National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Carl Sandburg Home National Historic Site

Natural Resource Report NPS/CARL/NRR—2017/1373

ON THE COVER
Photo of the barn, pasture and back driveway at Carl Sandburg Home National Historic Site. Photo courtesy of the National Park Service (2006).

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Executive Summary

This report provides a comprehensive assessment of the state of natural resources at the Carl Sandburg Home National Historic Site (CARL). 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 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, is further subdivided into level-two and level-three categories. Biological integrity, a level-one category for example, is divided into 4 level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Infestations and diseases, in turn, include 2 level-three categories: insect pests and plant diseases. As the categories move from level-one to level-three, the resolution of the data involved also increases. These proposed 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 conducted assessments of 27 Level 3 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 may be determined specifically for this NRCA or this effort can provide baseline information for future planning.

As a unit of the National Park System, CARL 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, the Carl Sandburg Home is fundamentally a cultural park under the Historic Sites Act of 1935 (16 U.S.C sec. 461-467). CARL faces a number of resource related issues, many of which are related to surrounding population growth and land use. The park lies within the Flat Rock, NC municipality and is located approximately 4.8 km (3 mi) from Hendersonville, NC. Increased development reduces wildlife habitat availability in areas outside of the park and further encourages invasive exotic species encroachment inside the park boundaries.

Furthermore, as the surrounding population continues to grow, visitor rates to the park will increase, placing added stress on the park's natural resources.

This NRCA identified 3 areas where management and monitoring will be particularly important to achieve its mission of conserving the park's natural resources. Recognizing that there is some overlap between them, these include: 1) protecting and restoring unique vegetative communities found on the property, 2) monitoring and managing the impacts of non-native plants, insects, and diseases, and 3) monitoring the effects of acidic deposition on soils, water quality, terrestrial communities, and aquatic communities.

CARL contains two unique natural communities including the globally imperiled (G2) Appalachian Low Elevation Granitic Domes Communities and the globally vulnerable (G3) Blue Ridge Table Mountain Pine-Pitch Pine Woodland. The Granitic Dome communities are suffering from trampling by park visitors and the introduction of non-native invasive plants. In addition, both the Granitic Domes and Table Mountain Pine-Pitch Pine woodlands contain a number of fire-adapted species that are being displaced by fire-intolerant species in response to the exclusion of fire from these sites since the mid-1900s. Current monitoring efforts have identified 118 non-native plants species in the park. Forty-two of these have been ranked for their invasiveness, with 33 of those considered to be a threat to natural vegetation in the park. Invasive non-native plants threaten all native plant communities within CARL, and will likely be an increasing challenge in the future. The number of non-native insects and diseases in the region continues to grow and pose a serious threat to CARL's natural communities. In most cases, there are no effective treatments to combat non-native insects and diseases once they become established. Atmospheric deposition of acid pollutants, primarily in the form of nitrogen and sulfur compounds, is the greatest threat to water quality in the park, and also impacts soils and vegetation. Soils in CARL are inherently low in bases and have little capacity to buffer the effects of acidic deposition. CARL has little information on soil properties, though water acidification data show little improvement despite recent reductions in atmospheric deposition of acid pollutants. This suggests it may take at least several decades for systems to recover from past acid deposition.

Acknowledgements

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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; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

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

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

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

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

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

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

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

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

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

Important NRCA Success Factors

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

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

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

NRCA Reporting Products…

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

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

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

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

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

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

Chapter 2. Introduction and Resource Setting

Figure 2.1.1. Photo of the Carl Sandburg home in Henderson County, NC (NPS 2014c).

2.1. Introduction

2.1.1. Park History and Enabling Legislation

Carl Sandburg was a famous writer, folk singer, and social activist, as well as a Pulitzer Prize-winning poet and biographer (Figure 2.1.2). Carl Sandburg's wife, Lilian, was an active goat farmer and raised prized goats for milk and show, both of which took priority over landscape maintenance (Figure 2.1.1). After Carl's death on June 22, 1967, Lilian, requested that Congressman Roy Taylor and Secretary of the Interior Stewart Udall authorize the Carl Sandburg Home as a National Park so that Sandburg's legacy could be preserved forever (NPS 2014a). In September 1967, North Carolina congressman Roy Taylor introduced the measure, P.L. 90-592, H.R. 13099, to establish the Carl Sandburg Farm National Historic Site. Shortly thereafter, Senators Samuel J. Ervin and B. Everett Jordan introduced the Senate version. On October 17, 1968, President Lyndon Johnson signed the Congressional authorization bill that established the 100-hectare (247-acre) site under a slightly different name: Carl Sandburg Home National Historic Site (hereafter, also referred to as CARL, historic site, site, and park) as a National Park Service unit. The property was then sold and its contents and cultural resources donated to the park service (NPS 2014b). The Carl Sandburg site was officially opened in 1974. A boundary expansion was authorized in 1980 to accept 6.5 hectares (16 acres) of land donated by the North Carolina Nature Conservancy. Today, the park is managed with the landscape restored to its historic period, 1960-1967, when the grounds were managed with a relaxed style and the woodlands were left to succession.

Figure 2.1.2. Photo of Carl Sandburg (©Elizabeth Buehrmann).

2.1.2. Geographic Setting

CARL is located on the edge of the southeastern Appalachian Mountains of North Carolina, approximately 4.8 kilometers (~3 miles) southeast of Hendersonville, NC (population of 13,137 in 2010) and within the township of Flat Rock, NC (population of 3,114) (Figure 2.1.3) (U.S. Census Bureau 2010). The 106-hectare (264-acre) site is characterized by moderate relief and has elevations ranging from 658 to 848 meters (2,160 to 2,783 feet). It consists of pastures, ponds, two small streams, hiking trails, and fifty structures, including the Sandburgs' former residence and their goat barn complex. Most parcels directly adjacent to the park are privately-owned and range from heavily forested on the western boundary to medium and high density development on the southern border. One parcel on the western boundary is North Carolina state-owned.

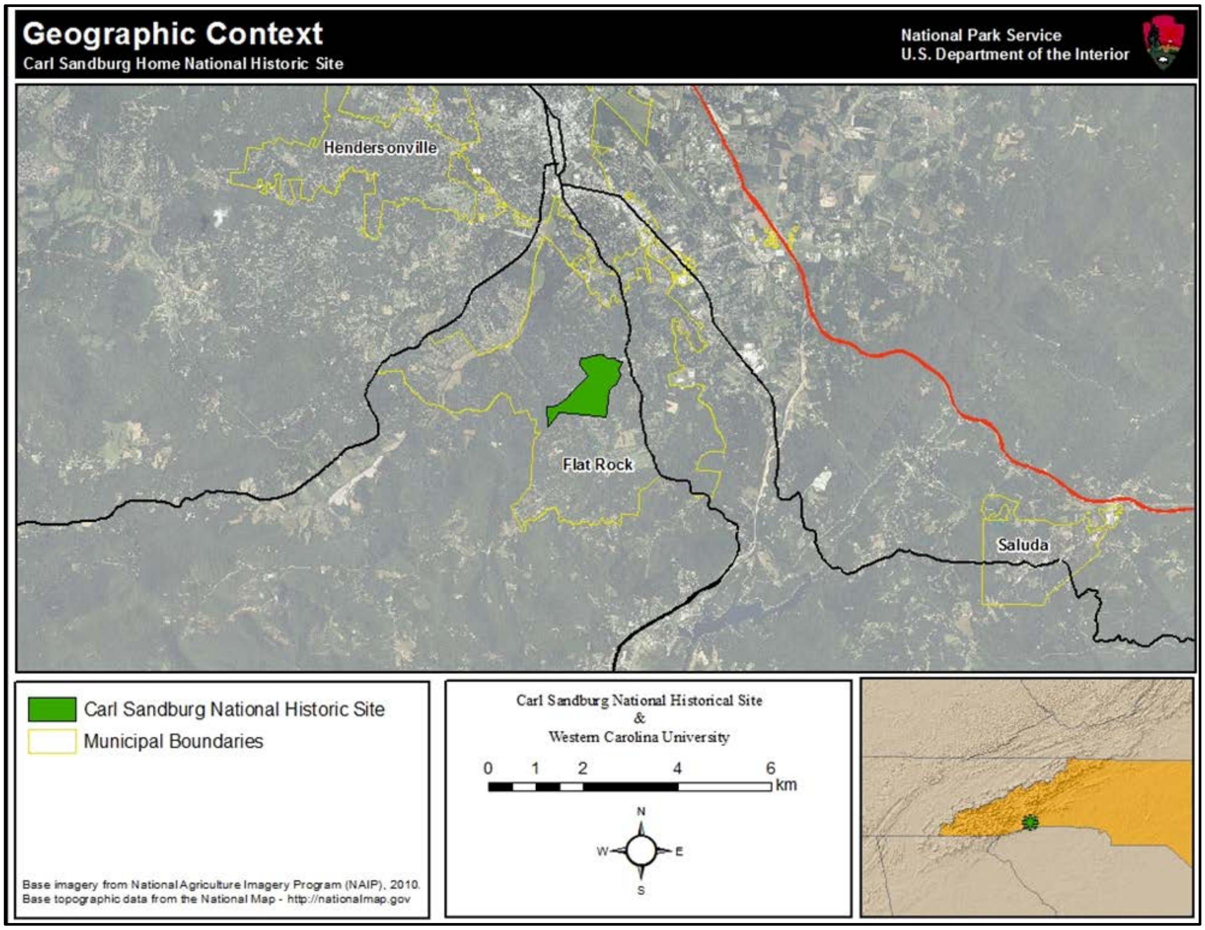


Figure 2.1.3. Map of the geographical location of Carl Sandburg Home National Historic Site (NCDOT 2013).

