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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Guilford Courthouse National Military Park

Natural Resource Report NPS/GUCO/NRR—2017/1372

ON THE COVER
Battlefield scene at Guilford Courthouse National Military Park. Photo by NPS (Stephen Ware)

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Natural Resource Report NPS/GUCO/NRR—2017/1372

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Executive Summary

This report provides a comprehensive assessment of the state of natural resources at the Guilford Courthouse National Military Park (GUCO). The primary goals of the NRCA were to: 1) document the current conditions and trends for important park natural resources, 2) list important data and knowledge gaps, and 3) identify some of the factors that are influencing park natural resource conditions. The information delivered in this NRCA can be used to communicate current resource condition status to park stakeholders. It will also be used by park staff to support the implementation of their integrated approach to the management of park resources.

We followed the NPS ecological framework approach and grouped resources into five general categories: air and climate, geologic resources, water, biological integrity, and landscapes. Each of these general categories, referred to as level-one, are further subdivided into level-two and level-three categories. Biological integrity, a level-one category for example, is divided into 3 level-two categories: invasive species, focal species or communities, and at-risk biota. Focal species or communities, in turn, include five level-three categories: wetland communities, riparian communities, forest/woodland communities, aquatic communities, and terrestrial vertebrates. As the categories move from level-one to level-three, the resolution of the data involved also increases. These proposed assessment metrics reflect the input obtained during scoping meetings and site visits, as well as data availability. To the extent possible, each assessment metric was evaluated quantitatively with a final condition level determined by: 1) the amount of deviation from established reference conditions, 2) overall trends, and 3) comparison with other parks or other regional conditions. This NRCA includes assessments of 23 level-three resources.

Since the primary purpose of the NRCA is to provide a snapshot of current conditions we focused largely on the most recent data available. However, temporal trends are important when assessing current conditions for most metrics, such as, LULC changes, climate, air and water quality, thus trends were evaluated where possible. Where relevant inventory and monitoring data were available, these were applied directly to the assessment of resource condition. Where such data are lacking, we relied upon synthesis from existing assessment reports and, in some cases, geospatial analyses (i.e., in assessing adjacent land-cover changes). Reference conditions are based upon both state and federal standards (where available) or target conditions identified by NPS staff. Where reference or target conditions have not yet been established, values and conditions were defined specifically for this NRCA.

As a unit of the National Park System, GUCO is responsible for the management and conservation of its natural resources as mandated by the National Park Service Organic Act of 1916. As a National Historic Site within the National Park Service, GUCO is fundamentally a cultural park under the Historic Sites Act of 1935. Guilford Courthouse comprises approximately 101 hectares (250 acres) within the City of Greensboro in Guilford County, NC and is contained in the upper Cape Fear River drainage. Elevation ranges from approximately 241 to 265 meters (790 to 870 feet) above sea level with land cover consisting of mature hardwood forests, grassland/meadows, two small streams, and a trail system.

GUCO faces a number of resource related issues, many of which are related to its urban setting. The park's resources are threatened by adjacent commercial and residential land uses. Many of the park's vegetative communities have been highly disturbed by past agricultural practices and development, and are considered to be so human-modified that they are of minimal conservation value. The remaining vegetative communities are severely threatened by exotic plants and pests, which are an ongoing management challenge for park managers. These stresses will only increase as population growth and its associated development continue. The greatest land cover change adjacent to GUCO occurred between 1992 and 2001 and consisted mostly of forest loss. This corresponded with a 21% increase in population for Guilford County during the 1990's. From 2001 to 2011, the land cover changes were far less drastic and remained more stable. However, impacts from the adjacent urban land uses warrant moderate concern as they impact most resources within the park.

Regional air quality data for the period from 2008 to 2012 suggest that air quality parameters in the park range from warranting moderate to significant concern. Visibility warrants significant concern. Haze is a serious issue in the eastern U.S. and although trends over the long-term are improving, major reductions in haze are still needed to improve visibility within the park. Estimated deposition of sulfur and nitrogen were high and warrant significant concern. Mercury deposition levels warrant moderate concern based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. Ground-level ozone also warrants moderate concern due to its effects on human health and vegetation. Particulate matter concentrations near GUCO have steadily declined over the past decade. Although the most recent data are below the ecological threshold, there is insufficient long-term data to suggest this is the current trend.

Generally water chemistry in GUCO is in good condition, with the exception of pH, which warrants moderate concern due to surface waters in GUCO having an average pH below the 6.0 standard. Other water chemistry parameters include acid neutralizing capacity, stream water temperature, specific conductance, and dissolved oxygen are within acceptable ranges. Although data is limited, sulfate and nitrate concentrations measured from two sites exceeded reference values. The exceedance of these reference values combined with the observed acidic conditions suggest that the elevated levels of sulfate and nitrate are of moderate concern. *E. coli* values are generally below the EPA threshold, though that threshold was exceeded on a relatively frequent basis. Therefore water quality with respect to bacteria warrants moderate concern. GUCO has limited data on water toxics, and therefore their conditions and trends could not be determined.

The presence of exotic invasive species at GUCO warrants significant concern and is a major threat to the native species and vegetative communities. The high abundance and distribution of the nonnative species within GUCO, as well as adjacent residential and commercial properties, make the control and treatment of these species exceedingly difficult.

The ecological communities in GUCO have experienced stress due to the extensive impact of humans in this area. Wetlands in GUCO appear to be hydrologically intact, but have been altered by timber harvests at some point in the past. The park's two existing wetlands warrant moderate concern. As described above, forest, wetland and riparian communities are suffering from the presence of invasive, exotic species. Both the forest communities and the riparian communities warrant significant concern due to the threat to native species diversity. Within GUCO, there are only five plant species that are considered uncommon in the immediate area, though all of these species are ranked as extremely globally secure. However, there has not been systematic monitoring of these plants until very recently, and as a result there is little information about their population trends.

Reptile and amphibian species diversity warrants significant concern. Numerous species of reptiles, amphibians, and non-volant mammals expected to be present in the park were not found. This is likely due to the loss and alteration of habitat. Diversity of mammalian insectivores and rodents have shown a decline, while abundance of urban tolerant species, such as white-tailed deer, gray squirrels, and raccoon have increased. Therefore mammal species diversity warrants moderate concern, though the condition continues to deteriorate. Volant species, such as birds and bats appear to be in good condition. Current conditions of aquatic communities are generally unknown due to lack monitoring data.

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Chapter 1. NRCA Background Information

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

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

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

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

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

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

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

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

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

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

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

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

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

Important NRCA Success Factors

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

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

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

NRCA Reporting Products…

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

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

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

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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.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Park History and Enabling Legislation

Guilford Courthouse National Military Park (hereafter, also referred to as GUCO and park) was established on March 2, 1917 to commemorate the Revolutionary War Battle which occurred on the site in 1781. Its establishment marked the first battlefield of the American Revolution to be preserved by the Federal Government (NPS 2016).

Long before the Revolution, the land had been settled by Quakers and was mostly cultivated in corn or used as grazing land. Following the end of the war, the land continued to be cultivated, until it eventually came under the ownership of the Guilford Battle Ground Company which was formed in 1887 to "redeem, preserve, and beautify the battleground." As part of its mission to "beautify" the area, the company built a pond and kept much of the area clear of undergrowth and heavy forest (NPS 2016).

Beginning in 1910, the Guilford Battle Ground Company worked to have the property recognized as of national significance and to have it protected as a national preserve. It was not until 1917 that the legislation created the Guilford Courthouse National Military Park. From 1917 to 1933 the land was under the administration of the United States War Department. The "beautification" of the park continued as they planted decorative shrubs and trees and set up several monuments throughout the park. In 1933, all battlefields under the administration of the War Department were transferred to the U.S. Department of the Interior to be administered by the National Park Service. After this transfer the mission of the park changed from one of recreation to one of historic preservation. Many changes occurred to restore the battlefield to its proper historic setting, such as the draining of the lake and the end of intensive land management (NPS 2016).

2.1.2. Geographic Setting

Guilford Courthouse National Military Park comprises approximately 101 hectares (250 acres) within the City of Greensboro in Guilford County, NC and the upper Cape Fear River drainage. Elevation ranges from approximately 241-265 meters (789-869 feet) above sea level with land cover consisting of mature mixed hardwood forest, grassland/meadows, two small streams and a trail system.

The temperate climate of the piedmont region of NC where GUCO is located is characterized by hot summers and mild winters. In a typical year, the park experiences a mean temperature of 15 °C (59 °F) and an average total precipitation amount annually, which mostly falls as rain, of 107 cm (42 inches). Table 2.1.1 shows the monthly precipitation and temperature normals from 1981 to 2010 for Greensboro, NC- the closest National Climatic Data Center station to GUCO. Monthly precipitation in this area remains relatively invariable throughout the year, ranging from approximately 8 to 10 cm (3 to 4 inches) per month. The two wettest months are July and September, in which over 10 cm (4 in) of precipitation typically falls. February is the driest month, with approximately 7.5 cm (2.96 in) of total precipitation normally. January is typically the coldest month in this area, with the average temperature being about 2.8 °C (37 °F), the minimum temperature falling around -1.1 °C (30 °F), and the maximum temperature only rising to about 8.9 °C (48 °F). The warmest month in this area is July, with the average temperature being about 26.1 °C (79 °F), the lowest temperature being approximately 20.5 °C (69 °F), and the highest temperature being about 31.1 °C (88 °F) (National Climatic Data Center 2010).

Table 2.1.1. Monthly precipitation and temperature normal form 1981-2010 in Greensboro, NC (National Climatic Data Center 2010).

Month	Precipitation (Inches)	Minimum Temperature (°F)	Average Temperature (°F)	Maximum Temperature (°F)
January	3.06	29.5	38.9	48.3
February	2.96	32.4	42.4	52.5
March	3.73	39.1	50.0	60.9
April	3.57	47.3	58.8	70.2
May	3.38	56.1	66.8	77.5
June	3.73	65.3	75.1	84.8
July	4.48	69.1	78.5	87.9
August	3.88	68.0	77.1	86.3
September	4.19	60.6	70.2	79.7
October	3.13	48.8	59.5	70.3
November	3.11	39.6	50.2	60.8
December	2.98	32.0	41.3	50.7

2.1.3. Park Visitation

Visitation statistics for GUCO date back to 1937. Peak visitation years are from 1960 to 1974 and from 1996 to 2002. The year 2001 saw the most visitors, with over 858,000 people visiting the park during that year. Prior to 1960, GUCO received on average less than 50,000 visitors each year (Figure 2.1.1) (NPS 2015).

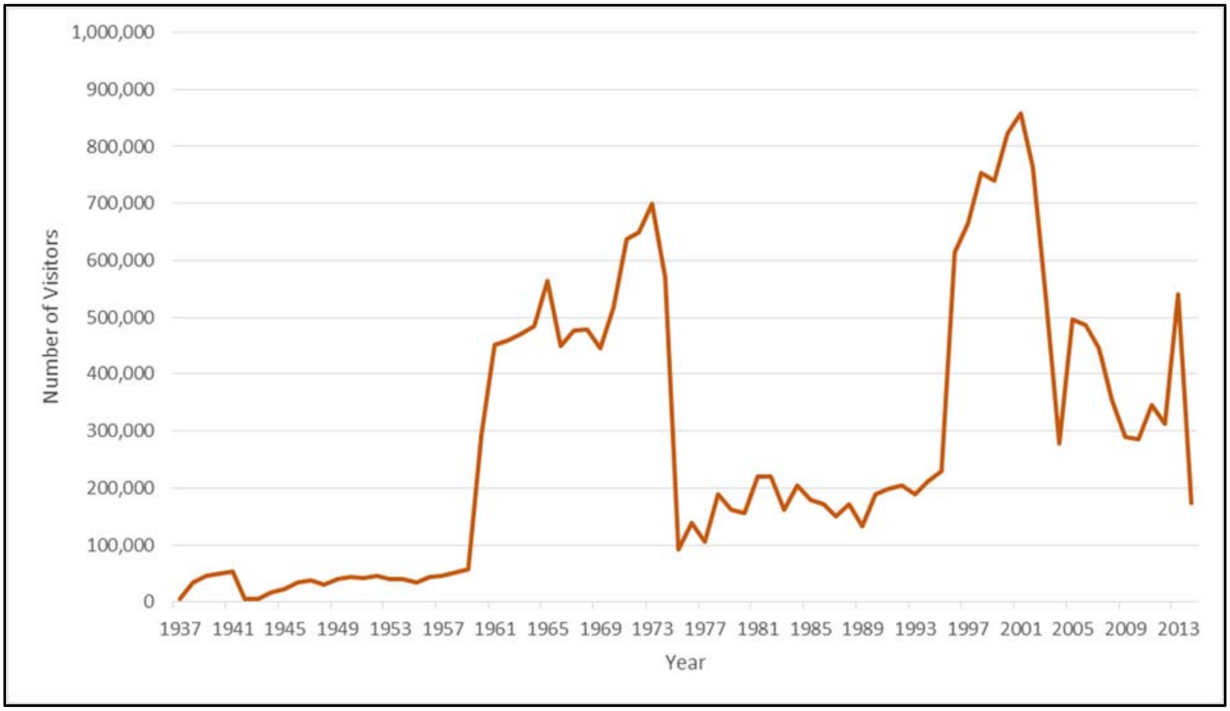


Figure 2.1.1. Annual recreational visitation for GUCO from 1937-2014 (NPS 2015).

2.2. Natural Resources

GUCO is characterized by a mixture of culturally modified vegetation, successional mixed-hardwood forests (White and Pyne 2003) with two small streams and riparian zones occurring mostly within the forested areas.

2.2.1. Ecological Units and Watersheds

GUCO is part of the Piedmont Level III ecoregion which is the transitional area between the mountainous ecoregions of the Appalachians and the flat coastal plain to the southeast. On a finer scale GUCO is split between the Northern Inner Piedmont and the Southern Outer Piedmont Level IV ecoregions. Both of these ecoregions are characterized by dissected irregular plains, low to high hills and ridges, low to moderate gradient streams with mostly cobble, gravel, and sandy substrates. Forests found in these areas are generally mixed oak or oak-hickory-pine forests. Species that are common are white oak (*Quercus alba*), southern red oak (*Quercus falcata*), black oak (*Quercus velutina*), mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), some Virginia pine (*Pinus virginiana*), and shortleaf pine (*Pinus echinata*). On more mesic sites American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), tulip poplar (*Liriodendron tulipifera*), and red maple (*Acer rubrum*) are common as well (EPA 2015).

GUCO is situated near the northern border of the Cape Fear River Basin. This basin extends from southern Rockingham County and southern Caswell County to Brunswick and New Hanover counties, where the Cape Fear River flows into the Atlantic Ocean. Major Cape Fear River tributaries include Haw River and Deep River. These rivers merge and join the Cape Fear River at the border of Chatham and Lee counties. GUCO is located within the sub-watershed of the Haw River.

2.2.2. Resource Descriptions

Soils

Soils in GUCO formed primarily in residuum weathered from high-grade metamorphic rocks that may be high in mica content. This type of parent material in combination with the region's warm, wet climate produces acidic soils with low fertility. There are four principle soil types: Cecil sandy loam, Cecil-Urban land complex, Madison sandy loam, and Wehadkee silt loam (Figure 2.2.1). See section 4.2 for a more thorough description of the soils in GUCO.

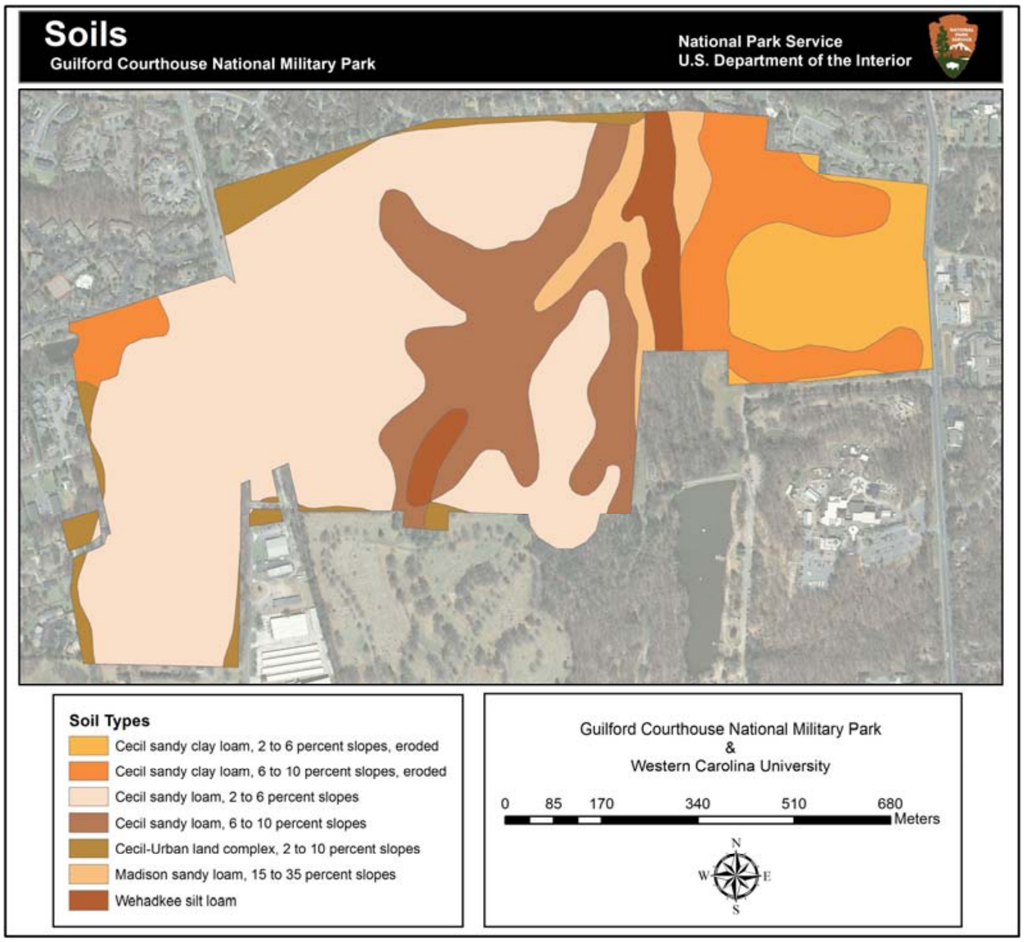


Figure 2.2.1. Soil survey for the Guilford Courthouse National Military Park (USDA NRCS 2016).

Hydrology

There are two small streams that run through the park (Figure 2.2.2). Richland Creek is the main stream that runs through the park and it is located on the eastern side of the park. The other stream, Hunting Creek, flows northeast and joins Richland Creek. Richland Creek eventually flows into Richland Lake located northeast of the park. Water quality is an important indicator of ecological health as poor water quality may impact biota and lead to deterioration of the local ecological health.

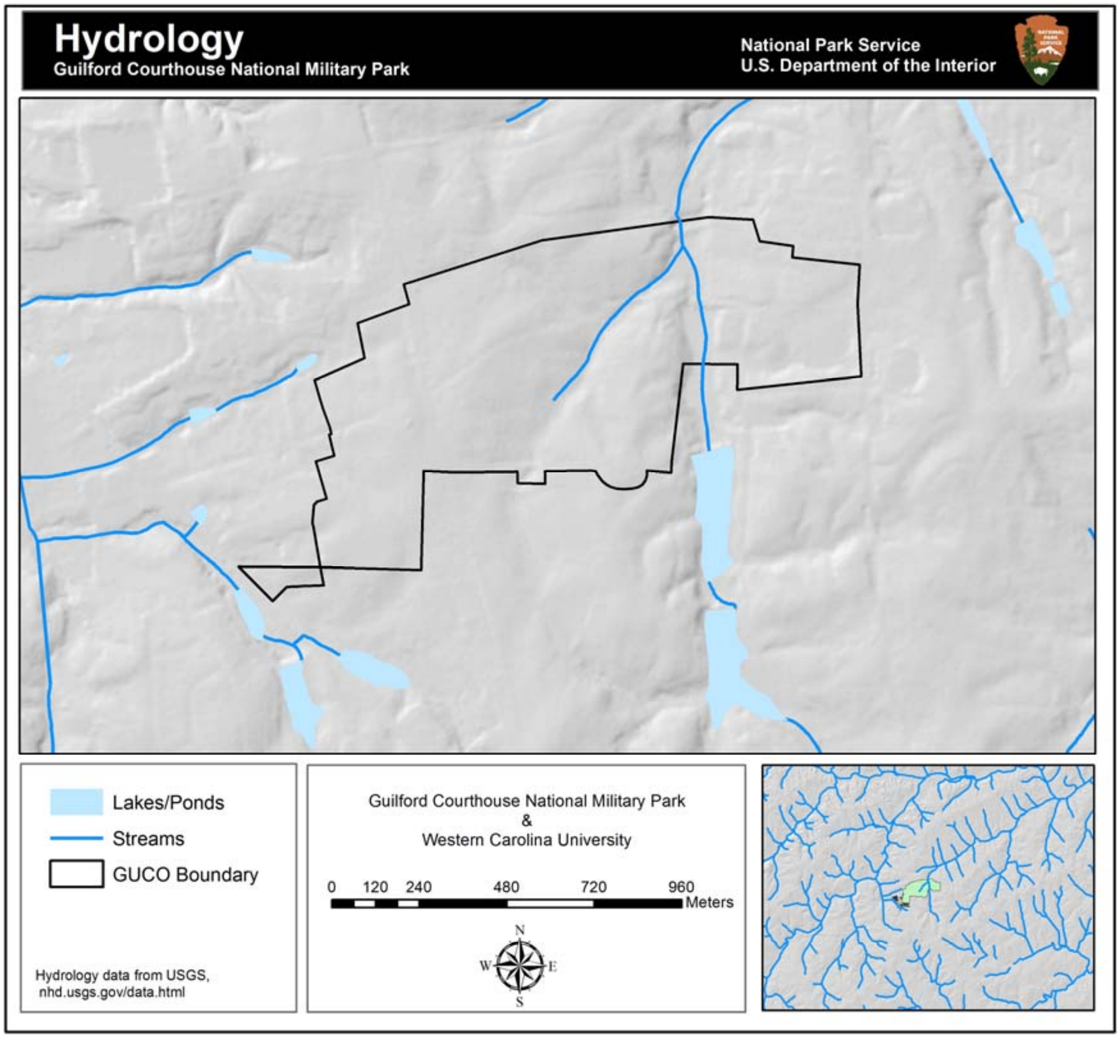


Figure 2.2.2. Streams located within GUCO boundaries.

Wildlife

Wildlife species that live in GUCO are generally relatively widespread and common throughout piedmont North Carolina. Due to the park's urban setting, historical agriculture use, and increasing forest fragmentation many non-volant mammal, reptile, amphibian, and fish species appear to be absent from the park. A study in 2007 by Kalcounis-Ruppell et al. recorded twelve species of non-volant mammals, only 34% of the 35 species expected. Several of the expected reptile and amphibian species were undetected as well (Reed and Gibbons 2005). Bird species at GUCO are by far the most diverse and stable in condition. An inventory conducted by Gerwin and Browning (2006) from January 2005 to June 2006 documented 65 species, the majority of which were year-round residents. Despite its location, GUCO provides wildlife habitat in an otherwise completely urban and suburban setting.

Vegetation

The Center for Remote Sensing and Mapping Science at the University of Georgia mapped eleven vegetation community types as well as infrastructure, ponds, and other anthropogenic land covers, Because of the severe fragmentation and history of human disturbances, there are few intact ecological communities at GUCO (CUPN 2003). In addition, most of the forest is considered successional having originated after 1933 (NPS 2015). Seven upland forest community types were identified. Four of these forest types are considered human modified and are of no commercial value (White and Pyne 2003). These forest types are discussed in section 4.5.3. The Piedmont Small Stream Sweetgum Forest was also identified, and is discussed in section 4.5.2.

2.2.3. Resource Issues Overview

GUCO faces a number of resource related issues, many of which are related to its urban setting surrounded by population growth and commercial and residential land use. The park lies within the city limits of Greensboro, NC and the majority of the surrounding land is developed. Adjacent residential communities threaten park resources for a number of reasons. Septic systems and lawn chemicals are a potential threat to water quality. Threats to wildlife include increasing road traffic and threats due to feral cats and dogs in the park. Another concern for the natural resources is the introductions of invasive plant species crossing over from neighboring residences. Furthermore as the surrounding population continues to grow, visitation rates to the park will continue to increase, placing increased stress on the park's natural resources.

In an effort to minimize development surrounding the battlefield the park has attempted to acquire properties within the adjacent area of GUCO. In total the park encompasses 101 hectares (250 acres), one-fourth of the actual battlefield (NPS 2014).

<u>Air Quality</u>

Air pollution can significantly affect park resources, visitor enjoyment, and public health. Air pollutants can adversely impact water quality, soil pH, vegetation, species distribution, cultural features, visibility, and human health (NPS ARD 2015a). GUCO is located in central North Carolina, a region downwind of many sources of air pollution – some of these sources are nearby, while others are transported from industrial cities of the southeastern and midwestern United States (NPS 2008). Sulfur dioxide and nitrogen oxides from fossil fuel combustion, including electric power generation and automobiles, are the major sources of air pollution in this region (EPA 2015).

Sources of pollution affecting air quality in GUCO include fossil fuel burning power plants, industry, and automobiles. Air pollution from acid deposition has been shown to cause measureable effects on ecosystem structure and function (Likens and Bormann 1974). Sulfur and nitrogen wet deposition values recorded at monitors near GUCO indicate levels are high, exceeding the ecological threshold. Mercury wet deposition for GUCO was moderate, however, predicted methylmercury concentrations in park surface waters were high, warranting moderate concern. Ozone has been recognized as the most widespread air pollutant in eastern North America, causing impacts to human health (EPA 1999). Although levels near GUCO are not as high as those in other urban areas of North Carolina, they do warrant moderate concern. Particle pollution represents one of the most widespread human health threats, possibly greater than ozone because it can occur year-round (EPA 2013). Most recent $PM_{2.5}$ data fall below the ecological threshold, but there is insufficient long-term data suggesting this is the trend and, thus, a moderate concern. Haze is one of the most basic forms of air pollution that degrades visibility across the landscape. Haze is particularly an issue in the eastern U.S., and the region in which GUCO is located has consistently experienced values well in excess of estimated natural conditions. Natural resource managers at GUCO have identified deposition of nitrogen, sulfur, and mercury, and concentrations of ozone and particulate matter, and their impacts on visibility, as air quality concerns for GUCO.

Water Quality

Water quality is an important indicator of ecological health in the park. Threats to water quality in the park include surface runoff from improper trail use or pet waste left behind by visitors. Adjacent residential communities using septic systems and lawn chemicals are also potential threats to water quality. Measurements of water chemistry, including pH, temperature, specific conductance, and dissolved oxygen, were below the reference conditions. Acid neutralizing capacity (ANC), however, remained above the reference condition and warrants moderate concern. Measurements of water toxicity in the park are extremely limited or nonexistent, therefore confidence is low. Four samples from two sites were used to determine sulfate and nitrate concentrations. All eight of these samples exceeded the reference value warranting moderate concern, however, the low sample number contributes to our low confidence. Water quality conditions and trends with respect to trace metals cannot be determined at this time given the lack of data for surface waters within the park. *Escherichia coli (E. coli)* samples in the park occasionally exceeded the reference values and may be associated with the influx of water to the site from lakes within the Greensboro County Park which are utilized extensively by waterfowl (NPS 2012).

Climate Change

Climate is a dominant factor affecting natural and cultural resources in national parks. Climate constantly changes, but we may see changes of unprecedented magnitude in the near future. The Intergovernmental Panel on Climate Change (IPCC 2014) reviewed all global circulation models and concluded that warming over most land areas, with fewer cold days and more warm days, is virtually certain for the rest of the 21st century. There is uncertainty in model projections of the magnitude and timing of the warming trend, but there is agreement on the direction of the trend (IPCC 2014). In addition to temperature increases, climate change may bring unexpected and increased variations in local weather (IPCC 2014). Models predict more frequent occurrences of extreme weather events and these extreme weather events could challenge the ability of park managers to preserve and protect natural and cultural resources (IPCC 2014).

To understand the exposure to climate change that our national parks will likely face in the near future, Monahan and Fisichelli (2014) investigated how recent climates compare to historical conditions for 289 national park units, including GUCO. They found that recent climatic conditions are already shifting beyond the historical range of variability. Two temperature variables they assessed were “extreme warm” (annual mean temperature and mean temperature of the warmest quarter) relative to the 1901-2012 historical range of variability (Monahan and Fisichelli 2014). Future changes are likely and opportunities exist to proactively incorporate possible climate change effects into park management at GUCO, including natural and cultural resource protection as well as park operations and visitor experience.

Exotic Invasive Plant Species

Due to GUCO's urban setting, the threat caused by exotic, invasive species is inevitable. Exotic, invasive species tend to establish around park boundaries, disturbed areas, floodplains, and areas of high use. These plants have the potential to compromise key ecological processes by reducing native species richness and altering community structure.

Soundscape

The soundscape of a national park is defined as the total ambient sound level of the park, which includes both natural ambient sound and human-made sounds (NPS 2000). The mission of the NPS is to preserve the natural resources, including the natural soundscape, associated with national park units. According to the NPS, many visitors come to national parks to equally enjoy both the natural scenery and the natural soundscape. Undesirable sounds impact park visitors, as they detract from their overall park experience (Gramann 1999).

The reference condition for soundscape in any national park is that of an area free from human-made sounds (e.g., vehicles, trains, air traffic, and other human uses), but rather consisting solely of natural sounds such as wind, water, and animal sounds (Ambrose and Burson 2004). Soundscape protocols have been developed by the NPS (2000). As part of these protocols, selected locations have been identified for each park to help determine the soundscape status over a period of one to ten years. These protocols also include various metrics of natural ambient sound levels, natural sound frequencies, and sources of sounds. Additionally, these protocols address soundscape changes in the face of increasing visitor numbers and surrounding development. GUCO is uniquely located in an urban environment and thus experiences the impact of noise from roads within the park. Noise from nearby traffic and urban expansion is attributed to increases in noise and other acoustic impacts over time. Prior studies have indicated the condition of the soundscape at GUCO warrants moderate concern under urban criteria (NPS 2015b). Sound levels in the park are predicted to be above levels that impact visitor experience by causing the audience to miss portions of an interpretive program (NPS 2015).

Chapter 3. Study Scoping and Design

3.1. Preliminary Scoping and Design

This NRCA represents a cooperative agreement between the National Park Service (NPS) and Western Carolina University (WCU). Stakeholders include resource management staff at the Guilford Courthouse National Military Site (GUCO), Cumberland Piedmont I&M Network (CUPN), NPS Southeast Regional Office (SERO), and WCU investigators. An initial site visit and scoping meeting was conducted in February 2013 with most discussion focused upon refining the proposed framework and the availability of additional inventory-monitoring data and existing reports. Preliminary assessment frameworks were provided to NPS in September 2013 and based upon feedback we adopted a modified version of the 2005 NPS ecological monitoring framework (Fancy et al. 2009).

3.2. Study Design

3.2.1. Assessment Framework and Indicators

We developed a hierarchical resource assessment system modified from the NPS Ecological Monitoring Framework. First we divided assessment indicators into more general level-one categories: 1) Air and Climate, 2) Geology and Soils, 3) Water, 4) Biological Integrity, and 5) Landscapes. Each of these categories is further subdivided into more specific level-two and level-three categories (Table 3.2.1). These proposed assessment metrics reflect the input obtained during scoping meetings and site visits as well as data availability. To the extent possible, each assessment metric was evaluated quantitatively with a final condition level determined by: 1) the amount of deviation from established reference conditions, 2) overall trends, and 3) comparison with other parks or other regional conditions. Where relevant inventory and monitoring data were available, these were applied directly to the assessment of resource condition. Where such data are lacking, we relied upon synthesis from existing assessment reports and, in some cases, geospatial analyses (i.e., in assessing adjacent land-cover changes). An overview of the general methods are provided below while more detailed discussions are provided within each assessment section of chapter 4.

Table 3.2.1. Ecological Monitoring framework for GUCO natural resource condition assessment.

Level 1 Category	Level 2 Category	Level 3 Category
Air and Climate	Air Quality	Nitrogen deposition
		Mercury deposition
		Ozone concentration
		$PM_{2.5}$ concentration
		Visibility/haze
Soil & Geologic Resources	Soil Quality	Soil function and dynamics

Table 3.2.1 (continued). Ecological Monitoring framework for GUCO natural resource condition assessment.

Level 1 Category	Level 2 Category	Level 3 Category
Water	Water Quality	Hydrogen concentration and acid neutralizing capacity
		Steam water temperature
		Specific conductance
		Dissolved oxygen concentration
		Dissolved sulfate and nitrate concentration
		Dissolved aluminum concentration
		Metal concentrations
		Coliform bacteria
Biological Integrity	Invasive Species	Invasive/exotic plants
	Focal Species or Communities	Wetland communities
		Riparian communities
		Forest/woodland communities
		Aquatic communities
		Terrestrial vertebrates
	At-risk Biota	Plant species of special interest
Landscapes	Landscape Dynamics	Land

3.2.2. Reporting Areas

Resources were evaluated park-wide, with the exception of air quality and landscape conditions. Air quality monitoring data were available within the region but not specifically at GUCO; thus, the condition assessment was based upon these regional data. Human driven land use changes have occurred both adjacent to the park boundary and throughout the region; thus, condition was based upon multi-scale assessments of land use-land cover change. Species inventory and monitoring data were collected from numerous sites within GUCO and were evaluated in the context of the entire park's land use-land cover.

3.2.3. General Approach and Methods

Where relevant inventory and monitoring data are available, these were applied directly to assessment of resource condition. Where such data were lacking we relied upon more regional data sources and review and synthesis from existing assessment reports and, geospatial analyses. Approaches and methods for each indicator are described separately.

Air Quality

Due to the lack of available on-site air quality monitoring data overall, assessments of acid and mercury deposition were estimated from annual averages obtained from the National Atmospheric Deposition Program – National Trends Network (NADP-NTN 2014), and U.S. Mercury Deposition Network (NADP-MDN 2015). Estimates of annual average ozone concentrations were obtained from the Air Quality System (AQS) monitoring sites (EPA 2013a). For sites without on-site or nearby monitors, these five-year averages were interpolated for all atmospheric deposition monitoring locations (i.e., parks) using an IDW method to estimate five-year average values for sites across the contiguous U.S. Estimated values for each national park unit are made available to the public through the NPS AirAtlas website (NPS ARD 2014). Data used in this assessment consisted of estimated annual averages of total nitrogen and total sulfur wet deposition. Conditions for atmospheric deposition are based on wet deposition in the unit kg/ha/yr because dry deposition data are not available for most areas. Wet deposition for sites within the contiguous U.S. was calculated by multiplying nitrogen or sulfur concentrations in precipitation by a normalized precipitation amount. Annual wet deposition measurements were then averaged over five-year periods spanning the years 1999-2012 at all National Atmospheric Deposition Program – National Trends Network (NADP-NTN 2014) monitoring sites. For sites without on-site or nearby monitors, these five-year averages were interpolated for all atmospheric deposition monitoring locations (i.e., parks) using an inverse distance weighting (IDW) method to estimate five-year average values for sites across the contiguous U.S.

The estimated current nitrogen and sulfur condition for GUCO is derived from the national analysis at the geographic center of the park. Some of the sites from the national analysis are a considerable distance away from GUCO; however, they represent the best available data for this NPS site (NPS 2008, NPS ARD 2014) (Appendix A). A resulting condition greater than 3 kg/ha/yr is assigned a warrants significant concern status; a curret nitrogen or sulfur condition from 1-3 kg/ha/yr is assigned a warrants moderate concern status; a resource is considered in Good Condition if the current nitrogen or sulfur condition is <1 kg/ha/yr (NPS ARD 2013b). Ten-year trends in annual sulfate and nitrate wet deposition are reported using monitoring data from across the U.S. to provide a national and regional context for current conditions reported at GUCO (NPS ARD 2013a).

Water Quality

Five measures were selected for the evaluation of water chemistry. They include two parameters that allow for the characterization of stream water acidification (pH, acid neutralizing capacity) and three measures, including dissolved oxygen (DO), specific conductance, and water temperature that provide insights into the overall water quality of the park. Although temperature is not a chemical parameter, it is included here as it has a strong influence on water chemistry.

Since October, 2004 sampling and water quality analysis have been conducted quarterly on alternating fiscal years at two sites within the park for temperature, specific conductance, pH, dissolved oxygen, and acid neutralizing capacity (ANC). An additional site (Tannenbaum Spring) was added to the monitoring program in October 2009. All data are available, and were obtained for this assessment, from annual water quality reports and the National Park Service's STORET (NPSTORET) database maintained by the NPS' Water Resources Division (NPS WRD).

Wetlands

A wetlands inventory was conducted at GUCO in 2004 (Roberts and Morgan 2006). Characteristics including hydrology, hydric soils, dominant wetland plant species, location, type, estimated size, function and potential value, were recorded for each wetland. A qualitative evaluation using the reported characteristics was used to assess the trend and conditions of the wetlands.

Riparian Communities

Data used in this assessment includes forest characteristics from the Vascular Plant Inventory and Plant Community Classification for Guilford Courthouse National Military Park (White and Pyne 2003) and the digital vegetation map depicting vegetation cover at GUCO (Jordan and Madden 2010). The methodology consisted of a qualitative evaluation of the community type's species composition and biological integrity (i.e., presence or absence of invasive plant species and erosion).

Aquatic Communities

For this report, data and analyses presented in aquatic biological samplings (Long 2005, Parker et al. 2012) were compared to fish and benthos samples collected between 1998 and 2013 from nearby streams as part of the periodic monitoring conducted by the North Carolina Department of Environment and Natural Resources (NCDENR). Long (2005) adopted the Index of Biotic Integrity (IBI) protocol used by NCDENR as described by in their 2001 Standard Operating Procedure manual (NCDENR 2001, current version is 2013a), but modified to fit the limitations of the small stream reaches available for sampling. Under this protocol, sample reaches may be given an integrity score that then may be placed into an Integrity Class. NCDENR also conducts periodic samples of aquatic macroinvertebrates from streams around the state which they use to calculate scores that are in turn used to produce bio classifications (NCDENR 2013b).

Soil Quality

The 1977 Guilford County Soil Survey conducted by the United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS) (Stephens 1977) was the primary source of soils information used in this assessment. A qualitative evaluation of this report was used to identify current condition. No information was available to assess trends.

Exotic Plants

Two documents and one dataset were used in this resource condition assessment. The Nonnative Plant Management Plan for Guilford Courthouse National Military Park was written to help prioritize nonnative species for control and make recommendations for preventative strategies, including education and outreach initiatives (O'Driscoll and Shear 2009). As part of the project, a nonnative plant species inventory was conducted within the forest communities. Sixty-two nonnative forest and forest edge species were documented. Additionally, the authors assigned priorities to species using the Alien Plant Ranking System (APRS) version 5.1 (APRS Implementation Team 2000).

GUCO has adopted Cumberland Piedmont Network's (CUPN) plan for early detection and treatment of invasive species to combat further invasions of network parks (Keefer et al. 2014). This plan uses opportunistic observations to identify the locations of invasive species, and defines habitat-specific treatment recommendations based on the invasive species regional status, impacts, trends, and dispersal dynamics. The goal is to eradicate incipient populations of invasive species before they become widely established. The report identified 17 early detection candidate species and four more species which are being considered for inclusion on the list.

