and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* 71: 355-366.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. USEPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Bolen, E.G., and W.L. Robinson. 2003. Wildlife Ecology and Management. Prentice Hall, Upper Saddle River, NJ.

Borgmann, K.L., and A.D. Rodewald. 2004. Nest predation in an urbanizing landscape: the role of exotic shrubs. *Ecological Applications* 14: 1757–1765.

Bowen, B. 2011. Natural areas protection at its best; protecting the Tennessee purple coneflower (*Echinacea tennesseensis*). *Natural Areas Journal* 31: 326-330.

Brinson, M. 1993. A hydrogeomorphic classification for wetlands. Technical Report WRP-DE-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Cartwright, J.M. 2014. Soil ecology of a rock outcrop ecosystem: abiotic stress, soil respiration, and microbial community profiles in limestone cedar glades. Dissertation. Tennessee State University, Nashville.

Choate, J.R., J.K. Jones, Jr., and C. Jones. 1994. Handbook of the Mammals of the South-Central States. Louisiana State University Press, Baton Rouge.

Clark, W.C. 1985. Scales of climate impacts. *Climatic Change* 7: 5-27.

Cofer, M.S., J.L. Walck, and S.N. Hidayati. 2008. Species richness and exotic species invasion in middle Tennessee cedar glades in relation to abiotic and biotic factors. *Journal of the Torrey Botanical Society* 135: 540-555.

Conant, R., and J.T. Collins. 1991. A Field Guide to the Reptiles and Amphibians of Eastern/Central North America. Houghton Mifflin, Boston.

Conard, R. 2011. The changing face of the country: environmental history and the legacy of the Civil War at Stones River National Battlefield. *The George Wright Forum* 28: 161-181.

Cowardin, L.M., V. Carter, F.C. Golet, and L.T LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, DC.

Crabtree, T. 2014. Rare plant list. Tennessee Natural Heritage Program, Nashville, TN.

Cumberland Piedmont Network (CUPN). 2013. Forest Vegetation Resource Brief - Stones River NB. Resource Brief-2203535.

Davey, C.A., K.T. Redmond, and D.B. Simeral. 2007. Weather and Climate Inventory, NPS, Cumberland Piedmont Network. Natural Resource Technical Report NPS/CUPN/NRTR—2007/009. NPS, Fort Collins, Colorado.

Davis, C.R., and Hansen, A.J. 2011. Trajectories in land use change around US National Parks and challenges and opportunities for management. *Ecological Applications*, 21: 3299-3316.

Dukes, J.S., and H.A. Mooney. 1999. Does global change increase the success of biological invasions? *Trends in Ecology and Evolution* 14: 135-139.

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

Faaborg, J. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267: 93-102.

Fancy, S.G., J.E. Gross, and S.L. Carter. 2009. Monitoring the Condition of Natural Resources in US National Parks. *Environmental Monitoring and Assessment* 151:161-174.

Farmer, J.J., and E.F.P. Hollyday. 1999. Regional Subsurface Correlation of the Pierce Limestone and Adjacent Limestones of Middle Tennessee. Tennessee Department of Environment and Conservation, Nashville, TN.

Frost, C. 1998. Presettlement Fire Frequency Regimes of the United States: A First Approximation. *In* Teresa L. Pruden and Leonard A. Brennan (eds.). Fire in Ecosystem Management: Shifting the

Paradigm from Suppression to Prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

Ford, B., S. Carr, C. Hunter, J. York, and M. Roedel. 2000. Partners in Flight Bird Conservation Plan: Physiographic Area 14: The Interior Low Plateaus. Draft version. American Bird Conservancy.

Furness, R.W., and J.J.D. Greenwood. 1993. Birds as Monitors of Environmental Change. Chapman and Hall, London.

Galloway, J.J. 1919. Geology and natural resources of Rutherford County, Tennessee. Bulletin 22: Tennessee Division of Geology, Nashville, TN.

Gibbons, J.W., and K.A. Buhlmann. 2001. Reptiles and amphibians. Pages 372-390 *in* J.G. Dickson, editor. Wildlife of southern forests: habitat and management. Hancock House Publishers, Blaine, WA.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of reptiles, Déjà Vu amphibians. *BioScience* 50: 653-666.

Gordon, D.R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: lesson from Florida. *Ecological Applications* 8: 975-989.