The temperate moist climate of the western North Carolina region where CARL is located is characterized by hot summers and mild winters. In a typical year, the park experiences 180 frost-free days and a mean temperature of 12.8 °C (55.1 °F). The average total precipitation amount annually, which mostly falls as rain, is 144 cm (56.6 in) (State Climate Office of North Carolina 2008). Table 2.1.1 shows the monthly precipitation and temperature from 1981 to 2010 for Hendersonville, NC- the closest National Climatic Data Center (NCDC) station to CARL. Monthly precipitation in this area remains relatively invariable throughout the year, ranging from approximately 7.6 to 12.7 cm (3 to 5 in) per month. The two wettest months are March and August, in which over 12.7 cm (5 in) of precipitation typically falls. October is the driest month, with approximately 8.9 cm (3.5 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 -2.8 °C (27 °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 23.9 °C (75 °F), the lowest temperature being approximately 18.9 °C (66 °F), and the highest temperature being about 28.9 °C (84 °F) (NOAA-NCDC 2010).

Table 2.1.1. Monthly precipitation and temperature from 1981-2010 in Hendersonville, NC (NOAA-NCDC 2010).

Month	Precipitation (in)	Minimum Temperature (°F)	Average Temperature (°F)	Maximum Temperature (°F)
January	4.77	26.90	37.30	47.70
February	4.54	29.90	40.60	51.20
March	5.12	35.90	47.30	58.80
April	4.00	43.40	55.50	67.50
May	3.91	53.20	64.00	74.70
June	4.98	61.50	71.40	81.30
July	4.95	65.60	75.00	84.30
August	5.08	64.60	73.70	82.80
September	4.70	57.20	66.90	76.60
October	3.47	45.90	56.90	67.90
November	4.58	36.70	47.90	59.10
December	4.66	30.00	39.70	49.30

2.1.3. Park Visitation

Visitation statistics for CARL date to 1974, the year the park officially opened to the public. During the first year of operation 19,700 people visited the park. Subsequent visitation rates fluctuated between 30,000 and 50,000 and peaked at 65,197 in 1991. Following 1991, the number of visitors appeared to steadily decline; however, beginning in 2005, inaccurate numbers were being recorded due to visitor counter failures, creating challenges to recording accurate visitor numbers (NPS 2012). Years following 2005 are incorrect and should be duly noted (Figure 2.1.4).

Figure 2.1.4. Number of recreation visitors to Carl Sandburg Home National Historic Site from 1974 to 2010 (NPS 2014b).

There are no camping facilities or concessioners lodges at CARL, the site is a day use-only park. The park receives the most visitors during the summer and fall months (June through November) and the least number of visitors during the winter months (December through February) (Figure 2.1.5) (NPS 2014b). Activities that attract visitors include the Carl Sandburg home tour, goat farm, and hiking trails. Beyond the historical attractions at the park, many residents in the area use the trails for routine exercise and dog-walking. The park's status as a national historic site extends beyond its technical capacity by being unofficially adopted into the Flat Rock community's greenway system.

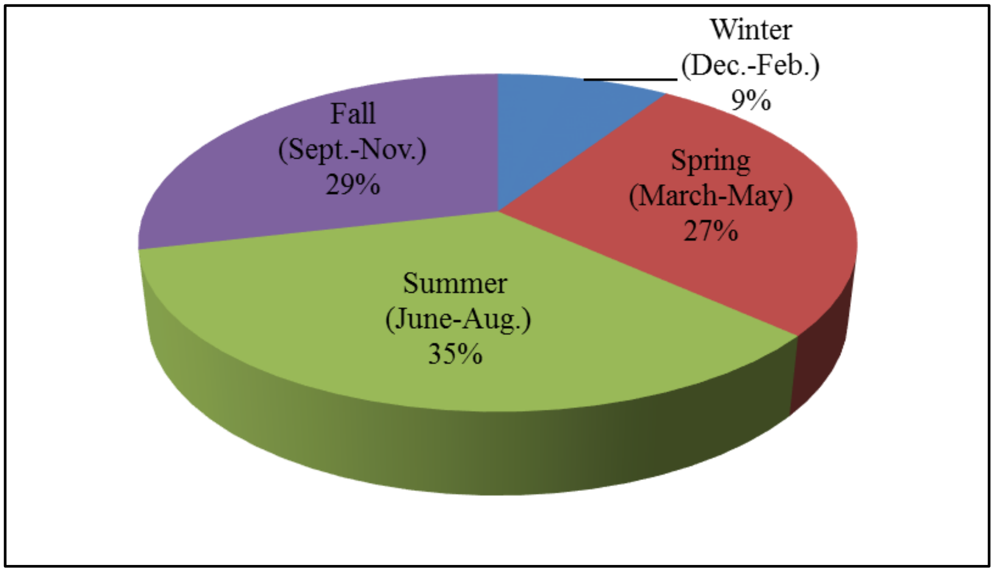


Figure 2.1.5. Percentage of recreation visitors by season 1974-2012 (NPS 2012).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

CARL is part of the Blue Ridge Level III ecoregion, which is characterized by a highly varied mountainous terrain and is among the most biodiverse temperate broadleaf ecoregions worldwide (Wicken et al. 2011, Griffith et al. 2002). On a finer scale, CARL lies within the Broad Basins Level IV ecoregion (Figure 2.2.1). This region is generally drier and has lower relief than other areas in the Blue Ridge. It typically contains deep, well-drained loamy to clayey soils.

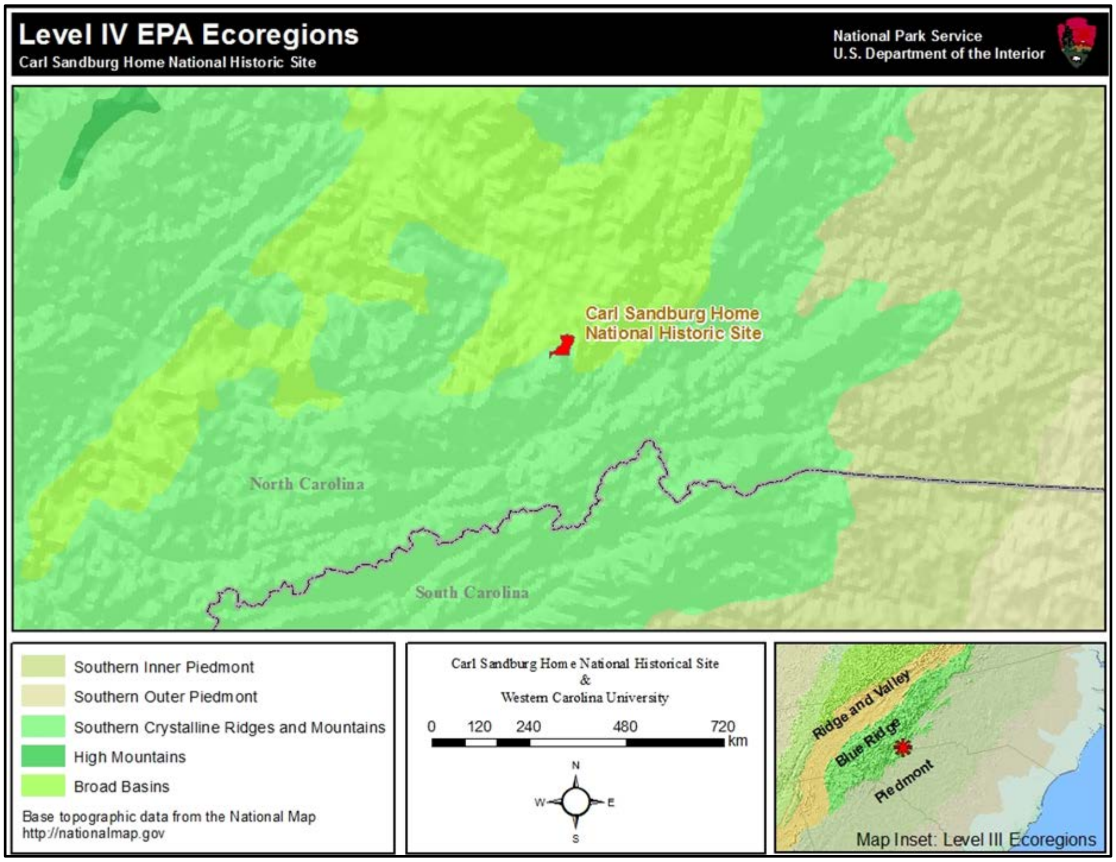


Figure 2.2.1. Map of CARL location within the EPA Level IV Broad Basins ecoregion, in close proximity to the Southern Inner Piedmont region. The park shares many biophysical characteristics with both ecoregions which makes it particularly diverse (EPA 2013a, NPS 2013).