Focal Species & Communities – Vegetation

The current condition and trend of GUCO's focal vegetation communities were evaluated considering the biological integrity of each community as an indicator of their health and long-term viability. We focused on each community's species composition and disturbance patterns. The primary information/data sources for the assessment included a vascular plant and community inventory (White and Pyne 2003), CUPN vegetative monitoring plots (White et al. 2011), and a forest Vegetation Resource Brief (CUPN 2013).

Focal Species & Communities – Vertebrates

Given a lack of baseline information for major terrestrial vertebrate groups, field studies were conducted at GUCO between 2002 and 2006. The condition assessments presented here were based largely upon the findings presented within these reports and assessment of current scientific literature with a focus on the comparison of expected vs. actual occurrences of species within each major group. For reptiles, amphibians, and mammals (including bats) we considered species individually, but based condition estimates on overall composition. For birds (where species richness was much greater) we evaluated abundance within three major habitat guilds based upon information provided by the report authors and published in the literature (O'Connell et al. 2000, Lichstein et al. 2002, Greenberg et al. 2006): a) forest—representing both interior obligates and species generally associated with forest habitat, b) Edge/Generalist—including both forest edge species and overall habitat generalists, and c) Open—species requiring or preferring non-forest type conditions such as pasture/grassland.

Land Use – Land Cover Conditions

Land use-land cover conditions around GUCO were evaluated using the National Land Cover Database for 1992 (Vogelman et al. 2001), 2001 (Homer et al. 2007), 2006 (Fry et al. 2011), and 2011 (Homer et al. 2015). Since the landscape at GUCO has long been residential and agricultural we primarily evaluated the loss of forest land cover in the region with conditions in 1992 used as a starting point and special emphasis placed upon conditions immediately adjacent to GUCO.

Reference Conditions

Where available, state, federal, and NPS specific standards and/or recommendations were used to establish reference conditions for evaluating resources including air and water quality. In addition reference conditions were identified based upon the CUPN Vital Signs monitoring protocols (Leibfreid et al. 2005) which in addition to relevant state and federal standards or target conditions identified by CUPN managers. Where reference or target conditions have not been established the ideal condition of no impact (i.e., no trees exhibiting dogwood anthracnose or zero loss of natural vegetation cover over time), or researcher judgement.

<u>Summary Indicator Symbols</u>

Table 3.2.2. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

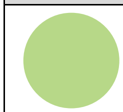
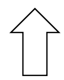
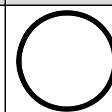
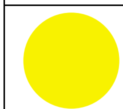
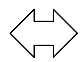
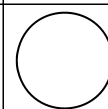
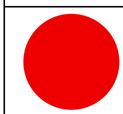
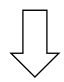
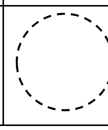
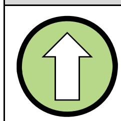
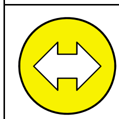
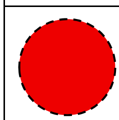
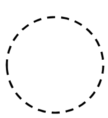
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3.2.3. Example indicator symbols with verbal descriptions.

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

Chapter 4. Natural Resources

4.1. Air Quality

Air pollution can significantly affect park resources, visitor enjoyment, and public health. Air pollutants can adversely impact water quality, soil pH, vegetation, species distribution, cultural features, visibility, and human health (NPS ARD 2015a). Guilford Courthouse National Military Park is located in central North Carolina, a region downwind of many sources of air pollution – some of these sources are nearby, while others are transported from industrial cities of the southeastern and midwestern U.S. Sulfur dioxide and nitrogen oxides from fossil fuel combustion, including electric power generation and automobiles, are the major sources of air pollution in this region (EPA 2015).

There are federal mandates for clean air in national parks as part of the Clean Air Act of 1970 (CAA). The CAA includes special provisions for 48 park units, called "Class I" areas under the CAA; all other NPS areas are designated as Class II, including GUCO. While the most stringent protections are provided to Class I areas, the legislation also aims to limit the level of additional pollution allowed in Class II areas, and potential impacts to these areas are to be considered. To comply with CAA mandates for protection of park resources, the NPS established an air quality monitoring program that measures long-term air quality trends in parks (NPS ARD 2015b). The program has three primary components: visibility, ozone, and atmospheric deposition, each of which can impact park resources, visitor enjoyment, and public health (NPS ARD 2015b). Air quality monitoring sites in the Cumberland Piedmont Network, which includes GUCO, are shown in Figure 4.1.1.

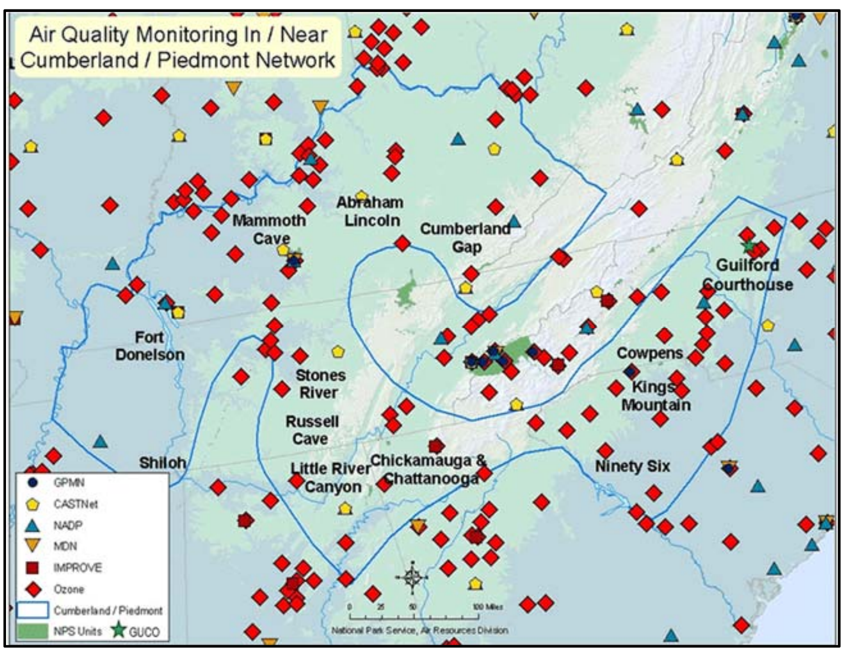


Figure 4.1.1. Map of air quality monitoring sites near GUCO (Cumberland Piedmont Vital Signs Network, NPS ARD 2015c).

While NPS visibility, ozone, and atmospheric deposition are the focus of the NPS air quality monitoring program, there are also other air pollutants of concern at GUCO. Thus, air quality related measures featured in this assessment are:

- Wet deposition of nitrogen (N) and sulfur (S)
- Deposition of mercury (Hg)
- Concentrations of ground-level ozone (O_3)
- Concentrations of suspended fine particulate matter ($PM_{2.5}$)
- Visibility (measured in terms of Haze Index in deciviews)

4.1.1. Acid Deposition

Relevance

Airborne pollutants are deposited to the earth through a process called atmospheric deposition. Pollutants that come down with rain, snow, or other precipitation are wet deposition, while pollutants that come down as dust, particles, or gas are dry deposition. Total deposition includes both wet and dry deposition. Sulfur and nitrogen compounds in air pollution (e.g., industry, agriculture, oil and gas development) can deposit into ecosystems and cause acidification, excess fertilization (eutrophication), and changes in soil and water chemistry that can affect community composition and alter biodiversity (Fowler et al. 2013).

During the 1970s, the scientific community saw a rapid increase in literature on atmospheric deposition and concern about its potential effects on the environment. Likens and Bormann (1974) first brought major attention to this issue when they reported an increase in the acidity of rainfall over the eastern U.S. Their findings indicated measureable effects on ecosystem structure and function, and suggested considerations be made in proposals for new energy sources and the development of air pollution emission standards. The following 20 years saw an abundance of research to measure atmospheric deposition and study its effects on the environment through the National Atmospheric Deposition Program (NADP 2012). Additional monitoring networks have also been established to augment the availability of atmospheric deposition data. These include the Ammonia Monitoring Network (AMoN), which provides land managers, air quality modelers, ecologists, and policymakers critical data that allows them to assess long-term trends in ambient ammonia concentrations, and the Clean Air Status and Trends Network (CASTNET) which provides long-term air quality monitoring data in rural areas to determine trends in regional atmospheric nitrogen and sulfur concentrations and deposition fluxes. Research has shown that atmospheric deposition can directly impact both aquatic and terrestrial systems by lowering pH of streams and soils, affecting forest health and aquatic wildlife populations (Driscoll et al. 2001). Pollutant levels associated with acid deposition (SO_X and NO_X) have dropped across much of the United States as a result of regulatory and emission standards imposed by the Clean Air Act (EPA 2013).

Although nitrogen is an essential plant nutrient, excess nitrogen from atmospheric deposition can stress ecosystems. Excess nitrogen acts as fertilizer, favoring some plants and leaving others at a competitive disadvantage. This creates an imbalance in natural ecosystems, and over time may lead to shifts in the types of plant and animal species present, increases in insect and disease outbreaks, disruption of ecosystem processes (such as nutrient cycling), and changes in wildfire frequency (Bobbink et al. 2010, De Schrijver et al. 2011, Greaver et al. 2012). Natural resource managers are particularly concerned about the tendency for non-native invasive plant species to thrive in elevated nitrogen environments, and the negative impacts of surplus nitrogen on native plants.

Data and Methods

Data used in this assessment consisted of estimated annual averages of total nitrogen and total sulfur wet deposition. Conditions for atmospheric deposition are based on wet deposition in the unit kg/ha/yr because dry deposition data are not available for most areas. Wet deposition for sites within the contiguous U.S. was calculated by multiplying nitrogen or sulfur concentrations in precipitation by a normalized precipitation amount. Annual wet deposition measurements were then averaged over five-year periods spanning the years 1999-2012 at all National Atmospheric Deposition Program – National Trends Network (NADP-NTN 2014) monitoring sites. For sites without on-site or nearby monitors, these five-year averages were interpolated for all atmospheric deposition monitoring locations (i.e., parks) using an inverse distance weighting (IDW) method to estimate five-year average values for sites across the contiguous U.S. Estimated values for each national park unit are made available to the public through the NPS AirAtlas website (NPS ARD 2014).

The estimated current nitrogen and sulfur condition for GUCO is derived from this national analysis at the geographic center of the park. Some of the sites from this national analysis are a considerable distance away from GUCO; however, they represent the best available data for this NPS site (NPS 2008, NPS ARD 2014) (Appendix A). A resulting condition greater than 3 kg/ha/yr is assigned a warrants significant concern status; a current nitrogen or sulfur condition from 1-3 kg/ha/yr is assigned a warrants moderate concern status; a resource is considered in good condition if the current nitrogen or sulfur condition is <1 kg/ha/yr (NPS ARD 2013b). Ten-year trends in annual sulfate and nitrate wet deposition are reported using monitoring data from across the U.S. to provide a national and regional context for current conditions reported at GUCO (NPS ARD 2013a).

Reference Conditions

Determining the reference condition for sulfur and nitrogen wet deposition is necessary to identify ecosystems and resources in national parks at risk for acidification and excess nitrogen enrichment. Natural background for both total sulfur and total nitrogen deposition in the eastern U.S. is 0.5 kg/ha/yr which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007, NPS ARD 2013b). NPS ARD recommends a nitrogen or sulfur wet deposition of <1 kilogram per hectare per year (kg/ha/yr) as the condition to protect sensitive ecosystems (NPS ARD 2013b). If park ecosystems are ranked very high in sensitivity to acidification or nutrient enrichment effects from atmospheric deposition relative to all Inventory & Monitoring parks, the condition category is adjusted to the next worse condition category (NPS ARD 2013b).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to park resources. A critical load is defined as the level of deposition below which harmful effects to the ecosystem are not expected. For GUCO, Pardo et al. (2011) suggested following critical load ranges for total nitrogen deposition in the Eastern Temperate Forests ecoregion:

- 4.0-8.0 kg/ha/yr to protect lichen
- 3.0-8.0 kg/ha/yr to protect forest
- <17.5 kg/ha/yr to protect herbaceous vegetation

To maintain the highest level of protection in the park, the minimum of these critical load ranges (3.0 kg/ha/yr) is an appropriate management goal.

Conditions and Trends

For the 2008-2012 time period, estimated sulfur wet deposition at the park was 3.3 kg/ha/yr (Figure 4.1.2) (NPS ARD 2014), and falls within the significant concern condition category. Although GUCO receives high levels of sulfur deposition, ecosystems in the park are not typical of sulfur-sensitive systems and were rated as having very low sensitivity to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a, Sullivan et al. 2011b). During that same period of time, estimated nitrogen wet deposition was 4.3 kg/ha/yr, which also warrants significant concern (Figure 4.1.2) (NPS ARD 2014). Although GUCO receives high levels of nitrogen deposition, ecosystems in the park are not typical of nitrogen-sensitive systems and were rated as having very low sensitivity to nutrient-enrichment effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011c, Sullivan et al. 2011d). Both of these conditions are consistent with data from other parks across the eastern U.S. (Figures 4.1.3 and 4.1.4) (NPS ARD 2013a).

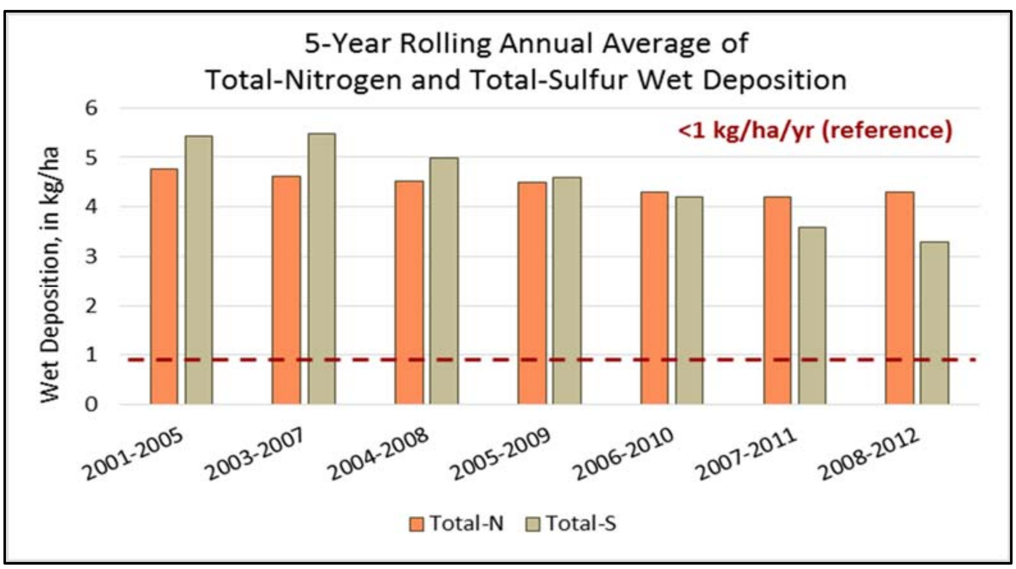


Figure 4.1.2. 5-year rolling annual averages of total-nitrogen and total-sulfur wet deposition for GUCO (NPS ARD 2014).

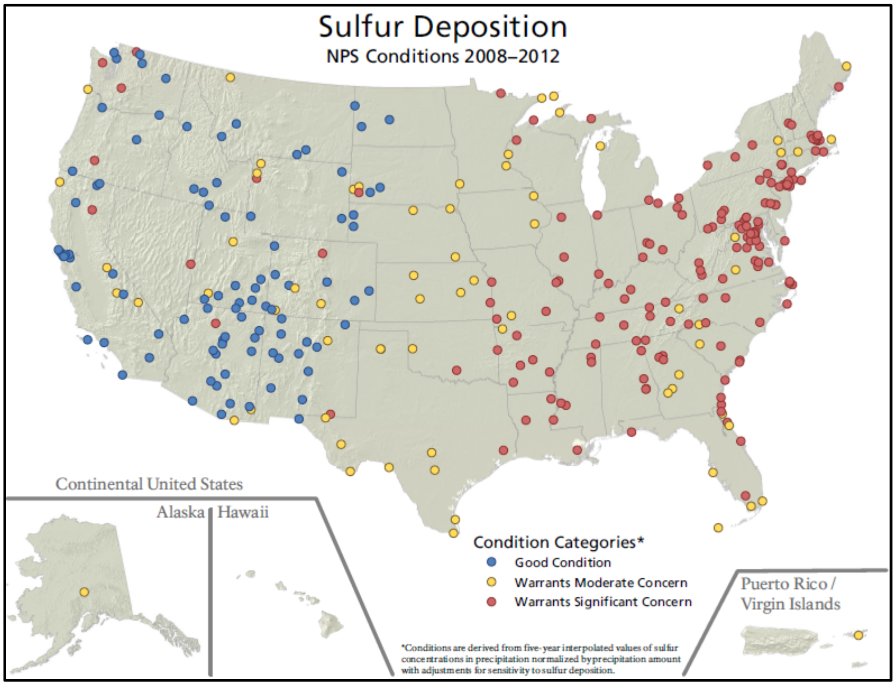


Figure 4.1.3. Map of sulfur deposition conditions in U.S. national parks, 2008-2012 (NPS ARD 2013a).

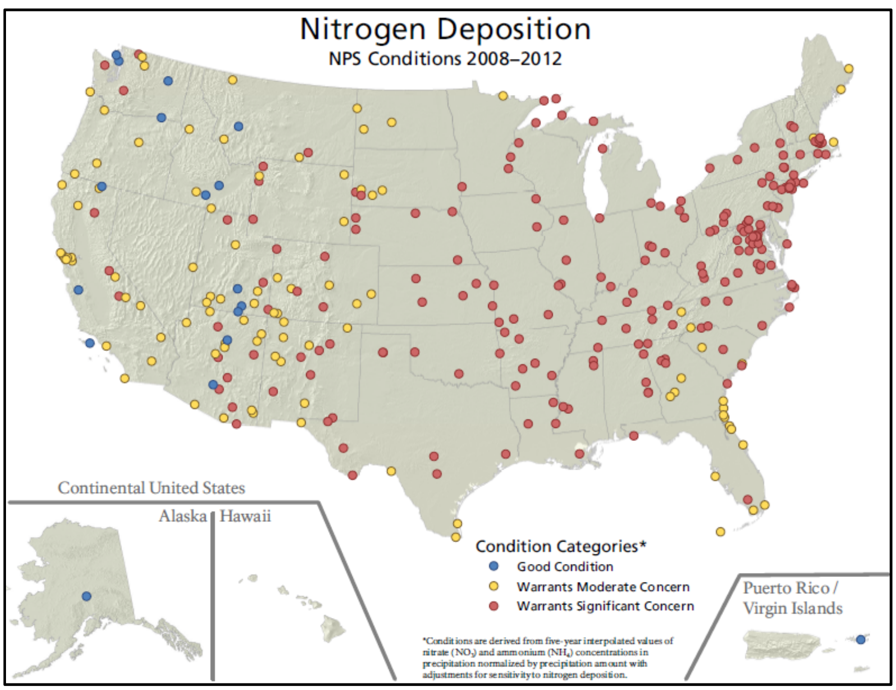


Figure 4.1.4. Map of nitrogen deposition conditions in U.S. national parks, 2008-2012 (NPS ARD 2013a).

The estimated maximum average for total nitrogen deposition for the 2010-2012 time period was 10.3 kg/ha/yr in the Eastern Temperate Forests ecoregion (NADP-TDEP 2014) of GUCO (for example, see the 2012 totals as shown in Figure 4.1.5) (NADP-TDEP 2014). Therefore, the total nitrogen deposition level in the park is above the minimum ecosystem critical loads for some park vegetation communities, suggesting that lichen and forest vegetation types may potentially be at risk for harmful effects.

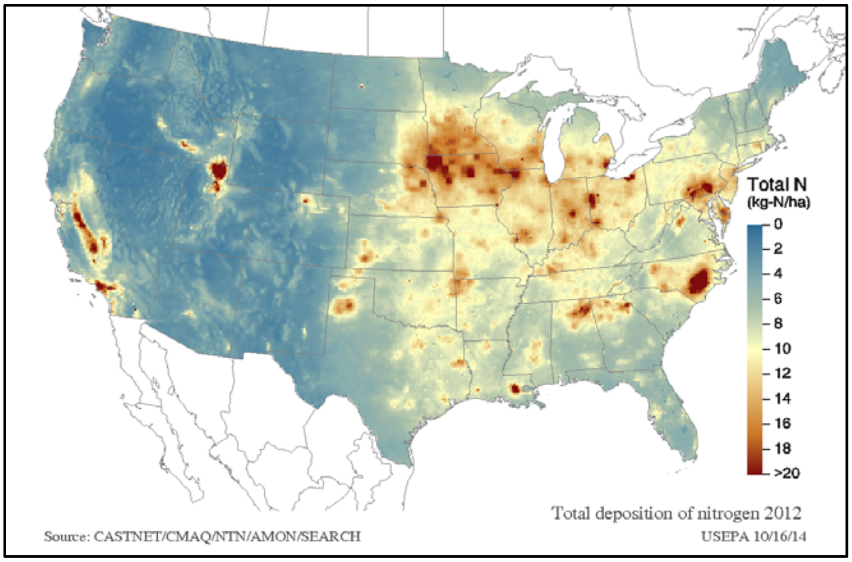


Figure 4.1.5. Map of total deposition of nitrogen in the contiguous U.S., 2012 (NADP-TDEP 2014).

NPS ARD requires a monitor within 16 kilometers (10 miles) of the park to calculate trends for wet deposition. As such, current trend information for sulfate and nitrate concentrations in precipitation is not available (NPS ARD 2013b). However, trends from monitors in Tennessee and North Carolina can be used to indicate regional trends in wet sulfate and nitrate concentrations. For 2003-2012, the trend in wet sulfate concentrations in rain and snow improved and wet nitrate remained relatively unchanged at Great Smoky Mountains National Park (GRSM) (NADP Monitor ID: TN11, TN). For the same time period, data from the Piedmont Research Station in North Carolina indicate wet sulfate and nitrate concentrations in precipitation improved (NADP Monitor ID: NC34, NC). These trends reflect national reductions in sulfate and nitrate emissions especially since 1997 (Driscoll et al. 2001), and are consistent with improving trends in most parks across the U.S. (Figures 4.1.6 and 4.1.7) (NPS ARD 2013a).

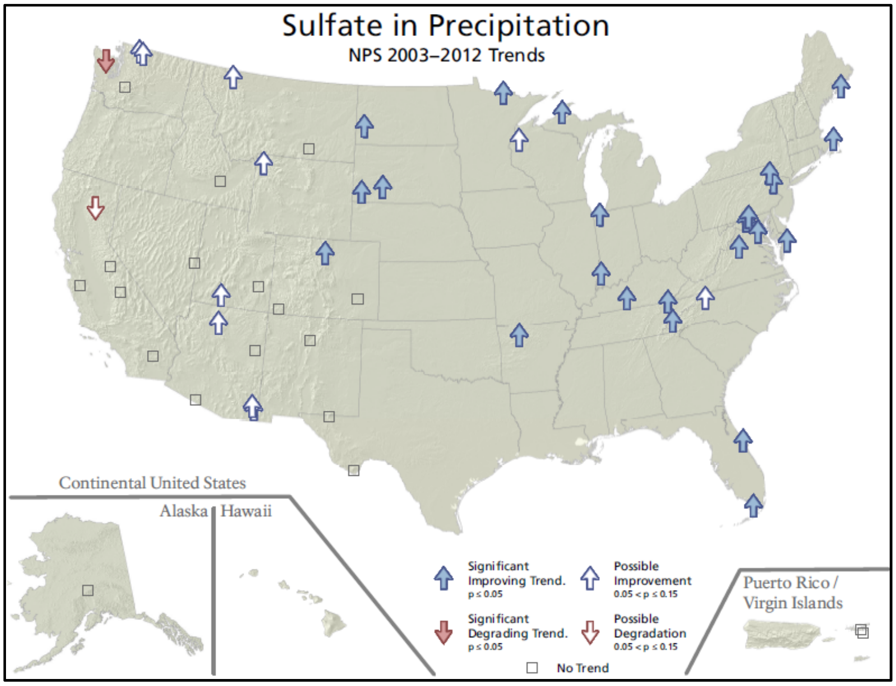


Figure 4.1.6. 10-year trends in annual sulfate in precipitation, 2003-2012 (NPS ARD 2013a).

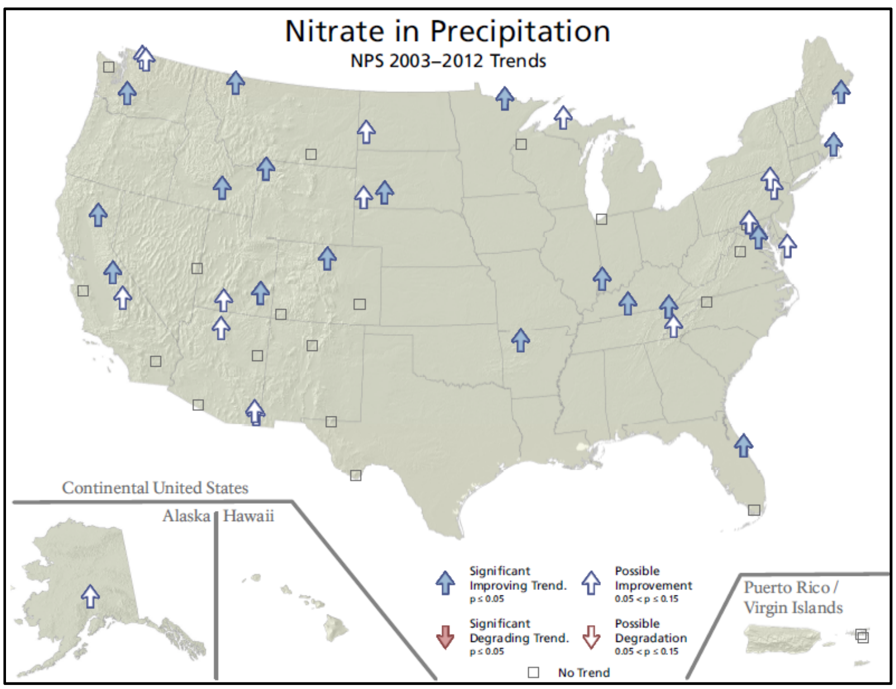


Figure 4.1.7. 10-year trends in annual nitrate in precipitation, 2003-2012 (NPS ARD 2013a).

<u>Confidence and Data Gaps</u>

Due to the fact that wet deposition of sulfur and nitrogen were not measured directly at the park, but instead were estimated by interpolation, the degree of confidence in the condition assessment for sulfur and nitrogen deposition at GUCO is medium (Table 4.1.1) (NPS ARD 2013b).

Summary Condition

Table 4.1.1. Graphical summary of status and trends for sulfate and nitrate (NPS ARD 2013b).

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Total Sulfur (Wet deposition in kg/ha/yr)		Estimated wet sulfur deposition was 3.3 kg/ha/yr (2008-12); condition warrants significant concern; NPS ARD advises against using interpolated values for trends (Data Source(s): NADP-NTN via AirAtlas)
Air Quality	Total Nitrogen (Wet deposition in kg/ha/yr)		Estimated wet nitrogen deposition was 4.3 kg/ha/yr (2008-12); condition warrants significant concern; NPS ARD advises against using interpolated values for trends (Data Source(s): NADP-NTN via AirAtlas)

Sources of Expertise

- Tamara Blett, Ecologist, Air Resources Division
- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, Air Resources Division
- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.1.2. Mercury

Relevance

Mercury (Hg) is a naturally occurring element found in water, air, and soil, and exists in several forms. In addition to natural sources such as volcanoes and geothermal vents, numerous human-caused sources of mercury near national park sites include coal-fired combustion, municipal and medical incineration, and mining operations. Atmospheric mercury deposited to surface waters can change into toxic methylmercury, which can enter the food chain (Boening 2000). Once methylmercury enters the food chain it accumulates in organisms as it moves higher in the chain, particularly birds and fish (Scheuhammer et al. 2007). Exposure to high levels of mercury in humans may cause damage to the brain, kidneys, and the developing fetus (EPA 2013). High mercury concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success (Clarkson and Magos 2006, Wiener et al. 2012). Additionally, the EPA's Mercury and Air Toxic Substances (MATS) rule, which requires a 90% reduction in Hg emissions from certain coal- and oil-fired power plants, will be implemented in 2015 (EPA 2012). As a result, it is expected that domestically-sourced atmospheric mercury deposition will decrease in the coming years.

Data and Methods

Although NPS ARD has not established condition benchmarks for atmospheric deposition of mercury, an evaluation of mercury bioaccumulation/exposure risk, fish consumption advisories, and in-park data or representative studies can be useful in determining the extent of deposition impacts to park resources. No monitoring data were available to directly assess mercury deposition at or near GUCO for this assessment. However, the NPS ARD mercury condition status for this assessment was derived from two data layers: 1) estimated current mercury deposition according to the National Atmospheric Deposition Program – Mercury Deposition Network (NADP-MDN 2015), and 2) predicted surface water methylmercury concentrations at NPS Inventory & Monitoring units (USGS 2015). It is important to consider both mercury deposition inputs and the mercury methylation ability when assessing mercury status because elemental or inorganic mercury must be methylated before it is biologically available and potentially harmful to fauna. Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, and pH) must also be considered.

Reference Conditions

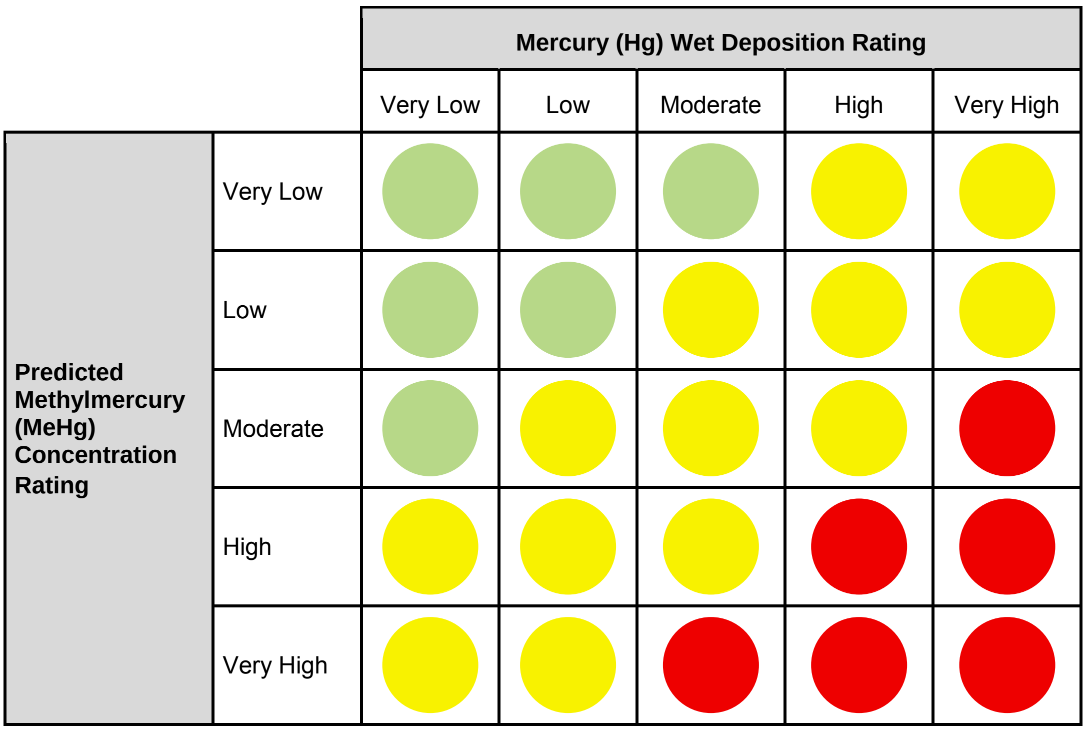
Defining the reference conditions for mercury deposition is necessary to protect human health and ecosystems at risk for injury from mercury deposition. The United Nations Environment Programme (UNEP) has determined the annual average atmospheric concentrations of gaseous elemental mercury in the troposphere over Europe and North America at background sites (i.e., unaffected by local sources) is between 1.5-1.7 $\mu g/m^3$ (AMAP/UNEP 2008). The U.S. Agency for Toxic Substances and Disease Registry (ATSDR) has established background or natural levels of mercury in urban outdoor air (10 and 20 $\mu g/m^3$), nonurban outdoor air (6 $\mu g/m^3$ or less), surface water (5 µg/liter of water), and soil (20 to 625 µg/gram of soil) (ATSDR 1999). Dry mercury deposition measurements are very limited; therefore, wet mercury deposition measurements (i.e., concentrations in precipitation) are used to establish ecological thresholds and characterize mercury trends (NPS ARD 2013).

NPS ARD assesses mercury condition according to the mercury risk status assessment matrix. In certain instances, in-park data on mercury and/or other toxic contaminants in biota can be applied to adjust the status. The estimated current mercury wet deposition (in $\mu g/m^2/yr$) for individual parks is the highest value derived from the park. That value is categorized from Very Low to Very High (Table 4.1.2). Similarly, the predicted methylmercury concentration in surface water is the highest value derived from the park (in ng/L). That value is categorized from Very Low to Very High (USGS 2015). Ratings from both data layers are then considered concurrently in the mercury risk status assessment (Table 4.1.3).

Table 4.1.2. Mercury (Hg) wet deposition and predicted methylmercury (MeHg) concentration ratings table (K. Pugacheva, NPS ARD).

Rating	Hg Deposition (μg/m²/yr)	Predicted MeHg Concentration (ng/L)
Very Low	<3	<0.038
Low	3-6	0.038-0.053
Moderate	6-9	0.053-0.075
High	9-12	0.075-0.12
Very High	>12	>0.12

Table 4.1.3. Mercury risk status assessment matrix (K. Pugacheva, NPS ARD).



Conditions and Trends

As indicated above, no data were available to assess mercury deposition at or near GUCO for this assessment, however, mercury deposition warrants moderate concern at GUCO. Given that landscape factors influence the uptake of mercury in the ecosystem, the moderate status is based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters (USGS 2015). For the 2011-2013 time period, estimated mercury wet deposition at the park was moderate, estimated to be 8.98 μg/m^2/yr (NADP-MDN 2015), and predicted methylmercury concentrations in park surface waters at the park was high, estimated to be 0.12 ng/L (USGS 2015). The combination of a moderate rating for wet mercury deposition with a high rating for predicted methylmercury concentrations yields a warrants moderate concern status (see Table 4.1.3). Maps showing interpolated values for total mercury wet deposition in 2013 over the continental U.S. (Figure 4.1.8) and ten-year trends in annual mercury concentrations in precipitation from 2003-2012 from 15 other parks across the U.S. (Figure 4.1.9) are provided for context (NPS ARD 2013a).

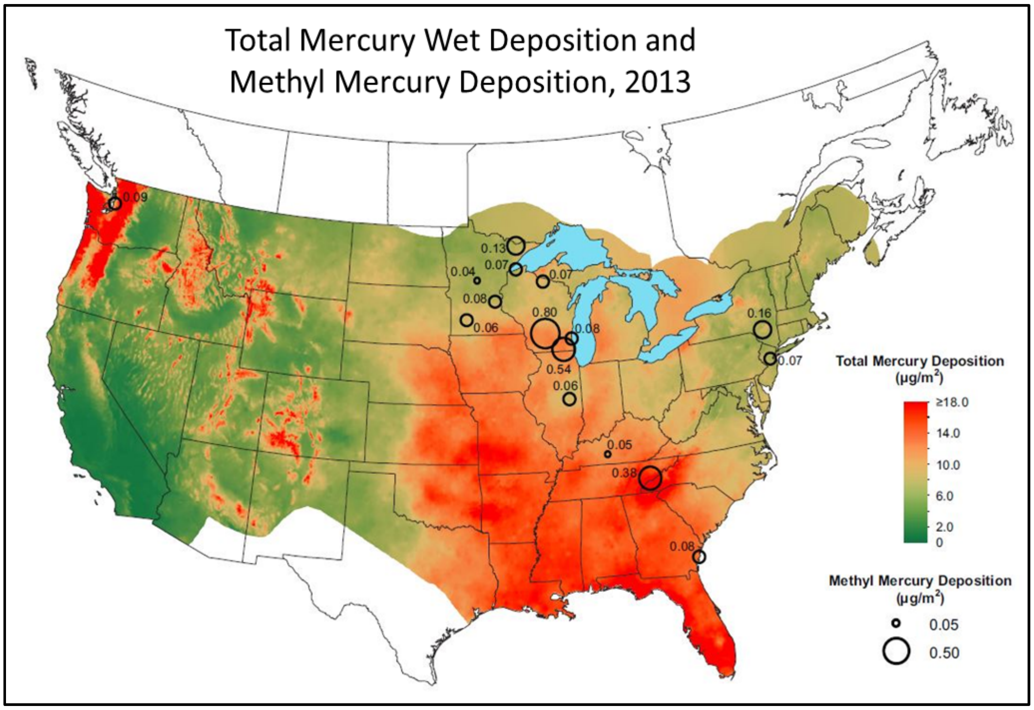


Figure 4.1.8. Interpolated values for total mercury wet deposition for the U.S. in 2013 using PRISM precipitation data. Circles represent 2013 annual methylmercury wet deposition (NPS ARD 2013a).

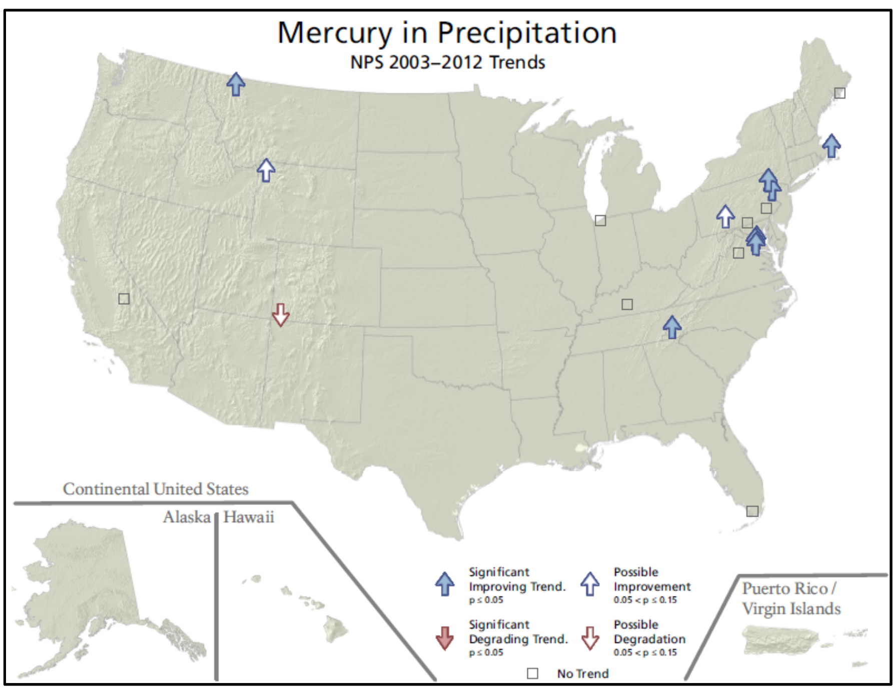


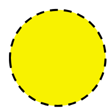
Figure 4.1.9. 10-year trends in mercury in precipitation, 2003-2012 (NPS ARD 2013a).