Gross, J.E., L.K. Svancara, and T. Philippi. 2009. A guide to interpreting NPScape data and analyses. NPS, Fort Collins, CO.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley. M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, VA.

Hall, E.R. 1981. The mammals of North America, 2 vol. John Wiley and Sons Ltd., New York.

Hogan, T.L., and M. Webber. 1999. Vascular flora of Stones River National Battlefield including notes on natural communities and rare species. National Park Service.

Hogan, T., R. Sutter, and N. Rudd. 1995. Vascular plant inventory, baseline and photo point monitoring, and rare species monitoring of the calcareous glades of Stones River National Battlefield. National Park Service.

Hunt-Foster, R., Kenworthy, J.P., Santucci, V.L., Connors, T.L., and Thornberry-Ehrlich. 2009. Paleontological resource inventory and monitoring-Cumberland Piedmont Network. Natural Resource Technical Report NPS/NRPC/NRTR-2009/235: Natural Park Service, Fort Collins, Colorado.

Jernigan, J.W., B. Carson, and T. Leibfreid. 2011. Cumberland Piedmont Network ozone and foliar injury report – Chickamauga and Chattanooga NMP, Mammoth Cave NP and Stones River NB: Annual report 2010. Natural Resource Data Series NPS/CUPN/NRDS—2011/219. National Park Service, Fort Collins, Colorado.

Jernigan, J.W., B.C. Carson, and T. Leibfreid. 2012. A protocol for monitoring ozone and foliar injury throughout the Cumberland Piedmont Network. Natural Resource Report NPS/CUPN/NRR—2012/559. NPS, Fort Collins, Colorado.

Jernigan, J.W. 2014. *Cumblerand Piedmont Network (CUPN) Natural Resource Condition Summary Table for STRI Air Quality*. Retrieved from http://science.nature.nps.gov/im/units/cupn/parks/stri.cfm?tab=1#products (accessed November 3rd, 2014).

Jordan, T.R., and M. Madden. 2010. Digital vegetation maps for the NPS Cumberland-Piedmont I&M network. Natural Resource Technical Report NPS/CUPN/NRTR – 2010/406.

Kellog, R. 1939. Annotated list of Tennessee mammals. Proceedings of the United States National Museum 86: 245-303.

Kennedy, M.L. 1991. Annotated checklist of the mammals of western Tennessee. *Journal of the Tennessee Academy of Science* 66: 183-185.

Kennedy, M.L., and H.L. LaMountain. 2007. Inventory of mammals at Stone River National Battlefield. Nation Park Service.

Kenney, M.A., A.E. Sutton-Grier, R.F. Smith, and S.E. Gresens. 2009. Benthic macroinvertebrates as indicators of water quality: The intersection of science and policy. *Terrestrial Arthropod Reviews* 2(2): 99- 128.

Kohut, R. 2007. Assessing the risk of foliar injury from ozone on vegetation in parks in the US NPS's Vital Signs Network. *Environmental Pollution* 149:348-357.

Leibfreid, T.R., R.L. Woodman, and S.C. Thomas. 2005. Vital Signs Monitoring Plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype Monitoring Program: July 2005. NPS, Mammoth Cave, Kentucky.

LeFohn, A.S. and V.C. Runeckles. 1987. Establishing standards to protect vegetation -- ozone exposure/dose considerations. *Atmospheric Environment* 21(3): 561-568.

Loss, S.R., T. Will, and P.P. Marra. 2013. The impact of free-ranging domestic cats on wildlife of the United States. *Nature Communications* 4: 1396. DOI: 10.1038/ncomms2380.

McKee, D.M. 1986. Survey of the fishes of the Upper Stones River, Tennessee. Thesis. Middle Tennessee State University, Murfreesboro, TN.

Meffe, G.K., C.R. Carroll, and Contributors. 1997. Principle of conservation biology. Sinauer Associates, Inc., Sunderland, MA.

Meiman, J. 2005. Cumberland Piedmont Network Water Quality Report, Stones River

National Battlefield. Published report, Mammoth Cave National Park, KY.

Meiman J. 2005. Cumberland Piedmont Network Water Quality Report; Stones River National Battlefield. Mammoth Cave, KY. Unpublished Report-2184818.