Relative to other areas in the Blue Ridge, the Broad Basins ecoregion has more pasture, cropland, industrial areas, and human settlements (Griffith et al. 2002). Additionally, ecosystems in this ecoregion tend to have species more characteristic of the Piedmont regions (e.g., shortleaf pine [*Pinus echinata*], Virginia pine [*P. virginiana*], white oak [*Quercus alba*], and southern red oak [*Q. falcata*]) (Griffith et al. 2008). Unique ecological units located within the Carl Sandburg National Historic Site include Appalachian Highlands Granitic Domes, Blue Ridge Table Mountain Pine-Pitch Pine woodland (White 2003), ponds, wetlands, pasture, and Appalachian Highlands Pitch forests (Jordan and Madden 2010).

CARL is situated in the far southeastern border of the French Broad-Holston basin. This basin extends from southwest Virginia into eastern Tennessee and south into western North Carolina. The Upper French Broad River (Figure 2.2.2), which runs through the center western North Carolina, further delineates the basin. The Mud Creek watershed is at the southeast terminus of the Upper French Broad River. Finally, this watershed is further divided into three smaller sub-watersheds, the largest being the Upper Mud Creek sub watershed, in which CARL is located. Within the park, drainage patterns originate on Big Glassy and Little Glassy Mountains. These two drainages unite to form Meminger Creek, which exits the park beneath Little River Road boundary (Figure 2.2.6) (Thornberry-Ehrlich 2012).

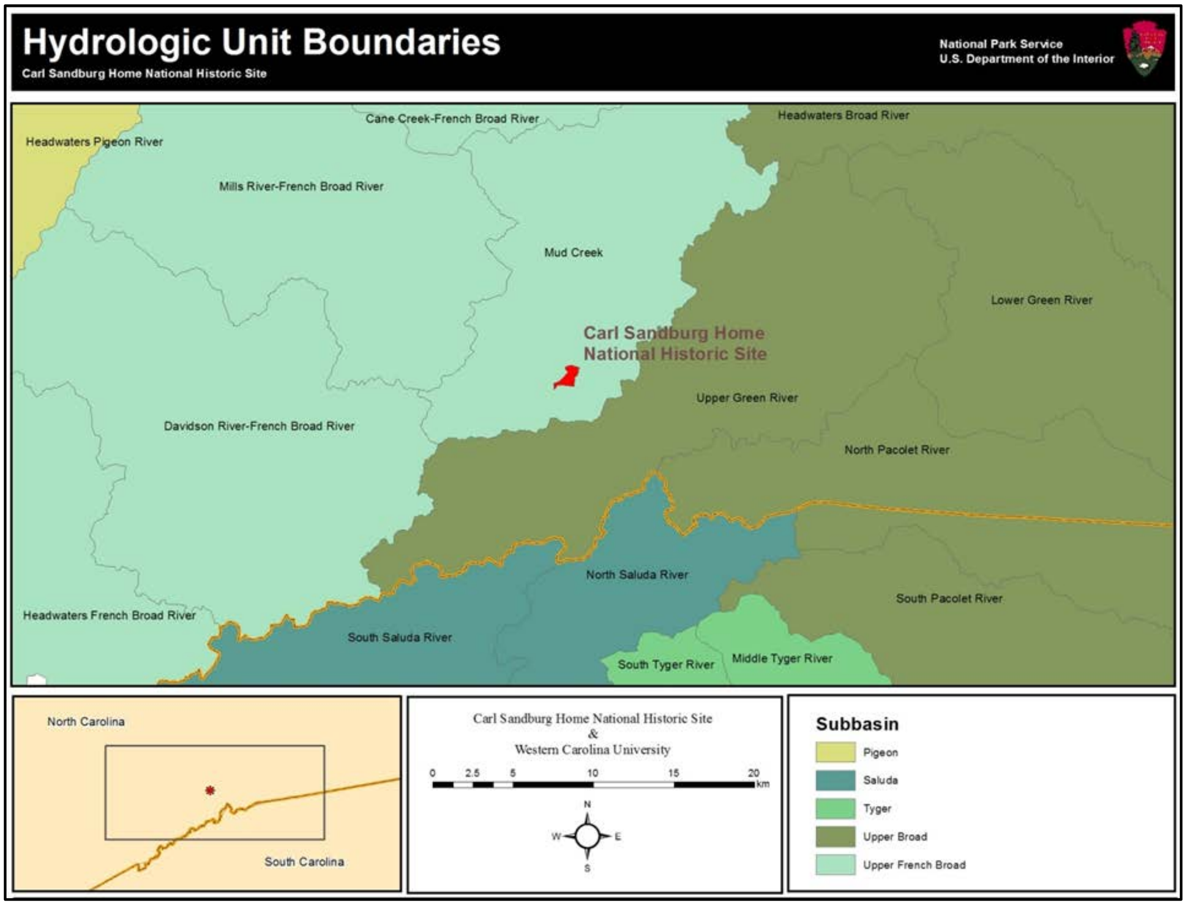


Figure 2.2.2. Map of the Upper French Broad sub-basin, which includes the Mud Creek watershed, where CARL is located (USGS National Map: http://nationalmap.gov/).

2.2.2. Resource Descriptions

Geology and Soils

The elevation at CARL ranges from 658 meters (2,160 feet) along the northern border to 848 meters (2,783 feet) at the top of Big Glassy Mountain. The park lies in the Balsam Mountains, a subrange of the Great Smoky Mountains, and is situated within in the Inner Piedmont geologic province, which is characterized by northeast trending rock belts bounded by faults. The dominant bedrock unit in the park is Henderson Augen Gneiss, formed from heat and pressure associated with the numerous collisions that uplifted the Appalachian Mountains in the middle Ordovician period (Thornberry-Ehrlich 2012). Exposed bedrock domes (Figures 2.2.3 and 2.2.4) are characteristic of Henderson Augen Gneiss and give rise to unique plant communities inside the park, which consist of short-lived, drought resistant plants and lichens that are typically more characteristic of desert environments than that of the Appalachians (e.g., little bluestem [*Schizachyrium scoparium*] and quill fameflower [*Talinum teretifolium*] (NPCA 2009, NatureServe 2013).

Figure 2.2.3. Granitic dome at Carl Sandburg Home National Historic Site (NPS).