Confidence and Data Gaps

There are no monitors for measuring mercury wet deposition at or near GUCO; thus, this represents a major data gap. Results from nationwide studies suggest moderate concern for mercury deposition at GUCO, but the degree of confidence in the condition assessment for mercury deposition at GUCO is low. Due to a lack of on-site or nearby monitoring data, there was no assessment of trend (Table 4.1.4).

Summary Condition

Table 4.1.4. Graphical summary of status and trends for mercury.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Mercury (Wet deposition in µg/l/y and concentration in ng/L)		Estimated mercury wet deposition was 8.98 µg/m2/yr; estimated methylmercury concentration in park surface waters was 0.12 ng/L; warrants moderate concern, trend in condition was not assessed; low confidence in the assessment (Data Source(s): NADP-MDN and USGS via NPS ARD)

Sources of Expertise

- Colleen Flanagan Pritz, Ecologist, Air Resources Division
- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, Air Resources Division
- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.1.3. Ozone

Relevance

Tropospheric ozone (O_3) has been recognized as the most widespread phytotoxic air pollutant in eastern North America (EPA 1996). Once thought to be prevalent only in urban areas where emissions of nitrogen oxides are high, ozone and its precursors are known to be transported to rural and natural areas downwind (Aneja et al. 1990). Low levels of ozone have been shown to impact human health causing skin and eye irritation, shortness of breath, and decreased lung function to sensitive individuals; high levels of ozone can cause symptoms in anyone of the general population (EPA 1999). Research has also established that ozone is equally detrimental to the health of vegetation. Trees adversely affected by ozone commonly exhibit reduced photosynthesis rates (Grulke 2003), reduced height and/or diameter growth (Somers et al. 1998), biomass loss (Shafer and Heagle 1989) and/or foliar injury (Neufeld et al. 1992). If damage is great enough an entire forest ecosystem can be significantly altered (McLaughlin and Downing 1995, Chappelka and Samuelson 1998). It has thus been suggested that the ecological threshold is likely lower than the current primary eight-hour standard of 75 parts per billion (ppb) (Heck and Cowling 1997). A risk assessment concluded that plants at GUCO were at high risk for ozone damage (Kohut 2004, Kohut

2007, Jernigan et al. 2014). There are at least 29 ozone-sensitive plants in the park, including tulip poplar and black cherry (*Prunus serotina*) (NPSpecies 2015).

Data and Methods

Data used in this assessment consisted of estimated annual averages of ozone concentrations. Conditions for human health risk from ozone are based on the 4th-highest daily maximum eight-hour ozone concentration in ppb. Annual 4th-highest daily maximum eight-hour ozone concentrations were averaged over five-year periods spanning the years 1999-2012 at all CASTNET and Air Quality System (AQS) monitoring sites. For these five-year average calculations, annual ozone data must meet a 75% data completeness criterion. For sites without on-site or nearby monitors, these five-year averages were interpolated for all ozone monitoring locations (i.e., parks) using an IDW method to estimate five-year average values for sites across the contiguous U.S. Estimated values for each national park unit are made available to the public through the NPS AirAtlas website (NPS ARD 2014).

The estimated current ozone condition for human health risk at GUCO is the value derived from this national analysis at the geographic center of the park. Some of these sites are a considerable distance away from GUCO; however, they represent the best available data for this NPS site (NPS 2008, NPS ARD 2014) (Appendix A). A resulting condition greater than or equal to 76 ppb is assigned a warrants significant concern status; a current ozone condition from 61-75 ppb is assigned warrants moderate concern status; a resource is considered in good condition if the current ozone condition is ≤60 ppb (NPS ARD 2013b). In instances where the NPS unit falls within an area designated by the EPA as "nonattainment" (not meeting) for the ground-level ozone standard of an eight-hour average concentration of 75 ppb, the ozone condition is assigned warrants significant concern status (NPS ARD 2013b).

Conditions for vegetation health risk from ozone exposure are measured using the maximum 3-month twelve-hour W126 in ppm-hrs. Annual maximum three-month twelve-hour W126 values were averaged over five-year periods spanning the years 1999-2012 at all CASTNET and AQS monitoring sites. Five-year averages were interpolated for all ozone monitoring locations (i.e., parks) using an IDW method to estimate five-year average values for sites across the contiguous U.S. Estimated values for each national park unit are made available to the public through the NPS AirAtlas website (NPS ARD 2014). The estimated current ozone condition for vegetation health risk at GUCO is the value derived from this national analysis at the geographic center of the park. A resulting condition greater than 13 ppm-hrs is assigned a warrants significant concern status. A current ozone condition from 7-13 ppm-hrs is assigned a warrants moderate concern status. A resource is in good condition if the current ozone condition is <7 ppm-hrs. Ten-year trends in annual ozone concentrations were calculated from a representative monitoring site data (AQS Monitor ID: 37-081-0013) (NPS ARD 2014). Ten-year trends in annual ozone concentrations are also reported using monitoring data from across the U.S. to provide a national and regional context for current conditions reported at GUCO (NPS ARD 2013a).

Reference Conditions

Defining the reference condition for ozone concentration is necessary to detect when concentrations reach levels of concern to human health and identify park resources at risk for injury from elevated ozone concentrations. Determining natural background concentrations of ozone is challenging, requiring measurements in remote locations when photochemical conditions and winds are not ideal for ozone production and/or transport (Reid 2007). Background concentrations in the U.S. reported by Altshuller and Lefohn (1996) are 35 ± 10 ppb. More recently, Lefohn et al. (2001) have suggested stratospheric intrusion is responsible for surface ozone concentrations of ≥60 ppb. The National Ambient Air Quality Standard (NAAQS) for ground-level ozone is set by the EPA, and is based on human health effects (EPA 2012). The NPS ARD recommends a benchmark for good condition ozone status of 60 part per billion (ppb) or less, which is 80% of the human health-based NAAQS (NPS ARD 2013b).

The W126 metric is a biologically relevant measure that focuses on plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the human health standard. The W126 preferentially weights the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours. The highest three-month period that occurs during the growing season is reported in parts per million-hours (ppm-hrs). NPS ARD benchmarks for the W126 metric are based on information in EPA's Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards (EPA 2014), which outlines use of the W126 metric for assessing plant response to ground-level ozone. This document also compiles the latest scientific evidence about impacts to vegetation from ground-level ozone. Research indicates that for a W126 value of less than or equal to 7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species. For a W126 value greater than or equal to 13 ppm-hrs, tree seedling biomass loss is 4-10% per year in sensitive species. Thus, NPS ARD recommends a W126 of <7 ppm-hrs to protect most sensitive trees and other vegetation.

Conditions and Trends

For the 2008-2012 time period, human health risk from ground-level ozone warrants moderate concern at GUCO. This condition is based on NPS ARD benchmarks and the 2008-2012 estimated ozone of 73.9 ppb (Figure 4.1.10) (NPS ARD 2013b, NPS ARD 2014). Vegetation health risk from ground-level ozone also warrants moderate concern at GUCO for this time period. This condition is based on NPS ARD benchmarks and the 2008-2012 estimated W126 metric of 12.1 ppm-hrs (Figure 4.1.11) (NPS ARD 2014). These conditions are consistent with data from parks across the U.S. (Figure 4.1.12) (NPS ARD 2013a).

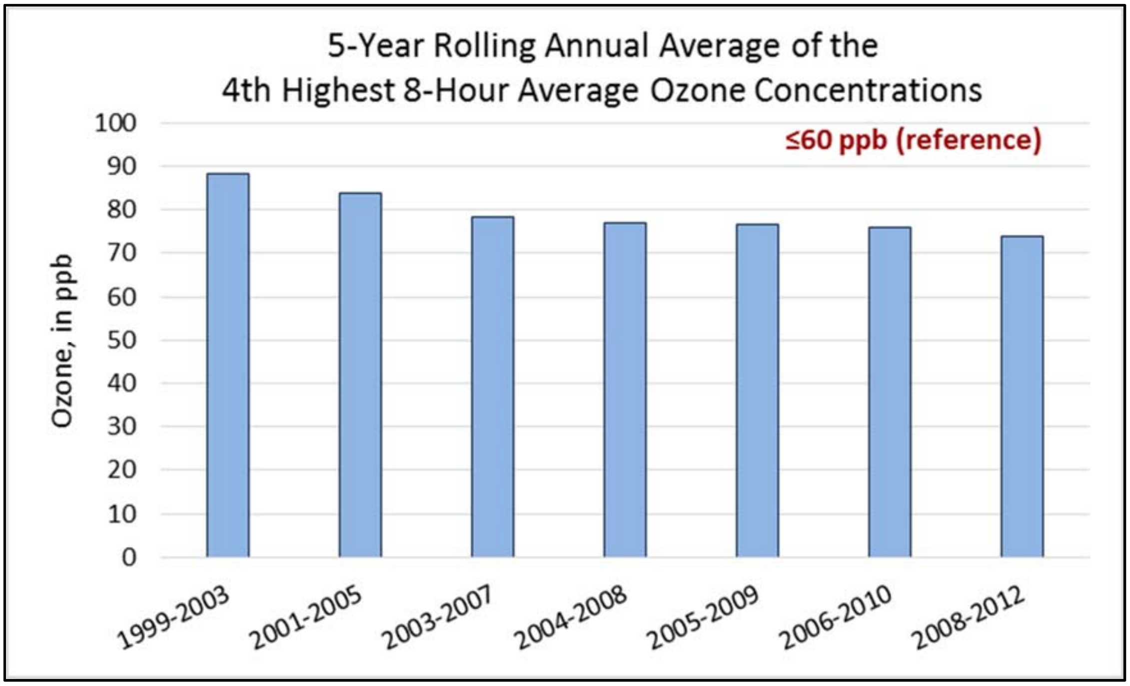


Figure 4.1.10. 5-year rolling annual averages of 4th highest 8-hour ozone concentration for GUCO (NPS ARD 2014).

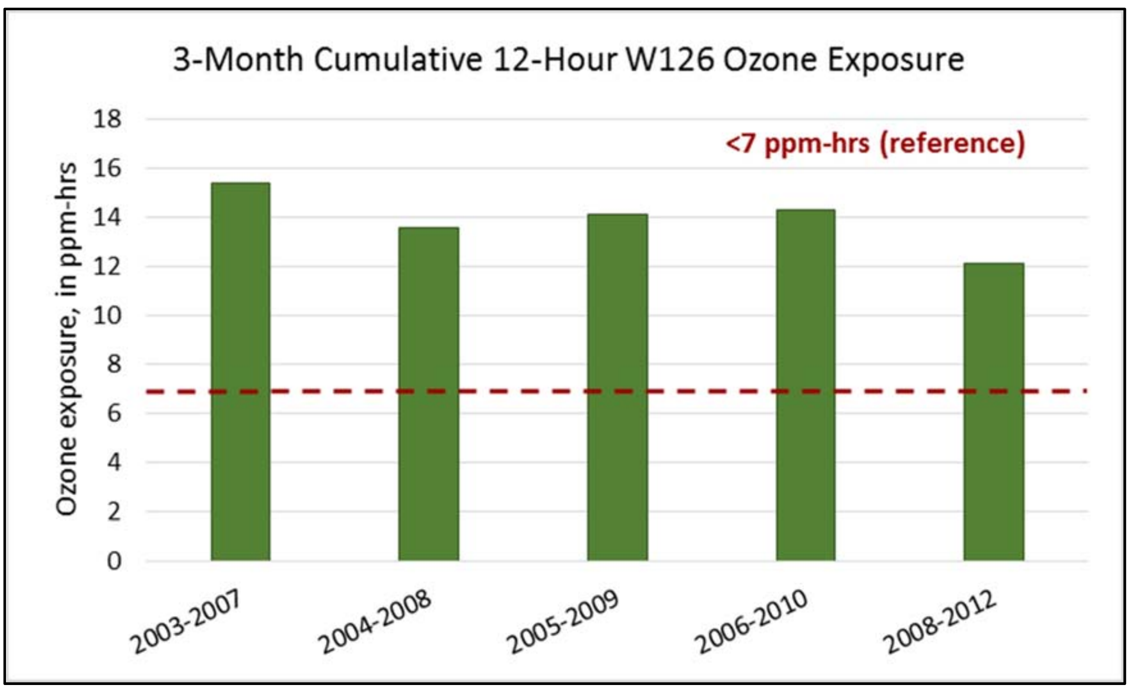


Figure 4.1.11. 5-year rolling annual averages of the W126 ozone metric for GUCO (NPS ARD 2014).

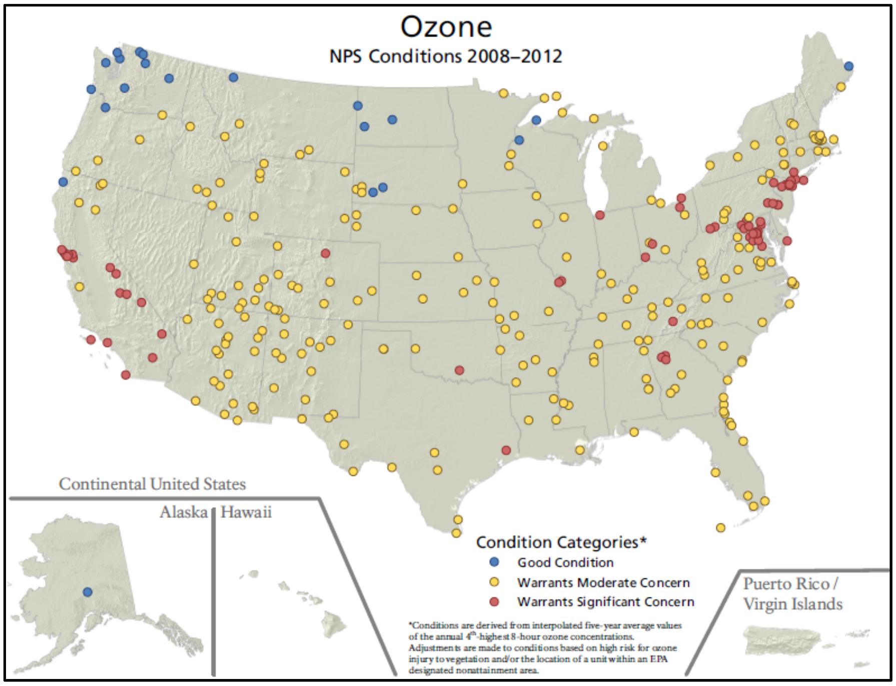


Figure 4.1.12. Map of ozone conditions in U.S. national parks, 2008-2012 (NPS ARD 2013a).

NPS ARD requires a monitor within 10 kilometers (6 miles) of the park to calculate trends for ozone (NPS ARD 2013b). For the 2003-2012 time period, the trend in both ozone concentrations and W126 at GUCO remained relatively unchanged (i.e., no statistically significant trend). Ozone concentrations have improved over the past decade in most parks across the U.S. (Figure 4.1.13) (NPS 2013a). These trends reflect implementation of EPA's ozone precursor control programs, which began in the mid-1990s (EPA 2005). Although regional data indicate improving trends, reductions are still needed to lessen adverse impacts on not only the health of park visitors, but also park resources and ecosystems.

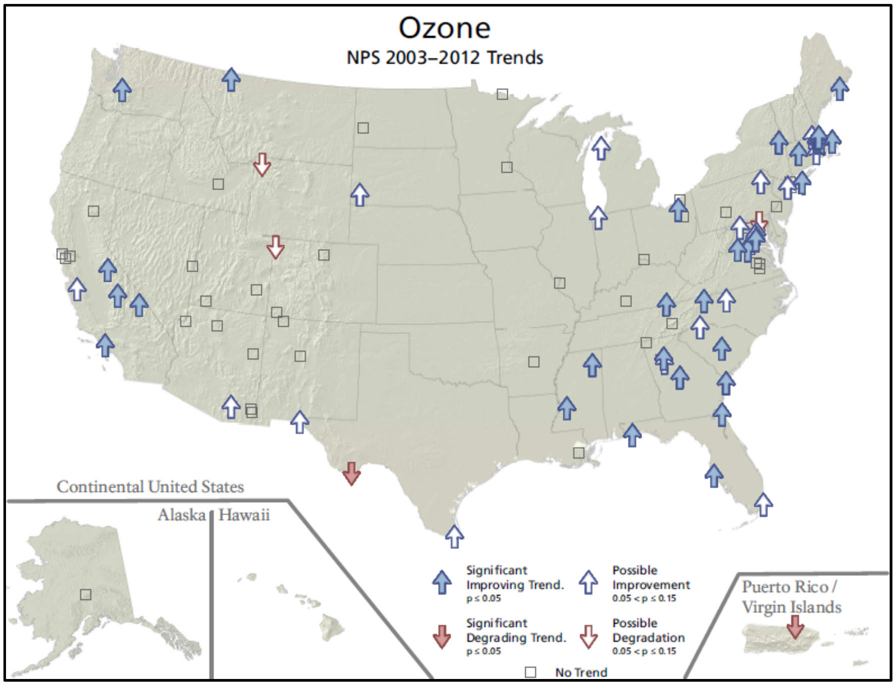


Figure 4.1.13. 10-year trends in annual 4th highest 8-hour ozone concentration (NPS ARD 2013a).

Confidence and Data Gaps

The degree of confidence at GUCO is medium because estimates are based on interpolated data from more distant ozone monitors (Table 4.1.5). These AQS sites are located within ~30 km (18.5 miles), and while this is not ideal, these data represent the best available for GUCO. Unlike other regional scale pollutants, ozone concentrations vary widely across short spatial scales, and thus, point measurements are limited in their applicability across space. The operational scale of ozone in urban settings is usually <10 km (6 miles) (Diem 2003). This complexity is controlled by local sources of ozone precursors (especially nitrogen oxides), topography, micro-climates, and rates of ozone deposition.

Summary Condition

Table 4.1.5. Graphical summary of status and trends for ozone.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Ozone Concentration in ppb (human health) and exposure in ppm-hrs (veg health)		Estimated ozone concentration was 73.9 ppb and estimated W126 was 12.1 ppm-hrs (2008-12); warrants moderate concern; trend relatively unchanged (2003-12) (Data Source(s): EPA AQS via AirAtlas)

Sources of Expertise

- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network

- Ksienya Pugacheva, Natural Resource Specialist, Air Resources Division
- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.1.4. Particulate Matter ($PM_{2.5}$)

Relevance

Particle pollution represents one of the most widespread human health threats, possibly greater than ozone because it can occur year-round (EPA 2013b). Particulate matter ($PM_{2.5}$) is a term for a class of atmospheric pollutants that exist suspended in air as liquid or solid particles ≤2.5 µm in diameter (EPA 2004). These very fine particles are released into the air from anthropogenic stationary and mobile sources such as power plants, automobiles, and construction activities, as well as from natural sources like forest fires and dust storms. Particulate matter can be emitted directly or formed in the atmosphere through chemical reactions. Research has indicated that wide variation in source, size, and physical and chemical properties of particulates result in a broad range of effects to both human health (e.g., asthma, chronic bronchitis, and premature death) and the environment by altering essential nutrient and biogeochemical cycles (EPA 2004). Numerous physical and chemical effects on ecosystems have been documented and vary depending on mode of deposition making inputs difficult to quantify (Grantz et al. 2003). Fine particles ($PM_{2.5}$) are also the main cause of reduced visibility (regional haze) in the United States, including many of our national parks (EPA 2013b).

Data and Methods

Data used in this assessment consisted of estimated annual average particulate matter ($PM_{2.5}$) concentrations for three-year time periods spanning the years 1999-2012. Ambient concentrations of $PM_{2.5}$ were not monitored on-site, but data were obtained from two nearby sites (AQS Monitor IDs: 37-081-0013 and 37-081-0014) located in Greensboro (~5 km SE [3 mi]) and Colfax (~16 km SW [10 mi]), respectively (EPA 2013a). These air quality data are from monitors in the Environmental Protection Agency's Air Quality System (AQS). These monitoring sites represent the best available data for this NPS site, and represent a sufficiently long record with which to examine current conditions and assess trends over the past decade.

Reference Conditions

The reference condition for particulate matter ($PM_{2.5}$) concentrations is necessary to detect when concentrations reach levels of concern to human health, visibility, and park ecosystems. Natural background concentrations of particulate matter ($PM_{2.5}$) have been difficult to define; the EPA first established the NAAQS standards for fine particle pollution in 1997 and further revised them in 2006 and 2012 (EPA 2012). There are currently two primary and secondary standards for $PM_{2.5}$: the annual primary and secondary standards are attained when the three-year average of the annual mean concentration is ≤12 $\mu g/m^3$ and ≤15 $\mu g/m^3$, respectively; the 24-hour (daily) primary and secondary standard is the same and is attained when the three-year average of the annual 98th percentile is ≤35 $\mu g/m^3$ (EPA 2012). For this assessment, the annual primary standard of ≤12 $\mu g/m^3$ was used as reference condition (and ecological threshold) for particulate matter ($PM_{2.5}$) concentrations.

Conditions and Trends

The three-year rolling annual average $PM_{2.5}$ concentration (2010-2012) for the monitor location closest to GUCO was 8.3 µg/m^3. This value is below the ecological threshold of ≤12 µg/m^3, and indicates minimal to moderate concern for particulate matter ($PM_{2.5}$) condition in the park (EPA 2013a). Particulate matter concentrations near GUCO have steadily declined over the past decade, with values decreasing 33% over the entire time period monitored, from the fourteen-year high value of 14.1 µg/m^3 (2004-2006) to 8.3 µg/m^3 in 2012 (Figure 4.1.14). Data from this monitoring station indicate that $PM_{2.5}$concentrations have met annual NAAQS standards since the 2007-2009 time period. These trends reflect the EPA's continued efforts to limit fine particle pollution emissions by strengthening the annual standard in 1997 and again in 2006 (EPA 2012). The State of North Carolina's Clean Smokestacks Act of 2002 required emissions reductions from electric utilities within the State. Duke Energy's Asheville Plant installed sulfur dioxide controls in 2005 which would have contributed to the improvements in $PM_{2.5}$ observed beginning in 2006. North Carolina has reduced SO_2 emissions from electric generating utilities by 92% and NO_X emissions by 76% between 2000 and 2014. Tennessee has seen SO_2 and NO_X emission reductions from electric generating utilities by more than 85% between 2000 and 2014. Mobile source emissions of NO_X have been reduced by about 70% (EPA 2015). These trends are consistent with improving trends across much of the U.S., and are likely a direct result of these regulatory efforts to protect human health from particle pollution by strengthening state and federal health standards for $PM_{2.5}$ (Figure 4.1.15) (EPA 2013c). Although the most recent data fall below the ecological threshold of ≤12 µg/m^3, there is insufficient long-term data suggesting this is the current or future trend, thus these data indicate moderate concern for $PM_{2.5}$ condition in the park.

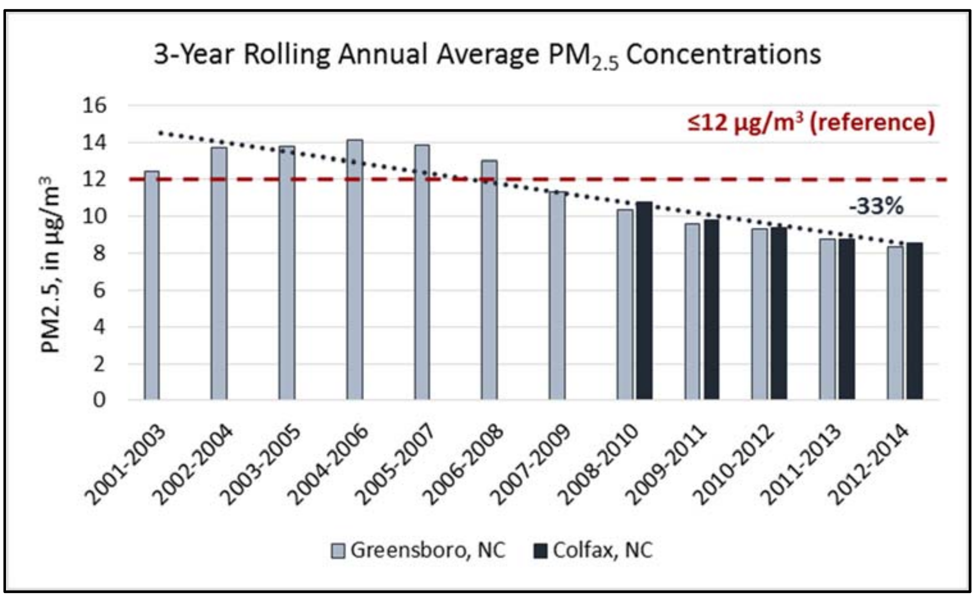


Figure 4.1.14. 3-year rolling annual average $PM_{2.5}$ concentrations for GUCO (EPA 2013a).

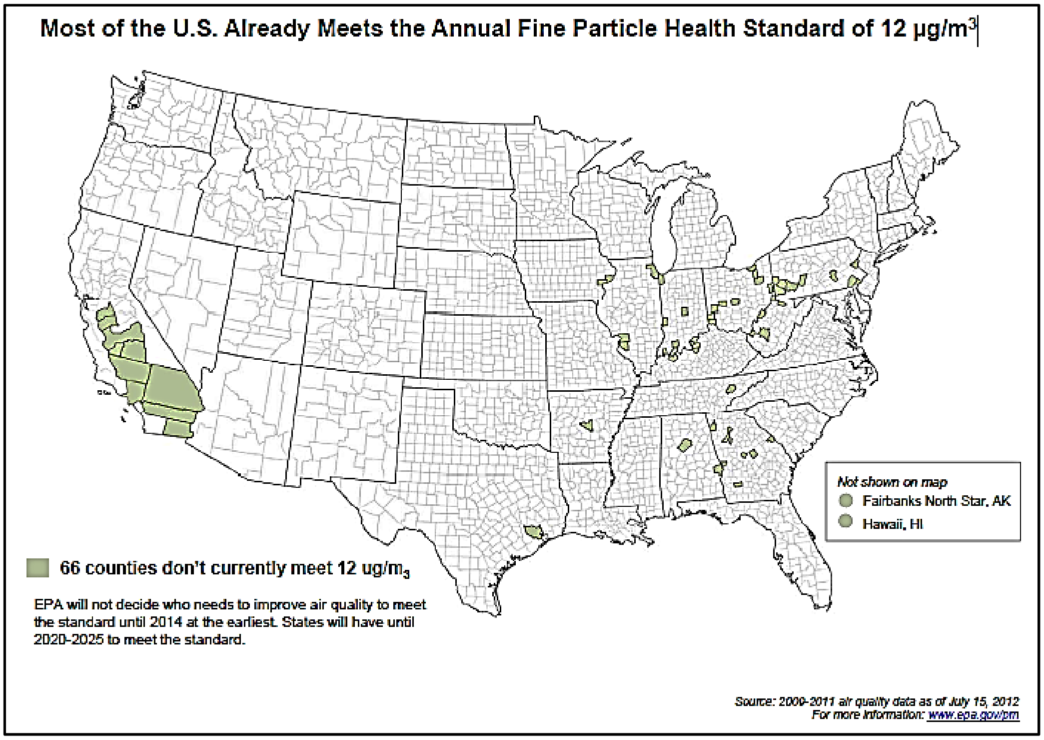


Figure 4.1.15. Nonattainment areas for the 2012 annual $PM_{2.5}$ NAAQS (EPA 2013c).

<u>Confidence and Data Gaps</u>

Monitoring of $PM_{2.5}$ concentrations near GUCO began in 1999 (at Greensboro) as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE 2013) program. Fine particle pollution monitoring has also taken place sporadically at other locations around the park since 1999; data from these stations were not assessed. As such, there is medium confidence in the current assessment of both condition and trend of fine particulate matter ($PM_{2.5}$) pollution at GUCO (Table 4.1.6).

<u>Summary Condition</u>

Table 4.1.6. Graphical summary of status and trends for particulate matter ($PM_{2.5}$).

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	$PM_{2.5}$ Concentration in µg/m3		$PM_{2.5}$ concentration was 8.3 µg/m3 (2010-12); warrants moderate concern; values have declined since 1999; recent levels have fallen below threshold of ≤12 µg/m3 (Data Source(s): EPA AQS and IMPROVE via EPA AirData)

<u>Sources of Expertise</u>

- Pat Brewer, Regulatory, Policy, Smoke Management, Air Resources Division

- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, Air Resources Division
- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.1.5. Visibility

Relevance

Regional haze is a general term for one of the most basic forms of air pollution that degrades visibility across the landscape. Regional haze is caused when sunlight interacts with fine particles suspended in the atmosphere, which absorb, scatter, and reflect light, reducing the clarity of park viewsheds (EPA 2012b). Both natural (organic matter, dust, soil) and anthropogenic (automobile, utility, industry) sources of particles can cause reduced visibility; however, sulfates formed from coal-fired power plant emissions are particularly good at scattering light, and are thus the major cause of reduced visibility in the eastern U.S. (EPA 2012b). In 1999, EPA passed strict regulations to initiate a major effort to improve air quality in national parks and wilderness areas (EPA 2012b). Regional haze is a key concern in national parks like those in western North Carolina, including GUCO, as viewing scenery is the top reason ten million visitors come to the area annually and generate over $2 billion in tourism revenues every year (Jim Renfro, personal communication 2012).

Data and Methods

Data used in this assessment consisted of estimated haze index values in deciviews (dv). Conditions for visibility are based on visibility on mid-range days, defined as the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions (i.e., Group 50 visibility minus natural conditions), where Group 50 is defined as the mean of the visibility observations falling within the range from the 40^{th} through the 60^{th} percentiles. Annual average measurements for visibility on mid-range days were averaged over five-year periods spanning the years 1999-2012 at all IMROVE monitoring sites. For sites without on-site or nearby monitors, these five-year averages were interpolated for all atmospheric deposition monitoring locations (i.e., parks) using an inverse distance weighting (IDW) method to estimate five-year average values for sites across the contiguous U.S. Estimated values for each national park unit are made available to the public through the NPS AirAtlas website (NPS ARD 2014).

The estimated current visibility condition for GUCO is the value derived from this national analysis at the geographic center of the park. These sites are a considerable distance away from GUCO; however, they represent the best available data for this NPS site (NPS 2008, NPS ARD 2014; Appendix A). A resulting condition greater than 8 dv above estimated natural conditions is assigned a warrants significant concern status; a current visibility condition from 2-8 dv above estimated natural conditions is assigned a warrants moderate concern status; a resource is in good condition if the current visibility condition is <2 dv above estimated natural conditions (NPS ARD 2013b).

Visibility trends were computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the Clean Air Act, which include improving visibility on the haziest days and allowing no deterioration on the clearest days (NPS ARD 2013b). If the Haze Index trend on the 20% clearest days was deteriorating, the overall visibility trend was reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days was reported as the overall visibility trend. These data are compared with monitoring data from across the U.S. to provide a national and regional context for current conditions reported at GUCO (NPS ARD 2013a).

Reference Conditions

The Clean Air Act established a national goal to return visibility to "natural conditions" in Class I areas, and NPS ARD recommends a visibility benchmark condition for all NPS units, regardless of Class designation, consistent with the CAA goal. Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment (EPA 2003). NPS ARD recommends that average visibility days should be <2 dv above estimated natural conditions as a benchmark for good visibility condition (NPS ARD 2013b).

Conditions and Trends

For the 2008-2012 time period, visibility warrants significant concern at GUCO. This condition is based on NPS ARD benchmarks and the 2008-2012 estimated visibility on mid-range days of 9.6 dv above estimated natural conditions (7.3 dv) (Figure 4.1.16) (NPS ARD 2013b, NPS ARD 2014). These visibility conditions are consistent with data from other parks across the region and the eastern U.S. (Figure 4.1.17) (NPS 2013a).

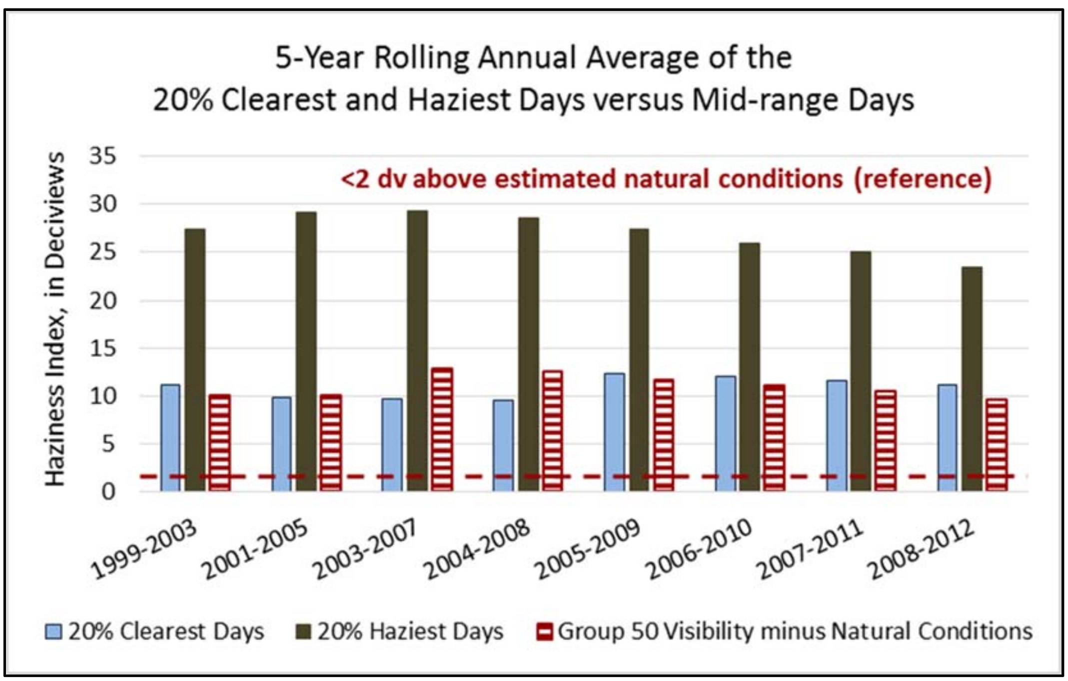


Figure 4.1.16. 5-year rolling annual averages of visibility values on haziest (worst) days, clearest (best) days, and mid-range days for GUCO (NPS ARD 2014).

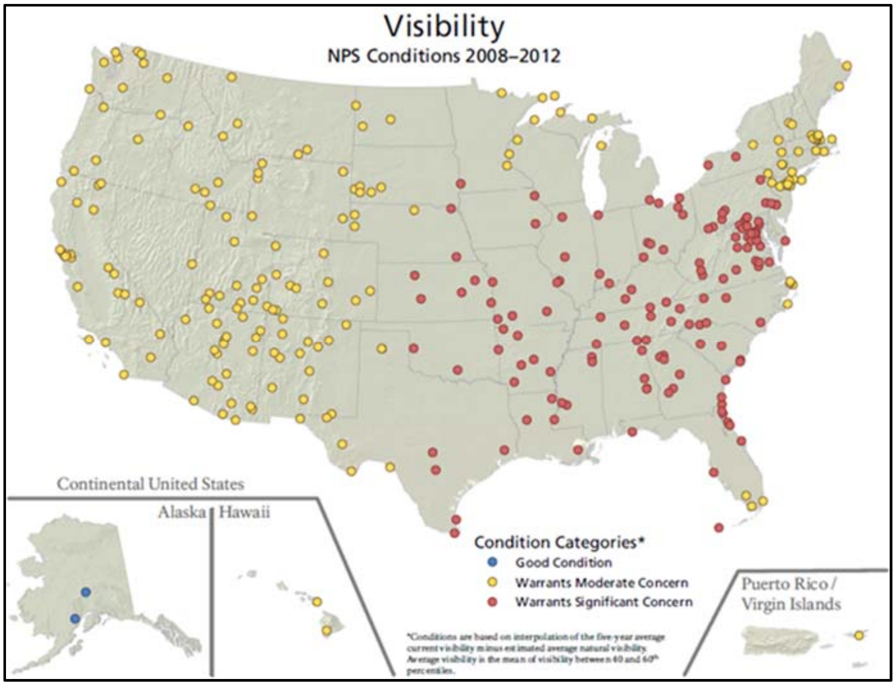


Figure 4.1.17. Map of visibility conditions in U.S. national parks, 2008-2012 (NPS 2013a).

Haze is particularly an issue in the eastern U.S., and the region in which GUCO is located has consistently experienced annual mean deciview values on the haziest days well in excess of estimated natural conditions. Although GUCO does not have a representative monitor, there are improving visibility trends in most parks across the eastern U.S., which are likely due to tighter NAAQS standards for $PM_{2.5}$ Best Available Retrofit Technology Rules, and Reasonable Progress measures under the Regional Haze Rule (Figures 4.1.18 and 4.1.19) (EPA 2012a, NPS ARD 2013a). Although observed trends over the long-term are improving, high deciview values on mid-range days indicate that major reductions are still needed to reduce regional haze and improve visibility within the park back to natural conditions.

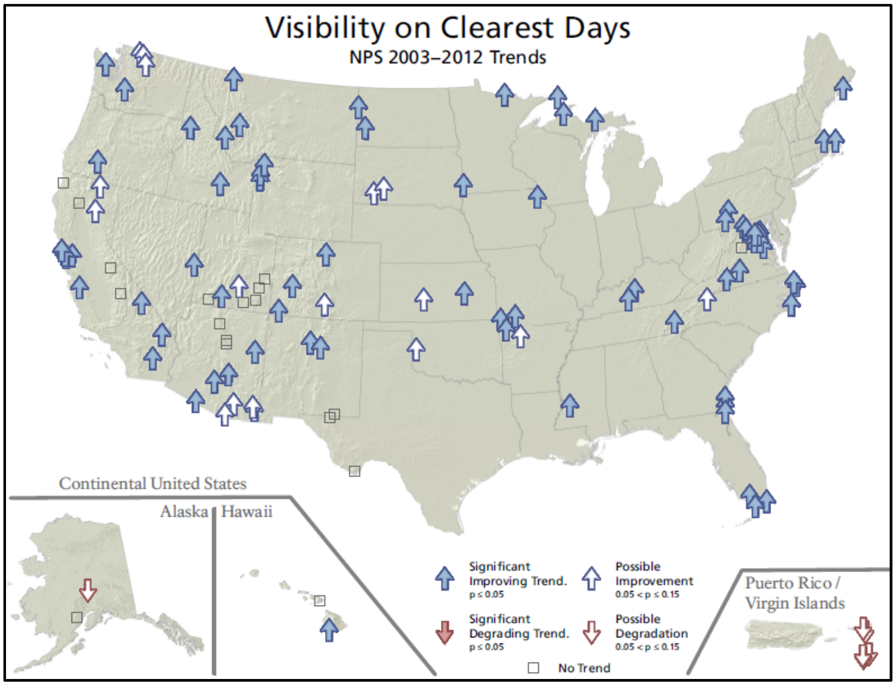


Figure 4.1.18. 10-year trends in visibility on clearest days, 2003-2012 (NPS ARD 2013a).