Meiman J. 2010. Stones River National Battlefield Water Quality Summary Fiscal Year 2010. Resource Brief-2194321.

Miller, B.T., J. Spiess, and M.L. Niemiller. 2005. Inventory of amphibians and reptiles of Stones River National Battlefield. NPS.

Monahan, W.B., J.E. Gross, L.K. Svancara, and T. Philippi. 2012. A guide to interpreting NPScape data and analyses. Natural Resource Technical Report NPS/NRSS/NRTR—2012/578. NPS, Fort Collins, Colorado.

Mullen, D. 2006. Fish Inventory at Stones River National Battlefield. Unpublished Report. Department of the Interior, NPS, Cumberland Piedmont Network.

National Oceanic and Atmospheric Administration, National Climatic Data Center. 2014. *Annual Climatological Summary, 1893-2014* [Data Set].

National Park Service (NPS). 1998. Director's Order #18: Wildland Fire Management.

NPS. 1999. Stones River National Battlefield General Management Plan 1999. US Department of the Interior.

NPS. 2003a. Stones River National Battlefield Fire Management Plan 2003. US Department of the Interior.

NPS. 2003b. Environmental Assessment for the Fire Management Plan at Stones River National Battlefield. US Department of Interior.

NPS Air Resources Division. 2004. Assessing the Risk of Foliar Injury from Ozone on Vegetation in Parks in the Cumberland/Piedmont Network.

NPS. 2007. Landscape Dynamics in Cumberland Piedmont Parks. NPS. Resource Brief-2197583.

NPS. 2008. Air Atlas summary tables for I&M Parks. Available at http://www.nature.nps.gov/air/permits/aris/networks/docs/SummariesAirAtlasRevised11072003.pdf (accessed June 16, 2014).

NPS. 2009. Stones River National Battlefield Integrated Pest Management Plan. US Department of the Interior.

NPS. 2010. Rating air quality conditions. Air Resources Division, Natural Resources Program Center. NPS, Denver, Colorado. http://www.nature.nps.gov/air/Planning/docs/20100112_Rating-AQ-Conditions.pdf (accessed 29 June 2014).

NPS. 2012a. National Park Service Inventory and Monitoring Program. Available at http://science.nature.nps.gov/im/ (accessed June 16, 2014).

NPS. 2012b. NPS Air quality estimates: ozone, wet deposition, and visibility. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm (accessed June 1, 2014).

NPS, Air Resources Division. 2013. Air quality in national parks: trends (2000–2009) and conditions (2005–2009). Natural Resource Report NPS/NRSS/ARD/NRR—2013/683. NPS, Denver, Colorado.

NPS. 2013a. Inventory & Monitoring (I&M). (n.d.). Available at http://science.nature.nps.gov/im/units/cupn/monitor/waterquality.cfm (accessed September 19, 2014).

NPS. 2014a. Stones River National Battlefield Fire Management Plan 2014. US Department of the Interior.

NPS. 2014b. Annual Park Recreation Visitation (1904-Last Calendar Year), Stones River National Battlefield. Available at https://irma.nps.gov/Stats/SSRSReports/Park Specific Reports/Annual Park Recreation Visitation (1904 - Last Calendar Year)?Park=STRI (accessed March 17, 2015).

NPS. n.d. Stones River National Cemetery. Retrieved from Civil War Era National Cemetery: Honoring Those who Served: http://www.nps.gov/history/nr/travel/national_cemeteries/Tennessee/Stones_River_National_Cemetery.html (accessed 3 September 2014).

NatureServe. 2004. International ecological classification standard: international vegetation classification. NatureServe, Arlington, VA.

Niemiller, M.L., R.G. Reynolds, B.M. Glorioso, J. Spiess, and B.R. Miller. 2011. Herpetofauna of the cedar glades and associated habitats of the Inner Central Basin of middle Tennessee. *Herpetological Conservation and Biology* 6: 135-149.

North American Bird Conservation Initiative, U.S. Committee. 2009. The state of the birds, United States of America, 2009. U.S. Department of Interior, Washington, DC.

Nordman, C.W. 2004. Vascular plant community classification for Stones River National Battlefield. NatureServe, Durham, NC.

Ollinger, S.V., J.D. Aber, and P.B. Reich. 1997. Simulating ozone effects on forest productivity: interactions among leaf-, canopy-, and stand-level processes. *Ecological Applications* 7:1237-1251.