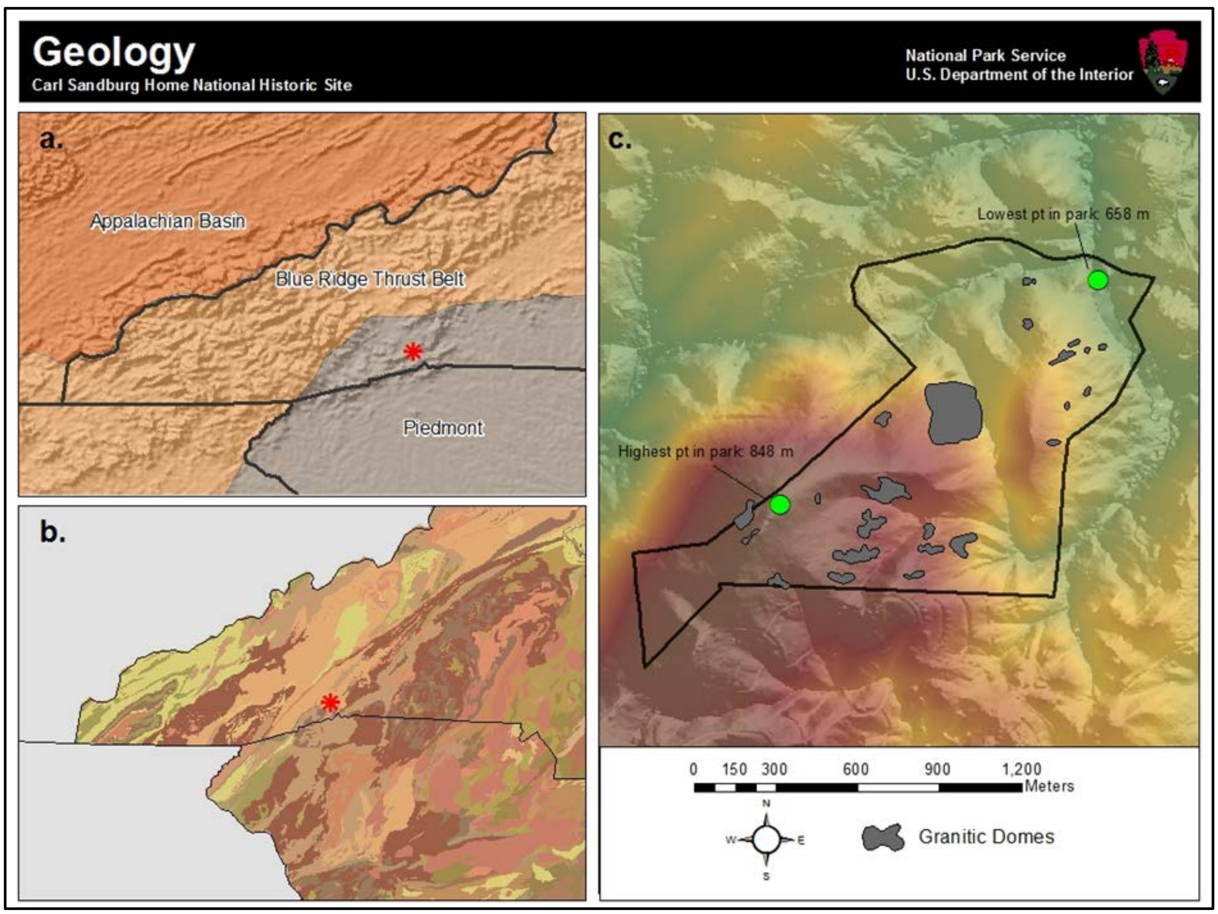


Figure 2.2.4. Maps of the geology of CARL. The bedrock in CARL, Henderson Augen Gneiss, is revealed as exposed granitic domes. These domes host unique plant communities and species (Thornberry-Ehrlich 2008).

Most soils in CARL are moderately deep and somewhat excessively drained and are located on gently sloping to very steep ridges and slide slopes (USDA NRCS 2015). These soils, which mainly consist of the Ashe and Edneyville series, were formed from the underlying gneiss that is typical of the Broad Basins ecoregion and occur throughout much of the southwestern section of the park. They are typically found on ridges to steep side slopes in the Blue Ridge Mountains and are affected by soil creep in the upper solum (NCSS 2001a, NCSS 2013).

The large open area directly in front of the Sandburg home is actively maintained to preserve the historic viewshed. This area, as well as the goat barn complex and goat pasture, is also in the Edneyville series. The Tate soil series is located at the toe of the slope that terminates at the western end of Side Lake and comprises roughly 5 hectares (12 acres). This soil series is formed from colluvium weathered from felsic to mafic high-grade metamorphic rock and is typically found in benches, fans, and toeslopes (NCSS 2004). Finally, the Hayesville series occurs along the northern border of the park; much of this area is actively maintained to preserve a portion of the historic pasture at CARL. Like the Ashe and Edneyville soil series, this series is typically located on ridges to steep side slopes and is formed from residuum weathered from igneous and high-grade metamorphic rock (Figure 2.2.5) (NCSS 2001b).

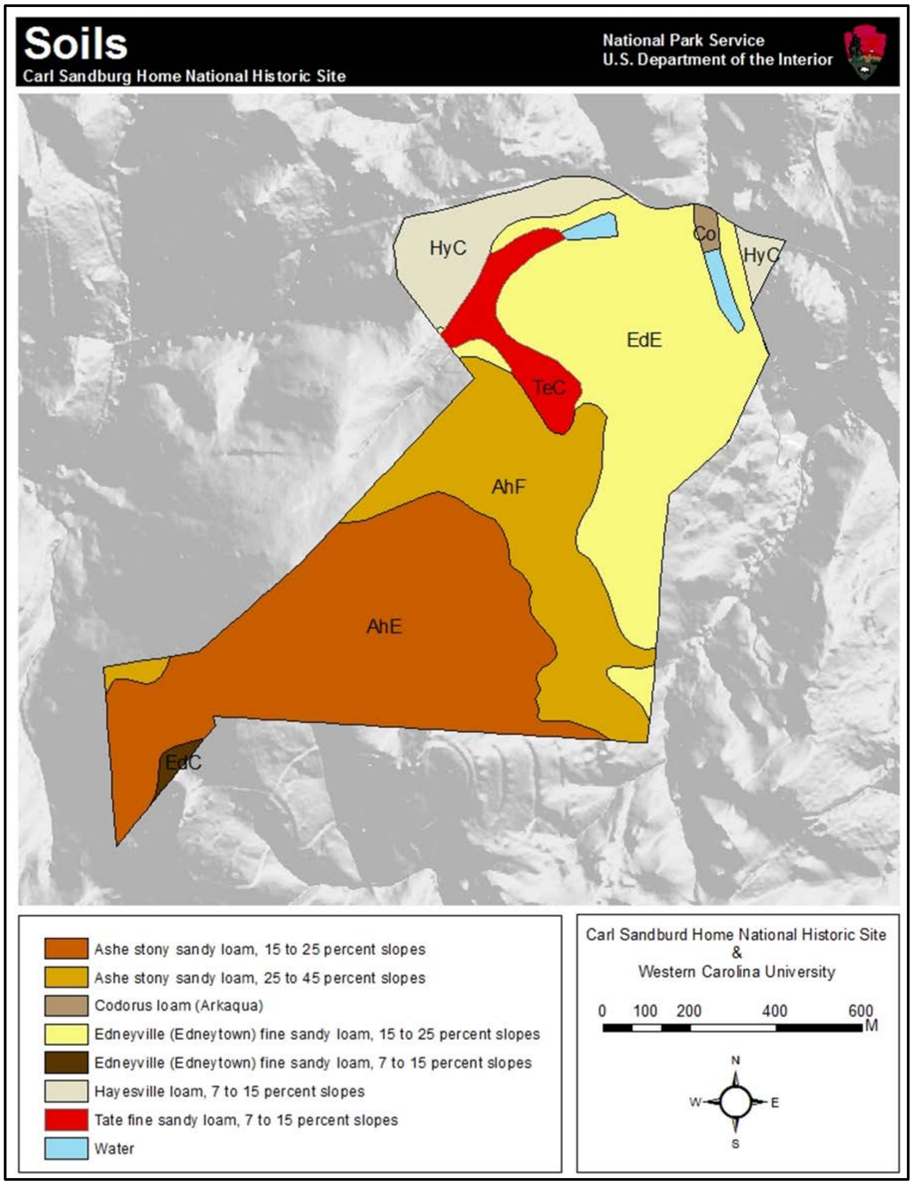


Figure 2.2.5. The soils in CARL are typical of the Broad Basins ecoregion. Most soils are moderately deep and excessively drained (USDA NRCS 2015).

Hydrology

There are two major tributaries present in CARL: an unnamed creek that drains into Side Lake in the northern portion of the park and Meminger Creek, which originates from Big Glassy Mountain and drains into Front Lake, located in the northeastern portion of the park. Both lakes are artificial impoundments. Two smaller ponds, Trout Pond and Duck Pond, a headwater spring, and a number of smaller streams, are also part of the Meminger Creek drainage (Figure 2.2.6).