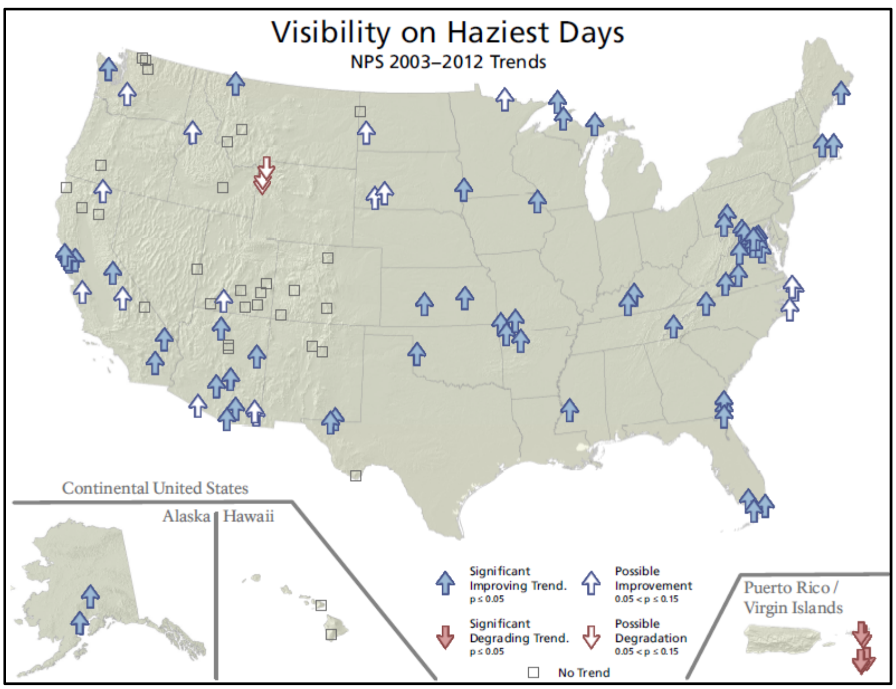


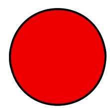
Figure 4.1.19. 10-year trends in visibility on haziest days, 2003-2012 (NPS ARD 2013a).

Confidence and Data Gaps

The degree of confidence at GUCO is medium because estimates are based on interpolated data from more distant visibility monitors (Table 4.1.7). These IMPROVE sites are located >180 km (112 miles) away, and while this is not ideal, these data represent the best available for GUCO. However, haze tends to operate at a regional scale, and therefore, there is medium confidence in the current assessment of condition of visibility; current trend information for visibility is not available (Table 4.1.7) (NPS ARD 2013b).

Summary Condition

Table 4.1.7. Graphical summary of status and trends for visibility.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Visibility / Haze (Haze Index in deciviews [dv])		Estimated visibility on mid-range days was 9.6 dv (2008-12); warrants significant concern; trend info not available; exceeds significant concern level of <8 dv above estimated natural conditions (Data Source(s): IMPROVE via AirAtlas)

Sources of Expertise

- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, Air Resources Division
- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.2. Soil and Geologic Resources

4.2.1. Soil Function and Dynamics

Relevance

Soils have a large impact on GUCO resources by: 1) serving as a medium for plant growth, 2) influencing precipitation chemistry before it reaches surface and ground waters, and 3) providing physical support for traffic by humans, animals, and machinery. The soils in GUCO formed primarily in residuum weathered from high-grade metamorphic rocks that may be high in mica content. This type of parent material in combination with the region's warm, wet climate produces acidic soils with low fertility. These soils have given rise to the characteristic vegetative communities found at GUCO including pine.

Reference Conditions

We defined the reference condition for soils to consist of soil properties sufficient to support the native vegetative communities found at GUCO, and human and vehicular traffic without causing erosion or sedimentation.

Data and Methods

The locations and general properties of different soil types were derived from soil surveys conducted by the Natural Resource Conservation Service (formerly Soil Conservation Service) as part of a county-wide inventory in 1977 (Stephens 1977) and a custom report for GUCO completed in 2016 (USDA NRCS 2016). In addition, a wetlands investigation assessed hydric soils found in two small wetlands (Roberts and Morgan 2006).

Current Condition and Trend

Eight soil map units and four primary soil series are found in GUCO (Figure 4.2.1) (Table 4.2.1). There are four principal soil types: Cecil sandy loam, Cecil-Urban land complex, Madison sandy loam, and Wehadkee silt loam. Cecil sandy loam is the predominant soil in the uplands and covers more than 85% of the park (Table 4.2.1). Cecil soils have brown sandy loam surface and a thick subsoil of yellowish red sandy clay loam and red clay. These soils were the most heavily cultivated, and as a result, the soils under most of the eastern third of the park are considered to be eroded versions of this type (Stephens 1977, White and Pyne 2003). The Cecil-Urban land complex consists of areas of Cecil sandy loam that have been heavily disturbed or developed by humans. Madison sandy loam occurs on fairly steep slopes on both sides of Richland Creek and consists of a surface layer of reddish brown sandy loam and a subsoil of red clay. Wehadkee silt loam is only found on the bottomlands of Richland Creek and the old lakebed of Lake Wilfong and consists of a surface layer of brown silt loam about 20 cm (8 inches) thick and a subsoil of silt loam. The organic matter content of this type is higher than for the other soil types in the park (Stephens 1977, White and Pyne 2003).

Table 4.2.1. Soil map unit descriptions and area of each soil map in GUCO (USDA NRCS 2016).

Guilford County, North Carolina (NC081)			
Map Unit Symbol	**Map Unit Name**	**Acres in GUCO**	**Percent of GUCO**
CcB	Cecil sandy loam, 2 to 6 percent slopes	109.4	50.7%
CcC	Cecil sandy loam, 6 to 10 percent slopes	36.2	16.8%
CeB2	Cecil sandy clay loam, 2 to 6 percent slopes, moderately eroded	19.8	9.2%
CeC2	Cecil sandy clay loam, 6 to 10 percent slopes, moderately eroded	20.5	9.5%
CfB	Cecil-Urban land complex, 2 to 10 percent slopes	8.5	3.9%
ClC2	Clifford sandy clay loam, 6 to 10 percent slopes, moderately eroded	3.8	1.8%

Table 4.2.1 (continued). Soil map unit descriptions and area of each soil map in GUCO (USDA NRCS 2016).

Guilford County, North Carolina (NC081)			
Map Unit Symbol	**Map Unit Name**	**Acres in GUCO**	**Percent of GUCO**
MaE	Madison sandy loam, 15 to 35 percent slopes	9.1	4.2%
W	Water	0.1	0.0%
WhA	Wehadkee loam, 0 to 2 percent slopes, frequently flooded	8.3	3.8%
Totals for Area of Interest		**215.7**	**100.0%**

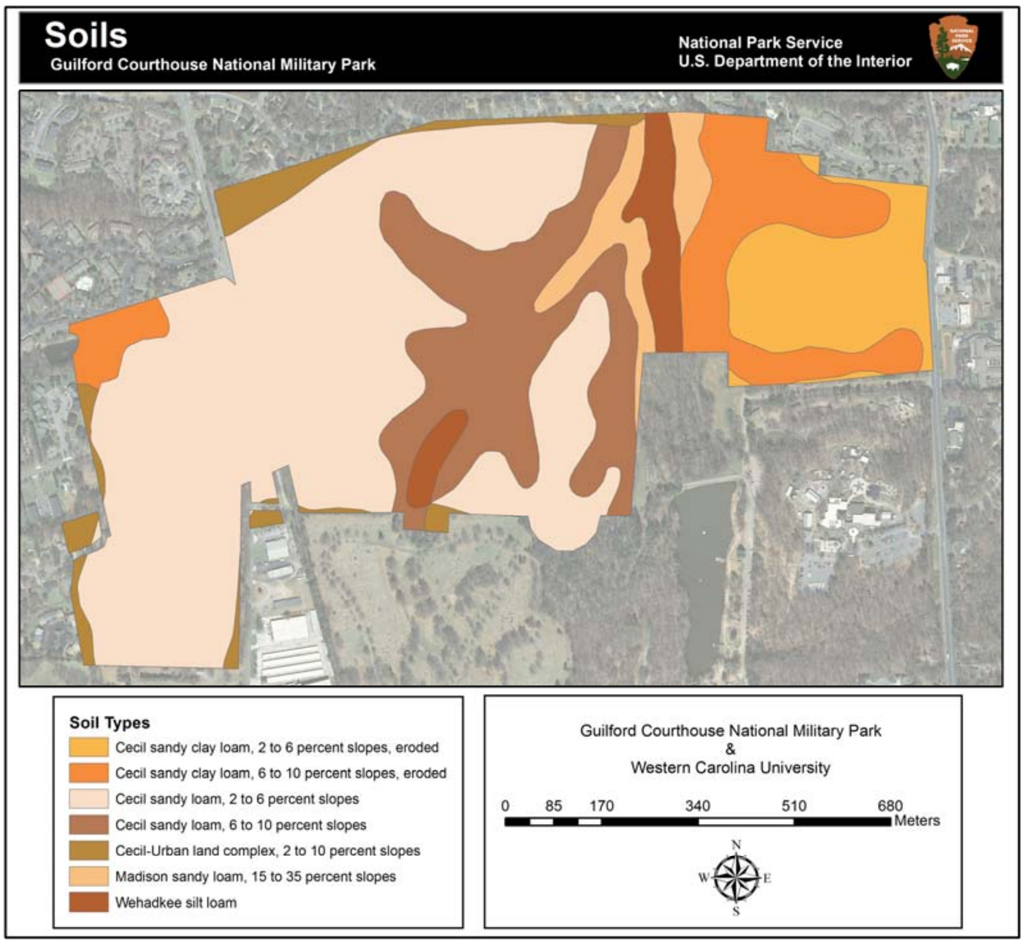


Figure 4.2.1. Soil survey for the Guilford Courthouse National Military Park (USDA NRCS 2016).

<u>Confidence and Data Gaps</u>

The Guilford County Soil Survey conducted in 1977 (Stevens 1977) is virtually the only source of soils information available for GUCO, and with the exception of the wetlands study (Roberts and

Morgan 2006) there are no data available regarding the physical or chemical properties of GUCO soils. There is no regular soil measurement or monitoring program, due in part to the rich archaeological resources found at the park. There is also no temporal or repeated spatial soil monitoring. We are confident that the current soil condition is degraded due to past cultivation and disturbance; however due to lack of data we cannot assign a trend.

Summary Condition

Table 4.2.2. Graphical summary of status and trends for soil quality.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Soil & Geologic Resources	Soil Function and Quality		Reference condition consists of soil properties sufficient to support the native vegetative communities found at GUCO, and human and vehicular traffic without causing erosion or sedimentation. Current condition is degraded by past cultivation and other disturbances.

4.3. Water Quality

The majority of the predominately forested GUCO landscape is drained by Hunting Creek, a small, incised, northeast trending tributary to Richland Creek. Hunting Creek receives the majority of its runoff from within the park boundaries (Figure 4.3.1). In contrast, Richland Creek heads in an urbanized area south of the park and flows north through two lakes within the Greensboro Country Park before traversing GUCO (Figure 4.3.1). A small section of the park, located in the Hoskins Farmstead area drains westward before flowing north into Horsepen Creek. Surface waters within the park are designated by the State of North Carolina as “WS-IV” (NCDEQ 2011) Waters (NPS 2012). Although recreational use of surface waters is limited, they are viewed as a critical ecological resource and determinant of the park’s overall ecological resource condition. Water quality is a particularly important ecological indicator as poor water quality may impact biota and lead to a deterioration of local ecological health.

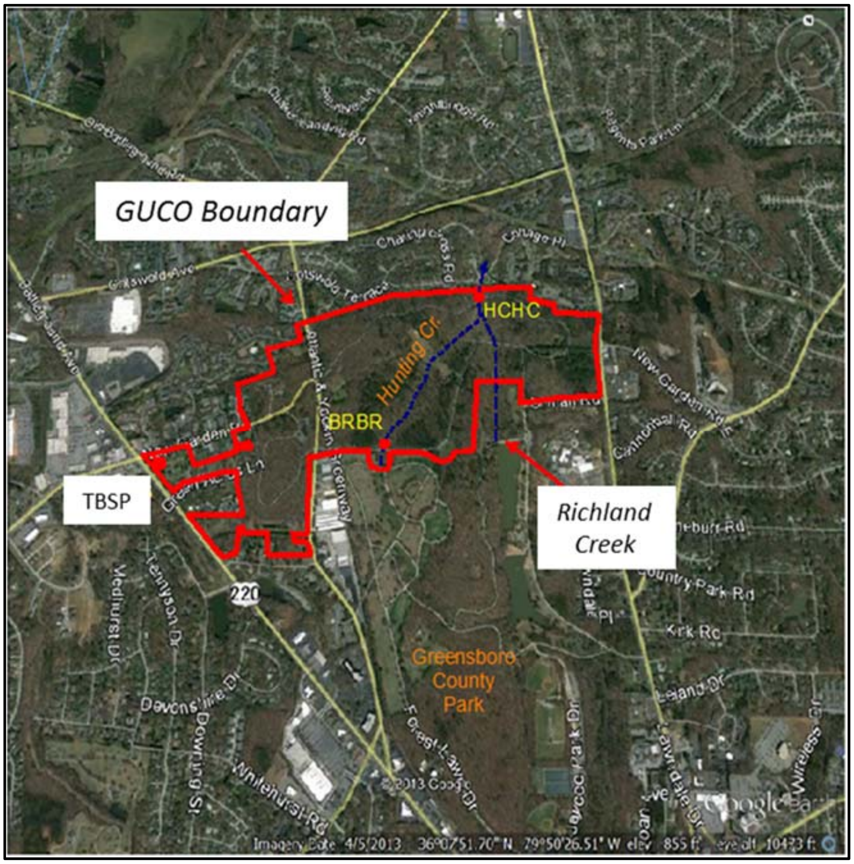


Figure 4.3.1. Map showing location of sampling sites (red filled circles) within GUCO. HCHC – Hunting Creek; BRBR – Bloody Run; TBSP – Tannenbaum Spring (photo from Google Earth).

4.3.1. Water Chemistry

Relevance

As is true for surface waters through the eastern and southeastern U.S., a potential water quality concern is the atmospheric deposition of acid pollutants in the form of sulfur (S) and nitrogen (N) compounds. Such acid deposition has the potential to lead to episodic or long-term (chronic) acidification of surface waters (Baumgardner et al. 2003). The effects of acidic waters on aquatic biota differ between species and life stages. Nonetheless, as illustrated by Table 4.3.1, the potential ecological effects of low pH waters on fish and other aquatic biota increase with increasing acidity. At high concentrations, hydrogen ions or protons (H^+) can be lethal or cause sublethal physiological stress in aquatic biota (Woodward et al. 1991, MacAvoy and Bulger 1995, Baldigo et al. 2007, Neff et al. 2009). The primary effect of acid toxicity in fish is the disruption of ion regulation which can lead to lowered blood pressure and circulatory failure. Ion regulation is primarily disrupted by the interference of protons with the gill transport system, resulting in a decline in sodium uptake and an increase in whole body sodium loss (Grippo and Dunson 1996, Neff et al. 2009). In addition to its direct effects on aquatic biota, acidic waters with a pH <~6.0 have the potential to increase the mobility, solubility, and toxicity of other toxic pollutants, particularly metals (Driscoll et al. 1980, Gensemer and Playle 1999).

Table 4.3.1. Possible ecological consequences of acidic stream waters on biota within the northeastern U.S. (Baker et al. 1996).

pH Range	Biological Effects
>6.5	No adverse effects
6.0-6.5	Loss of sensitive benthic invertebrates
5.5-6.0	Loss of acid-sensitive fish Reduced reproduction insensitive fish species Increase in green algae in periphyton
5.0-5.5	Loss of most fish species Green algae dominate periphyton Loss of most mayflies, stoneflies, caddis flies, and shellfish Reduced biomass and productivity
<5.0	Loss of all fish species Decreased nutrient cycling rates Decline in periphyton species richness Decline in benthic invertebrates Reproductive failure of acid-sensitive amphibians

Data and Methods

Five measures were selected for the evaluation of water chemistry. They include two parameters that allow for the characterization of stream water acidification (pH, acid neutralizing capacity) and three measures, including dissolved oxygen (DO), specific conductance, and water temperature that provide insights into the overall water quality of the park. Although temperature is not a chemical parameter, it is included here as it has a strong influence on water chemistry.

Since October, 2004 sampling and water quality analysis have been conducted quarterly on alternating fiscal years at two sites within the park (Table 4.3.2) for temperature, specific conductance, pH, dissolved oxygen, and acid neutralizing capacity (ANC). An additional site (Tannenbaum Spring) was added to the monitoring program in October 2009. The general characteristics of the sites are as follows:

- Hunting Creek: This site is located just downstream of the confluence between Hunting Creek and Richland Creek; thus, the stream reach receives runoff from areas both within and outside of the park;

- Bloody Run (also called Graveyard Springs): The Bloody Run monitoring site is located along the southern border of the park. The stream reach is characterized by a deep, narrow channel with eroding banks that is positioned downstream of a square culvert that extends below a road. South (upstream) of the culvert the channel abruptly transitions into a wide shallow depression that extends into a cemetery. Drainage is primarily derived from the road and, outside the park, from overland flow within the cemetery;

- Tannenbaum Spring: The monitoring site is located within a wide, shallow depression that receives water from Tannenbaum Spring as well as overland flow from manicured areas of lawn.

All of the data is available, and was obtained for this assessment, from the National Park Service's STORET (NPSTORET) database and water quality reports.

Table 4.3.2. Summary of water quality data collection dates at GUCO.

Year	Bloody Run	Hunting Creek	Tannenbaum Spring
2004	April 19 July 12 October 18	April 19 July 12 October 18	---
2005	January 24 October 4	January 24 October 4	---
2006	January 5 April 10 July 11	January 5 April 10 July 11	---
2007	October 22	October 22	---
2008	February 5 April 24 July 28	February 5 April 24 July 28	---
2009	October 21	October 21	October 21
2010	January 22 April 20 July 20	January 22 April 20 July 20	January 22 April 20 July 20
2011	October 25	October 25	October 25
2012	January 24 April 24 July 12	January 24 April 24 July 12	January 24 April 24 July 12
2013	October 24	October 24	October 24
2014	January 21 April 15 July 15	January 21 April 15 July 15	January 21 April 15 July 15

The assessment considers both spatial and temporal variations in the examined water quality data. Spatially, the analysis focused on two scales: 1) data collected at specific locations within GUCO, and 2) data collected at multiple sites throughout GUCO and used to assess variations in water quality on a park-wide basis. Temporally, trends in the examined water quality parameters were evaluated over an approximately ten year monitoring period.

Reference Conditions

Surface Water Acidification

Stream water acidification was assessed using two parameters: pH and ANC. Both state and federal water quality criteria exist for pH. The EPA criterion to support freshwater aquatic life and sustain wildlife is set at a pH of 6.5-9.0 (EPA 1986). The acceptable, narrative standard set by North Carolina Department of Environment and Natural Resources is 6.0-9.0 (NCDENR 2007). Herein, the utilized reference values are based on the North Carolina standard and set at 6.0-9.0.

ANC is widely utilized to characterize the acid-base chemistry of surface- and groundwater. Essentially, ANC is the difference between proton acceptors and proton donors within a water sample. As such, it serves as an index of both the susceptibility of stream waters to acidification (Webb et al. 1989) (Table 4.3.3), and the extent to which stream waters have been acidified (Hemond 1990). ANC is not affected by temporal variations in the total inorganic carbon content of the waters and, thus, is often regarded as a more appropriate indicator of the water's acidic condition (Hemond 1990). Acid stream waters are defined as those in which ANC < 0 mg/L ($CaCO_3$).

Table 4.3.3. Summary of stream system sensitivity to acidic conditions (Webb et al. 1989; based on studies of native brook trout in Virginia).

ANC Range (µeq/L)	ANC Range (mg/L)	Classification
< 0	<0	Acidic
0 - 50	0-2.5	Extremely Sensitive
50 - 200	2.5-10.0	Sensitive
>200	>10.0	Not Classified

Currently, state and federal standards for ANC do not exist. However, a reference value of 2.5 mg/L $CaCO_3$ (or 50 µeq/L) is used as a reference value herein on the basis of: 1) past studies of ecosystem sensitivity to acidification, such as presented in Table 4.3.3 (Webb et al. 1989, Cai et al. 2012), and 2) a default total maximum daily load (TMDL) management target of 2.5 mg/L (50 µeq/L) set by the Tennessee Department of Environment and Conservation for Great Smoky Mountain National Park (TDEC 2010). The proposed ANC target is thought to be the value that would result in a pH within the range of 6 to 9 for impaired watersheds.

Other Water Chemistry Indicators

Three indicators were selected to assess the general quality of the park's water with respect to water chemistry, including: specific conductance, dissolved oxygen (DO), and temperature. Specific conductance is a measure of the water's ability to conduct an electric current, and is usually reported in microsiemens per centimeter (µS/cm). It is closely linked to the concentration of ions in the water; the higher the concentration, the more conductive the water. Thus, specific conductance is often used to assess the concentration of total dissolved solids, including pollutants, within surface waters.

Conductivity in natural (uncontaminated) rivers in the U.S. range from about 5 to 1,500 µS/cm. Due to the large range in conductivity observed within unpolluted surface waters, there are no state or federal water quality criteria for specific conductance. However, stream waters within the Blue Ridge and the North Carolina Piedmont typically exhibit values ranging from below 50 to around 200 µS/cm (Harned and Meyer 1983, Crawford 1985, Webster et al. 2012, Miller unpublished data). Given the noted ranges for specific conductance, 200 µS/cm is put forth as a general reference value.

Temperature, or the intensity of heat stored within a body of water, is an important water quality parameter in that it: 1) affects the solubility of oxygen and chemical pollutants in the water, and 2) influences metabolic oxygen demand and growth rates. Increases in water temperatures increase metabolic oxygen demand while reducing the dissolved oxygen content of the water. In general, chemical pollutants are also more soluble at higher temperatures.

All aquatic species possess a range of water temperatures that they prefer. Water temperatures above or below this range pose a risk to their health. In most instances, the primary concern is for water temperatures to exceed the upper limit of acceptability, particularly during the summer months. For this evaluation, 29 °C (84.2 °F) is used as a reference, following the water quality criteria set by North Carolina for streams in the mountains and upper piedmont (Table 4.3.4).

Table 4.3.4. North Carolina temperature water quality criterion.

Parameter	North Carolina
Temperature	Temperature: not to exceed 2.8 °C above the natural water temperature and in no case to exceed 29 °C (84.2 °F) for mountain and upper piedmont waters (NCDENR 2007)

DO is essential to the metabolism of aquatic organisms and is required for high quality waters. It also influences a host of other water quality parameters, such as water clarity, odor, and taste as well as the solubility and availability of nutrients. The concentration of DO in water is strongly influenced by water temperature; warm waters hold less DO than do cold waters (Swenson and Baldwin 1965). Thus, DO concentrations are subject to seasonal fluctuations in temperatures. Moreover, fish tend to utilize more DO in warm waters than cold. Trout, for example, may require five to six times more oxygen in waters at 25 °C (77 °F) than at 5 °C (41 °F).

A number of studies suggest that dissolved oxygen concentrations of at least 4-5 mg/L are required to support a diverse population of fish species. The North Carolina criteria for DO are an average daily value of 5 mg/L, or instantaneous value of 4 mg/L (Table 4.3.5). These criteria are used as a reference for this evaluation.

Table 4.3.5. Dissolved oxygen water quality criteria set by North Carolina and the EPA.

Parameter	North Carolina	EPA
Dissolved Oxygen	Dissolved oxygen: for non-trout waters, not less than a daily average of 5.0 mg/L with a minimum instantaneous value of not less than 4.0 mg/l (NCDENR 2007)	Dissolved oxygen, cold-water criteria - levels greater than or equal to 4 mg/L are thought to be protective of freshwater aquatic life (EPA 1986)

Conditions and Trends

Surface Water Acidification (pH, ANC)

Data collected since 2004 show that surface waters within the park tend to be slightly acidic, exhibiting mean and median pH values between 2004 and 2012 of 6.6 and 6.6, respectively, when data from all three sites are considered. There are only slight variations in pH between the three monitoring sites with Hunting Creek possessing waters with pH values that are slightly higher than at the other two sites. Six measurements over the monitoring period were found to be below the 6.0 reference value (Table 4.3.6): four from Bloody Run and two from Tannenbaum Spring (Figure 4.3.2). Data collected through 2012 show that low pH values are associated with relatively low flow conditions (Figure 4.3.3). However, flow may not be the only control on pH as: 1) pH values measured in 2014 are, in general, lower than those recorded for the sites before 2013, and 2) all six pH measurements below the utilized standard of 6.0 were taken after 2011 (Figure 4.3.2). Although it is unclear at this time whether these lower, recently collected pH values represent a long-term trend or a short-term fluctuation in the data, it is possible that the lower values represent an increase in stream water acidification.

Table 4.3.6. Summary of standard value exceedance by site between 2004 and 2014. *E.coli* – MPN/100ml water; DO – mg/L; temperature - °C.

Site	Descriptive Statistics	Low pH	*E. coli*	DO	Temperature
Bloody Run (Graveyard Spring)	Observations	24	20	23	24
	Standard Value	6	576	5	29
	# Exceeding Standard	2	3	4	0
	Percent of Exc.	17	20	22	0
Hunting Creek	Observations	14	19	23	23
	Standard Value	6	576	5	29
Hunting Creek	# Exceed Standard	0	5	0	0
	Percent of Exc.	0	26	0	0
Percent of Exc. Tannenbaum Spring	Observations*	12	12	12	12
	Standard Value	6	576	5	29
	# Exceed Standard	2	1	2	0
	Percent of Exc.	17	8	17	0
Totals	**Observations**	**50**	**51**	**48**	**49**
	Standard Value	**6**	**576**	**5**	**29**
	# Exceeding Standard	**6**	**10**	**7**	**0**
	Percent of Exc.	**12**	**20**	**15**	**0**

*Data collected between 2009 and 2014

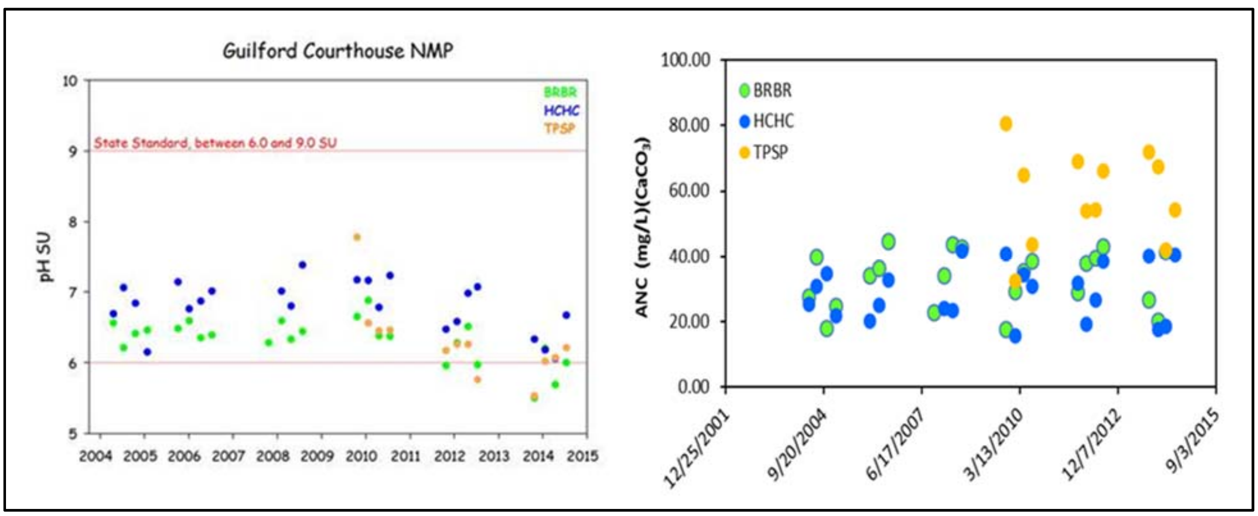


Figure 4.3.2. pH (left) and ANC (right) measured at the three monitoring sites within GUCO during the monitoring period.

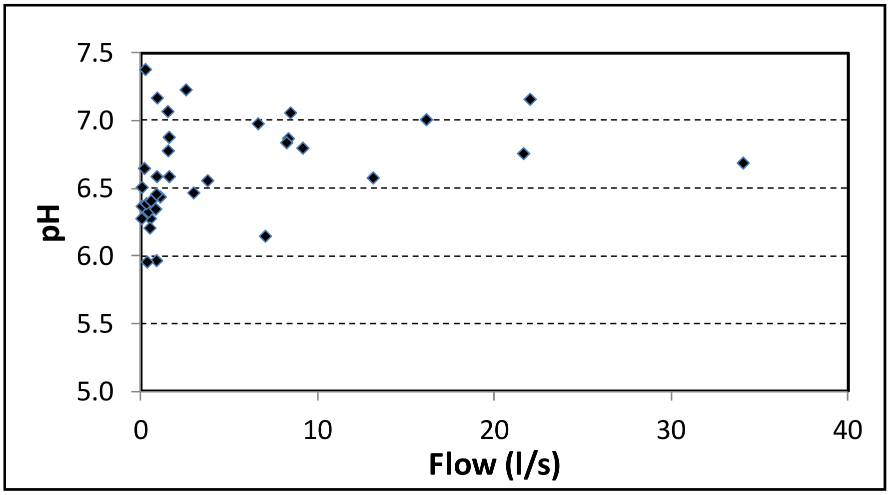


Figure 4.3.3. Changes in pH with stream flow. Data from all three sites within GUCO between 2004 and 2012 (some pH measurements are missing flow data).

ANC was usually above 20 mg/L ($CaCO_3$) (although values as low as 15.6 were measured at Hunting Creek) (Figure 4.3.2). Concentrations were consistently higher at the Tannenbaum Spring site than at the other two sites. The higher values are likely to reflect higher base cation concentrations associated with higher inputs of groundwater to the site. The influence of base cations on ANC from groundwater is consistent with its observed logarithmic decline within increasing stream flow during the monitoring period (Figure 4.3.4) as the decline is likely to result from cation dilution as cation “poor” waters associated with precipitation enter the streams during runoff events. Unlike pH, ANC does not appear to vary through time at any of the monitoring sites, in spite of a change in the utilized measurement technique. Before October 2006 ANC was analyzed with a Hach digital titrator; after October 2006 ANC was analyzed using the approved, superior Gran Titration method. Regardless of the cause, the observed ANC values suggest that the stream waters within GUCO are not particularly sensitive to changes in pH.

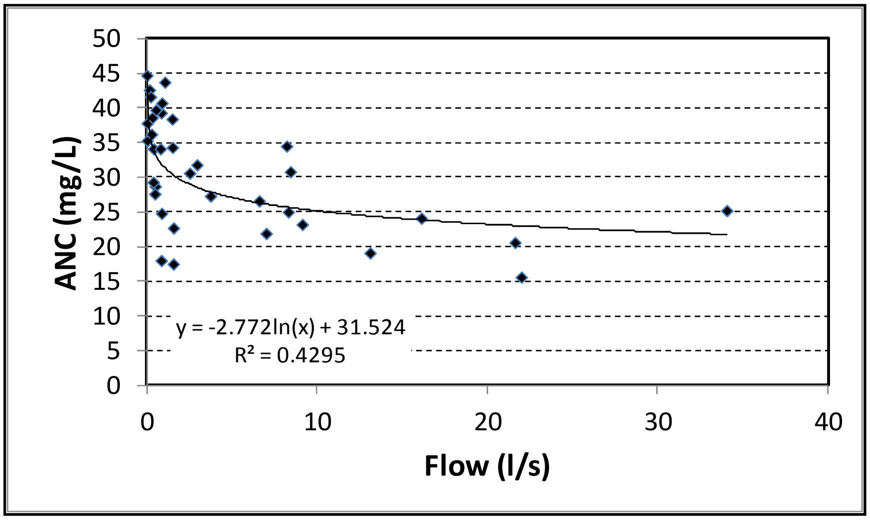


Figure 4.3.4. Changes in ANC with stream flow. Data from all three sites within GUCO between 2004 and 2012.

Other Water Quality Parameters

Water temperatures for the entire data set and for the individual sites are well below the 29 °C (84.2 °F) threshold set by the State of North Carolina for WS-IV stream waters (NCDENR 2007) (Figure 4.3.5). In addition, the maximum temperature measured over the monitoring period at the three sites was 27.4 °C (81.3 °F) or below. With regards to temporal trends, yearly variations in mean annual water temperatures occur, but temperature has not changed significantly over the monitoring period.

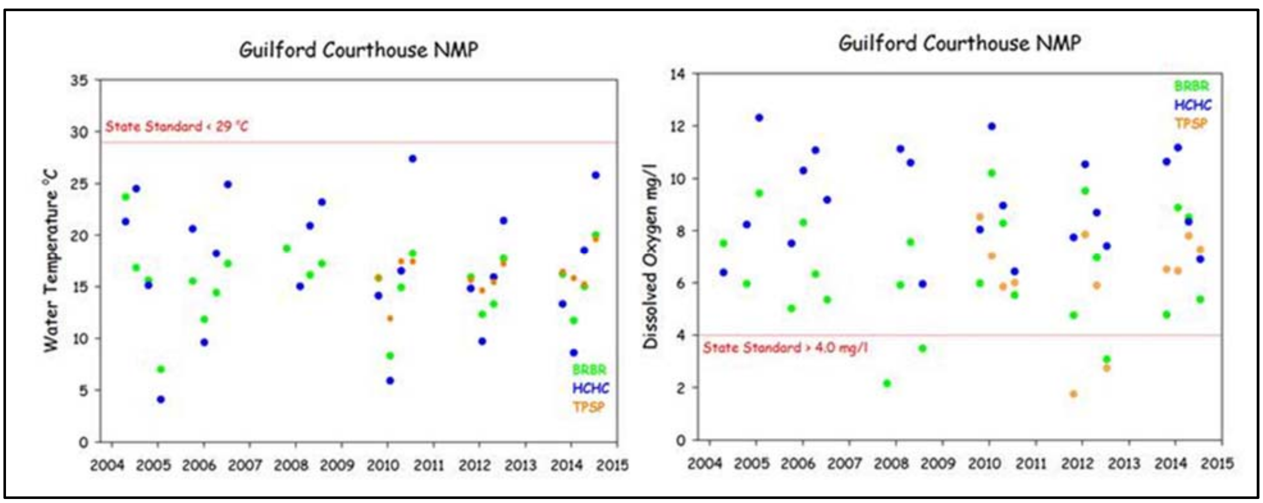


Figure 4.3.5. Water temperature (left) and dissolved oxygen concentration (right) measured at three sites within the park between 2004 and the end of 2014.

In general, DO values were above both the average 5 mg/L threshold and the instantaneous 4 mg/L threshold set by North Carolina and used herein as a reference (Figure 4.3.5). DO was below the 4 mg/L instantaneous threshold on five occasions. The lower DO values reflect in part warmer water temperatures. A comparison of the two graphs in Figure 4.3.5 show that DO measurements were below 5.0 mg/L in 2007 and 2008 when water temperatures were relatively high, and well above 5.0 mg/L in 2005 when water temperatures were relatively low. DO values are higher than might be expected in 2004 and lower in 2011 given the range of measured water temperatures, suggesting that other factors in addition to water temperature may affect DO concentrations. In fact, Figure 4.3.6 shows that low DO values are associated with low flow conditions. This is not unexpected as aeration of the water associated with turbulence is often limited during low flow conditions.

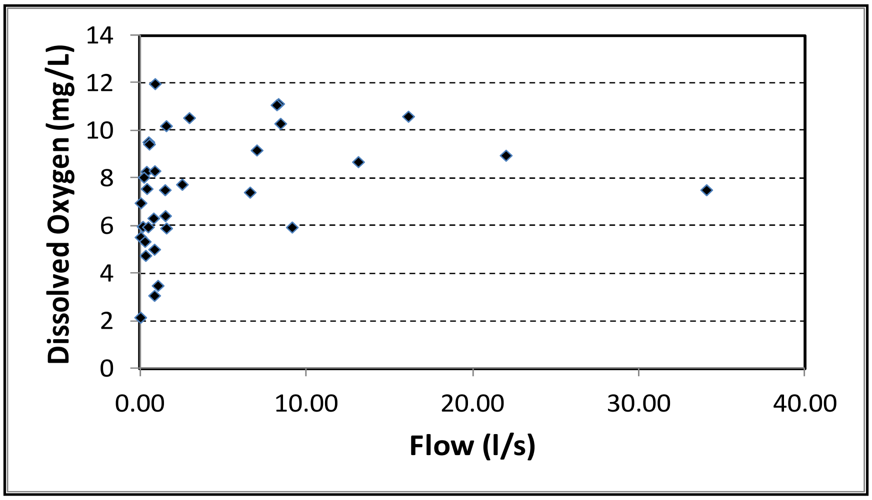


Figure 4.3.6. Changes in DO concentration between 2004 and 2012 with stream flow.

Specific conductance values measured between 2004 and 2014 ranged from 54.7 to 177.1 µS/cm (Figure 4.3.7). On a site by site basis, Bloody Run and Hunting Creek exhibited similar values, whereas conductance was slightly higher at Tannenbaum Spring. The higher values at Tannenbaum Spring may be related to relatively high groundwater inflow at the site during runoff events. The prolonged contact of groundwater with rock materials often results in higher levels of dissolved constituents, and thus specific conductance.

Park-wide, the measured specific conductance values are similar to data collected from surface waters within the Cape Fear (Crawford 1985) and Yadkin (Harned and Meyer 1983) river basins for waters that are thought to be in good condition. For example, data collected within the Yadkin River basin between 1970-1978 ranged from 34-95 µS/cm at a site near Yadkin College and 15-190 µS/cm at a site on the Pee Dee River near Rockingham. Both sites were considered to possess waters of relatively good condition in comparison to the water within the Rocky River near Norwood which exhibited conductance values between 60 and 698 µS/cm.

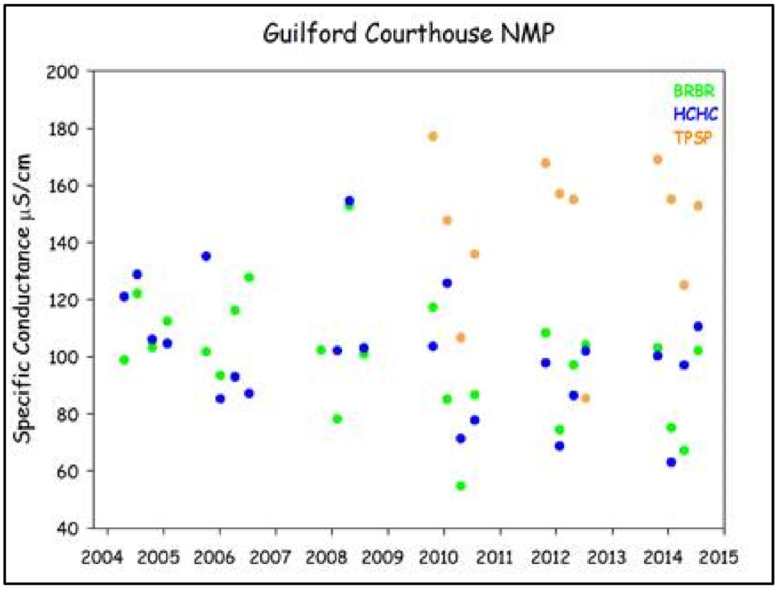


Figure 4.3.7. Specific conductivity measured at the three monitored sites within GUCO between 2004 and 2014.