Omernik, J., and Griffith, G. 2009. Ecoregions of Tennessee (USEPA). Retrieved from http://www.eoearth.org/view/article/152206 (accessed April 15, 2014).

O'Neill, R.V., J.R. Krummel, R.H. Gardner, G. Sugihara, B. Jackson, D.L. DeAngelis, B.T. Milne, M.G. Turner, B. Zygmunt, S.W. Christensen, V.H. Dale, and R.L. Graham. (1988) Indices of landscape pattern. *Landscape Ecology*, 1: 153-162.

Palmer, W.C. 1965. Meteorological Drought. Office of Climatology. U.S. Government Printing Office, Washington, D.C.

Parker, C.R. 2003. A benthic macroinvertebrate monitoring program for Big South Fork

National River and Recreation Area. US Geological Survey. National Park Service.

Parmer, H.E.1985. Birds of the Nashville area. 4th edition. Nashville Chapter, Tennessee Ornithological Society, Nashville, TN.

Radeloff, V.C., S.I. Stewart, T.J. Hawbaker, U. Gimmi A.M. Pidgeon, C.H. Flather, R.B. Hammerand D.P. Helmers. 2010. Housing growth in and near United States protected areas limits their conservation value. Proceedings of the National Academy of Sciences of the United States of America, 107: 940-945.

Ray, J. 2004. Ozone Monitoring Protocol: Guidance on Selecting and Conducting Ozone Monitoring. National Park Service Air Resource Division Research and Monitoring Branch, Lakewood, CO.

Ray, J.D. 2013. Annual data summary 2011: Gaseous pollutant monitoring program. Natural Resource Data Series NPS/NRSS/ARD/NRDS—2013/443. National Park Service, Denver, Colorado.
http://www.nature.nps.gov/air/Pubs/pdf/ads/2011/NPS_GPMP_Annual_Data_Summary_2011_1-31-2013.pdf (accessed December 5, 2014).

Redmond, W.H., and A.F. Scott. 1996. Atlas of amphibians in Tennessee. The Center for Field Biology, Austin Peay State University, Clarksville, TN.

Reed, P.B. 1998. National list of plant species that occur in wetlands: 1988 national summary. Biological Report 88 (24). U.S. Fish and Wildlife Service, St. Petersburg, FL.

Roberts, T.H., and K.L. Morgan. 2006. Inventory and classification of wetlands at Stones River National Battlefield, Murfreesboro, Tennessee. National Park Service.

Robinson, J.L. 2012. Patterns of ecological performance and aquatic insect diversity in high quality protected area networks. Dissertation. University of Tennessee, Knoxville, TN.

Sauer, J.R., and W.A. Link. 2011. Analysis of the North American Breeding Bird Survey using hierarchical models. *Auk* 128: 87-98.

Springer, M.E., and J.A. Elder. 1980. Soils of Tennessee. The University of Tennessee Ag. Sta. Knoxville. USDA Soil Conservation Service Bulletin 596.

Stark B.P., and A.D. Smith. 1998. *Neoperla coosa* (Plecoptera: Perlidae), a new stonefly species for Alabama. *Entomological News* 109(3):153-158.

Stedman, S.J., and B.H. Stedman. 2006. Final report of bird inventory: Stones River National Battlefield, 2003-2005. National Park Service.

Stoddard. J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.J. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. *Ecological Applications* 16(4):1267-1276.

Stones River National Battlefield. 2009. Integrated pest management plan. First edition. National Park Service.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodriguez, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783-1786.

Summer, H., and C. Nordman. 2008. Accuracy assessment: Stones River National Battlefield. NatureServe, Durham, NC.

Sundin, G., L. Worsham, N.P. Nibbelink, M.T. Mengak, and G. Grossman. 2013. Natural Resource Condition Assessment for Fort Donelson National Battlefield. Natural Resource Report NPS/FODO/NRR—2013/621. National Park Service.

Tennessee Department of Environment and Conservation (TDEC). 2011. Rules of Tennessee Department of Environment and Conservation, Tennessee Water Quality Control Board, Division of Water Pollution Control. Chapter 1200 4-3.