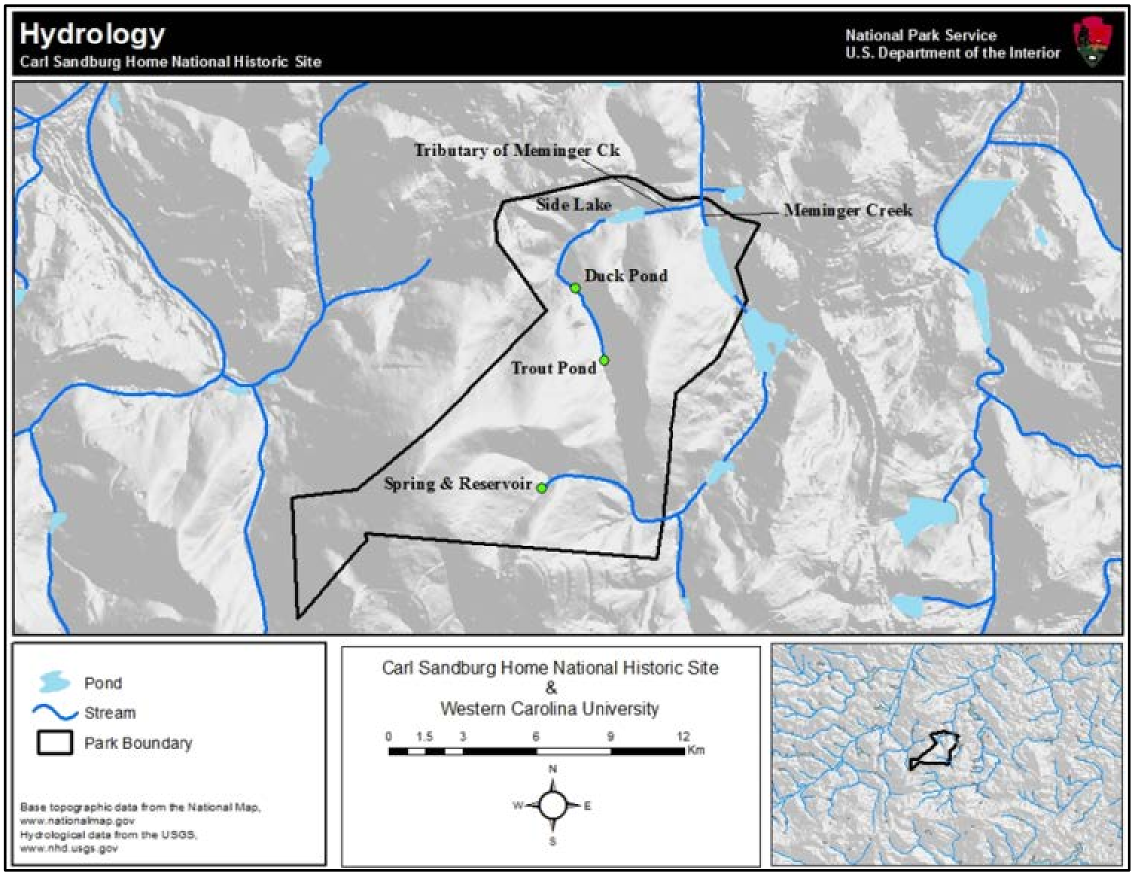


Figure 2.2.6. Streams and ponds located within CARL boundaries (NPS).

Air Quality

CARL has been designated by the EPA as a Class II air quality area. To comply with Clean Air Act (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).

Land Use

Surrounding land use can have major impacts on a park's aesthetic qualities and the value of its natural resources. Air quality, water quality, viewsheds, species composition, and a host of other natural resources can all be affected by surrounding land use. As of June 2012, there were 31 privately owned parcels adjacent to the CARL boundary (Henderson County Government 2014). CARL is located in the Village of Flat Rock on U.S. Highway 25 and is 4.8 kilometers (3 miles) south of Hendersonville in Henderson County. Flat Rock and Hendersonville are popular locations for retirement communities whose populations are growing at a steady rate. Residential home subdivisions and accompanying development are changing the character of the landscape surrounding CARL. Most land cover immediately adjacent to CARL's boundary is classified as either forest or low intensity development (areas with a low percentage of impervious surface and high tree canopy cover).

On a smaller scale, the park is surrounded by a mix of forest, developed, and agricultural land cover. Land cover transition between 2001 and 2010 in a 15 kilometer (9.3 mile) area surrounding CARL follows a broader land cover transition trend in the eastern U.S, which consists of increasing agricultural abandonment and development (USGS 2012).

Wildlife

CARL is located at the edge of the Blue Ridge ecoregion and is in very close geographic proximity to the North Carolina Piedmont region. Wildlife species, particularly amphibians and bats, may therefore be more diverse when compared to other parks in the Cumberland/Piedmont network of the U.S. National Park System (Reed and Gibbons 2005, Loeb 2007).

CARL is home to approximately 25 documented mammal species. Among these are eight bat species, one of which, the small-footed bat (*Myotis leibii*) (Figure 2.2.7), is considered one of the rarest in the eastern U.S. (Loeb 2007). Other mammalian species typical of the park include eastern gray squirrels (*Sciurus carolinensis*), eastern chipmunks (*Tamius striatus*), eastern cottontail rabbits (*Sylvilagus floridanus*), raccoons (*Procyon lotor*), opossums (*Didelphus virginiana*), shrews, mice and voles. Predator species such as bobcats (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), black bears (*Ursus americacanus*) and coyotes (*Canis latrans*) are intermittent users of the Sandburg site (Pivorun and Fulton 2007).

Figure 2.2.7. The small-footed bat, considered one of the rarest bats in the Eastern United States, has been documented at CARL (Image courtesy of Kentucky Bat Working Group).

Fourteen freshwater fish species occur in the small lakes, ponds and small streams at CARL and one grass carp (*Ctenopharyngodon idella*) was also observed in Front Lake (Table 2.2.1). The two streams harbored species expected of the upper French Broad Basin. Among them are river chub (*Nocomis micropogon*), warpaint shiner (*Luxilus coccogenis*), creek chub (*Semotilus atromaculatus*), and central stoneroller (*Campostoma anomalum*). Two species, redbreast sunfish (*Lepomis auritus*) and flat bullhead (*Ameiurus platycephalus*), are exotic to the French Broad River Drainage. The standing water habitats (i.e., lakes and ponds) hold a less diverse suite of species. These include creek chub and four species of bass and sunfish (Scott 2006).

Table 2.2.1. Fish species observed in water bodies within CARL. A total of 14 species were collected, with one observation of grass carp in Front Lake.

Occurrence of Fish Species by Site							
Common Name	**CARL 1**	**CARL 2**	**Spring & Reservoir**	**Trout Pond**	**Duck Pond**	**Side Lake**	**Front Lake**
River chub	X	X					
Smoky sculpin	X						
Bluegill	X	X				X	X
Flat bullhead	X	X					
Central stoneroller	X	X					
Creek chub	X	X			X		
Warpaint shiner	X	X					
Warmouth	X						
Black crappie	X						
Redbreast sunfish	X	X				X	X
Golden shiner	X						
Grass carp							X
Largemouth bass						X	X
Reader sunfish						X	X
White sucker		X					
Total Number of Species	**11**	**8**	**0**	**0**	**1**	**4**	**4**

During a bird inventory conducted at CARL from May 2003 to February 2005, 50 species were observed during the breeding season and forty species during the winter season (Pearson and Smith 2006). Fifty-one total species were detected during the survey. The most common breeding birds were associated with edge and woodland habitats. These species included the Northern Cardinal (*Cardinalis cardinalis*), Eastern Towhee (*Pipilo erythrophthalmus*) (Figure 2.2.8), Blue Jay (*Cyanocitta cristata*), Scarlet Tanager (*Piranga olivacea*), Hooded Warbler (*Setophaga citrina*), and Ovenbird (*Seiurus aurocapilla*).

Herpetofaunal species were surveyed between 2002 and 2005 in the park (Reed and Gibbons 2005). Twenty-eight species were documented during that effort. In addition, a population of green salamander (*Aneides aeneus*) was discovered on the park in 2007 (NPSpecies 2015), bringing the total number of documented amphibians and reptiles to 29. While the federally endangered bog turtle (*Clemmys muhlenbergii*) has been documented in close proximity to the park, researchers were unable to locate this species and concluded the park was unlikely to support this species due to the availability of only "marginally suitable habitats" (Reed and Gibbons 2005).

Figure 2.2.8. The Eastern Towhee is one of the many birds found within CARL (Cornell Lab of Ornithology).

Vegetation

CARL's climate and geology give rise to diverse vegetation communities. Additionally, the park's combination of exposed granitic domes, agricultural fields, forests, and ponds contribute to its relatively high plant diversity.

A vascular plant inventory was performed by NatureServe South between 2001 and 2003 (White 2003). In conjunction with this project, the Center for Remote Sensing and Mapping Science, Department of Geography, University of Georgia (Jordan and Madden 2010), mapped vegetation communities using aerial photograph interpretation during 2000 and 2002 (Figure 2.2.9). Fourteen distinct vegetation associations within eleven distinct ecogroups are found within the park's boundaries. Two of these vegetation associations, the Appalachian Highlands Granitic Domes and the Appalachian Highlands Pitch and Table Mountain Pine Woodlands, have been assigned a globally imperiled (G2) status and globally vulnerable (G3) status respectively. The Granitic Dome association is fairly common in patches within the park, but is very rare on a global scale. These exposed rock outcrops typically contain a diverse group of lichens, herbs, and woody species.