Figure 4.3.7 shows that there is no systematic temporal trend in specific conductance during the monitoring period. In addition, while specific conductance often varies systematically with changes in stream discharge, no such statistically significant trend was apparent for the sites at GUCO (Figure 4.3.8).

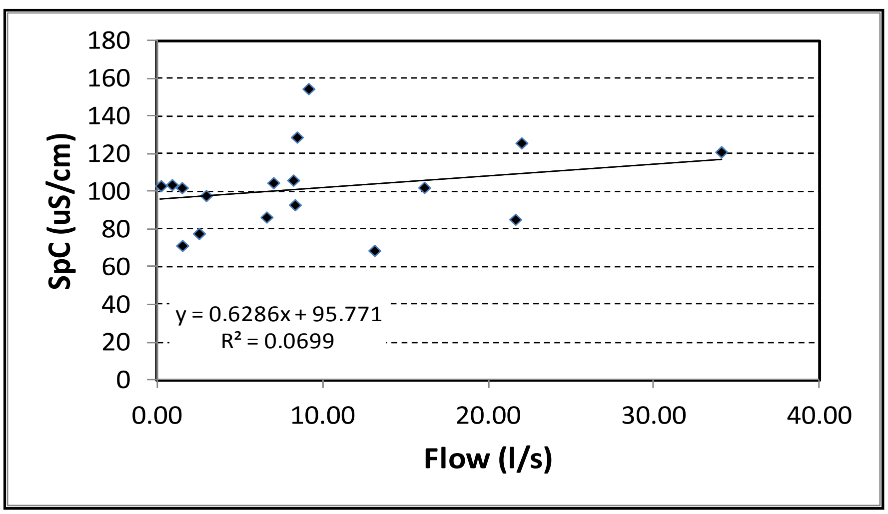


Figure 4.3.8. Variations in specific conductance at Hunting Creek with changing flow conditions between 2004 and 2012. The trend line sown is not statistically significant.

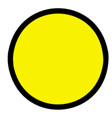
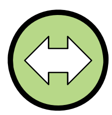
Confidence and Gaps

In general, there is high confidence in the measured parameters used to assess water chemistry. With the exception of ANC, data have been collected for a period of approximately ten years from three sites within the park (all located within a relatively small area). However, the concentration of many contaminants, including pH, ANC, and DO vary as a function of stream flow (Miller and Orbock Miller 2007, Neff et al. 2013). Past sampling has utilized a single grab sample approach, resulting in the collection of waters over a relatively small range of flow conditions. Thus, it is currently unclear how the selected water quality metrics vary during large flood events. The collection of water quality and discharge data throughout several storm events is needed to enhance the analysis and interpretation of water quality.

Summary Condition

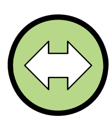
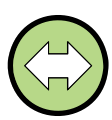
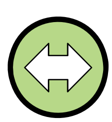
Stream water chemistry is summarized below with regards to surface water acidification and the general water quality within the park. With regards to the former, surface water acidification is a moderate concern within GUCO as pH values have frequently fallen outside of the utilized range of reference values since 2011.

Table 4.3.7. Graphical summary of status and trends for water quality, based on pH and ANC.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Hydrogen (H^+) concentration (pH units)		Surface waters since 2011 are often below a pH 6.0; ANC, however, does not fall below the 2.5 mg/L (50 µeq/L) reference target. Reference Condition: North Carolina Water Quality Standard for fish and aquatic life (Class C); Tennessee State ANC TMDL default target set for the GRSM (TDEC 2010)
Water Quality	ANC, Difference between proton acceptors and donors in stream water (µeq/L)		

Water quality chemistry in general, however, is in good condition.

Table 4.3.8. Graphical summary of status and trends for water quality, based on general water chemistry factors.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Stream Water Temperature (°C)		Temperature of headwater streams consistently below reference standard, Reference Condition based North Carolina Standards for aquatic life
Water Quality	Specific Conductance (µS/cm)		Conductivity consistently below regional reference. Specific Conductance based on regional data collected from "reference" basins
Water Quality	Dissolved Oxygen Concentration (mg/L)		DO consistently above reference value. Dissolved oxygen based on the North Carolina Standard (Class C)

Sources of Expertise

- Joe Meiman, Hydrologist, National Park Service

4.3.2. Toxics

Relevance

Stream Water Acidification

Air quality monitoring data collected since the 1980s have shown that the southern Appalachians and upper piedmont in North Carolina and eastern Tennessee receive some of the highest levels of sulfur and nitrogen deposition in the U.S. (e.g., Nodvin et al. 1995, Shubzda et al. 1995, Smoot et al. 2000, NADP 2006, Sullivan et al. 2007). For example, acid depositional rates measured within Great Smoky Mountain National Park at the Elkmont and Noland Divide monitoring sites are well above those measured in other parks throughout the U.S. (Figure 4.3.9). The acid pollutants are thought to be primarily derived from regional coal-fired power plants and, to a much lesser degree, vehicular traffic emissions (Chestnut and Mills 2005). Although sulfate and nitrate deposition in the GUCO area is lower than within the Blue Ridge physiographic province, depositional rates have historically, and continue to be, relatively high in comparison to many other areas of the U.S. (Figure 4.3.10).

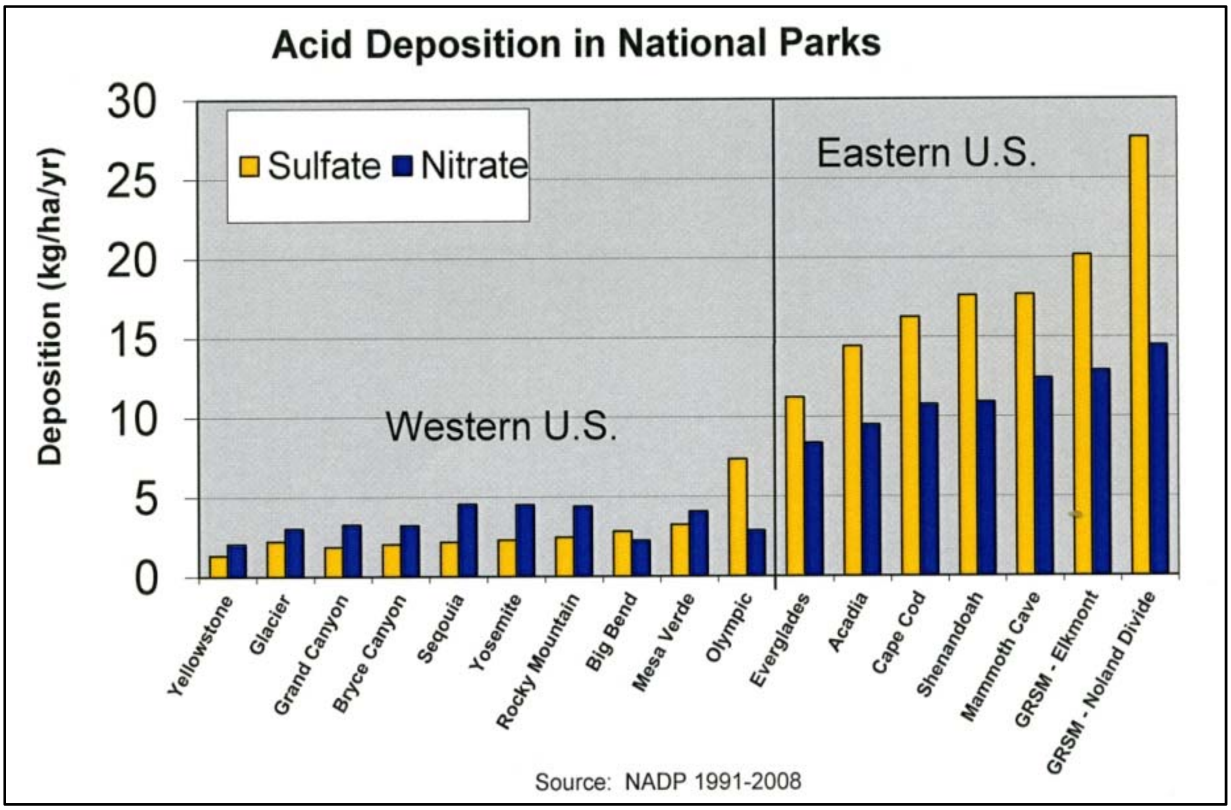


Figure 4.3.9. Average annual wet deposition of sulfate and nitrate in U.S. national parks (Vana-Miller et al. 2010).

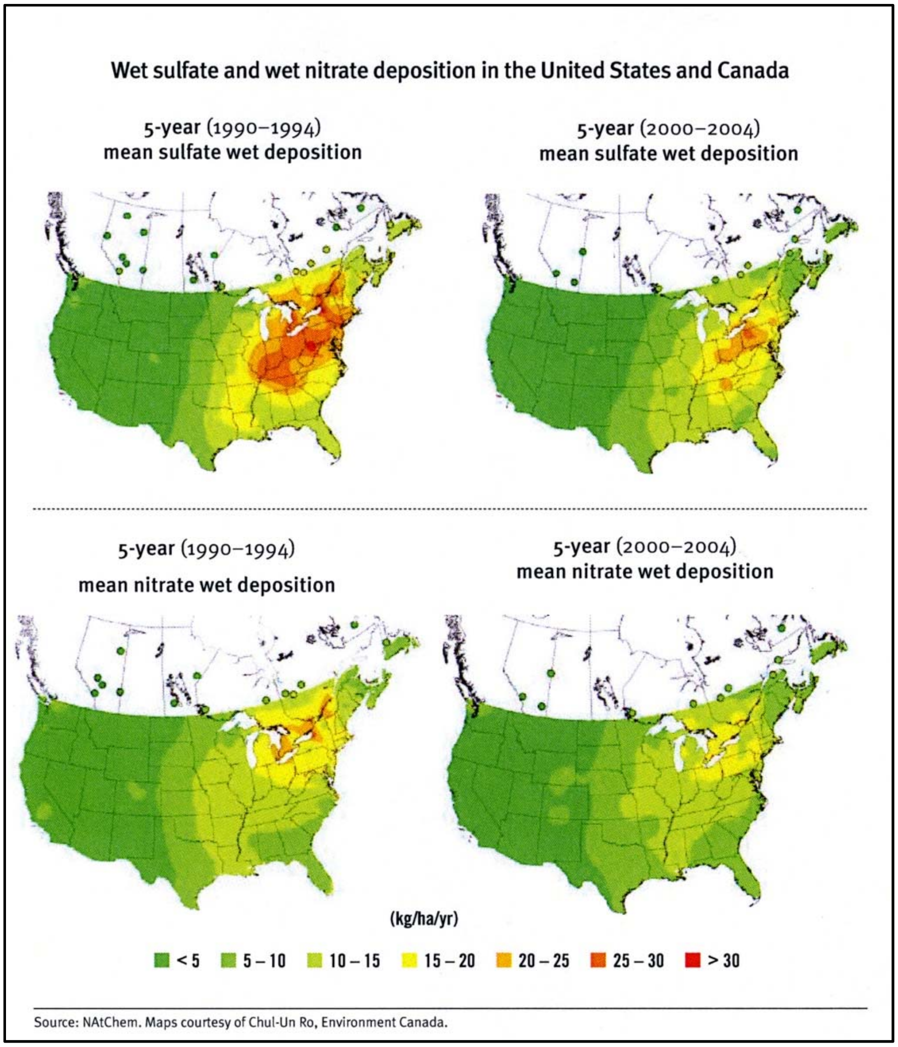


Figure 4.3.10. Spatial variations in sulfate and nitrate deposition within the U.S. (maps from Environment Canada 2003).

The concern over surface water acidification is exacerbated in many parts of the eastern U.S. including the GUCO area by low concentrations of base metals/base cations within the underlying bedrock. The lack of significant cation within the underlying rocks limits the ability of natural stream waters to buffer the input of acidic runoff (Herlihy et al. 1996), making surface waters particularly sensitive to acidification. In the case of GUCO, the bedrock underlying the park is composed of metamorphosed granite of the Churchland Pluton to the north and metamorphosed felsic intrusive rocks including biotite schists and amphibolites of the Carolina Slate Belt to the south. The two rock units are separated by a shear zone that is composed of both rock units (Mininger and Nunnery 2001) (Figure 4.3.11).

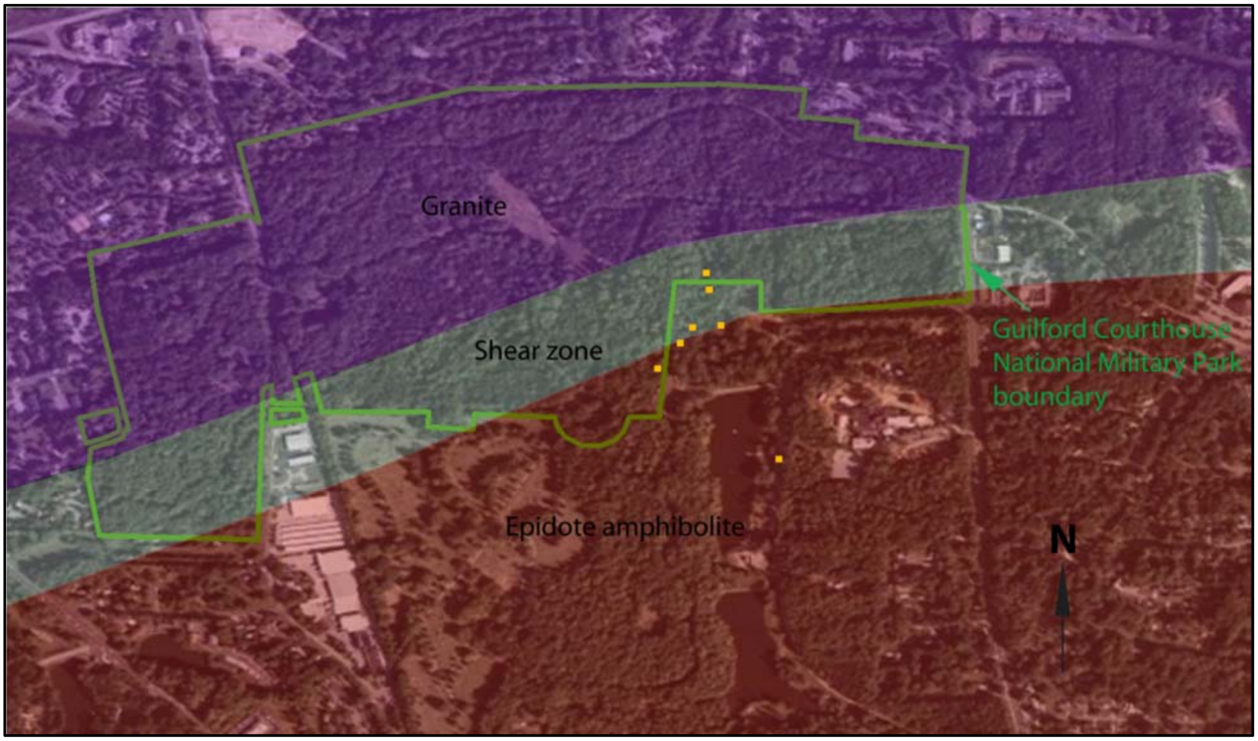


Figure 4.3.11. Geologic map of GUCO overlain on aerial photograph. Major rock units include granites typical of the Churchland Pluton and amphibolite rocks typical of the Carolina Slate that are separated by a shear zone characterized by heavily deformed and broken rocks. Location of bedrock outcrops are shown by yellow squares. Mapping by Mininger and Nunnery (2001). Graphic created by Trista L. Thornberry-Ehrlich (Colorado State University) and extracted from NPS (2011). Base map compiled by Jason Kenworthy (NPS Geologic Resources Division) from ESRI ArcImage Server, USA Prime Imagery.

Trace Metals

A potential water quality concern that is often linked to the acidification of surface waters is the potential mobilization of toxic metals and metalloids (e.g., aluminum, cadmium, copper, lead, and zinc) from soils and sediments. Dissolved aluminum (Al), especially when occurring in the form of inorganic monomeric aluminum (AlIM), is of particular concern in acidic waters (Driscoll et al. 1980, Driscoll 1985, Hermann et al. 1993, Baldigo and Murdoch 1997). AlIM has been shown to disrupt fish gill ion transport and lead to the whole body loss of sodium, inhibiting ion regulation (Driscoll 1985, Driscoll et al. 2001). Dissolved Al have been shown to be particularly high in acidified stream waters, prompting numerous investigations of the impact of dissolved Al on aquatic biota in low pH waters (Huckabee et al. 1975, Deyton et al. 2009, Neff et al. 2009, Cai et al. 2012, Neff et al. 2013). Within Great Smoky Mountain National Park, for example, Cai et al. (2012) found that park-wide mean dissolved Al concentrations for both base flow and storm flow were above 0.2 mg/L, a value that they argue is a threshold for impacts on aquatic biota.

Another trace metal of potential concern is mercury (Hg). Although numerous Hg sources exist, the atmospheric deposition of Hg serves as a primary, if not the predominant, source for many terrestrial and aquatic ecosystems. It is emitted into the atmosphere from both natural sources (e.g., volcanic activity) and anthropogenic sources (e.g., fossil fuel combustion, precious metal mining, non-ferrous metal smelting, chlor-alkali plants, and waste incineration). About 50 to 70% of the atmospheric Hg is thought to come from anthropogenic sources. Coal-fired power plants are widely considered to be largest supplier of Hg to the atmosphere (EPA 1997). Once in the atmosphere it can be transferred to terrestrial and aquatic ecosystems through wet and dry deposition, litter fall, throughfall, and cloud deposition (Fisher and Wolfe 2012). Data provided by the Mercury Deposition Network (2006) show that the region, including GUCO, is subjected to high rates of Hg deposition (Figure 4.3.12).

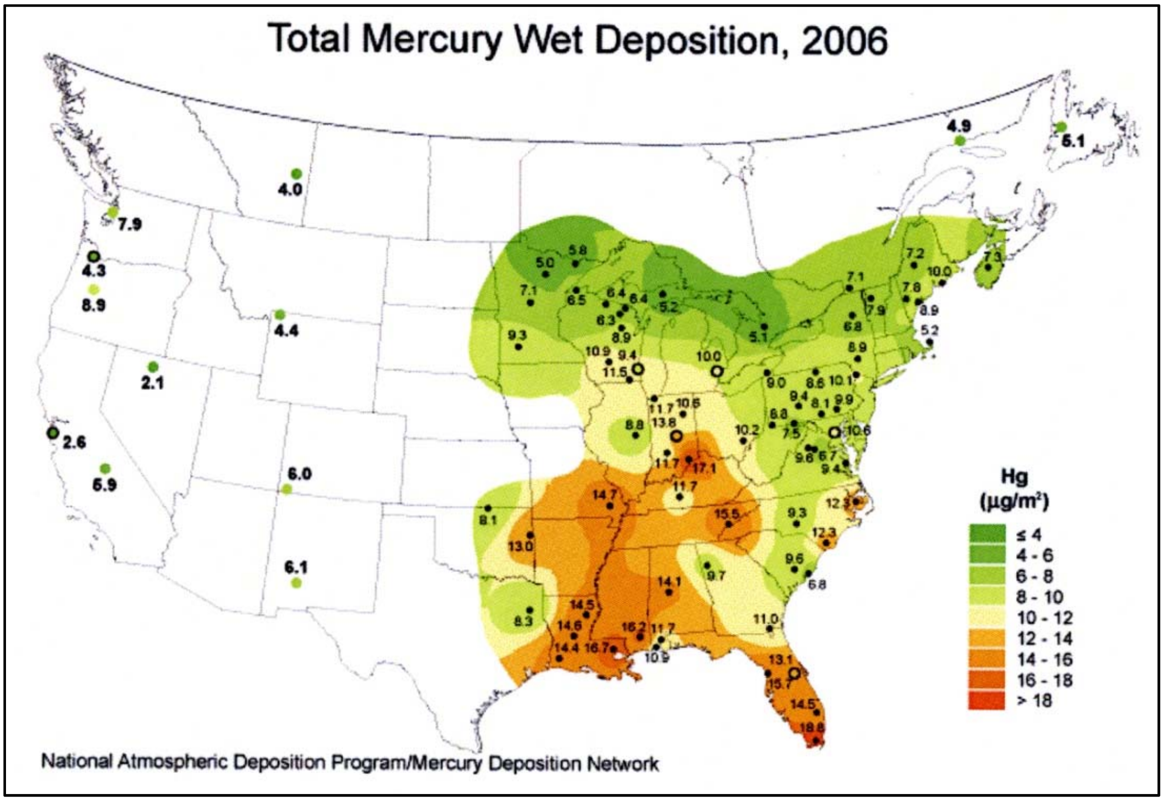


Figure 4.3.12. Map shows total wet mercury deposition in 2006 within the U.S. (Mercury Deposition Network 2006).

Other toxic trace metals, such as cadmium (Cd), copper (Cu), zinc (Zn), and lead (Pb), are often associated with urban runoff (Miller and Orbock Miller 2007), and therefore may be of concern within Richland Creek which traverses the park.

Data and Methods

Sulfate and nitrate concentrations were measured on four occasions at two sites in the park (Blood Run and Hunting creeks) during the 2004-2005 sampling period. Toxic trace metal concentrations have not been analyzed for surface waters within the park.

Reference Conditions

Sulfate and Nitrate Concentrations

The EPA has established drinking water standards for sulfate (161 μeq/L, 10 mg/L) and nitrate (5,205 μeq/L, 250 mg/L), respectively. Within GUCO, however, the primary concern is their potential effect on stream water acidification. Thus, the drinking water standards are not directly applicable to this assessment. The influence of both constituents on acidification varies with a host of watershed parameters (e.g., geology, soil type and thickness, discharge and vegetation cover) (see, Neff et al. 2009, 2013 for example). Thus, reference conditions are proposed here on the basis of the concentrations observed on a local and regional scale.

Regionally, Argue et al. (2011) using data collected from headwater streams along the Appalachian Trail (from Maine to Georgia) found that median sulfate and nitrate concentrations varied between nine separate ecoregions. Sulfate ranged from 49.76 to 233.18 μeq/L whereas nitrate ranged from 1.02 to 6.71 μeq/L. Sullivan et al. (2007) compiled nitrate and sulfate data from 66 watersheds in North Carolina, Tennessee, and South Carolina. They found that sulfate values within these watersheds ranged from 9.8 to 207.4 μeq/L, whereas nitrate values ranged from 0 to 23.1 μeq/L. Sulfate and nitrate concentrations at the Coweeta Long-term Ecological Research Station (Coweeta) are on the order of 12 μeq/L and < 5 μeq/L, respectively throughout the year (Hartman et al. 2009). These values are on the low end of the concentration range cited by Sullivan et al. (2007) and Argue et al. (2011). Zhou et al. (2014) estimated the mean, pre-industrial sulfate and nitrate concentration within12 watersheds in Great Smoky Mountain National Park to be 9.5 $\pm$ 7.1 μeq/L and 1.2 $\pm$ 0.7 μeq/L, respectively, both within the range found at Coweeta.

The majority of data presented above were derived from mountainous terrains that are likely to exhibit higher rates of precipitation and atmospheric sulfur and nitrogen deposition. Nonetheless, concentrations of 0.56 mg/L (12 μeq/L) for sulfate and <0.31 mg/L (<5 μeq/L) for nitrate as found at Coweeta and estimated as a pre-industrial – 1850 – value for the area are reasonable reference concentrations.

Trace Metals

The chemistry of Al in natural waters is complex as it can exist as free Al, or form a number of inorganic and organic complexes (species), depending on a wide range of parameters including pH, temperature, and the dissolved organic carbon (DOC) content of the water. The pH of the water acts as a particularly important control on its solubility and speciation (Howells et al.1990, Spry and Wiener 1991, Driscoll and Postek 1996). Aluminum is relatively insoluble under neutral pH conditions (6.0 - 8.0), but its solubility is enhanced under acidic and alkaline conditions (pH <6 or >8), or where complexing ligands are present. Free Al and inorganic monomeric aluminum (Al_{IM}) are considered to be the most toxic chemical forms to fish and other aquatic biota (Gagen and Sharpe 1987). Dissolved Al, particularly Al_{IM}, tends to disrupt ion transport within fish gills by replacing calcium on the gill surfaces. Thus, dissolved Al may result in ion regulatory problems as well as respiratory issues associated with the coagulation of mucous on fish gills (Driscoll 1985, Exley et al. 1991, Hermann et al. 1993, Cai et al. 2012). The toxicity of Al is influenced by several factors, including the pH and dissolved DOC content of the water. Calcium concentrations are also important as calcium is known to reduce the permeability of biological membranes and may therefore reduce ion losses and Al toxicity. The base cation concentration of the water (i.e., water hardness) may also influence the toxicity to biota. These external influences are important because toxicity thresholds may vary spatially between the watersheds in a region as a result of their overall water chemistry.

The EPA Water Quality Criterion (1986a, 2013) for freshwater (87 µg/L for chronic exposure and 750 µg/L for acute exposure) is based on a pH range of 6.5 to 9.0, and represents the *total recoverable* Al within the waters (rather than the *dissolved* aluminum concentration). State criteria for *dissolved* Al do not exist. Thus, the 87 µg/L total recoverable Al concentration is used here as reference value. It should be noted, however, that surface waters may exhibit pH values that are below 6.5, above which the EPA standard applies. In these more acidic waters, Cai et al. (2012) suggested that toxic effects, particularly in trout, may occur at dissolved concentrations of >0.2 mg/L (200 µg/L) for total dissolved Al and Al_{IM}. How applicable these values are to fish species found within the stream and lakes at GUCO is currently unknown.

The geochemistry of mercury is complex as it can it exist in a number of inorganic and organic chemical forms and may undergo a wide range of geochemical transformations. Inorganic forms, including metallic mercury (Hg^0), mercurous mercury (Hg_2^{2+}), and mercuric mercury (Hg^{2+}), occur naturally in the environment, and are produced by a wide variety of industrial activities. Inorganic forms of mercury, including metallic mercury, can be transformed to the mercuric species, after which it is often converted by methanogenic bacteria to organic Hg forms including monomethyl and dimethyl mercury. Monomethyl mercury (or simply methyl-mercury) is the most common form of the two organic species and is readily accumulated in biota, particularly fish. In humans, about 95% of the ingested organic mercury is absorbed following ingestion, most commonly by consuming contaminated fish or other aquatic biota. Significant exposure of inorganic Hg affects the nervous system, gastrointestinal tract, and/or the kidneys, whereas the exposure to organic forms may impair the development of the central nervous system and/or cause brain and liver damage (Miller and Villarroel 2011).

Both state and federal water quality criteria exist for total Hg in stream waters. The EPA Criteria for freshwater ecosystems is a maximum dissolved Hg exposure of 1.4 µg/L and a chronic exposure limit of 0.77 µg/L. The water quality criterion for the State of North Carolina is based on the total recoverable Hg in water, rather than the dissolved concentration. It is 0.012 µg/L. Here the North Carolina and EPA criteria are used as reference concentrations for total recoverable and dissolved acute/chronic exposures, respectively.

A number of trace metals in addition to Al are toxic to aquatic biota and may affect water quality within the park. Table 4.3.9 below provides a comparison of the various water quality criteria that have been put forth for North Carolina and the EPA for a number of these metals. The utilized reference values are based on the North Carolina standards for total recoverable metals and the EPA standards for dissolved metal concentrations.

Table 4.3.9. State and federal water quality standards for selected metals.

Metal	North Carolina (total recoverable) (µg/L)	EPA (dissolved) (µg/L)
Arsenic (As)	50	340 (acute); 150 (chronic)
Cadmium (Cd)	2	2 (acute); 0.25 (chronic); for hardness of 100 mg/L
Copper (Cu)	7	Based on Biotic Ligand Model which requires 10 input parameters (temperature, pH, dissolved organic carbon (DOC), calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity)
Chromium (Cr)	50	570 (acute); 74 (chronic); for Cr III at a hardness of 100 mg/L
Iron (Fe)	1,000	1000
Lead (Pb)	25	65 (acute); 2.5 (chronic); for hardness of 100 mg/L
Manganese (Mn)	---	---
Mercury (Hg)	0.012	1.4 (acute); 0.77 (chronic)
Nickel (Ni)	88	470 (acute); 52 (chronic) (for hardness of 100 mg/L)
Silver (Ag)	0.06	3.2 (acute); for hardness of 100 mg/L
Zinc (Zn)	50	120 (acute & chronic) (for hardness of 100 mg/L)

Conditions and Trends

Sulfate and Nitrate

Mean sulfate concentrations determined in 2004-2005 were found to be 1.6 and 3.5 mg/L for Blood Run and Hunting Creek, respectively. Concentrations ranged from 1.4 to 4.3 mg/L, and were consistently higher by about a factor of two at Hunting Creek. Mean nitrate concentrations were calculated to be 2.1 and 0.6 mg/L for Blood Run and Hunting Creek, respectively. Interestingly, the higher nitrate concentrations were consistently observed at Blood Run, ranging from 1.4 to 2.7 mg/L. Although the data are limited, sulfate and nitrate concentrations measured in all four samples from the two sites (eight samples total) exceeded the regional reference values used herein. Exceedance of the regional reference values is consistent with the observed acidic conditions of the surface waters as measured by pH, and suggests that the elevated levels of both sulfate and nitrate is of moderate concern. Temporal trends in sulfate and nitrate cannot be determined using the existing dataset.

Trace Metals

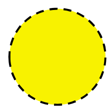
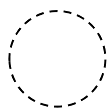
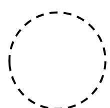
Water quality conditions and trends with respect to trace metals cannot be determined at this time given the lack of data for surface waters within the park.

Confidence and Gaps

Sulfate and nitrate data were collected approximately ten years ago from grab samples during a one year period. Thus, the data are limited and the noted concentrations within the park exhibit a high degree of uncertainty. Trace metal and metalloid concentration data are also lacking for the park. It follows, then, that data for these toxic parameters represents a current gap in the water quality analysis.

<u>Summary Condition</u>
Due to differences in the available data and potential toxic effects on aquatic biota, Al, sulfate, nitrate, and trace metals are summarized separately.

Table 4.3.10. Graphical summary of status and trends of water quality, based on the concentration of dissolved aluminum, nitrate, sulfate, and other trace metals.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Sulfate, nitrate Total dissolved concentration (mg/L)		Data within the park are limited; existing data suggest that regional standards are continuously exceeded. Reference Condition: Based on regional conditions
Water Quality	Dissolved aluminum concentration, aluminum in water passing through 0.45 µm filter (µg/L)		Concentrations of dissolved aluminum frequently exceed the 200 µg/L reference value. Reference Condition: Based on review of toxic affects to biota by Cai et al. (2012)
Water Quality	As, Cu, Hg, Fe Mn, Zn concentration Total and/or dissolved concentrations (µg/L)		Concentrations of these metals rarely exceed the reference values. Reference Condition: Based EPA and/or state guidelines

<u>Sources of Expertise</u>
- Joe Meiman, Hydrologist, National Park Service

4.3.3. Microorganisms

<u>Relevance</u>
Pathogens negatively impact more river miles in the U.S. than any other type of contaminant (EPA 2002a). The types of pathogens found in natural surface waters are enormous, making it impossible to routinely monitor for specific organisms. Thus, waters are generally analyzed for specific groups of bacteria that are thought to be indicators of contamination by human or animal wastes. The most frequently utilized indicators are total coliforms, or the more specific subsets including fecal coliforms, *Escherichia coli (E. coli)*, and enterococci. Since some strains of total coliforms are associated with plant materials, they tend to be poor indicators of human and other animal waste. In contrast, *E. coli* and enterococci are primarily associated with the feces of warm-blooded animals. In addition, both have been shown to exhibit a stronger correlation to swimming-associated gastroenteritis than the other indicators (EPA 2001), prompting the EPA to recommend the use of enterococci and *E. coli* as indicators of fecal contamination of freshwater (EPA 2002b).

Data and Methods

Data were obtained for fecal coliform in 2004 and 2005 from two monitoring sites within the park, whereas sampling after 2005 focused on *Escherichia coli (E. coli)*. An additional site (Tannenbaum Spring) was added to the monitoring program in October 2009.

Reference Conditions

For this evaluation we used the North Carolina State standard as a reference for fecal coliform (200 cfu/100 mL of water) (Table 4.3.11). North Carolina does not have a standard for *E. coli*. Therefore, we utilized the EPA recommendation (576 MPN/100 mL**)** for waters in which there is infrequent swimming.

Table 4.3.11. Fecal coliform criteria set by North Carolina.

Parameter	North Carolina (Fecal Coliform)	EPA (*E. coli*)
Bacteria	Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100ml (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100ml in more than 20 percent of the samples examined during such period. Violations of the fecal coliform standard are expected during rainfall events and, in some cases, this violation is expected to be caused by uncontrollable nonpoint source pollution (NCDENR, 2007).	30 day mean – 126 MPN/100 mL with no one value over 235 cfu/100mL; 235 to 576 cfu/100 mL for instantaneous measurement of freshwaters depending on use; 576 MPN/100mL for waters designated as "infrequent swimming."

Conditions and Trends

Fecal coliform values ranged from 67 to 519 per 100 ml. Park-wide nine of the 39 *E. coli* samples exceed the 576 MPN/100 ml threshold for waters in which there is infrequent swimming. The threshold was exceeded at least once at all three sites (Table 4.3.2); Hunting Creek possessed the largest number of samples exceeding the threshold, and exhibited slightly higher *E. coli* values. The higher *E. coli* values may be associated with the influx of water to the site from lakes within the Greensboro County Park which are utilized extensively by waterfowl (NPS 2012). The period from 2008-2010 exhibited the highest values (Figure 4.3.13). Pathogen contamination of surface waters is known to vary widely with flow conditions. Although there is currently insufficient data to understand the controls on the episodic bacterial contamination of the site, the high values between 2008 and 2010 may reflect the prolonged periods of low flow associated with a drought at the time.

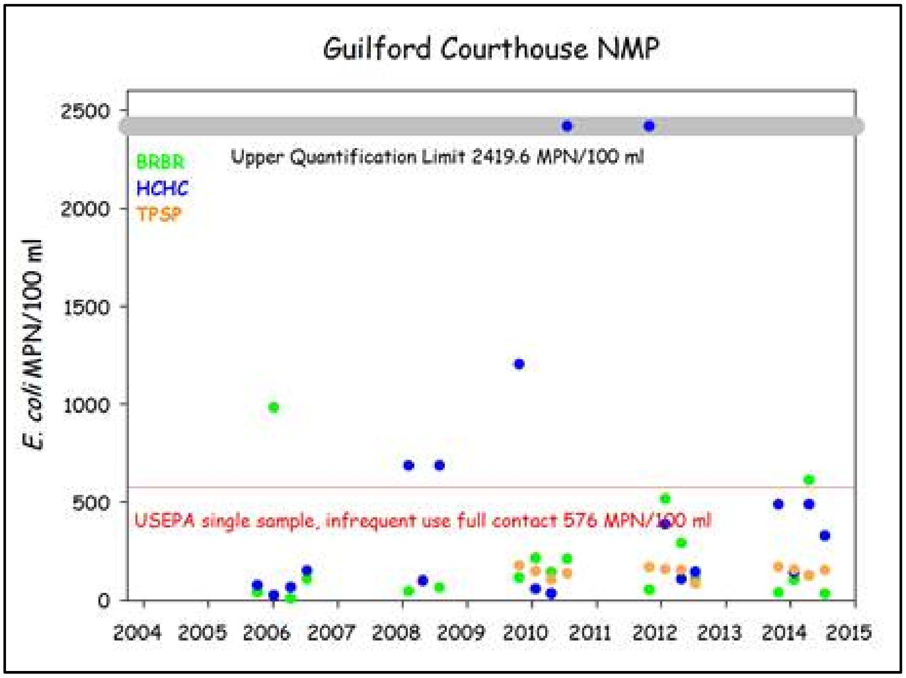


Figure 4.3.13. Park-wide variations in *E. coli* from 2005 to 2014. Prior to 2005, fecal coliform was analyzed.

Given that *E. coli* values exceeded the EPA threshold value of 576 MPN/100mL for waters infrequently used for swimming more than 20% of the time, surface water contamination by pathogens may be of concern (the limited data result in a low to medium level of confidence in the assessment). However, there is currently insufficient data to assess either the current condition or the trend in water quality with respect to bacteria within the park.

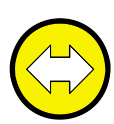
Confidence and Gaps

In general, there is a high degree of confidence in the assessment of water quality with respect to coliform bacteria. Data have been collected for a period approaching ten years from several sites within the park.

Summary Condition

E. coli values are generally below the EPA threshold value of 576 cfu/100mL for waters infrequently used for swimming during the monitoring period. However, the threshold was exceeded on a relatively frequent basis (Table 4.3.12) (Figure 4.3.13). Thus, water quality with respect to bacteria is thought to be moderate but stable.

Table 4.3.12. Graphical summary of status and trends for water quality, based on the presence of coliform bacteria.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Coliform Bacteria (MPN/100ml)		Reference value for *E. coli* was occasionally exceeded. North Carolina standard for fecal coliform (200 cfu/100 mL of water); EPA Criteria for *E.coli* (576 MPN/100 mL)

Sources of Expertise

- Joe Meiman, Hydrologist, National Park Service

4.4. Invasive Species

4.4.1. Invasive Exotic Plants

Relevance

Exotic invasive species are a major stressor that affects vegetation communities and are ranked highly among a core set of vital signs in the CUPN. Although most remain relatively innocuous in the landscape, some exotic invasive species are aggressive plants that may compromise key ecological processes by reducing native species richness and altering community structure, among other impacts (Schofield 1989, Hobbs et al. 1992, Kourtev et al. 2002, O'Driscoll and Shear 2009). Within the CUPN parks, exotic invasive species tend to establish and occur around boundaries, disturbed areas, floodplains, and/or high visitor use areas (CUPN 2013).

GUCO is surrounded by a highly urbanized area which includes residential and commercial areas and high traffic thruways. Exotic species are an ongoing management challenge for park resource managers. Nonnative plant species have been combatted since the National Park Service began operations at GUCO in the 1930s. Early control efforts were carried out without the benefit of baseline information of nonnatives in the park. O'Driscoll and Shear (2009) state that "…the failure to address the issue at the larger landscape scale resulted in only limited gains in terms of controlling or eliminating invasives." More recent efforts to control these plant species through integrated pest management principles resulted in limited success.

Figure 4.4.1. Wisteria at GUCO has formed dense infestations that seriously compromise native plant communities (NPS photo).

Data and Methods

Two documents and one dataset were used in this resource condition assessment. The Nonnative Plant Management Plan for Guilford Courthouse National Military Park was written to provide "basic information, analyses, and recommendations that are still missing and must be addressed in order to achieve long-term management goals" (O'Driscoll and Shear 2009). As part of the project, a nonnative plant species inventory was conducted within the forest communities. Sixty-two nonnative forest and forest edge species were documented. Additionally, the authors assigned priorities to species using the Alien Plant Ranking System (APRS) version 5.1 (APRS Implementation Team 2000).

GUCO has adopted CUPN's plan for early detection and treatment of invasive species to combat further invasions of network parks (Keefer et al. 2014). This plan uses opportunistic observations to identify the locations of invasive species, and defines habitat-specific treatment recommendations based on the invasive species regional status, impacts, trends, and dispersal dynamics. The goal is to eradicate incipient populations of invasive species before they become widely established. The report identified 71 early detection candidate species and four more species which are being considered for inclusion on the list.