Tennessee Exotic Pest Plant Council. 2001. Invasive Exotic Pest Plants in Tennessee. Tennessee Exotic Pest Plant Council. Available at http://www.tneppc.org/Invasive_Exotic_Plant_List/The_List.html

Tennessee Exotic Pest Plant Council. 2009. Invasive Exotic Pest Plants in Tennessee. Tennessee Exotic Pest Plant Council. Available at http://www.tneppc.org/invasive_plants (accessed February 11, 2015).

Thornberry-Ehrlich, T.L. 2012. Stones River National Battlefield: Geologic resources inventory report. Natural Resources Report NPS/NRSS/GRD/NRR-2012/566: NPS, Fort Collins, Colorado.

Tuberville, T.D., J.D. Willson, M.E. Dorcas, and J.W. Gibbons. 2005. Herpetofaunal species richness of southeastern national parks. *Southeastern Naturalist* 4: 537-569.

United States Army Corps of Engineers. 1987. Corp of Engineers wetlands delineation manual. WRP Technical Note Y-87-1. U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

United States Census Bureau. 2014. Murfreesboro (city), Tennessee. Washington, D.C. Available at http://quickfacts.census.gov/qfd/states/47/4751560.html (accessed April 15, 2014).

United States Department of the Interior. 1999. Stones River National Battlefield: General Management Plan. National Park Service.

United States Environmental Protection Agency (USEPA). 1996. Biological Criteria: Technical guidance for stream and small rivers, revised edition. Report # EPA-822-B-96-001. Office of Water. Washington D.C.

USEPA. 1997. Volunteer Stream Monitoring: A Methods Manual.

USEPA 841-B-97-003, Office of Water.

USEPA. 2009. Air quality index: A guide to air quality and your health. EPA-456/F-09-002. Office of Air Quality Planning and Standards, Outreach and Information Division, Research Triangle Park, NC.

USEPA. 2010. Waterbody Report for West Fork of the Stones River. Available at http://iaspub.epa.gov/tmdl/attains_waterbody.control?p_list_id=TN05130203018_3000&p_cycle=2010&p_state=TN&p_report_type=T (accessed August 30, 2014).

USEPA. 2008. National air quality: Status and trends through 2007. EPA-454/R-08-006. Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC.

USEPA. 2010. Waterbody Report for Lytle Creek of the Stones River. Available at http://iaspub.epa.gov/tmdl/attains_waterbody.control?p_au_id=TN05130203022_1000&p_cycle=2010 (accessed August 30, 2014).

USEPA. 2011. Ozone - Good up high bad nearby. Available at http://www.epa.gov/oar/oaqps/gooduphigh/good.html#1 (accessed September 9, 2014).

USEPA. 2013. Air & radiation: particulate matter. Available at http://www.epa.gov/air/particlepolution/basic (accessed June 29, 2014).

USEPA. 2014. Climate impacts on ecosystems. Available at http://www.epa.gov/air/particlepolution/basic (accessed September 19, 2014).

Van Dyke, F. 2003. Conservation biology: foundations, concepts, applications. McGraw-Hill, Boston, MA.

Walck, J.L. 2006. Yam eradication and site restoration. National Park Service.

Wallace. J.B., and J.R. Webster. 1996. The role of macroinvertebrates in stream ecosystem function. *Annual Review of Entomology* 41:115-139.

Wiens, J.A. 1989. Spatial scaling in ecology. *Functional Ecology* 3: 385-397.

Wilson, C.W., Jr., 1964, Geologic Map and Mineral Resources Summary of the Walterhill Quadrangle, Tennessee: Tennessee Division of Geology, Nashville, TN.

Wilson, C.W., Jr., 1965, Geologic Map and Mineral Resources Summary of the Murfreesboro Quadrangle, Tennessee: Tennessee Division of Geology, Nashville, TN.

Wiss, Janney, Elstner Associates, Inc. & John Milner Associates, Inc. 2007. Stones River National Battlefield Cultural Landscape Report.

Withers, D.I. (compiler). 2009. A guide to the rare animals of Tennessee. Division of Natural Areas, Tennessee Department of Environment and Conservation, Nashville, TN.

Worsham, L, G. Sundin, N. Nibbelink, G. Grossman, and M. Mengak. 2013. Natural resource condition assessment for Big South Fork National River and Recreation Area. Natural Resource Report NPS/BISO/NRR—2013/619. NPS, Fort Collins, CO.

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