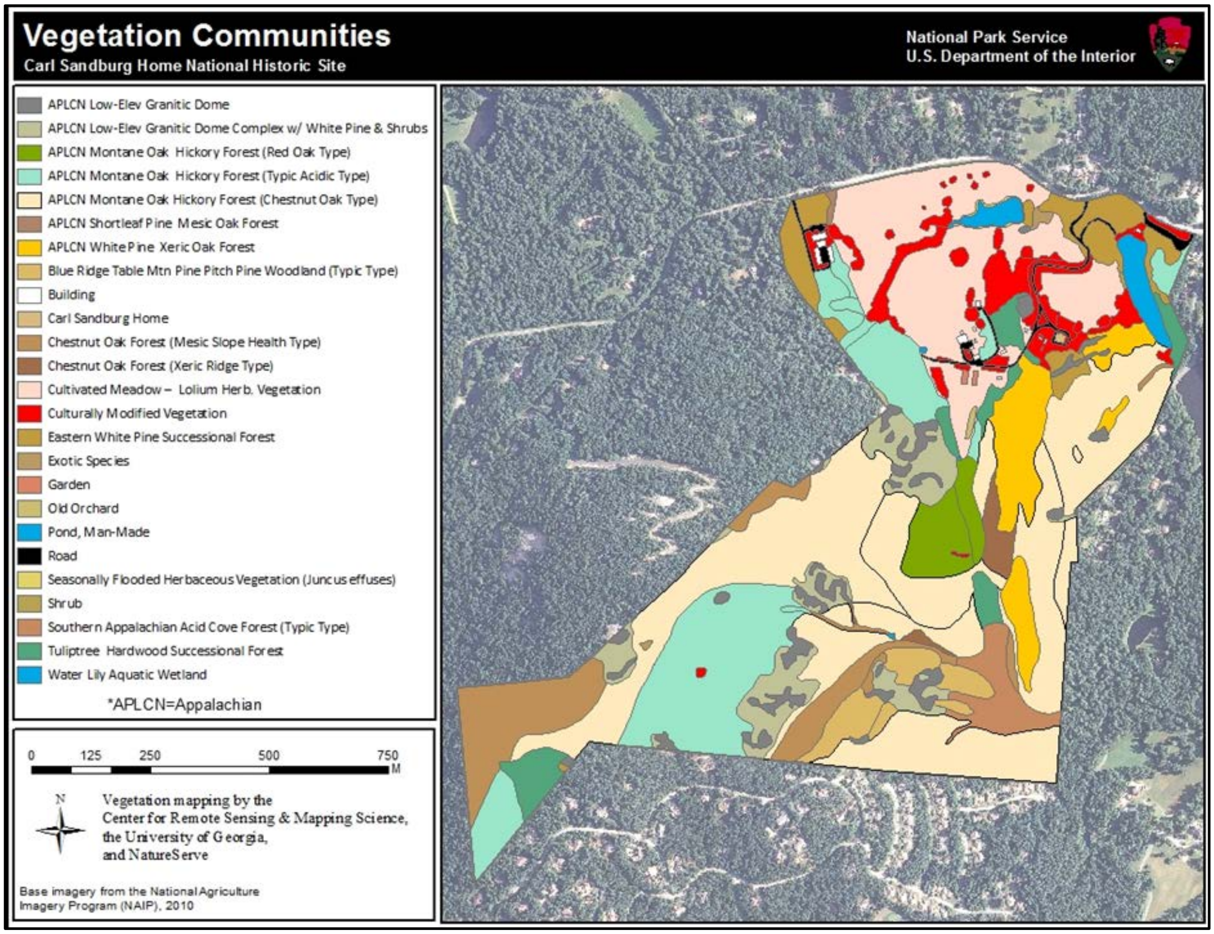


Figure 2.2.9. There are 14 distinct vegetation communities within CARL, making it remarkably diverse for a park of its size (Jordan and Madden 2010).

The Blue Ridge Table Mountain Pine-Pitch Pine Woodland, which occurs on the exposed dry ridge tops and adjacent slopes in the southeastern corner of the park, has been identified within the park. In the absence of fire this community has/is succeeding into a close-canopied hardwood community of red maple (*Acer rubrum*), scarlet oak (*Quercus coccinea*), and chestnut oak (*Quercus prinus*). Within this close-canopied environment, very little pitch pine (*Pinus rigida*) regeneration can occur, if at all (White 2003). Red maple is a fire intolerant species. Scarlet oak and chestnut oak are less fire tolerant than pitch pine, however it would be inaccurate to refer to these two species as fire intolerant.

CARL is home to at least 520 species of vascular plants (NPS 2016a). Past inventories have found several species of note that are either globally rare or uncommon. Piedmont ragwort (*Packera millefolia*), Meminger's ragwort (*Packera memmingeri*), and North Fork heartleaf (*Hexastylis rhombiformis*) are all ranked G2 species. Piedmont ragwort is on the North Carolina threatened list. North Fork heartleaf is endemic to a small area extending south from Asheville, North Carolina to the headwaters of the Saluda River in South Carolina. G3 and G3/G4 (globally apparently secure) species include Carolina hemlock (*Tsuga caroliniana*), Biltmore's carrionflower (*Smilax biltmoreana*), netted nutrush (*Scleria reticularis*), northern catalpa (*Catalpa speciosa*), and

Allegheny mountain golden-banner *(Thermopsis mollis*). The remaining species are G4, G4/G5 (globally secure), or species that have not been ranked.

2.2.3. Resource Issues Overview

CARL faces a number of resource related issues, many of which are related to surrounding population growth and land use. The park lies within the Flat Rock, NC municipality and is located approximately 4.8 kilometers (3 miles) from Hendersonville, NC. These two towns grew approximately by 24% and 29% respectively between 2000 and 2010 (U.S. Census Bureau 2010). The town of Saluda, which had a population of 715 in 2010, is approximately 9 kilometers (5.6 miles) southeast of the park. Increased development reduces wildlife habitat availability in areas outside of the park and further encourages invasive exotic species encroachment inside the park boundaries. Furthermore, as the surrounding population continues to grow, visitor rates to the park will continue to increase, placing increased stress on the park's natural resources. Erosion caused by unauthorized trail use causes sedimentation into waterways. Adjacent residential communities also threaten the park's resources. Septic systems, lawn chemicals, and land uses such as livestock grazing are a potential threat to water quality (Figure 2.2.10).

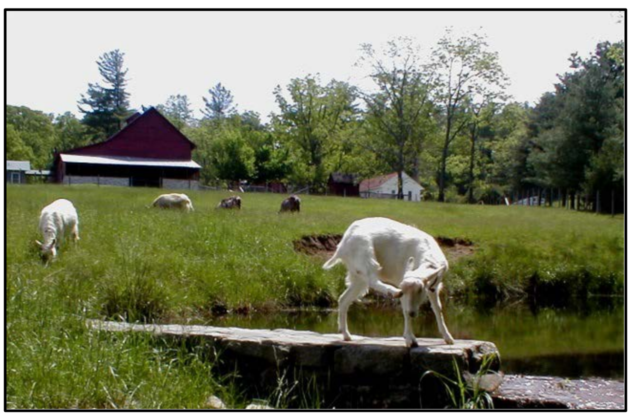


Figure 2.2.10. Livestock grazing threatens water quality within the park (NPS).

Two ecogroups, Blue Ridge Table Mountain Pine-Pitch Pine Woodland and Appalachian Low Elevation Granitic Dome communities, within the park are threatened and warrant active management. Although the Blue Ridge Table Mountain Pine-Pitch Pine Woodland group is regionally abundant, hardwood species make up a large component of the canopy within CARL. Natural fire regimens on the dry ridge tops thin out these hardwood species. However, years of heavy fire suppression have allowed more fire intolerant, oaks and red maple to dominate and close the canopy. Consequently, very little regeneration of pitch pine has occurred in the last few decades (White 2003). Although pitch pine is not considered rare regionally, it may be lost on the site without fire to allow for regeneration. Additionally, within the park, this vegetation association in its natural state may have contained a larger herb component. Herbaceous species such as Biltmore's carrion flower is regionally endemic and typically grows alongside this association in the park.

Due to their delicate nature, Appalachian Low Elevation Granitic Dome communities in the park are at risk. White (2003) reports that areas with off-trail use have increased spread of exotic plants and common field weeds, which are impacting fragile species in the granitic dome communities. Invasive and exotic species, including Chinese privet (*Ligustrum sinense*), Nepalese browntop (*Microstegium vimineum*), Asiatic dayflower (*Commelina communis*), and orchard grass (*Dactylis glomerata*) have migrated into these disturbed areas and displaced species of concern, including Michaux's saxifrage (*Saxifraga michauxii*), rough panic grass (*Dichanthelium leucothrix*), Small's ragwort (*Packera anonyma*), and Piedmont ragwort (*Packera millefolia*). Recommended management strategies include designating some of the granitic dome communities as off-limits to the public, actively controlling invasive exotics, and monitoring isolated patches to ensure they are not shaded out by adjacent woody species (White 2003).

<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). The Carl Sandburg Home National Historic Site is located in western 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 CARL 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 CARL indicate levels are high, exceeding the ecological threshold. Mercury wet deposition for CARL was very high, however, methylmercury concentrations in park surface waters were very low, warranting moderate concern. Ozone has been recognized as the most widespread air pollutant in eastern North America, causing impacts to human health (EPA 1999). Ozone is concentrated in mountainous regions, and although levels near CARL are not as high as those in the Smoky Mountains, they do warrant moderate concern for the park. Particle pollution ($PM_{2.5}$) represents one of the most widespread human health threats, possibly greater than ozone because it can occur year-round (EPA 2013b). 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, indicates 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 CARL is located has consistently experienced values well in excess of estimated natural conditions. Natural resource managers at CARL 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 CARL.