Unlike the CUPN's Invasive Species Early Detection Plan, in which species are ranked based on their potential to invade a park, the CUPN monitors long-term changes associated with invasive species that are already present in the park using the Long Term Vegetation Monitoring Protocol (White et al. 2011). Data including presence or absence of exotic invasive species in 20 long-term forest plots are collected every five years.

In evaluating the current condition and trend for exotic invasive plants at GUCO, our indicator was to determine which species pose the greatest risk to the park's resources.

Reference Conditions

The most desirable reference condition for a park is the complete absence of exotic species; however, this is not a realistic standard. A more practical reference condition considers manageability and impacts of invasive plant species in the park. Therefore, the reference condition will be considered as maintaining invasive exotic plant species at manageable and non-damaging levels.

Current Condition and Trend

The Nonnative Plant Management Plan (O'Driscoll and Shear 2009) produced a prioritized list of nonnative forest species at GUCO and ranked them as low, medium, or high threats based on Miller 2003. The study found that almost half (28) of the nonnative forest species documented at GUCO are considered highly aggressive invaders of southern forests and their margins (Table 4.4.1). Eleven species are ranked as medium threats and 23 species pose low threats.

Table 4.4.1. Records (number of occurrences documented during census) and patch area of high threat forest invasive plants at GUCO (O'Driscoll and Shear 2009).

Species	Common Name	Records	Total Patch Area (ha)
Microstegium vimineum	Japanese stiltgrass	196	4.30
Hedera helix	English ivy	345	2.00
Ligustrum sinense	Chinese privet	878	1.90
Elaegnus umbellata	autumn-olive	608	1.00
Lonicera japonica	Japanese honeysuckle	399	0.90
Vinca minor	common periwinkle	73	0.80
Rosa multiflora	multiflora rose	625	0.50
Wisteria floribunda	Japanese wisteria	189	0.50
Celastrus orbiculatus	Asiatic bittersweet	266	0.20
Lonicera fragrantissima	fragrant honeysuckle	208	0.10
Ailanthus altissima	tree of heaven	70	0.10
Eleagnus pungens	thorny-olive	108	0.08
Vinca major	bigleaf periwinkle	4	0.03
Euonymus fortune	winter creeper	114	0.02
Dioscorea oppositifolia	Chinese yam	33	0.02
Lespedeza cuneata	sericea	23	0.02
Ligustrum japonicum	Japanese privet	87	0.01
Albizia julibrissin	silk tree	105	<0.01
Rosa spp.	rose	7	<0.01
Phyllostachys aurea	golden bamboo	1	<0.01
Nandina domestica	sacred bamboo	87	<0.01
Euonymus alatus	burning bush	19	<0.01
Ligustrum vulgare	European privet	3	<0.01
Paulownia tomentosa	princess tree	3	<0.01
Ligustrum lucidum	glossy privet	2	<0.01
Lespedeza bicolor	shrub lespedeza	2	<0.01
Loincera sp.	bush honeysuckle	1	<0.01
Melia azederach	Chinaberry	1	<0.01

The plan notes that nonnative plant species appear to be most abundant in successional communities where the sites have experienced high levels of human disturbance within the past 100 years (Table 4.4.2). The western half of the park is invaded throughout, particularly in areas that are directly adjacent to Country Park, the Greensboro Science Center, and Drive-in Tracts. Also noted as problem areas are most bottomland sections of the park, where the community, Piedmont Small Stream Sweetgum Forest is located. This forest type is considered the most threatened natural community in the park because of the presence of aggressive exotic invasive species (White et al. 2003). Directly adjacent to this forest type is an area of wisteria vineland (Figure 4.4.2).

Table 4.4.2. Presence of invasive species by community class. Successional forests at GUCO support more nonnative plants than “natural” forest communities. Community classes were created by grouping dominant vegetation types from CUPN Vegetation Map for GUCO (Jordan and Madden 2010) (O’Driscoll and Shear 2009).

Community Class	Land Area (ha)	Total Records	Trace (#/ha)	Individual (#/ha)	Patch (#/ha)	All Records (#/ha)
Successional Forests	37	2,919	41	24	14	79
"Natural Forests"	31	1,403	21	14	11	45
Culturally-Modified	8	366	13	18	17	46

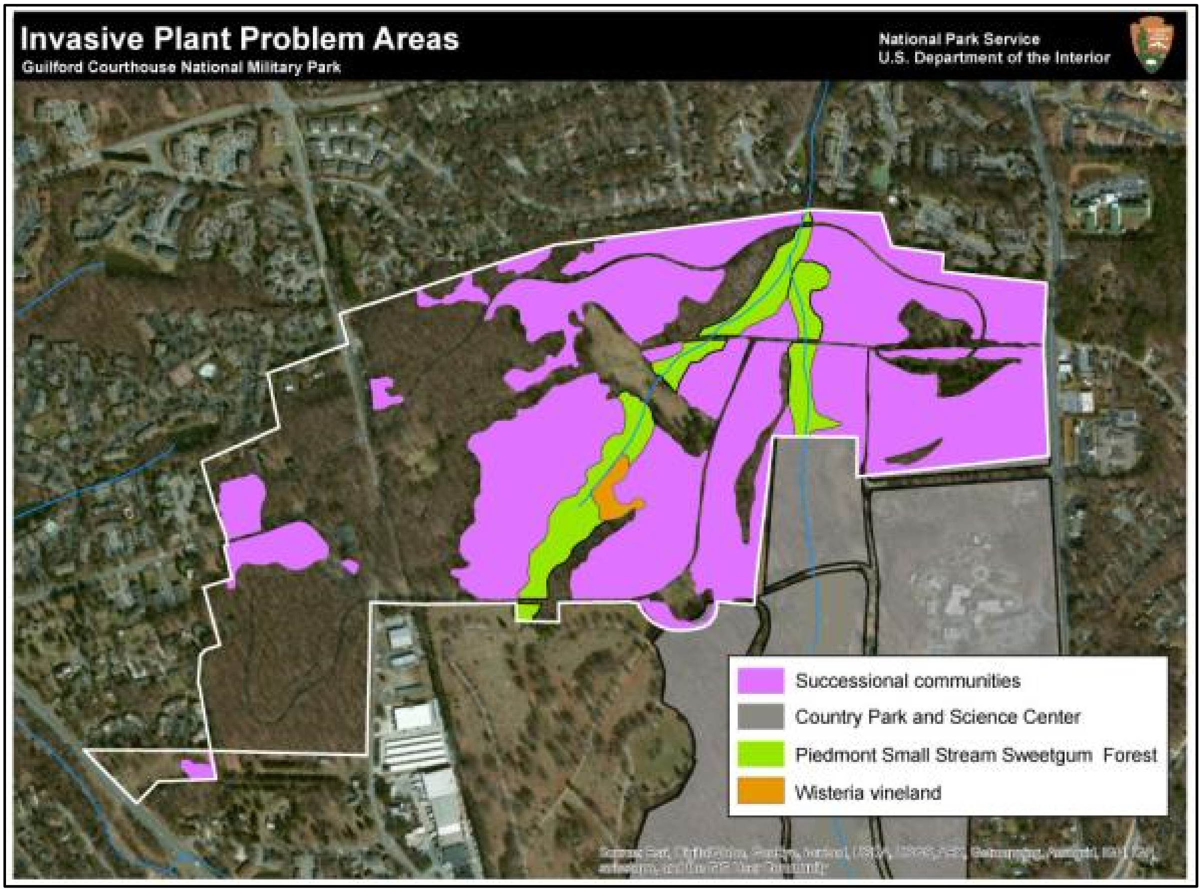


Figure 4.4.2. Map of invasive plants are found throughout GUCO. They tend to be most abundant in successional communities, the park's floodplain forest, and areas adjacent to municipal-owned properties (Jordan and Madden 2008).

The plan also documented several species that appear to cover at least 50% of the park's forested areas at varying densities. These species include Asiatic bittersweet (*Celastrus orbiculatus*), autumn olive (*Elaeagnus umbellata*), Chinese privet (*Ligustrum sinense*), English ivy (*Hedera helix*), Japanese honeysuckle (*Lonicera japonica*), Japanese stiltgrass (*Microstegium vimineum*), and multiflora rose (*Rosa multiflora*). Each of these species has invaded all forest types at GUCO and are considered serious ecological threats. Japanese holly (*Ilex crenata*), common periwinkle (*Littorina littorea*), thorny olive (*Elaeagnus pungens*), and fragrant honeysuckle (*Lonicera fragrantissima*) are found in roughly 25-50% of the forested areas, while Japanese wisteria (*Wisteria floribunda*), sweet cherry (*Prunus avium*), silk tree (*Albizia julibrissin*), tree-of-heaven (*Ailanthus altissima*), sacred bamboo (*Nandina domestica*), Beale's barberry (*Mahonia bealei*), creeping lillyturf (*Liriope spicata*), Japanese privet (*Ligustrum japonicum*), and winter creeper (*Euonymus fortune*) are found in approximately 10-25% of the forested areas.

As part of the plan, exotic invasive species found at GUCO were prioritized based on three characteristics: 1) significance of threat or impact (site characteristics), 2) innate ability to be a pest (species characteristics), and 3) difficulty of control. Using the APRS program to rank each species, the authors assigned priority rankings to nonnative forest species at GUCO (Table 4.4.3 and Figure 4.4.3).

Table 4.4.3. Priority ranking based on threat and control potentials of nonnative forest species at GUCO (O'Driscoll and Shear 2009).

Common/Species Name	Impact[1]	Control[2]	Priority[3]	Urgency[4]
Fragrant honeysuckle (*Lonicera fragrantissima*)	55	37	1	medium
Thorny olive (*Elaeagnus pungens*)	58	43	1	medium
Tree of heaven (*Ailanthus altissima*)	55	49	1	high
Asiatic bittersweet (*Celastrus orbiculatus*)	55	73	2	high
Autumn olive (*Elaeagnus umbellata*)	69	76	2	high
Chinese privet (*Ligustrum sinense*)	60	76	2	high
Common periwinkle (*Vinca minor*)	53	56	2	medium
English ivy (*Hedera helix*)	75	75	2	high
Japanese stiltgrass (*Microstegium vimineum*)	73	67	2	high
Japanese wisteria (*Wisteria floribunda*)	69	69	2	high
Multiflora rose (*Rosa multiflora*)	60	69	2	high
Beale's barberry (*Mahonia bealei*)	44	16	3	medium
Bigleaf periwinkle (*Vinca major*)	27	44	3	medium

[1]Impact values calculated by the APRS program based on species characteristics and site-specific conditions that may indicate to what extent a nonnative species threatens native communities. Values greater than 50 are considered relatively high impact.

[2]Control values are calculated based on information that may indicate the likelihood of effectively controlling the species. Values greater than 50 indicate that the species may be relatively easy to control at the site in question.

[3]APRS makes priority rankings based on Impact and Control values, placing species into 1 of 4 Priority blocks. Priority 1 species are thought to have relatively high impact potentials at the site but may be easier to control; Priority 2 species have high impacts and may be harder to control; Priority 3 species have relatively low impacts and may be easier to control; and Priority 4 species have relatively low impacts and may be harder to control. The APRS program recommends that control efforts directed towards species in order of priority ranking, e.g., Priority 1 species should be controlled first, and so forth.

[4]Urgency ratings should be used to direct management attention within Priority blocks. Species with high urgency ratings should be focused on first within each priority block.

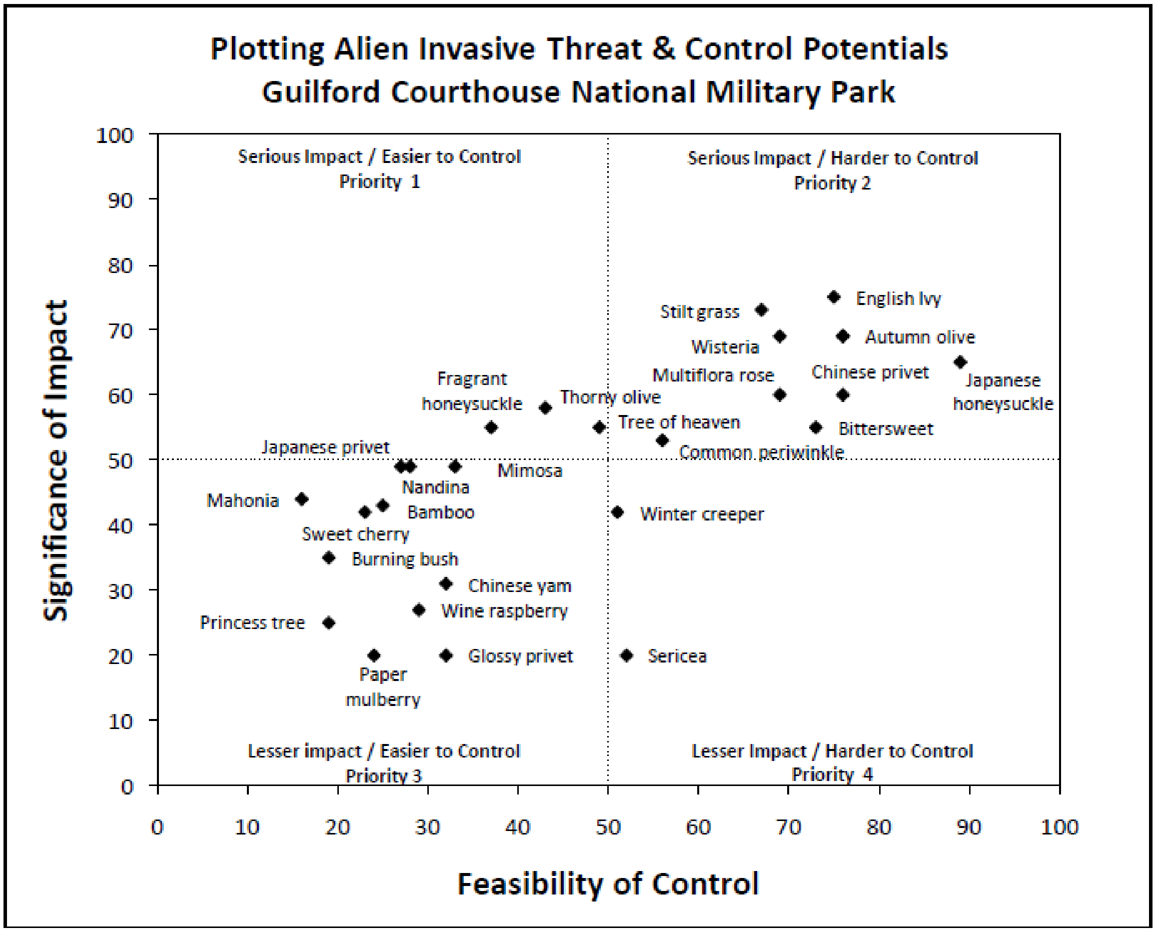


Figure 4.4.3. The ASPRS program was used to rank nonnative plants by their site-specific impact and control potentials (O'Driscoll and Shear 2009).

Exotic species that occur in the forest plots located in various vegetation communities in GUCO, are documented as part of the Long-Term Vegetation Monitoring program (White et al. 2011). Species that are considered "high priority" using the Monitoring program are based upon state Exotic Plant Pest Council lists. These states include Kentucky, Tennessee, South Carolina, North Carolina, Alabama, and Virginia. Exotic species were found in 100% of the forest plots (n=20) at GUCO. The average number of exotic species was 5.90 per plot and the average number of "high priority" exotic species was 4.55 per plot. The relative percent cover of exotic species per plot was 10.58, the second highest number among all CUPN parks (Figure 4.4.4).

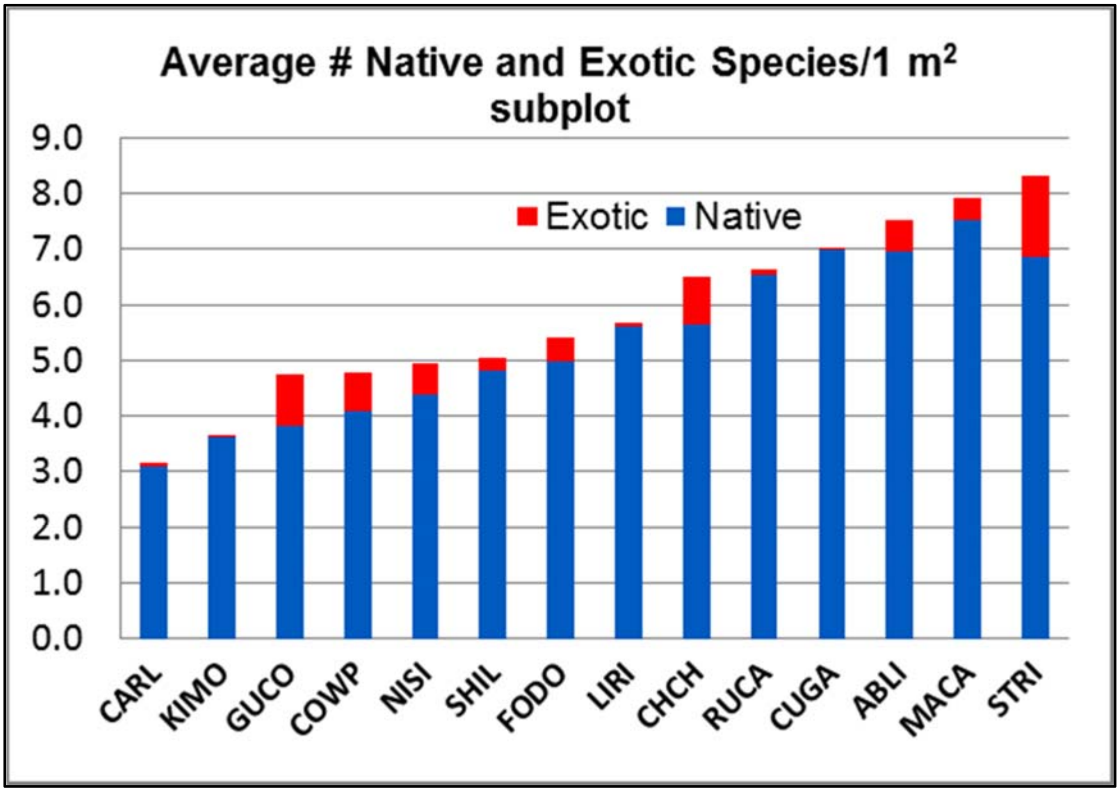


Figure 4.4.4. GUCO exceeds the other CUPN parks with the highest ratio of exotic species to native species (0.1955) (CUPN 2013).

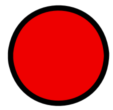
Exotic invasive plant species are a continuing problem at GUCO. Almost half of all nonnative plants documented in the park are considered highly aggressive exotic plant species. Invasive species were found in all 20 long-term monitoring plots in the park. The average number of "high priority" exotic invasive species found in these plots is 4.55 per plot. Although priority species tend to concentrate in high disturbance areas and successional communities, they are found throughout the park, making the control and treatment especially difficult. Compounding the effect, many of these species originate from outside the park's boundaries. Adjacent municipal parks, commercial, and residential properties are a continual source of exotic/invasive plant propagules. Based on the number of aggressive exotic invasive species and their distribution at GUCO, we assign a condition that warrants significant concern. There is insufficient data to assign a measured trend.

Confidence and Data Gaps

Using the data from the park's thorough and extensive nonnative plant management plan (O'Driscoll and Shear 2009) coupled with data from the CUPN long-term forest monitoring plots, we assign a high confidence level to this assessment

Summary Condition

Table 4.4.4. Graphical summary of status and trends for invasive exotic plants.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Invasive Species	Invasive Exotic Plants		The reference condition is considered as maintaining invasive exotic plant species at manageable and non-damaging levels. Exotic invasive plant species are a continuing problem at GUCO. Almost half of all nonnative plants documented in the park are considered highly aggressive exotic plant species. Invasive species were found in all 20 long-term monitoring plots in the park. The average number of "high priority" exotic invasive species found in these plots is 4.55 per plot.

Sources of Expertise

- Matt O'Driscoll, Ecologist, North Carolina State University
- Ted Shear, Ecologist, North Carolina State University
- Cumberland Piedmont Network Staff
- NatureServe
- Exotic Plant Management Team, National Park Service

4.5. Focal Species or Communities

4.5.1. Wetland Communities

Relevance

Wetlands can be highly productive and biologically diverse communities that enhance water quality, control erosion, sequester carbon, and regulate stream flows. They provide critical habitat for individual rare plant species. They also provide water sources for wildlife and breeding grounds for amphibians. Additionally, wetlands may also provide baselines for monitoring climate change, as they are highly sensitive to shifts in precipitation, temperature, and weather events. The National Park Service manages wetlands in compliance with NPS mandates and legal requirements (i.e., Section 404 of the Clean Water Act, State requirements under Section 401 of the CWA, and NPS Directors Orders #77-1). Parks are required to prevent the destruction, loss or degradation of wetlands; preserve and enhance the natural and beneficial values of wetlands; and avoid direct and indirect support of new construction in wetlands (NPS 2006).

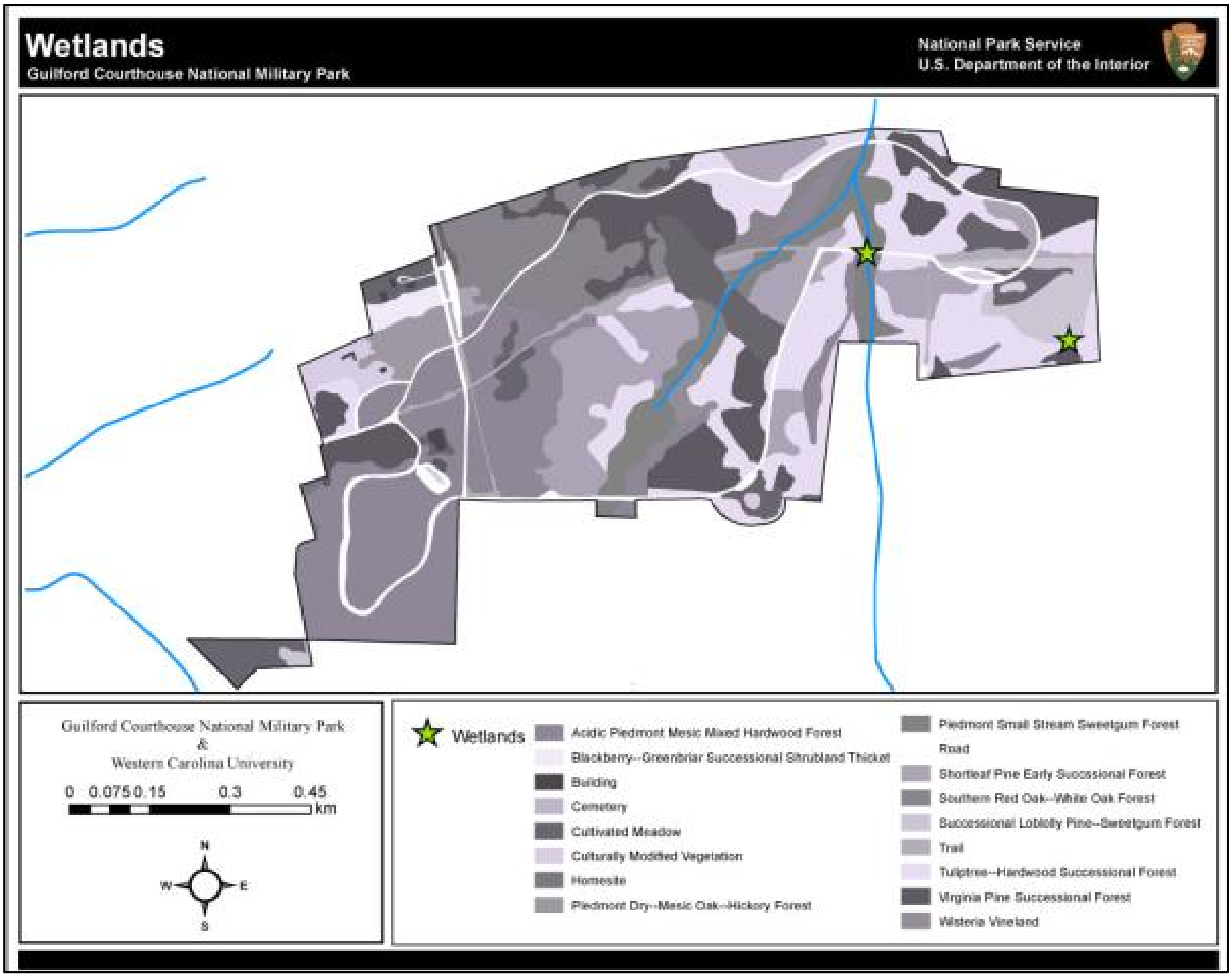


Figure 4.5.1. Locations of two small wetlands at GUCO.

Data and Methods

A wetlands inventory was conducted at GUCO in 2004 (Roberts and Morgan 2006). Characteristics including hydrology, hydric soils, dominant wetland plant species, location, type, estimated size, function and potential value, were recorded for each wetland. A qualitative evaluation using the reported characteristics was used to assess the trend and conditions of the wetlands.

Reference Conditions

The wetlands at GUCO appear to be naturally occurring. Healthy naturally occurring wetlands should exist in an undisturbed state and exhibit biological integrity (e.g., support wetland plants, absence of exotic invasive species), function in their full capacity as surface water storage and/or groundwater discharge units and function as carbon/nutrient export units.

Current Condition and Trend

The inventory identified two wetlands (one a depression wetland and the other a slope wetland) with a total area of 0.7 hectares (1.8 acres) (Figure 4.5.2). Based on the Cowardin classification system, both were considered palustrine, forested, deciduous wetlands (Cowardin et al. 1979). The depression wetland is seasonally flooded while the slope wetland is temporarily flooded. Both appear to be in tact hydrologically but each has experienced vegetation alterations in the form of timber harvest at some point in the past.

Figure 4.5.2. (top) Depression wetland at GUCO with the primary hydrology source being precipitation and runoff from adjacent upland. (bottom) Slope wetland at GUCO located adjacent to a stream (Roberts and Morgan 2006).

The primary function of the depression wetland is to provide wildlife habitat in the form of breeding habitat for amphibians (Table 4.5.1). Another less significant function of this wetland is to store limited amounts of surface water. However, it is not a considered a major function as the unit's small size (0.08 hectares [0.20 acres]) precludes it from storing enough water to reduce any measureable downstream flooding. Dominant plant species include black willow (*Salix nigra*), sweet gum (*Liquidambar styraciflua*), and woolgrass (*Scirpus cyperinus*). The exotic invasive, Chinese privet is also present on this site.

Table 4.5.1. Wetlands documented at GUCO with associated functions and values (Roberts and Morgan 2006).

HGM Class	Acres	Groundwater Discharge (to streams)	Surface Water Discharge	Carbon/ Nutrient Export	Provide Wildlife Habitat	Support Wetland Plants	Exotics Present
Depression	0.2	High	n/a	n/a	high	Medium	Chinese privet
Slope	1.6	Low	Low	High	High	Medium	Chinese privet, Japanese stilt grass

The slope wetland is 0.65 hectares (1.60 acres) and has relatively unaltered hydrology (Table 4.5.1). Functions performed by this wetland include groundwater discharge to the adjacent stream and carbon/nutrient export. This wetland was also noted as being in a relatively unaltered state aside from timber harvest before the park was created. Dominant species include green ash *(Fraxinus pennsylvanica*), black willow, silver maple (*Acer saccharinum*) and *Panicum* sp. Exotic invasive plant species present are Japanese stiltgrass, and Chinese privet.

In addition to the two wetlands inventoried, an area with hydric soils was identified as a possible former slope wetland. The authors note that former functions performed by this wetland likely included groundwater discharge to a stream, and carbon/nutrient export. The area is currently mowed and used to display numerous monuments of historical interest.

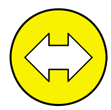
The park's two existing wetlands are in a condition that warrants moderate concern with an unchanging condition. Given their respective sizes and conditions they are functional wetlands. However, exotic invasive species are present in both units. These species have the potential to suppress native plant species, including wetland plants, from occurring in the units. Additionally, the widespread presence of exotic invasive species across the park presents a continual threat of invasion into the wetlands. A third area was identified as a likely former wetland. This area will not be considered in the assessment as it was converted to a field for historical marker displays before the park was created.

Confidence and Data Gaps

The park's wetlands inventory was performed in 2006. While the report was comprehensive some changes in the species composition of the units may have occurred since the inventory. Therefore, we assign a medium level of confidence to this assessment.

Summary Condition and Graphic

Table 4.5.2. Graphical summary of status and trends for wetland communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities	Wetland Communities		Reference condition consists of wetlands existing in an undisturbed state and exhibiting biological integrity, function in their full capacity as surface water storage and/or groundwater discharge units and function as carbon/nutrient export units. The park's two existing wetlands are in a condition that warrants moderate concern with an unchanging condition. Given their respective sizes and conditions they are functional wetlands. However, exotic invasive species are present in both units. These species have the potential to suppress native plant species, including wetland plants, from occurring in the units.

Sources of Expertise

- Thomas H. Roberts, Biologist, Tennessee Technological University
- Kenneth L. Morgan, Biologist, Tennessee Technological University

4.5.2. Riparian Communities - Piedmont Small Stream Sweetgum Forest

Relevance

In GUCO, riparian communities occur as the Piedmont Small Stream Sweetgum Forest, a later successional forest that contains the highest diversity of plant species of the community types in the park. It is also the only wetland forest in the park. It occurs in the floodplains along Richland Creek and along small unnamed creek that nearly bisects the park through the middle (Figure 4.5.3 and Figure 4.5.4). This community has a global ranking of G3 which means it is only somewhat secure in its range. High or medium quality examples of this forest across its range are very rare (White and Pyne 2003). GUCO contains approximately 5 hectares (13 acres) of Piedmont Small Stream Sweetgum Forest (Jordan and Madden 2010).

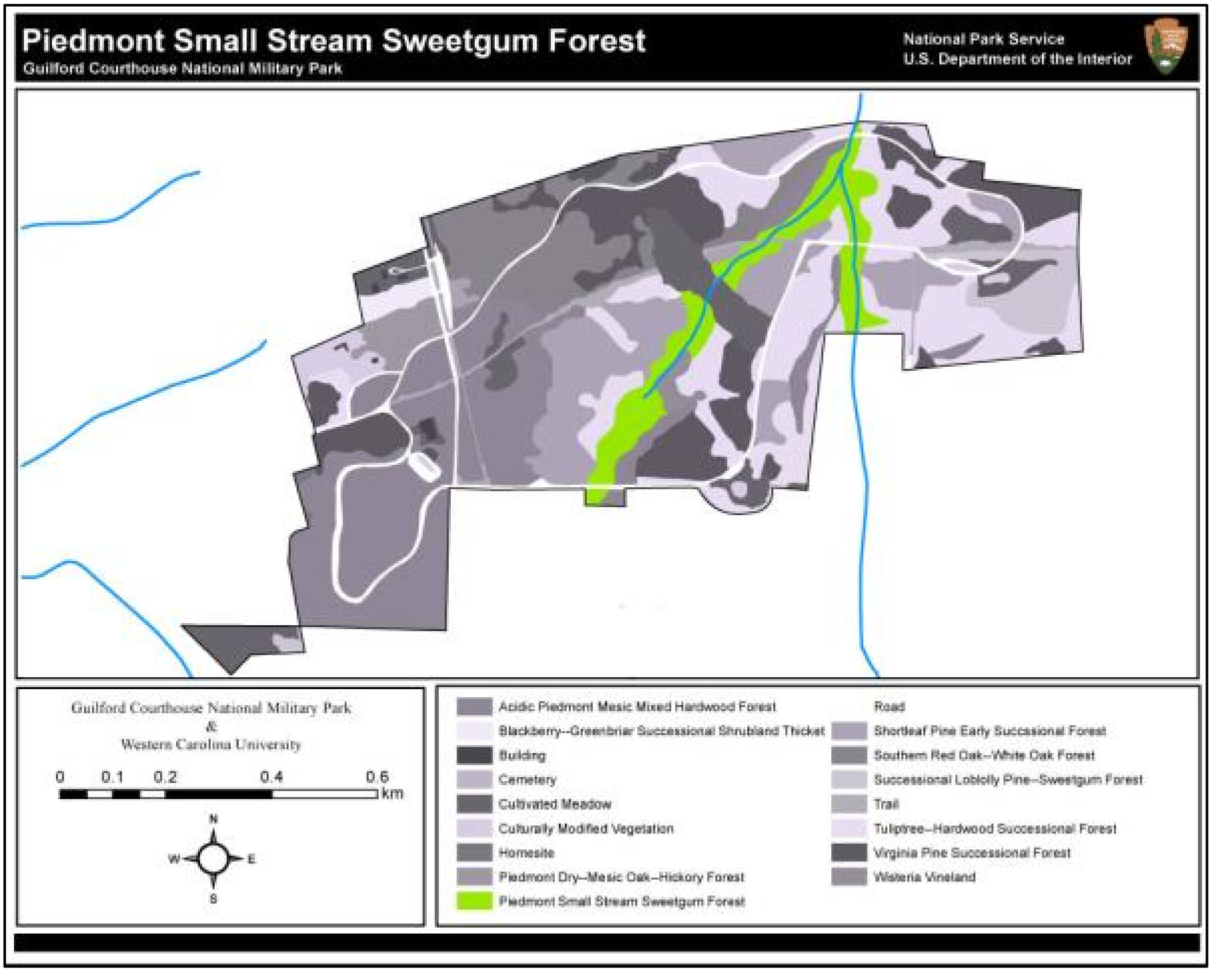


Figure 4.5.3. The park's Piedmont Small Stream Sweetgum Forest is located within the floodplains of Richland Creek and a small unnamed creek (Jordan and Madden 2010).

Figure 4.5.4. Piedmont Small Stream Sweetgum Forest at GUCO (NPS photo).

Data and Methods

Data used in this assessment includes forest characteristics from the Vascular Plant Inventory and Plant Community Classification for Guilford Courthouse National Military Park (White and Pyne 2003) and the digital vegetation map depicting vegetation cover at GUCO (Jordan and Madden 2010). The methodology consisted of a qualitative evaluation of the community type's species composition and biological integrity (i.e., presence or absence of invasive plant species and erosion).

Reference Conditions

Under unaltered conditions, the Piedmont Small Stream Sweetgum Forest type has a well-developed canopy, subcanopy, shrub, and herbaceous layer. The canopy consists of sweetgum, tulip poplar, sycamore (*Plantanus occidentalis*), American beech, Florida maple (*Acer barbatum*), red maple, and boxelder (*Acer negundo*). The understory may be very dense with flowering dogwood (*Cornus florida*), Florida maple and most of the canopy species listed above. In higher quality examples of this forest the shrub layer consists of northern spicebush (*Lindera benzoin*) and American hazelnut (*Corylus americana*). In low quality examples the shrub layer is dense with multiflora rose, Chinese privet, and other exotic invasive plant species. The reference condition for Piedmont Small Stream Sweetgum Forest will include characteristics of this type under unaltered conditions.

Current Condition and Trend

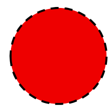
The canopy of this forest community is dominated by either sweetgum or tulip poplar. The understory generally contains sweetgum. Higher up on the terraces the understory may consist of Florida maple, flowering dogwood, and American beech. Multiflora rose, Chinese privet, and spicebush may be found in the tall and short layer of the understory. The herbaceous layer ranges from moderately dense to very dense with mostly Japanese stiltgrass along with other native and non-native species and adjacent upland species. This forest has been heavily degraded by recent disturbances including alterations in hydrology and exotic species invasion. White and Pyne (2003) report that while most species found on the park list only occur in this community, some stands have close to 100% coverage of Japanese stiltgrass which has lowered native plant diversity in the herbaceous layer. Other examples of this forest type have high coverage of multiflora rose and Chinese privet. Development upstream with an increase in associated impervious surface has negatively impacted this forest type in the park. "Flashy" streams have eroded channels 2 feet (0.6 m) or more below the rest of the stream bottom. Exotic invasive species have likely lowered the native plant diversity. Therefore, we assign a condition that warrants significant concern. Although exotic invasive species were documented as a major threat by White and Pyne (2003) more recent date is needed to establish a measured trend.

Confidence and Data Gaps

The data from the vascular plant inventory used in this assessment is well over a decade old. Updated reference data is needed to perform an accurate analysis of this forest type. Therefore, we assign a low level of confidence to this assessment.

Summary Condition and Graphic

Table 4.5.3. Graphical summary of status and trends for riparian communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities	Riparian Communities		The reference condition is unaltered Piedmont Small Stream Sweetgum Forest. This forest has been heavily degraded by recent disturbances including alterations in hydrology and exotic species invasion. White and Pyne (2003) report that while most species found on the park list only occur in this community, some stands have close to 100% coverage of Japanese stiltgrass which has lowered native plant diversity in the herbaceous layer. The data from the vascular plant inventory used in this assessment is well over a decade old. Updated reference data is needed to perform an accurate analysis of this forest type.

4.5.3. Forest/Woodland Communities

Relevance

Forest communities are a dominant component of the GUCO landscape and are one of the highest priority vital signs across the network (CUPN 2013). Studying the components of a forest provides information on the overall health of the forest ecosystem. Stressors affecting these systems include exotic species, forest pests, and climate change. In addition, forests provide recreational opportunities, wildlife habitat, protect soil and store carbon that might mitigate climate change (CUPN 2013).

Data and Methods

The primary data used in this assessment are described below. These include a vascular plant and community inventory conducted for GUCO in 2003 (White and Pyne 2003). In conjunction with this inventory, the Center for Remote Sensing and Mapping Science at the University of Georgia mapped vegetation communities using manual stereo interpretation of color-infrared aerial photography.

White et al. (2011) developed a vegetation monitoring protocol that addresses most aspects of monitoring vegetation communities. The monitoring is primarily designed to assess the status and trends of ecological health for park-wide vegetation communities, including key communities of management concern through detection of meaningful changes in species composition and vegetation structure within each park's forested habitat and determine whether these changes are correlated with trends in key stressors. CUPN established twenty 20 x 20 meter (65.6 x 65.6 feet) monitoring plots across the park between 2011 and 2013 (Figure 4.5.5). Species presence, frequency, cover, tree canopy cover, tree growth and health, evidence of forest pests, snags, coarse wood debris, and community characterization will be recorded in each plot every five years.