Water Quality

Surface waters at CARL are not directly impacted by extensive human development or agriculture activities; therefore, the state of North Carolina has designated the majority of these waters as WSII, High Quality Waters (NPS 2011). Although recreational use of these surface waters is prohibited, they are viewed as an aesthetic, interpretive and critical ecological resource. They also are a primary determinant of the site's overall resource condition. Water quality in particular is an important ecological indicator as poor water quality can act as a significant biotic stressor, lead to ecological system deterioration, and negatively affect the aesthetic value of the historic site (Deschu and Kavanagh 1986).

The primary threat, or stressor, of concern, with regards to water quality, is stream water acidification associated with the atmospheric deposition of acid pollutants. Data collected from four monitoring sites at CARL since 2002 show that stream water acidity varies and at times are lower than the reference criteria. Other water chemistry parameters included temperature, specific conductance (SC), and dissolved oxygen (DO) concentration, all of which were in good, stable condition.

Pathogens leading to gastroenteritis affect more river miles in the U.S. than any other type of contaminant (EPA 2002). The most frequently utilized indicators are fecal coliforms, which indicate contamination by human or animal waste. Data collected at CARL show that *Escherichia coli (E. coli)* levels within the park's surface waters were low.

Other water quality indicators include the presence of dissolved toxics such as sulfate, nitrate and aluminum. However, at the current time there is insufficient data to determine the current surface water quality condition in the historic site for sulfate, nitrate, and aluminum (Al).

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) 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 (IPCC 2014). 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 CARL. They found that recent climatic conditions are within the historical range of variability, as well as no extreme temperature or precipitation values relative to the 1901-2012 historical range of variability (Monahan and Fisichelli 2014). However, future changes are likely and opportunities exist to proactively incorporate possible climate change effects into park management at CARL, including natural and cultural resource protection as well as park operations and visitor experience.

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 this protocol, selected locations have been identified for each park to help determine the soundscape status over a period of 1-10 years. The protocol also includes various metrics of natural ambient sound levels, natural sound frequencies, and sources of sounds. Additionally, the protocol addresses soundscape changes in the face of increasing visitor numbers and surrounding development. Although no ambient sound level data or data regarding the distribution of non-natural sounds have been collected in CARL to date, park staff report nearby development, roads, air traffic, and recreational usage as the main sources of soundscape impacts.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

As a unit in the National Park System, Carl Sandburg Home National Historic Site is responsible for the management and conservation of its natural resources. This primary mandate is supported by the National Park Service Organic Act of 1916, which directs the park Service to:

> *Conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

As a National Historic Site within the National Park Service system, the Carl Sandburg Home is fundamentally a cultural park under the historic sites Act of 1935 (16 U.S.C sec. 461-467). The mission of the park is:

> *…dedicated to preserving the legacy of Carl Sandburg and communicating the stories of his works, life, and significance as an American poet, writer, historian, biographer of Abraham Lincoln, and social activist. The Carl Sandburg Home National Historic Site preserves and interprets the farm, Connemara, where Sandburg and his family lived for the last 22 years of his life (1945-1967).*

While the park's fundamental purpose is to carry on Carl Sandburg's legacy through the management of his home and museum archives, the woodlands are also integral to preserving Sandburg's overall life at the park.

Two important documents, the 2003 CARL General Management Plan (GMP) and the 2006 NPS Management Policies, broadly guide the management of natural resources in the park. The GMP is a strategic planning document that outlines the future management of the park for the next 15 to 20 years. The plan sets the basic philosophy and broad guidance for management decisions that affect the park's resources and the visitor's experience. The NPS Policies document provides a guide to underlying principles, laws, policies, and directives for managing for all National Park units. Specific management directives are discussed below.

In order to meet the broad and diverse mission and purposes of the park, five prescriptive management zones (PMZs) were identified in the 2003 GMP: historic discovery, historic interaction, visitor services, park services, and amphitheater relocation. The historic discovery zone "designates areas that are predominantly free of non-period of significance intrusions and where visitors may find solitude or a contemplative experience at most times." This zone would represent much of the naturalized area in the park. The historic interaction zone "designates areas that have a high degree of historic integrity but also include provisions for visitor education and resource interpretation." The visitor services zone "designates areas reserved for visitor service infrastructure" such as parking areas and comfort stations. Visitors enter the park only through the "visitor services zone." The park service's zone "designates areas reserved for park administrative and maintenance activities." The amphitheater relocation zone "designates three preferred areas where the existing amphitheater could be relocated." The 2003 GMP specifies the Sandburg Center Alternative as the NPS preferred alternative and the environmentally preferred alternative (Figure 2.3.1). In this alternative, "the park serves as a national and worldwide focal point for learning about Carl Sandburg" (NPS 2003). Along with providing high quality interpretive venues and a visitor's center outside the park's boundary, a congressionally legislated boundary expansion of up to 44.5 hectares (110 acres) would provide critical views and boundary protection for the park.

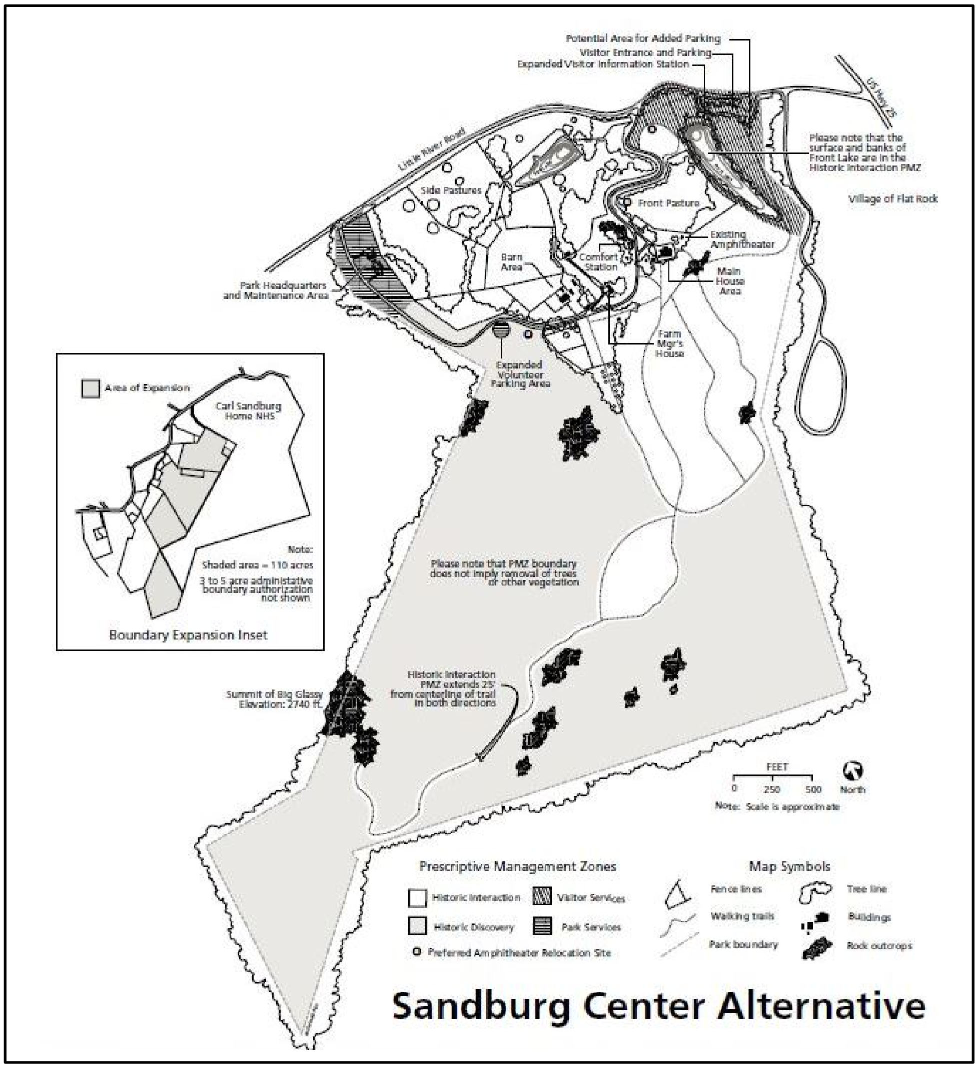


Figure 2.3.1. The 2003 General Management Plan for the Carl Sandburg Home National Historic Site cites the Sandburg Center Alternative as the preferred alternative. Along with prescriptive zones, the alternative calls for an expansion of park boundaries for the purposes of protecting viewsheds and park other park natural resources (Carl Sandburg General Management Plan, NPS 2003).