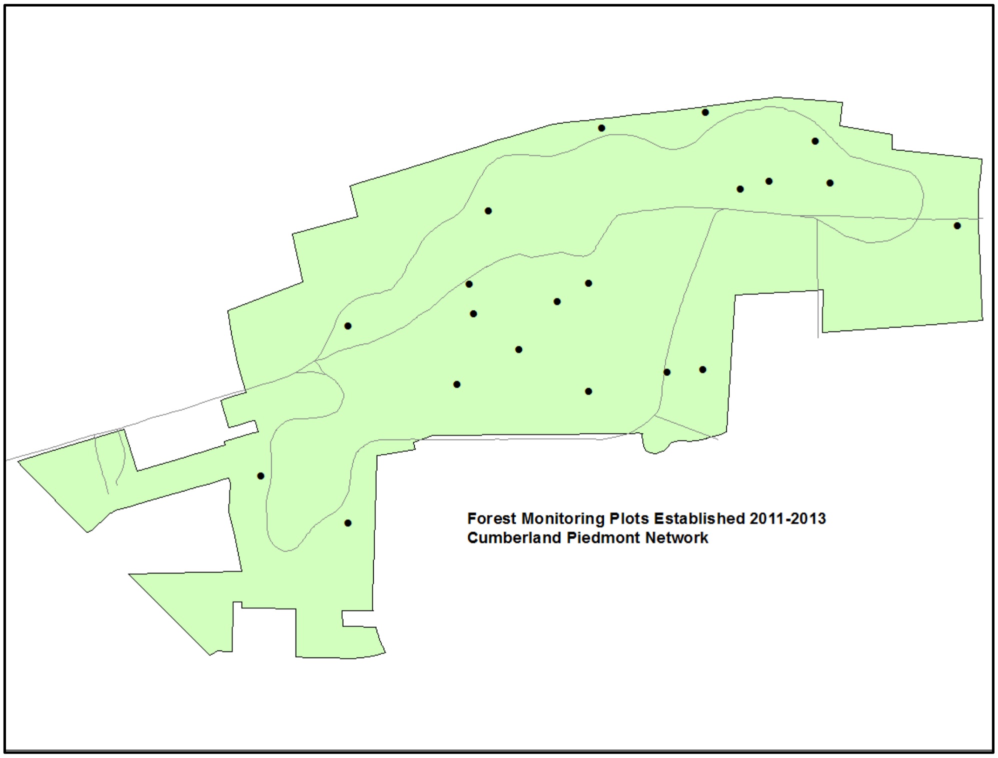


Figure 4.5.5. Forest monitoring plot locations at GUCO (CUPN 2013).

Data summaries and trends are also described in a 2013 Forest Vegetation Resource Brief (CUPN 2013) and the GUCO State of the Parks Report (NPS 2015).

Reference Conditions

The reference condition is based on overall forest structure and species composition. Species composition for each forest type should mimic what is expected based on Schafale (2012) and Schafale and Weakly (1990). Forest structure should represent a range of successional stages, and include significant areas with late-successional forest that are characterized by the presence of large diameter trees.

Current Condition and Trend

The Center for Remote Sensing and Mapping Science at the University of Georgia mapped 11 vegetation community types as well as infrastructure, ponds, and other anthropogenic land covers, (Figure 4.5.6). Because of the severe fragmentation and history of human disturbances, there are few intact ecological communities at GUCO (CUPN 2003), in addition, most of the forest is considered successional having originated after 1933 (NPS 2015). Seven upland forest community types were identified (Table 4.5.4). Four of these forest types are considered human modified and are of no conservation value (White and Pyne 2003). The Piedmont Small Stream Sweetgum Forest was also identified, and is discussed in section 4.5.2.

Table 4.5.4. Description of forest communities at GUCO.

Forest/Woodland Community	Community Type	Global Rank[1]	CEGL#[2]
Virginia Pine Successional Forest	Human modified	–	2591
Shortleaf Pine Early Successional Forest	Human modified	–	875
Successional Loblolly Pine—Sweetgum Forest	Human modified	–	8462
Acidic Piedmont Mesic Mixed Hardwood Forest	Natural	G3G4	8465
Tuliptree—Hardwood Successional Forest	Human modified	–	7221
Piedmont Dry—Mesic Oak—Hickory Forest	Natural	–	8475
Southern Red Oak—White Oak Forest	Natural	–	7244

[1]Global Ranks developed by NatureServe. G1=Critically imperiled; G2=Imperiled; G3=Vulnerable; G4=Apparently secure; G5=Secure; those denoted with ? indicate an inexact rank; those with two ranks (e.g., G4G5) indicate the range of uncertainty in the status.

[2]Community Element Global Identifier

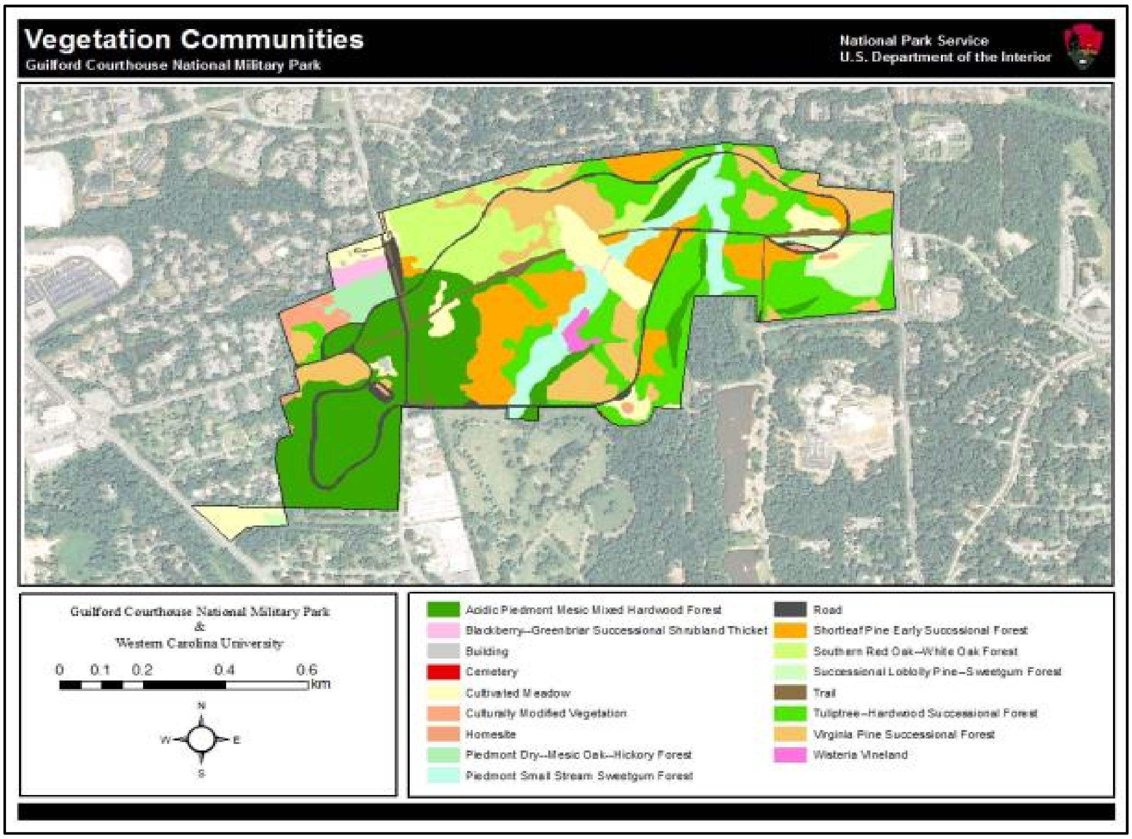


Figure 4.5.6. Vegetative communities and infrastructure at GUCO (data from Center for Remote Sensing and Mapping Science, Univ. of GA).

The following descriptions of each forest type were taken directly from White and Pyne (2003).

Virginia Pine Successional Forest

This human influenced association is limited to the upland areas of the park and is generally found on sites with a long history of land use. Virginia pine is a short lived tree that specializes in colonizing areas that have been heavily eroded or denuded to mineral soil. Some past land uses may have included yearly row crops for long periods of time, cotton, or repeated logging without any type of erosion control. Examples of this association occur from Pennsylvania to Alabama in the Piedmont.

Within the park, this community occurs in any location that was heavily farmed, grazed, or logged in the past 70 years. In places, a solid canopy of Virginia pine has formed. In other locations it is co-dominant with sweetgum and shortleaf pine. In general the herbaceous layer is extremely poor. However, the shrub and understory layers can be very dense with seedlings and saplings of later successional species such as Florida maple and red maple. Due to its highly disturbed nature, this community can be home to a number of invasive exotics, especially Japanese honeysuckle.

This association is considered a human modified community and thus is of no conservation concern. It is a very common type in this area due to the large scale abandonment of farmland over the last century in the Piedmont of North Carolina. Within the park, this community is most common in the central and eastern sections of the park in areas formerly under intense cultivation.

This community is easily invaded by invasive exotic species such as Japanese honeysuckle. Although this community is not of conservation concern, management of the invasive exotics within this community may prevent the spread of these exotics into adjacent higher priority communities.

Shortleaf Pine Early Successional Forest

This human influenced association is also limited to the upland areas of the park. Shortleaf pine colonizes plowed areas shortly after they are left fallow. The community type overlaps with that of the Virginia Pine Early Successional Forest in this part of the state, though Virginia pine is generally found in areas that were more heavily eroded prior to forest regeneration.

Within the park, this community occurs in any location that was heavily farmed, grazed, or logged in the past 70 years. In places, a solid canopy of shortleaf pine has formed. In other locations it is co-dominant with sweetgum and Virginia pine. In general the herbaceous layer is extremely poor. However, the shrub and understory layers can be very dense with seedlings and saplings of later successional species such as Florida maple and red maple. Due to its highly disturbed nature, this community can be home to a number of invasive exotics, especially Japanese honeysuckle.

As with the successional loblolly pine – sweetgum forest and the Virginia Pine Early Successional Forest, this association is considered a human modified community and thus is of no conservation concern. It is a very common type in the western parts of this area due to the large scale abandonment of farmland over the last century in the Piedmont of North Carolina. Within the park, this community is most common in the central and eastern sections of the park in areas formerly under intense cultivation.

As with the Virginia Pine Early Successional Forest, this community is easily invaded by invasive exotic species such as Japanese honeysuckle. Although this community is not of conservation concern, management of the invasive exotics within this community may prevent the spread of these exotics into adjacent higher priority communities.

Successional Loblolly Pine – Sweetgum Forest
Examples of this association are found in a wide variety of upland areas that have been altered in the past by farming or logging and are now regenerating. This type is one of the most common communities in the southeastern United States, but is most likely planted within the park, since GUCO is just outside of the natural range of loblolly pine (*Pinus taeda*) (Critchfield and Little 1966, Burns and Honkala 1990).

Stands within the park are strongly co-dominated by loblolly pine, Virginia pine, and sweetgum, but also may contain an understory of red maple. Vines such as poison ivy (*Toxicodendron radicans*), muscadine (*Vitis rotundifolia*), Japanese honeysuckle, and English ivy can invade the understory, especially in the drier habitats. Herbaceous species including marsh seedbox (*Ludwigia palustris*) and the invasive exotic Japanese stiltgrass dominate depression areas. Shade tolerant species of trees are very common in the shrub layer and understory.

This community is considered a human modified community and thus is of no conservation concern. This type is common throughout the Piedmont due to the history of large scale abandonment of farmland over the last century. Within the park, this community is most common in the central and eastern sections of the park in areas formerly under intense cultivation.

Loblolly pine successional communities are easily invaded by invasive exotic species such as wisteria (*Wisteria sinensis*), Japanese honeysuckle, English ivy, and Japanese stiltgrass. Although this community is not of conservation concern, management of the invasive exotics within this community may prevent the spread of these exotics into adjacent higher priority communities. The control of wisteria may be especially crucial in these areas due to its aggressive nature within the park boundary.

Acidic Piedmont Mesic Mixed Hardwood Forest
This community is generally found on undisturbed steep slopes adjacent to streams. It often persists in areas that are so steep that they were not plowed but were probably heavily logged. Under natural conditions these forests are uneven-aged, with old trees present alongside younger trees. Reproduction occurs primarily in canopy gaps. Rare, severe natural disturbances such as wind storms may allow pulses of increased regeneration and allow the less shade-tolerant species to remain in the community (Schafale and Weakley 1990).

Within the park, this community occurs only on east facing sheltered steep slopes adjacent to streams. The canopy of stands within the park is closed and consists of American beech with smaller amounts of northern red oak and southern red oak. Flowering dogwood, red maple, and American beech are common in the understory. The short shrub and herbaceous layers are sparse, with striped prince's pine (*Chimaphila maculata*) and Christmas fern (*Polysticum acrosticoides*) being the most common herb species. Spring ephemerals include mayapple (*Podophyllum peltatum*) and bloodroot (*Sanguinaria canadensis*).

This community is fairly common throughout its range in the Piedmont. It has most likely persisted on the landscape due to its occurrence on steep sites that are less susceptible to human disturbance (Schafale and Weakley 1990). It is ranked G3G4, meaning that it is somewhat threatened but stable globally. Within the park, this community is quite rare. The only known occurrences are on steep east and north facing slopes along Richland Creek and its tributaries.

Threats to this association within the park are minimal. The examples within the park are relatively stable and have not been disturbed recently. There is little invasive exotic growth within this community. At least two trails are present along the slope where this community exists, which may contribute to erosion of the slope.

Most threats to this ecosystem are from events beyond our control (windstorm, beech bark disease). No on-site management can protect this ecosystem from those events. It might be important, however, to monitor the trails that run by this community to ensure that erosion along the trail and trampling in the forest is kept to a minimum.

Successional Tuliptree – Hardwood Forest
Examples of this association are found primarily in areas which were once clearcuts, old fields, or were cleared by fire or other natural disturbances. These non-wetland forests are also found along mesic stream terraces. Examples occur throughout the Southeast from Alabama to Virginia.

Within the park, this community occurs in a wide variety of environments. It is most commonly associated with slightly protected gentle slopes whereas the successional pine communities often occur in more exposed flat upland positions on the landscape. This association occurs on sites that were formerly agriculture, so past land use history dictates current composition more than soils, exposure, or other environmental factors. Vegetation composition within the park varies widely in this broadly defined modified community. All occurrences are dominated by tulip poplar, but with differing levels of co-dominance by trees such as sweetgum, Virginia pine, scarlet oak (*Quercus coccinea*), and blackgum (*Nyssa sylvatica*). The shrub layer is usually fairly thick with saplings of later successional species such as Florida maple and beech and some exotic species such as Chinese privet and wisteria. Due to its highly disturbed nature, this community harbors numerous invasive exotic vines and shrubs.

As with the successional loblolly pine – sweetgum forest, this association is considered a human modified community and thus is of no conservation concern. It is a very common type in this area due to the large scale abandonment of farmland over the last century in the Piedmont of North Carolina. Within the park, this community is most common in the central and eastern sections of the park in areas formerly under intense cultivation.

As with the successional loblolly pine – sweetgum forest, this community is easily invaded by invasive exotic species such as wisteria, Japanese honeysuckle, English ivy, and Japanese stiltgrass. Although this community is not of conservation concern, management of the invasive exotics within this community may prevent the spread of these exotics into adjacent higher priority communities. The control of wisteria may be especially crucial in these areas due to its aggressive nature within the park boundaries. The wisteria vine-shrubland community most likely started out in a successional tulip poplar community until the wisteria vines began overtopping the canopy trees and killing them to form a more open area of wisteria.

Piedmont Dry – Mesic Oak – Hickory Forest
The sites on which this vegetation is found are described as `intermediate' in soil moisture (Jones 1988a, 1988b). In North Carolina, this is a matrix type, probably the most common forest type remaining in the Piedmont.

Within the park, this community occurs on Cecil sandy loam on very broad, smooth upland areas. Examples of this community within the park consist of a closed canopy dominated by white oak along with smaller amounts of red oak, mockernut hickory, and tulip poplar. The understory is very dense and consists of numerous stems of red maple, Florida maple, and flowering dogwood. The understory is sparse but better developed than other upland associations in the park. Plants in the herbaceous layer include wild yam (*Dioscorea villosa*), striped prince's pine, American lopseed (*Phryma leptostachya*), and Solomon's seal (*Polygonatum biflorum*). Muscadine is a common vine groundcover. Other plants of note that have been reported in the park in this association include bugbane (*Cimicifuga racemosa*), Carolina lily (*Lilium michauxii*), and feathery false Solomon's seal (*Maianthemum racemosa*). Spring ephemerals such as bloodroot and mayapple occur in small patches of this community.

This community was probably the matrix community in the area prior to farming and other human-induced activities. Within the state, it is still a very common community and is considered globally secure. Within the park, it is now restricted to small patches in the eastern part of the park near the visitor's center, mainly in areas where human disturbance has not occurred this century. Although this is a common community, the highest quality examples of this community should be preserved since they harbor a number of species which aren't found in other sections of the park and which may rely on those small parcels for their continued survival.

Threats to this community within the park, as with all of the other communities in this fragmented landscape, are mostly with invasive exotic species. Although not currently a large threat, Chinese privet is present in some examples of this community. A relatively unknown exotic, Chinese fir (*Cunninghamia lanceolata*) occurs in some areas of the park and may begin to occur in this community. If it does, it should be controlled immediately. Finally, the high population of white-tailed deer may be heavily impacting spring ephemerals in this community. Signs of deer browsing are present everywhere and it is well known that deer often impact spring ephemerals more heavily than most plants since they are the first plants to leaf out in late winter or early spring and are easily found by hungry deer. Monitoring of deer effects on vegetation may be important if spring ephemerals are a priority for conservation in the park.

Some species seen in this association are not found in most other associations in the park. These include Carolina lily, black bugbane, and kidney leaf buttercup. None of these plants are threatened or endangered, but they are rare in fragmented landscapes such as Guilford Courthouse National Military Park and should be given some special consideration.

Again, this community is still common and fairly secure throughout the region. However, high quality examples of this community are not so common. A particularly good example of this community is located south of the visitor's center within the loop road. Another example is located just to the west of Old Battleground Road as the road heads out of the southern part of the park.

Southern Red Oak – White Oak Forest

Within the park, stands are found on the drier uplands of the park over Cecil sandy loam. The canopy is dominated by southern red oak, post oak (*Quercus stellata*), white oak, and pignut hickory. The understory is dominated by oak saplings along with red maple, sweetgum, and Virginia pine. The shrub layer consists of small amounts of deerberry (*Vaccinium stamineum*) and/or early lowbush blueberry (*Vaccinium pallidum*). The herbacous layer is poorly developed and contains such acid loving species as striped prince's pine and downy rattlesnake plantain (*Goodyera pubescens*).

Although considered less common than the related Piedmont Dry – Mesic Oak-Hickory Forest, this community is still quite common and secure throughout its range in the southeast United States. Within the park, it occurs mostly in the northeast quarter of the park in upland areas.

Threats to this association are the same as with the Piedmont Dry – Mesic Oak-Hickory Forest. Invasive exotics may become a problem in the future, but are currently not prevalent.

This community is secure throughout its range, but the highest quality examples of this community should be considered in any future development plans in the park. One such high quality area occurs just east of the northern parking lot off of Old Battleground Road.

Based on monitoring work completed through 2013, a disproportionate amount of forest is in successional (younger) stages. This is not surprising given the fact that most forests were established after 1933. Species composition is suffering on two fronts. First is the presence of invasive exotic species in most forest areas. Second is the concern that a species shift may be occurring. The upper canopy is dominated by oaks and hickories, pine, tulip tree, sweetgum, and upland maple; however upland maple dominates the seedling and sapling layers (Figure 4.5.7). The loss of hard mast producing species (primarily oaks and hickories) could have a negative impact on wildlife.

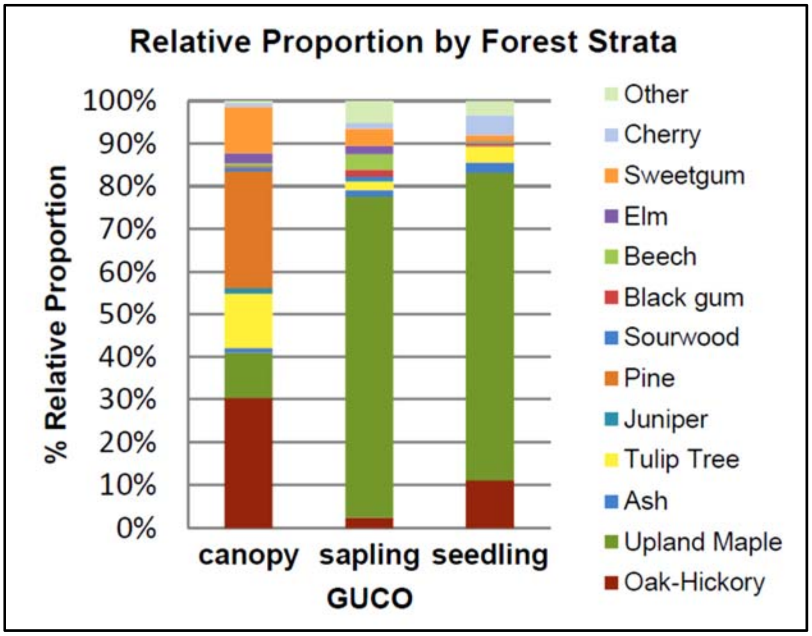


Figure 4.5.7. Tree species composition among forest strata at GUCO (CUPN 2013).

Confidence and Data Gaps

We are confident in current forest condition based on the detailed vegetative inventory that was conducted in 2003 and the forest monitoring work that was started in 2011. However, because the monitoring was only recently initiated we have little information on trends. Continued monitoring at regular intervals will likely provide this information.

Summary Condition

Table 4.5.5. Graphical summary of status and trends for forest/woodland communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities	Forest/Woodland Communities		The Species composition for each forest type should mimic what is expected based on Schafale (2012) and Schafale and Weakly (1990). Forest structure should represent a range of successional stages, and include significant areas with late-successional forest that are characterized by the presence of large diameter trees. Species composition is suffering from the presence of invasive exotic species in most forest areas and the possible loss of hard mast species from the canopy.

Sources of Expertise

- Teresa Leibfreid, Network Program Manager, Cumberland Piedmont Network
- Bill Moore, Ecologist, Cumberland Piedmont Network

4.5.4. Aquatic Communities

Relevance

Aquatic macroinvertebrate and fish assemblages are often recognized as integral components of water quality monitoring. GUCO contains two small streams in the headwaters Richland Creek, Hunting Creek and Bloody Run, a tributary to Hunting Creek (Figure 4.5.8). On many published maps, Hunting Creek is labeled as the upper reach of Richland Creek, but Long (2005) reports this as an error and more recently, the unnamed tributary to Hunting Creek has been identified as Bloody Run (NPS 2015).

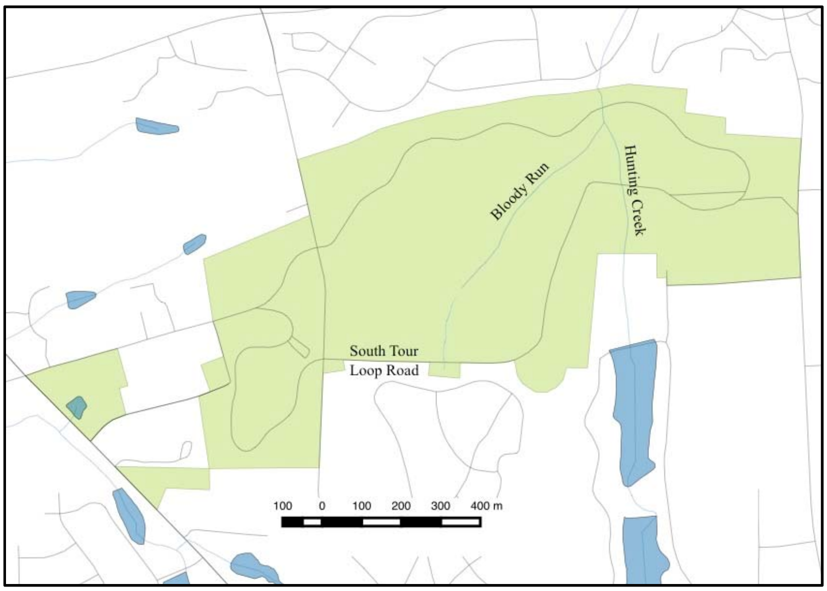


Figure 4.5.8. Roads and streams of Guilford Courthouse National Military Park, Greensboro, North Carolina.

Data and Methods

For this report, data and analyses presented in the single existing aquatic biological sampling (Long 2005) will be compared to fish and benthos samples collected between 1998 and 2013 from nearby streams as part of the periodic monitoring conducted by the North Carolina Department of Environment and Natural Resources (NCDENR).

Parameter Criteria

Long (2005) adopted the Index of Biotic Integrity (IBI) protocol used by NCDENR as described by in their 2001 Standard Operating Procedure manual (NCDENR 2001, current version is 2013a), but modified to fit the limitations of the small stream reaches available for sampling. Under this protocol, sample reaches may be given an integrity score that then may be placed into an Integrity Class (Table 4.5.6).

Table 4.5.6. Scores and classes for evaluating the fish community of wadeable streams in the Cape Fear drainage using the North Carolina Index of Biological Integrity (NCDENR 2013).

IBI Range	Rating
54-60	Excellent
46-52	Good
40-44	Good-Fair
34-38	Fair
≤32	Poor

NCDENR also conducts periodic samples of aquatic macroinvertebrates from streams around the state which they use to calculate scores that are in turn used to produce bio classifications (NCDENR 2013b).

Reference Conditions

Long (2005) sampled a total 901 individuals representing 14 species of fish over two seasons of sampling. This species richness is surprising given the small size of these streams, and may be due to downstream escapes from the small impoundments upstream on Hunting Creek (Figure 4.5.8). The IBI scores reported for the three stream reaches were 38 for the 152 meters (500 feet) reach of Hunting Creek and 20 and 16 respectively for a 183 meters (600 feet) and a 91 meters (300 feet) reach of Bloody Run (Long 2005). When compared to NCDENR IBI scores for the area (Figure 4.5.9), the score for Hunting Creek fall within those one might expect. The low scores for Bloody Run are almost certainly due to its small size and the extremely low score for its upper reach was due to only one species of fish being found there.

Figure 4.5.9. IBI Scores reported by NCDENR (2015a) and scores reported by Long (2005) for the streams of Guilford Courthouse National Military Park, Greensboro, North Carolina.

Parker et al. (2012) report that the U.S. Geological Survey conducted an inventory of the aquatic insect fauna in 17 national parks from 2005 to 2007, including GUCO, and that 33 species of macroinvertebrates were recorded from Hunting Creek and an unnamed tributary. These included three new Trichoptera occurrences for North Carolina (Lenat et al. 2010). NCDENR bio classifications based on benthic macroinvertebrate sampling corroborate the mediocre findings of the fish sampling (Figure 4.5.10). But, given that Greensboro is currently the third largest city in North Carolina, low integrity scores should be expected (Cuffney et al. 2010).

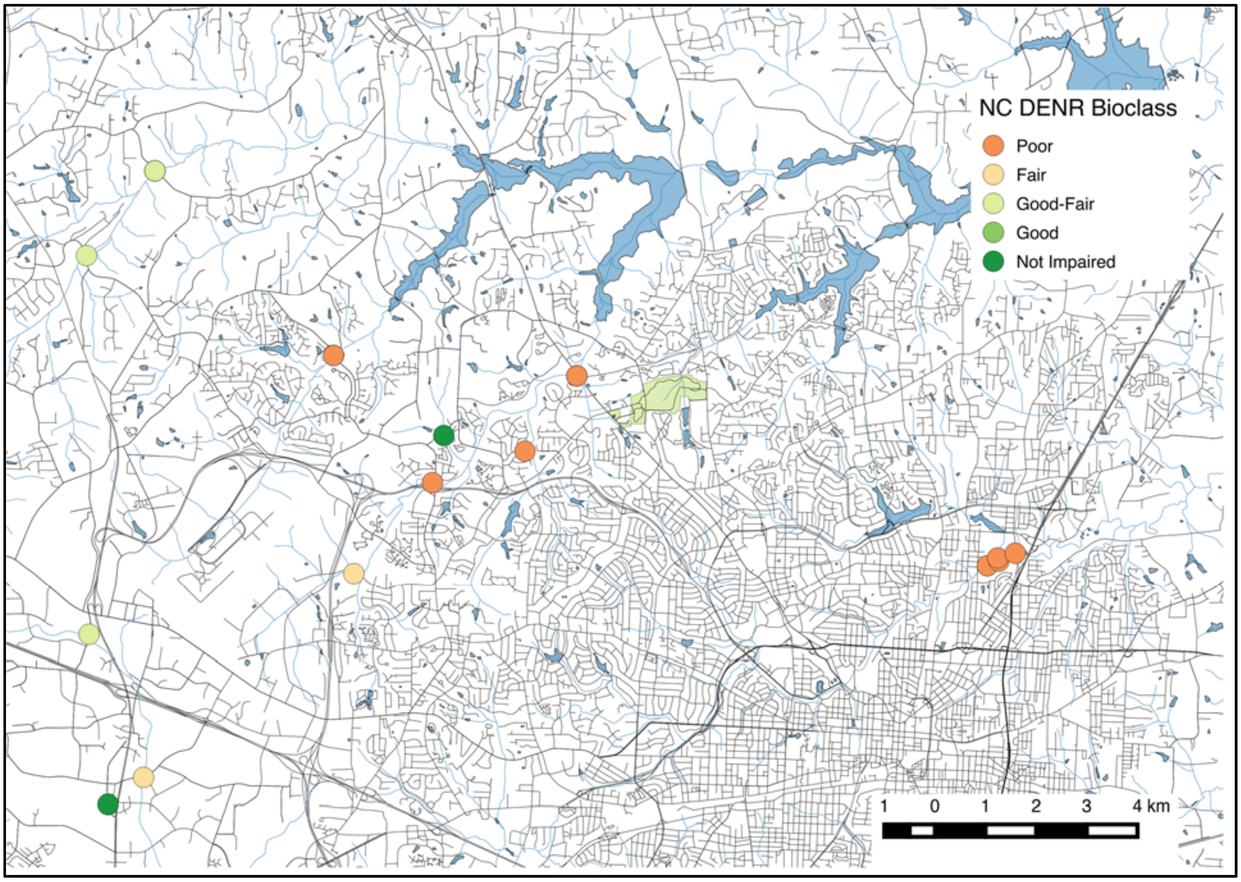


Figure 4.5.10. Map of roads and streams in the region surrounding Guilford Courthouse National Military Park (in light green). NCDENR benthos sampling stations are shown with dots colored to represent their most recent bio classification. Roads and streams are TIGER data (U.S. Census Bureau 2014), and NCDENR bio classifications from NCDENR (2015b).

Conditions and Trends

There are no recent data available to document current conditions. However, Long (2005) reported that fish IBI was "fair" in 2005, and the recent State of the Park Report indicates that a severe drought in 2007 resulted in drying of most surface water in the park. Thus we believe fish populations warrant moderate concern.

Confidence and Data Gaps

Given there has been no recent monitoring of the aquatic macroinvertebrate or fish assemblages, there is very little confidence in the current condition of the aquatic communities within the park.

Summary Condition

Table 4.5.7. Graphical summary of status and trends for fish and aquatic macroinvertebrates.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Aquatic Community	Fish IBI		2005 sample produced a “Fair” rating, but there has been no recent monitoring.
	Aquatic macroinvertebrate bio classification		There is no record of standardized macroinvertebrate monitoring.

4.5.5. Terrestrial Vertebrates

Relevance

Animals interact with habitat resources in complex ways, across multiple spatial scales, and exhibit tremendous variation in their sensitivity to environmental stressors. The outcome of these interactions is reflected in species composition and abundance and thus can provide relevant information about the quality of available habitat resources. However, the underlying complexity means detailed knowledge of individual species-habitat relationships is often lacking (Morrison 2001) requiring managers to rely on less direct measures or surrogate variables. In recent years there has been an increased effort in ecology to identify particular groups of species whose presence, absence or abundance can be used to indicate ecological condition (Lindenmayer et al. 2015). This has been a particular concern in assessing conditions in areas of high intensity land-use and land cover change (Niemi et al. 2015). While the development of specific indicators will be ongoing, several studies have shown that the suite of species occurring in a given habitat can provide useful indications of the condition of habitat resources (Rodrigues and Brooks 2007). Although data available for vertebrate taxa are limited they do provide information useful in evaluating ecological conditions at GUCO.

Data and Methods

Given a lack of baseline information for major terrestrial vertebrate groups, field studies were conducted at GUCO between 2002 and 2006. The condition assessments presented here were based largely upon the findings presented within these reports and assessment of current scientific literature with a focus on the comparison of expected vs. actual occurrences of species or taxonomic groups within each major vertebrate group.

Amphibian and reptile sampling was conducted from 2002-2005 using both field methods (primarily unconstrained search) and historic (museum) surveys to establish prior documentation of species occurrence (Reed and Gibbons 2005). Breeding birds were sampled between 2003-2004 using fixed radius point count plots placed at existing vegetation sampling points within the park between May and late June (Gerwin and Browning 2006). Point counts were conducted twice per year between May and late June. Species abundance was estimated using the maximum number of individuals counted within 100 meters (328 feet) of each census point during the breeding season. Total detections for each species reflect the sum of species abundances, as defined above, over all census points over 2003-2004 breeding seasons. Small mammals were sampled by trapping, cameras, and visual encounters within three major vegetation types: 1) managed grassland/field, 2) mixed hardwood forest, and 3) riparian edge (Kalcounis-Ruppell et al. 2007). Bats were sampled by Loeb (2007) using mist nets and acoustic sampling. Resource condition assessments for terrestrial vertebrates were based largely upon the findings of these reports.

While valuable, such single point surveys do not allow comparison with prior conditions or evaluation of trends over time. Further, given the difficulty in documenting a true species absence from an area (Miller et al. 2015), resource condition for terrestrial vertebrates was assessed considering the overall suite of species encountered. The assumption here is that while the presence or absence of any single species may not be informative about resource conditions presence of a high number of interior forest obligates or taxa highly tolerant to human disturbance provides a more robust indication of current conditions. Recent wildlife studies have used species response guilds (particularly for forest songbirds) where the overall community composition is used as an indicator of ecologic conditions (O'Connell et al. 2000, Lichstein et al. 2002).

Evaluations of current conditions are based primarily on comparisons of species or groups reasonably expected to occur w/in the park and those actually observed in the field. In the case of reptiles and amphibians, the authors provided a list of species based upon each animal's range, county historic (museum) records and earlier documentation as well as the scientific literature. For reptiles, amphibians, and mammals (including bats) we considered species individually but based condition estimates on overall composition. For birds (where species richness was much greater) we evaluated abundance within three major habitat guilds based upon information provided by the report authors and published in the literature (e.g., O'Connell et al. 2000, Lichstein et al. 2002, Greenberg et al. 2006).

<u>Reference Conditions</u>

Ideally, the patterns of species and community composition observed within non-disturbed forest ecosystems would represent reference condition for comparison. However, given the lack of non-disturbed conditions in the southeastern U.S., such baseline information is extremely rare for most locations. Subsequently conditions presented here were based upon the comparisons of species reasonably expected to occur w/in the park and those actually observed in the field. The presence or absence of any single species may not be indicative of overall resource condition, however, many studies have used species response guilds (i.e., interior vs. edge adapted habitats) thus evaluating the overall community. For example, while the presence or absence of any single species is less informative, the absence of numerous forest interior obligates (particularly any previously documented within the park), or the detection of organisms highly tolerant of human disturbances can provide a general indication of habitat conditions (O'Connell et al. 2000, Lichstein et al. 2002).

In the case of reptiles and amphibians, the authors provided a detailed list of "expected" species based upon each animal's range, county historic (museum) records and earlier documentation as well as the scientific literature. For avian taxa, numerous studies have examined subsets of species found within the southern and central Appalachians, and the Avian Conservation Implementation Plan compiled by Watson (2005) provided additional information about relevant conservation issues at GUCO and priority species occurring in the southern Blue Ridge.

Current Condition

Reptiles and Amphibians

Based upon range maps and habitat conditions numerous species expected to be present in the park were not found (Table 4.5.8). Although Reed and Gibbons (2005) suspected that some species (including both spring peepers (*Pseudacris crucifer*) and upland chorus frogs (*Pseudacris feriarum*) as well as eastern garter snake (*Thamnophis sirtalis*) are present and will likely be encountered in future work. They further suggest that the absence of some species is “likely due to loss or alteration of habitat within the region as well as the lack of ephemeral or other fish free ponds.”

Species expected but not observed were equally distributed between reptiles and amphibians which would seem to support the role of human land use in lowering species diversity. Reptiles have been shown to not only be more tolerant of some types of disturbance (Greenberg and Waldrop 2008) but in some cases to even maintain diversity in more heavily impacted urban landscapes (Barrett and Guyer 2008). That there were as many reptile as amphibian species expected but not encountered would suggest more long term impacts from human land use and should be of concern. As indicated in the landscape dynamics section the average distance to the nearest non-forest edge has decreased for all areas outside of the park with the greatest impacts observed within the first 400-1,000 meters from the park boundary with the conversion of forested areas to developed land cover (Table 4.7.3). The decrease of forested land cover and subsequent increase in distance between remaining forest patches, combined with road use within the park, has likely reduced migration among habitats for reptile and amphibian species (Reed and Gibbons 2005).

Table 4.5.8. Comparison of reptile and amphibian species expected and actually observed in GUCO (Reed and Gibbons 2005).

Group	Species Possible - Observed	Species Possible - Not Observed
Frogs &Toads	American toad	Green frog
		Southern leopard frog
	Eastern narrowmouth toad	Spring peeper
		Upland chorus frog
	Gray/Cope's gray treefrog	Fowler's toad
		Southern toad**
	Bullfrog	Southern cricket frog**
		Squirrel treefrog*

* Species probably does not occur in the park, but its existence is a remote possibility.

** Species is not expected to occur in the park, but has been previously documented.

Table 4.5.8 (continued). Comparison of reptile and amphibian species expected and actually observed in GUCO (Reed and Gibbons 2005).

Group	Species Possible - Observed	Species Possible - Not Observed
Salamanders	Southern two-lined salamander	Northern dusky salamander
		Spotted salamander
		Marbled salamander
	Three-lined salamander	Mud salamander
		Red salamander
	Slimy salamander	Mole salamander**
		Seal salamander**
Turtles	Eastern mud turtle	Eastern painted turtle
	Eastern box turtle	
	Common snapping turtle	
	Eastern river cooter	
Lizards	Five-lined skink	Fence lizard
		Ground skink
		Green anole**
		Broadhead skink
Snakes	Copperhead	Smooth earth snake
	Worm snake	Eastern hognose snake
	Black racer	Rough green snake
		Ribbon snake
Snakes (continued)	Brown snake	Garter snake
		Yellow-bellied slider
	Ringneck snake	Queen snake
		Mole kingsnake
	Rat snake	Corn snake
		Rough earth snake

* Species probably does not occur in the park, but its existence is a remote possibility.

** Species is not expected to occur in the park, but has been previously documented.

Birds

Approximately nine species (of 58 encountered) accounted for over 70% of all detections with white-throated sparrows being the most encountered species. Gerwin and Browning (2006) noted some particular absences including Red-breasted Nuthatch and Acadian Flycatcher. Nuthatches may be rare in GUCO due to high seed crops in the surrounding areas leading birds to use different wintering grounds. While GUCO has small stream habitats favored by Acadian Flycatchers, none were detected which also may suggest the likely impacts of surrounding urbanization. In examining habitat guilds, over 90% of detections were edge-open or generalist habitat species most of which are permanent residents (Tables 4.5.9 and 4.5.10). This makes sense given that the forests within the park occur within a highly urbanized landscape. Although a loss of habitat connectivity would be expected to impact herpetofauna and small mammals such loss of forested habitat may affect area sensitive or interior obligate songbird species (Watson 2005) and decrease overall habitat value for birds as development continues. Still, several forest habitat species were detected which suggests remaining forests at GUCO could serve as an important remnant forest patch within the greater urbanized landscape. The forested portions of the park may also help in allowing connectivity among other remnant forests within this landscape.

In evaluating conditions at GUCO based upon bird counts, the challenge is in evaluating the area simply as potential forest habitat for birds, or more realistically as a very small remnant of forest in a heavily urban landscape. The absence of many forest species suggests lower habitat quality for forest birds. However, GUCO is also surrounded by urban land use and thus even with the best conditions possible within the park, the area would not seem likely support a high diversity of forest species. Thus birds were considered to be in good condition but with low confidence in part because of limited data but also due to the difficulty in knowing what species to expect. Our condition assessment is consistent with that assigned in the current State of the Parks Report for GUCO (NPS 2015).

Table 4.5.9. Habitat guilds assigned for birds at GUCO. Abundance within 3 major habitat guilds based upon information provided by the report authors and published in the literature (O'Connell et al. 2000, Lichstein et al. 2002, Greenberg et al. 2006). Edge-Open—including both forest edge species as well as species requiring and preferring non-forest type conditions such as pasture/grassland, Generalist—overall habitat generalists, Forest—representing both interior obligates and species generally associated with forest habitat.

Edge-Open	Generalist	Forest
American crow	American robin	Brown creeper
American goldfinch	Blue jay	Fox sparrow
Brown thrasher	Blue-gray gnatcatcher	Golden-crowned kinglet
Brown-headed cowbird	Brown-headed nuthatch	Gray-cheeked thrush
Cedar waxwing	Carolina chickadee	Great-crested flycatcher

Table 4.5.9 (continued). Habitat guilds assigned for birds at GUCO. Abundance within 3 major habitat guilds based upon information provided by the report authors and published in the literature (O'Connell et al. 2000, Lichstein et al. 2002, Greenberg et al. 2006). Edge-Open—including both forest edge species as well as species requiring and preferring non-forest type conditions such as pasture/grassland, Generalist—overall habitat generalists, Forest—representing both interior obligates and species generally associated with forest habitat.

Edge-Open	Generalist	Forest
Chimney swift	Carolina wren	Hairy woodpecker
Common grackle	Eastern wood pewee	Hermit thrush
Common yellowthroat	Northern cardinal	Louisiana waterthrush
Dark-eyed junco	Red-bellied woodpecker	Pileated woodpecker
Downy woodpecker	Red-breasted nuthatch	Pine warbler
Eastern bluebird	Red-eyed vireo	Summer tanager
Eastern phoebe	White-breasted nuthatch	White-eyed vireo
Eastern towhee	Yellow-bellied sapsucker	Winter wren
Eastern tufted titmouse		Wood thrush
European starling		Yellow-rumped warbler
Field sparrow		
Gray catbird		
House finch		
House wren		
Indigo bunting		
Mourning dove		
Red-shouldered hawk		
Red-tailed hawk		
Ring-billed gull		
Ruby-crowned kinglet		
Ruby-throated hummingbird		
Song sparrow		
White-throated sparrow		
Yellow warbler		
Yellow-shafted flicker		

Table 4.5.10. Bird habitat guilds, number of species and detections within each and the proportion of all detections within each guild. Over 93 percent of species documented favor edge-open type habitats or are habitat generalists (O'Connell et al. 2000, Lichstein et al. 2002, Greenberg et al. 2006).

Habitat	Spp. Count	Detections	Proportion
Edge-Open	30	1,425	0.51
Generalist	13	1,189	0.42
Forest	15	188	0.06

Table 4.5.11. Species occurring within GUCO but not used in developing habitat guilds.

Species	Number of Detections	Survey Events
Accipiter sp.	1	1
Barred owl	2	2
Canada goose	37	12
Coopers hawk	5	5
Great blue heron	1	1
Red-shouldered hawk	2	2
Broad-winged hawk	1	1

Non-Volant Mammals

In total, twelve species (of 35 expected) non-volant mammals were recorded during the 2007 survey (Table 4.5.12). Five species were captured in traps with most being white-footed mouse in hardwood forest or riparian edge (Table 4.5.13). In comparing results from earlier surveys (Dietrich 1976, Shahady and Zirkle 1983) diversity in the insectivores and rodents show a decline while abundance of urban tolerant species such as white-tailed deer, gray squirrels, and raccoon had increased (Kalcounis-Ruppell et al. 2007).

Table 4.5.12. Observed vs. not observed for expected mammal species in GUCO (Kalcounis-Ruppell et al. 2007).

Expected Species	Observed	Not Observed
American mink		X
Black rat		X
Bobcat		X
Coyote		X
Domestic cat (*Felis catus*)	X	
Eastern chipmunk	X	

* Previously documented in GUCO

Table 4.5.12 (continued). Observed vs. not observed for expected mammal species in GUCO (Kalcounis-Ruppell et al. 2007).

Expected Species	Observed	Not Observed
Eastern cottontail	X	
Eastern fox squirrel beaver		X
Eastern gray squirrel	X	
Eastern harvest mouse*		X
Eastern mole*		X
Golden mouse*		X
Gray fox	X	
Hispid cotton rat	X	
House mouse		X
Least shrew*		X
Long-tailed weasel		X
Meadow jumping mouse*		X
Meadow vole*		X
Muskrat		X
Northern short-tailed shrew	X	
Norway rat		X
Raccoon	X	
Red fox*		X
River otter		X
Southeastern shrew*		X
Southern flying squirrel*		X
Southern short-tailed squirrel		X
Striped skunk		X
Virginia opossum	X	
White-footed mouse	X	
White-tailed deer	X	
Woodchuck	X	
Woodland vole*		X

* Previously documented in GUCO

Table 4.5.13. Mammals species captured in traps during 2005-2006 at GUCO (Kalcounis-Ruppell et al. 2007).

Species	Grassland	Hardwood	Riparian Edge	Total
Northern short-tailed shrew	1	0	3	**4**
Eastern chipmunk	1	0	0	**1**
White-footed mouse	1	26	11	**38**
Hispid cotton rat	1	0	0	**1**
Northern raccoon	0	6	5	**11**

The absence of so many species previously documented within the park suggests a resource in poor and declining condition although it is less clear why. Studies in urban ecosystems have shown among other factors that the spatial configuration of landscape features is especially important in urban ecosystems (Pickett et al. 2001) and the landscape adjacent to GUCO did change between the two major mammal inventories (see Landscape Dynamics section 4.7). In a review of 105 urban ecology studies, McKinney (2008) found that very high levels of urbanization negatively impacted virtually all groups though at moderate levels species diversity in some groups (esp. plants) actually increased. Only 12% of non-volant mammal studies reported increases in species diversity.

Kalcounis-Ruppell et al. (2007) noted that white-footed mice tend to increase in number after a disturbance (e.g., Greenberg et al. 2006) and that this increase along with decreases in non-sciurid rodent diversity suggests that resource availability (i.e., decreased food and/or nest availability) or altered community dynamics (i.e., increased competition or predation) may have changed in the recent past. Increases in human population growth adjacent to protected areas is being recognized as a national issue (Hansen et al. 2005). In addition to habitat alteration such land use change can also increase recreational use in parks and predation by house pets and small predators and has been shown to negatively impact small mammal populations (Nilon and Pais 1997). The 2015 State of the Parks Report (NPS 2015) indicated high levels of concern for forest composition and regeneration conditions, and moderate concern for snag abundance and stand structure thus habitat conditions internal to forests at GUCO may be influencing mammal populations as well.

It is not possible to do much more than speculate, although it seems feasible that some groups like rodents and insectivores were more negatively impacted by some type of change in resource condition. Despite potential causes and complicating factors, the absence of several previously documented and relatively common species raises concern for the mammals at GUCO.

Bats

Mist netting from six sites at GUCO produced four species captured across six sites all of which were expected species. Big brown bats (*Eptesicus fuscus*) were the dominant species captured throughout the park although other species captured included red bats (*Lasiurus borealis*), evening bats (*Nycticeius humeralis*) and tricolored bat (*Pipistrellus subflavus*) (Table 4.5.14). Big brown bats were quite abundant and of those captured, 22 were juveniles which may indicate that at least one maternity colony occurred within or nearby tor GUCO. In addition, a lactating red bat, two juvenile red bats, a lactating pipistrelle, and a juvenile pipistrelle were all captured, further suggesting the presence of reproductive populations of these bats (Loeb 2007).

Table 4.5.14. Number of individuals captured via mist netting within expected species and occurrence of species in acoustic samples at GUCO.

Species	Mist Net	Acoustic Samples
Big brown bat	39	+
Silver-haired bat	4	+
Brazilian free-tailed bat	-	-
Evening bat	2	+
Eastern pipestrelle	2	+

According to Loeb (2007), GUCO has a “relatively rich bat fauna but the dominance of the big brown bat means overall species diversity is low which is apparently a common pattern for urban parks. The species composition of the GUCO bat fauna was found to be similar to that found with bat detectors in a site approximately 10 km (6 mi) from GUCO (Kalcounis-Ruppell et al. 2007) and it does appear that important habitat resources (roosting areas, foraging habitat) are being provided by GUCO. This makes it an important habitat especially given the surrounding land use, and potential population declines in bats due to white nose syndrome.

<u>Confidence and Data Gaps</u>

Data gaps for evaluating the composition and abundance of vertebrate taxa are essentially the same in that only baseline data from one inventory exist; thus, evaluation of trends is not possible. Given the logistic challenges in assessing wildlife populations it is understandable only single point surveys are available, however, true assessments will require additional surveys in order to document actual presence or absence of expected species and more importantly to evaluate trends in these populations over time.

<u>Summary Condition and Graphic</u>

Table 4.5.15. Graphical summary of status and trends for terrestrial vertebrates.

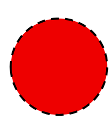
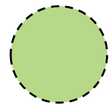
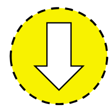
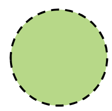
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Terrestrial Vertebrates	Reptile and amphibian species compositions		A number of commonly occurring species were not observed at GUCO suggesting sub-optimal habitat conditions for herpetofauna. Given increased pressure on remaining habitats (from adjacent land use) there is likely a downward trend and little chance of immigration. Further monitoring would be required to assign this.

Table 4.5.15 (continued). Graphical summary of status and trends for terrestrial vertebrates.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Terrestrial Vertebrates	Bird species composition		The predominance of edge and generalist species suggests the impacts of habitat fragmentation.
	Non-volant mammal species composition		A number of expected species were not observed in 2007. This included 10 species previously documented in the park. Gerwin and Browning (2007) attributed this to increased fragmentation at GUCO. Trend is included here because there were 2 prior mammal inventories with which to compare.
	Bat species composition		The presence of similar species composition as found in nearby areas and the presence of lactating individuals suggests good condition overall. Condition will no doubt change as white nose syndrome continues to spread.

4.6. At-risk Biota

4.6.1. Plant Species of Special Interest

Relevance

Although there are no federally threatened or endangered species in the park, some species are uncommon to the area surrounding GUCO. They may provide an indication of what the flora in the surrounding landscape looked like hundreds of years before the areas was settled, and could serve as seed sources to restore areas that have been heavily impacted by invasive exotic plants (White and Pyne 2003).

Data and Methods

The data used for this assessment come from the 2003 vascular plant inventory (White and Pyne 2003).

Reference Conditions

Ideal conditions for plant species of special interest include conserved and protected critical habitat in which these species occur, and sustainable populations that remain viable for the long-term.

Current Condition and Trend

White and Pyne (2003) identified five species in GUCO that are uncommon in the immediate area (Table 4.6.1). These are the only species in the park that are ranked below G5 (extremely globally secure). All of these species occur in either the oak-hickory or beech slope communities; and with the exception of the crippled cranefly orchid (*Tipularia discolor*), they occur primarily in areas that have not been plowed within the past 80-100 years.

Table 4.6.1. Plant species of special interest at GUCO (White and Pyne 2003).

Species	Common name	Park habitat	Global rank/NC rank
Tipularia discolor	Crippled cranefly	Oak woods and roadside	G4/S5
Lilium michauxii	Carolina lily	Oak forest	G4/S4
Dioscorea villosa	Wild yam	Oak woods	G4G5/S5
Cimicifuga racemosa	Black bugbane	Oak forest	G4/S4
Aristolochia serpentaria	Virginia snakeroot	Old field	G4/S4

Confidence and Data Gaps

The occurrences of plants of special interest were documented at GUCO during the vascular plant inventory conducted by White and Pyne (2003). However, there is no systematic monitoring of these plants or their populations outside of the 20 CUPN forest monitoring plots that have recently been installed. As a result, there is little information about plant population trends.

Summary Condition

Table 4.6.2. Graphical summary of status and trends for at-risk biota.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
At-risk Biota	Plant species of special interest		Reference conditions consist of sustainable populations that remain viable for the long-term. Plant occurrence was documented in the park, though no systematic data exists regarding population trends or viability.

4.7. Landscape Dynamics

4.7.1. Land Use Change - Forest Fragmentation

Relevance

Residential development has increased markedly in recent years and is of particular concern near or adjacent to protected areas such as national parks (Hansen et al. 2005). In addition to potential loss of biodiversity, forest fragmentation reduces the amount, quality and connectivity of habitats and increases risk of invasion by exotic species. As an urban park, GUCO has seen significant residential and urban land use in the area around the park potentially affecting species making use of habitat resources both within and beyond park boundaries

Data and Methods

Land use-land cover conditions were evaluated using the National Land Cover Database for 1992 (Vogelman et al. 2001), 2001 (Homer et al. 2007), 2006 (Fry et al. 2011), and 2011 (Homer et al. 2015). As these layers were not specifically developed for pixel by pixel comparisons of change detection (Fry et al. 2009) and because of differences in classifications used among years, we simplified the classes to include: 1) Forest (deciduous, conifer, mixed), 2) Non-Forest Vegetation (scrub, grass, pasture) 3) Low Intensity development (residential), 4) Medium and high level development (commercial, urban) and 4) Non-Vegetation (barren, rock, water). We then compared the proportion of area occupied by each class for GUCO and a series of distance bands outside of the park boundary (400m, 1km, and 5km). See Table 4.7.1 for specific class combinations.

To evaluate potential fragmentation we extracted all non-forest classes and applied a Euclidean distance function (ArcGIS 10.1 Spatial Analyst) which produces a raster layer where each pixel reflects the distance from non-forest land cover. We then calculated the mean distance within the same distance bands around GUCO for each year.

Table 4.7.1. Modified land cover classification for evaluation of landscape conditions around GUCO.

NRCA Classification	NLCD Classification 1992	NLCD Classification 2001-2011
Non-Vegetation	Open Water	Open Water
	Bare Rock, Sand, Clay	Bare Rock, Sand, Clay
Developed-Low Developed-Med/High	Low Intensity Residential	Developed-Low Intensity
	High Intensity Residential	Developed-Medium Intensity
		High Intensity Residential
	Commercial, Industrial, Transportation	Commercial, Industrial, Transportation
Forest	Deciduous Forest	Deciduous Forest
	Evergreen Forest	Evergreen Forest
	Mixed Forest	Mixed Forest
	Woody Wetlands	Woody Wetlands
Non-Forest Vegetation	Pasture, Hay	Pasture, Hay
	Row Crops	Row Crops
	Urban Recreational Grasses	Developed-Open Space
	Emergent Herbaceous Wetlands	Emergent Herbaceous Wetlands

Reference Conditions

The ideal reference condition for assessing LULC changes, fragmentation and connectivity would be zero (or some established minimum) loss of natural vegetation conditions over time. However, given that GUCO is an urban park in a landscape that has already undergone substantial changes we used conditions in 1992 as a starting point and evaluated the loss of natural (forest) vegetation conditions either through conversion to other land cover or modification through human activity.

Current Conditions

As seen in other areas of the southeast, the greatest amount of land cover change occurred between 1992 and 2001 consisting mostly of a loss of forest but interestingly within 1 km (0.6 mi) of GUCO a substantial loss of non-forest vegetation (Table 4.7.2). According to U.S. Census Bureau data presented by the city of Greensboro (City of Greensboro Growth and Development Trends 2012) this corresponds to a 21% increase in population for Guilford County during 1990s.

Table 4.7.2. Percent change within NLCD land cover classes at GUCO between 2001 and 2011.

Years	Location	Forest	Developed	Non-Forest Veg	Non-Veg
1992-2001	GUCO	1.86	0.00	-100.00	0.00
	400m	-14.49	4.06	-81.13	0.00
	1,000m	-27.88	13.04	-90.80	-43.75
	5,000m	-15.10	10.68	-30.63	7.77
2001-2006	GUCO	0.00	0.00	0.00	0.00
	400m	-2.03	0.25	0.00	0.00
	1,000m	-2.18	0.72	-68.75	0.00
	5,000m	-3.39	2.40	-11.07	-2.25
2006-2011	GUCO	0.00	0.00	0.00	0.00
	400m	-8.30	1.00	0.00	0.00
	1,000m	-0.59	0.08	0.00	0.00
	5,000m	-4.12	2.13	-12.09	2.22

As with land cover, average distance to the nearest non-forest edge showed the most dramatic changes from 1992-2001 for all areas outside of the park (Table 4.7.3). The distance within GUCO apparently increased between this same time period as some successional forests in the northern areas of the park were classified as low intensity development in 1992 (Figure 4.7.1). Overall the greatest impacts were observed within the first 400 - 1,000 meters (1,312 - 3,281 feet) from the park boundary driven apparently by conversion of forest to developed land cover.

Table 4.7.3. Change in average distance to nearest non-forest edge from 1992-2011.

Area	1992	2001	2006	2011
GUCO	55.13	72.21	72.21	72.21
400m	20.11	4.76	4.67	4.15
1,000m	12.88	5.58	5.51	5.46
5,000m	28.73	18.45	17.77	16.84

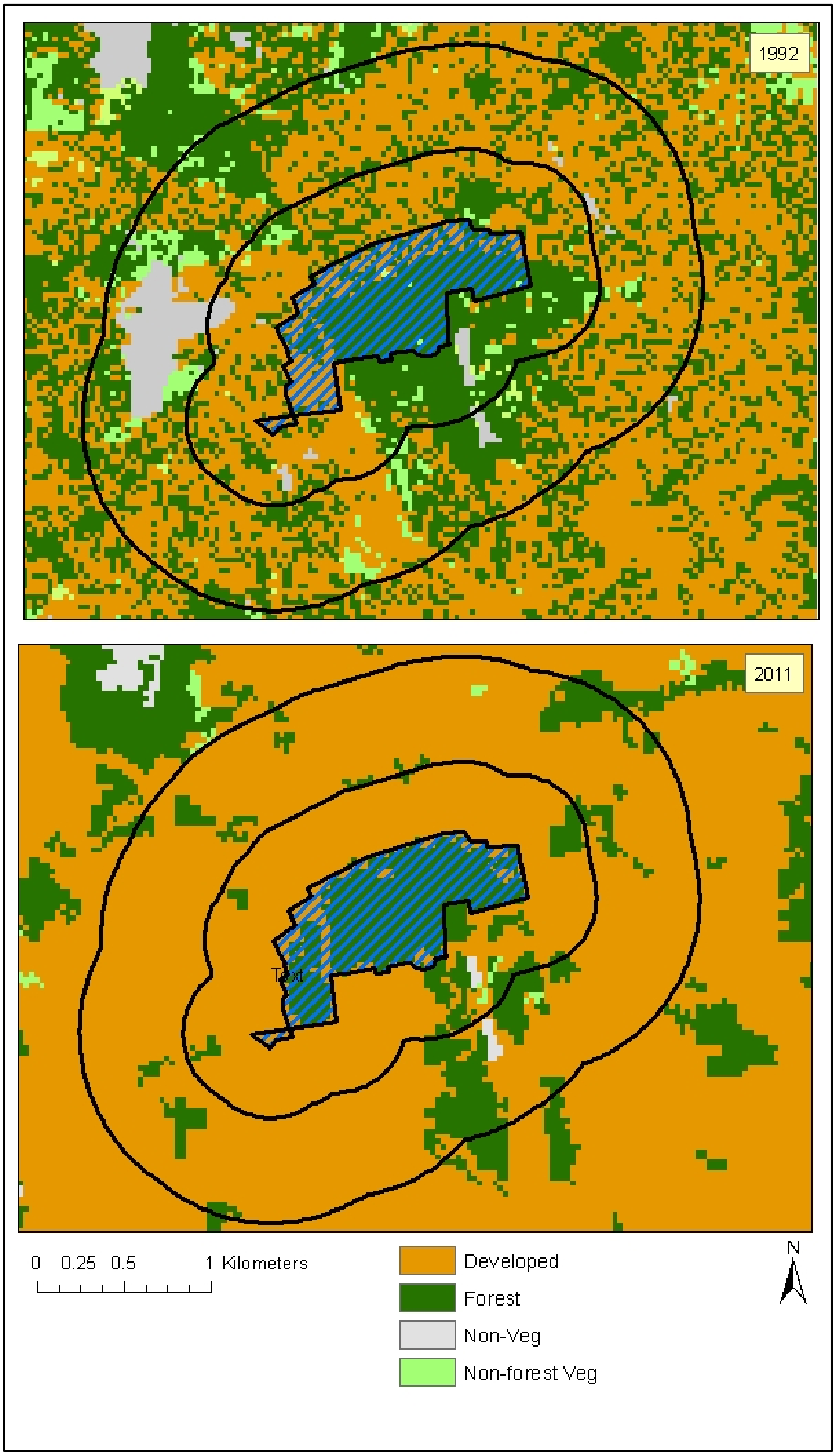


Figure 4.7.1. Changes in the landscape within 400 and 1,000km of GUCO for 1992 and 2011.

In assigning a condition score to GUCO for landscape dynamics, we again could consider the park as a very small remnant of a once much larger forest ecosystem; an island essentially. Or we can view the park as remnant of forest within an urban dominated landscape. Ecologically the former would be most compelling yet resource condition scores would be abysmal. Also, the reality is that GUCO is surrounded by heavy urban land use and has long been fragmented. According to the 2015 State of the Parks Report (NPS 2015) the 30 km radius surrounding GUCO is considered “fragmented” and below “good” condition as it contains only 48% “natural cover.” A “Good” condition requires >60% cover while areas <30% are “of concern.” (With and Crist 1995, McIntyre and Hobbs 1999, Wade et al. 2003).

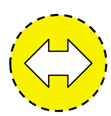
Although its speculation, the impacts associated with fragmentation seem to be reflected in species inventory results. While low species diversity among reptiles and amphibians implies poor current (2005-2007) habitat conditions but declines in diversity shown for mammals between 1976-1983 and 1983-2007 suggests a change in some aspect of resource quality during this time.

Confidence and Data Gaps

The 30 meter resolution of the NLCD data sets necessitates an over-simplification of land cover at smaller extents making very localized and quantitative measures impractical. Even so, the patterns shown in the NLCD data and our analyses coincide with the trends in population growth and land cover changes and current level of condition reported for Guilford County (NPS 2015).

Summary Condition and Graphic

Table 4.7.4. Graphical summary of status and trends for landscape dynamics.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Landscape Dynamics	Land use change-forest fragmentation		Trends seem to be stable but potential impacts from adjacent urban land use warrant at least moderate if not significant concern as they impact virtually all other resources.

4.8. Night Sky

4.8.1. Night Sky Condition

Relevance

Directly associated with an increase in human land use, is the loss of dark night skies. By some estimates as many as 99% of Americans live in areas considered to be light polluted (Cinzano et al. 2001) and at the rate light pollution is currently increasing, there will be almost no dark skies in the contiguous U.S. by 2025 (NPS 2016). Given the dependence of numerous species on natural light and dark cycles, alteration of the natural pattern can undoubtedly impact wildlife and is a concern at all national park units (NPS 2015). Specific impacts reported include habitat quality for birds, terrestrial and marine mammals, fish, and sea turtles, nocturnal wildlife activity and behavior, migration patterns, and predator-prey interactions (Rich and Longcore 2005).

Estimates of night sky condition can be obtained from the National Park Service's Night Skies division (http://www.nature.nps.gov/night/index.cfm). While quantitative data is lacking, the shift to more urbanized land use in the area around GUCO (see Landscape Analyses Figure 4.7.1, Table 4.7.3) would seem to leave little doubt that wildlife within the park have been affected to some degree by the loss of dark night skies. The 2015 State of the Parks Report for GUCO rated night skies as warranting significant concern but with a stable trend (NPS 2015).

Chapter 5. Natural Resource Conditions Summary

5.1. NRCA Overview

Guilford Courthouse comprises approximately 101 hectares (250 acres) within the City of Greensboro in Guilford County, NC and the upper Cape Fear River drainage. Elevation ranges from approximately 241 to 265 meters (790 to 870 feet) above sea level with land cover consisting of mature mixed hardwood forest, grassland/meadows, two small streams and a trail system. This NRCA describes the current conditions and trends for GUCO's natural resources. The resource assessments were largely based on summarizing existing data in combination with expert judgment from NPS scientists and project collaborators. The primary goals of the NRCA were to: 1) document the current conditions and trends for important park natural resources, 2) list critical data and knowledge gaps, and 3) identify some of the factors that are influencing park natural resource conditions. The information delivered in this NRCA can be used to communicate current resource conditions to park stakeholders. It will also be used to support park managers in the implementation of their integrated and strategic approach to the management of park resources.

5.2. Key Resource Summaries Affecting Management

GUCO is tasked with conserving both natural and cultural values. As a unit of the National Park System, GUCO is responsible for the management and conservation of its natural resources as mandated by the National Park Service Organic Act of 1916. GUCO faces a number of resource related issues, many of which are related to its urban setting. Many of the park's vegetative communities have been disturbed by past agriculture and development to the point that they are considered too human modified to be of conservation value. The remaining communities are severely threatened by exotic plants and pests, which are an ongoing management challenge for park managers. Increasing population growth and development around the park will only add to stresses on the park's natural resources.

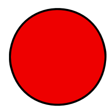
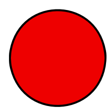
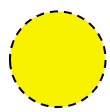
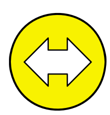
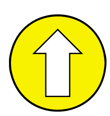
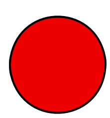
5.3. Compiled Resource Assessment Summary Condition Tables

The following sections provide an overview for each level 1 resource, as well as, the resource condition summary tables for each level 3 resource assessed in this NRCA.

5.3.1. Air Quality

Air quality in the park ranges from moderate concern to significant concern, depending on the indicator of condition. For the 2008-2012 time period, estimated sulfur and nitrogen wet depositions were high and warrant significant concern. However, most of the ecosystems within the park are not typically sulfur and nitrogen-sensitive systems and were rated as having very low sensitivity to acidification effects and nutrient-enrichment effects. Mercury deposition levels warrant moderate concern based on estimated wet mercury deposition and predicted levels of methylmercury in surface waters. Ground-level ozone also warrants moderate concern to human health and vegetation at GUCO based on the estimated ozone levels during the 2008-2012 time period. Particulate matter concentrations near GUCO have steadily declined over the past decade, with values decreasing 33% over the entire time period monitored (2004-2012). Although the most recent data fall below the ecological threshold, there is insufficient long-term data to suggest this is the trend, thus these data warrant moderate concern for the particulate matter condition in the park. Visibility monitored during the 2008-2012 time period warrants significant concern. Haze is a particular issue in the eastern U.S. and although trends over the long-term are improving, high deciview values on mid-range days indicate that major reductions are still needed to reduce regional haze and improve visibility within the park.

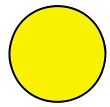
Table 5.3.1. Graphical summary of status and trends for air quality.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Total Sulfur (Wet deposition in kg/ha/yr)		Estimated wet sulfur deposition was 3.3 kg/ha/yr (2008-12); condition warrants significant concern; NPS ARD advises against using interpolated values for trends (Data Source(s): NADP-NTN via AirAtlas)
Air Quality	Total Nitrogen (Wet deposition in kg/ha/yr)		Estimated wet nitrogen deposition was 4.3 kg/ha/yr (2008-12); condition warrants significant concern; NPS ARD advises against using interpolated values for trends (Data Source(s): NADP-NTN via AirAtlas)
Air Quality	Mercury (Wet deposition in µg/l/y and concentration in ng/L)		Estimated mercury wet deposition was 8.98 µg/m2/yr; estimated methylmercury concentration in park surface waters was 0.12 ng/L; warrants moderate concern, trend in condition was not assessed; low confidence in the assessment (Data Source(s): NADP-MDN and USGS via NPS ARD)
Air Quality	Ozone Concentration in ppb (human health) and exposure in ppm-hrs (veg health)		Estimated ozone concentration was 73.9 ppb and estimated W126 was 12.1 ppm-hrs (2008-12); warrants moderate concern; trend relatively unchanged (2003-12) (Data Source(s): EPA AQS via AirAtlas)
Air Quality	$PM_{2.5}$ Concentration in µg/m3		$PM_{2.5}$ concentration was 8.3 µg/m3 (2010-12); warrants moderate concern; values have declined since 1999; recent levels have fallen below threshold of ≤12 µg/m3 (Data Source(s): EPA AQS and IMPROVE via EPA AirData)
Air Quality	Visibility / Haze (Haze Index in deciviews [dv])		Estimated visibility on mid-range days was 9.6 dv (2008-12); warrants significant concern; trend info not available; exceeds significant concern level of <8 dv above estimated natural conditions (Data Source(s): IMPROVE via AirAtlas)

5.3.2. Soil Function and Dynamics

Historic cultivation and other disturbances have resulted in degraded soil conditions at GUCO. However, these soil conditions are sufficient to support the native vegetative communities and are therefore considered of moderate concern and unchanging.

Table 5.3.2. Graphical summary of status and trends for soil and geologic resources.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Soil & Geologic Resources	Soil Function and Quality		Reference condition consists of soil properties sufficient to support the native vegetative communities found at GUCO, and human and vehicular traffic without causing erosion or sedimentation. Current condition is degraded by past cultivation and other disturbances.

5.3.3. Water Quality

Generally water chemistry in GUCO is in good, stable condition, with the exception of pH, which warrants moderate concern. pH data collected since 2004 shows surface water in GUCO to have an average pH below the 6.0 standard. Other water chemistry parameters including acid neutralizing capacity, stream water temperature, specific conductance, and dissolved oxygen concentration, are all within acceptable reference ranges. Although data is limited, sulfate and nitrate concentrations measured from two sites exceeded the reference values. The exceedance of the reference values in combination with the observed acidic conditions as measured by pH, suggest that the elevated levels of sulfate and nitrate is of moderate concern. Park data on dissolved concentrations of other toxics in water is limited or unknown and therefore conditions and trends are indeterminate. *E. coli* values are generally below the EPA threshold value, however the threshold was exceeded on a relatively frequent basis, therefore water quality with respect to bacteria is thought to warrant moderate concern.

Table 5.3.3. Graphical summary of status and trends for water quality.

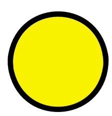
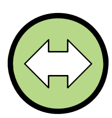
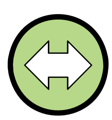
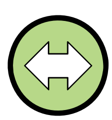
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Hydrogen (H+) concentration (pH units)		Surface waters since 2011 are often below a pH 6.0; ANC, however, does not fall below the 2.5 mg/L (50 µeq/L) reference target. Reference Condition: North Carolina Water Quality Standard for fish and aquatic life (Class C); Tennessee State ANC TMDL default target set for the GRSM (TDEC 2010)
Water Quality	ANC, Difference between proton acceptors and donors in stream water (µeq/L)		
Water Quality	Stream Water Temperature (°C)		Temperature of headwater streams consistently below reference standard, Reference Condition based North Carolina Standards for aquatic life
Water Quality	Specific Conductance (µS/cm)		Conductivity consistently below regional reference. Specific Conductance based on regional data collected from “reference” basins;

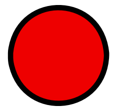
Table 5.3.3 (continued). Graphical summary of status and trends for water quality.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Dissolved Oxygen Concentration (mg/L)		DO consistently above reference value. Dissolved oxygen based on the North Carolina Standard (Class C)
Water Quality	Sulfate, Nitrate Total dissolved concentration (mg/L)		Data within the park are limited; existing data suggest that regional standards are continuously exceeded. Reference Condition: Based on regional conditions
Water Quality	Dissolved aluminum concentration, aluminum in water passing through 0.45 µm filter (µg/L)		Concentrations of dissolved aluminum frequently exceed the 200 µg/L reference value. Reference Condition: Based on review of toxic affects to biota by Cai et al. (2012)
Water Quality	As, Cu, Hg, Fe Mn, Zn concentration Total and/or dissolved concentrations (µg/L)		Concentrations of these metals rarely exceed the reference values. Reference Condition: Based EPA and/or state guidelines
Water Quality	Coliform Bacteria (MPN/100ml)		Reference value for *E. coli* was occasionally exceeded. North Carolina standard for fecal coliform (200 cfu/100 mL of water); EPA Criteria for E.coli (576 MPN/100 mL)

5.3.4. Invasive Exotic Species

The presence of exotic invasive species at GUCO warrants significant concern and is a major threat to the native species and plant communities in the park. The high abundance and distribution of the nonnative species within the park, as well as the adjacent residential and commercial properties, make the control and treatment of these species exceedingly difficult.

Table 5.3.4. Graphical summary of status and trends for invasive species.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Invasive Species	Invasive Exotic Plants		The reference condition is considered as maintaining invasive exotic plant species at manageable and non-damaging levels. Exotic invasive plant species are a continuing problem at GUCO. Almost half of all nonnative plants documented in the park are considered highly aggressive exotic plant species. Invasive species were found in all 20 long-term monitoring plots in the park. The average number of “high priority” exotic invasive species found in these plots is 4.55 per plot.

5.3.5. Focal Species or Communities

The ecological communities in GUCO have experienced stress due to the extensive impact of humans in this area. Wetlands in GUCO appear to be hydrologically intact, but have been altered by past timber harvesting. The park’s two existing wetlands currently warrant moderate concern with an unchanging condition. Forest, wetland and riparian communities are suffering from the presence of invasive, exotic species. Both the forest communities and the riparian communities warrant significant concern due to these species that threaten native species diversity.

Numerous species of reptiles, amphibians, and non-volant mammals expected to be present in the park were not found. This is likely due to the loss and alteration of habitat. Reptile and amphibian species diversity warrants significant concern. Diversity of mammalian insectivores and rodents have shown a decline, while abundance of urban tolerant species, such as white-tailed deer, gray squirrels, and raccoon have increased, therefore mammal species diversity warrants moderate concern, but continues to deteriorate. Volant species, such as birds and bats appear to be in good condition. Current conditions of aquatic communities are unknown due to lack of monitoring data.

Table 5.3.5. Graphical summary of status and trends for focal species and communities.

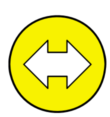
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities	Wetland Communities		Reference condition consists of wetlands existing in an undisturbed state and exhibiting biological integrity and function in their full capacity as surface water storage and/or groundwater discharge units and function as carbon/nutrient export units. The park’s two existing wetlands are in a condition that warrants moderate concern with an unchanging condition. Given their respective sizes and conditions they are functional wetlands. However, exotic invasive species are present in both units. These species have the potential to suppress native plant species, including wetland plants, from occurring in the units.

Table 5.3.5 (continued). Graphical summary of status and trends for focal species and communities.

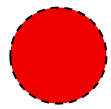
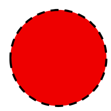
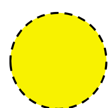
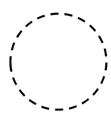
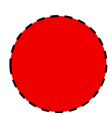
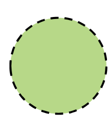
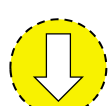
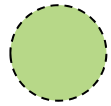
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities	Riparian Communities		The reference condition is unaltered Piedmont Small Stream Sweetgum Forest. This forest has been heavily degraded by recent disturbances including alterations in hydrology and exotic species invasion. White and Pyne (2003) report that while most species found on the park list only occur in this community, some stands have close to 100% coverage of Japanese stiltgrass which has lowered native plant diversity in the herbaceous layer. The data from the vascular plant inventory used in this assessment is well over a decade old. Updated reference data is needed to perform an accurate analysis of this forest type.
Focal Species or Communities	Forest/Woodland Communities		The Species composition for each forest type should mimic what is expected based on Schafale (2012) and Schafale and Weakly (1990). Forest structure should represent a range of successional stages, and include significant areas with late-successional forest that are characterized by the presence of large diameter trees. Species composition is suffering from the presence of invasive exotic species in most forest areas and the possible loss of hard mast species from the canopy.
Focal Species or Communities (Aquatic Communities)	Fish IBI		2005 sample produced a “Fair” rating, but there has been no recent monitoring.
	Aquatic macroinvertebrate bio classification		There is no record of standardized macroinvertebrate monitoring.
Focal Species or Communities (Terrestrial Vertebrates)	Reptile and amphibian species compositions		A number of commonly occurring species were not observed at GUCO suggesting sub-optimal habitat conditions for herpetofauna. Given increased pressure on remaining habitats (from adjacent land use) there is likely a downward trend and little chance of immigration. Further monitoring would be required to assign this.
	Bird species composition		The predominance of edge and generalist species suggests the impacts of habitat fragmentation.
	Non-volant mammal species composition		A number of expected species were not observed in 2007. This included 10 species previously documented in the park. Gerwin and Browning (2007) attributed this to increased fragmentation at GUCO. Trend is included here because there were 2 prior mammal inventories with which to compare.

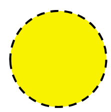
Table 5.3.5 (continued). Graphical summary of status and trends for focal species and communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species or Communities (Terrestrial Vertebrates)	Bat species composition		The presence of similar species composition as found in nearby areas and the presence of lactating individuals suggests good condition overall. Condition will no doubt change as white nose syndrome continues to spread.

5.3.6. Plant Species of Special Interest

Within GUCO, there are only five plant species that are uncommon in the immediate area, though each of these species is ranked as extremely globally secure. However, there has not been any systematic monitoring of these plants or their populations until very recently, and as a result there is little information about plant population trends.

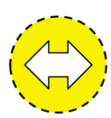
Table 5.3.6. Graphical summary of status and trends for at-risk biota.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
At-risk Biota	Plant species of special interest		Reference conditions consist of sustainable populations that remain viable for the long-term. Plant occurrence was documented in the park, though no systematic data exists regarding population trends or viability.

5.3.7. Landscape Dynamics

As seen in other areas of the southeast, the greatest amount of land cover change adjacent to GUCO occurred between 1992 and 2001 and consisted mostly of forest loss, but also included loss of non-forest vegetation. The increase in land development corresponded with a 21% increase in population for Guilford County during the 1990s. From 2001 to 2011, the land cover changes are far less drastic and this trend seems to be stable, but impacts from the increases in adjacent urban land use warrant moderate concern as they impact most resources within the park.

Table 5.3.7. Graphical summary of status and trends for landscape dynamics.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Landscape Dynamics	Land use change- forest fragmentation		Trends seem to be stable but potential impacts from adjacent urban land use warrant at least moderate if not significant concern as they impact virtually all other resources.

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Appendix A. Summary of Ambient Air Quality Data Collected in and Near GUCO

Source* (Parameters Measured)	Location	Site #
NADP-NTN (At Dep)	Rowan Mill, NC 75 km SW	NC34
AQS (O_3, $PM_{2.5}$)	Guilford Co, NC Within 30 km	370810011
	Forsyth Co, NC Within 30 km	Many
CASTNet (O_3)	Candor, NC 100 km S	CND125
IMPROVE ($PM_{2.5}$, Vis)	Linville Gorge WA, NC 180 km W	LIGO1

* National Park Service, Air Resources Division. Summary of Ambient Air Quality Data Collected in and near National Park Service Units in the Cumberland/Piedmont Network. Available at: http://www.nature.nps.gov/air/permits/aris/networks/docs/cupn_NC_SCMonitoringTable.pdf. (Accessed on May 20, 2015).

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