The park's forest management plan was completed in 2003 (Johnson 2003). The focus of the management plan is the 94 hectares (232 acres) of forest in the park. During the park's historic period, which is defined as the years that the Sandburgs occupied the home (1945-1967), the primary driving force behind management was to let nature take its course. As such, timber harvesting and prescribed burning are not considered part of the forest management plan, although lack of these management techniques will result in a continuation of forest succession resulting in a different forest than what the Sandburgs experienced (Johnson 2003).

The CARL administration identified ten primary objectives in the forest management plan:

- Allow nature to take its course, with the exception of wildfire
- Suppress wildfires

- Reduce wildfire hazard
- Maintain safety of trails (e.g., remove hazardous trees)
- Reduce environmental impacts of visitor use (e.g., erosion along trails)
- Maintain or enhance biodiversity
- Maintain forest health
- Protect globally rare granitic domes
- Reduce the effects of invasive exotic species
- Maintain health and vigor of historic trees

Depending on the forest cover type, several management needs were identified. Exotic species (including common privet [*Ligustrum vulgare*] and multiflora rose [*Rosa multiflora*]) removal could be undertaken through mechanical and chemical means. Reducing fine and heavy surface fuel levels in the park can be accomplished through labor-intensive cutting and hauling. Oak enrichment planting is recommended in areas where regeneration of the hardwood is low. Historic trees are located both in the forest portion of the park and in pastures and along driveways. Recommendations include cabling trees to reduce stress at weak points, complete removal if the tree is a hazard, pruning crowns, and mulching trees located by roads.

The park's directives for managing Side Lake (Long 2004) are guided by the park's mission and NPS Management Policies (2006), which provides direction for managing natural resources in a cultural setting. Since the 2003 GMP states that "cultural and natural resources of the park are managed to preserve the site's appearance as it was during 1955-1965, the period of Sandburg's most productive years," the park determined that the Side Lake management plan would involve reducing vegetation height and possibly selective removal of vegetation that may impinge on the cultural viewshed.

The granitic dome vegetation assessment and management plan by Woolsey and Walker (2008) documents dome locations, records plant species (both invasive and native), and assesses threats to the sensitive dome vegetation communities located in the park. Primary threats to these communities include inadvertent trampling by visitors, forest succession, and invasive plant species. The report recommends actively managing these areas as the natural communities of CARL are undergoing constant changes. These changes, as well as increased visitor use, a disruption in the fire regime, and continued invasion of exotic species will eventually cause the disappearance of the communities. In order for the park to meet its mandate in protecting the outcrops while still providing opportunities for visitors to enjoy and appreciate the sites, the management plan recommends restricting access to some domes, including those located off the current designated trail system, while allowing access to other domes, including those around the house. Additionally, management strategies must include invasive species removal and monitoring around the outcrops, soil erosion control, encouragement of native plant recruitment and seeding, and promotion of early successional species immediately adjacent to the outcrops.

The park's fire management plan (Gorder 2004) reflects the Sandburgs' desire for a "hands off" form of landscape management in the site's natural areas (woodlands and rock outcrops), with the exception of exotic vegetation species control and periodic removal of invasive species from the rock outcrops (Gorder 2004). The plan also proposes to suppress all wildland fire, regardless of origin. In order to lessen fire likelihood coming from within or outside the borders of the park, it recommends reducing hazard fuels. CARL is currently in the process of updating its fire management plan (NPS 2016b).

2.3.2. Status of Supporting Science

The Cumberland-Piedmont Inventory and Monitoring Network (CUPN) was established in 2001 to conduct biological inventories and monitor ecosystem health for 14 national park units in the Southeast Region of the National Park Service. Through a series of workshops, key resources were selected for long-term monitoring to determine the overall health of park ecosystems. These key resources are called "Vital Signs." In 2005, CUPN developed a Vital Signs Monitoring Plan (Leibfreid et al. 2005). Eight high priority Vital Signs for CARL were identified as warranting inventory and management in order to effectively detect, predict, and understand changes in the park's ecosystem: Air Quality, Water Quality, Invasive Plants, Invasive Animals, Vegetation Communities, Wetlands, Soil, and Landscape Dynamics.

Baseline inventories in the park will contribute to the monitoring program's continuing development. There are currently ten inventory reports that include animal, plant, and physical data (Table 2.3.1). Ongoing efforts to collect baseline data will help determine current and reference conditions, and specific metrics with which to monitor the park's Vital Signs. Additionally, there are eight plans to guide the management of the park's resources (Table 2.3.2).

Table 2.3.1. Status of National Park Service Inventory reports for Carl Sandburg Home National Historic Site.

Inventory Report	Title	Author/s	Year
Water Quality Data	Baseline Water Quality Data Inventory and Analysis: Carl Sandburg Home National Historic Site	NPS Water Resources Division	1998
Vascular Plants	Vascular Plant Inventory and Plant Community Classification for Carl Sandburg Home National Historic Site	Rickie D. White	2003
Herpetofaunal	Results of Herpetofaunal Surveys of Five National Park Units In North and South Carolina	Robert N. Reed & J. Whitfield Gibbons	2005
Birds	Bird Inventory of Carl Sandburg Home 2003-2004	Scott M. Pearson & Alan B. Smith	2006
Fish	Inventory of Fishes In Carl Sandburg Home National Historic Site	Mark C. Scott	2006
Wetlands	Inventory and Classification of Wetlands at Carl Sandburg Home National Historic Site, Henderson, NC	Thomas H. Roberts & Kenneth L. Morgan	2006

Table 2.3.1 (continued). Status of National Park Service Inventory reports for Carl Sandburg Home National Historic Site.

Inventory Report	Title	Author/s	Year
Weather & Climate	Weather and Climate Inventory National Park Service Cumberland Piedmont Network	Christopher A. Davey, Kelly T. Redmond, David B. Simeral	2007
Terrestrial Mammals	Terrestrial Mammals of Carl Sandburg Home National Historic Site, Flat Rock, NC	Edward Pivorun & Linda Fulton	2007
Bats	Bats of Carl Sandburg National Historic Site, Cowpens National Battlefield, Guilford Courthouse National Military Park, Kings Mountain Military Park, Ninety Six National Historic Site	Susan Loeb	2007
Vegetation Communities	Digital Vegetation Maps for the NPS Cumberland-Piedmont I&M Network	Thomas R. Jordan & Marguerite Madden	2010
Geology	Carl Sandburg Home National Historic Site: Geologic Resources Inventory Report	T. Thornberry-Ehrlich	2012

Table 2.3.2. Resource management plans and/or guidance documents for CARL.

Resource/Threat Assessed	Title	Author/s	Year
Fire	Fire Management Plan	J. Gorder	2004
Fish	Assessment of Fish Health in Front Lake, Carl Sandburg Home National Historic Site	James M. Long	2006
Dome Vegetation	A Vegetational Assessment of the Granitic Rock Outcrop Communities at Carl Sandburg Home National Historic Site	Jared Woolsey & Gary Walker	2008
Forests	Preserving and Protecting Historic Forests: Forest Management Plan for the Carl Sandburg Home National Historic Site	James E. Johnson	2003
Geohazards	Summary of Geohazards Data and Data Layers for the Blue Ridge Parkway in North Carolina, and the Carl Sandburg Home National Historic Site	North Carolina Geological Survey	2008
Riparian Vegetation	Management Plan for Side Lake Creek Riparian Vegetation at Carl Sandburg Home National Historic Site: Balancing Natural and Cultural Values	James M. Long	2004
Riparian Vegetation	Management Plan for Side Lake Creek Riparian Vegetation at Carl Sandburg Home National Historic Site: Balancing Natural and Cultural Values	James M. Long	2004
Nitrogen Deposition	Evaluation of the Sensitivity of Inventory and Monitoring National Parks to Nutrient Enrichment Effects from Atmospheric Nitrogen Deposition	T.J. Sullivan, T.C. McDonnell, G.T. McPherson, S.D. Mackey, D. Moore	2011
Strategic Natural Resource Management Planning	General Management Plan for the Carl Sandburg Home National Historic Site	National Park Service	2003

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. Stakeholders include resource management staff at the Carl Sandburg Home National Historic Site (CARL), Cumberland Piedmont I&M Network (CUPN), NPS Southeast Regional Office (SERO), and WCU investigators. Initial work for this NRCA began in August 2011 with the final task agreement signed in October of 2011. Site visits were conducted in December of 2011 with scoping meetings held during March 2012. Preliminary assessment frameworks were provided to NPS in February 2012 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 followed the NPS 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 four level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Infestations and diseases, in turn, include two level-three categories: insect pests and plant diseases. As the categories move from level-one to level-three, the resolution of the data involved also increases. The ecological monitoring framework used in this assessment is presented in Table 3.2.1.

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

Level 1 Category	Level 2 Category	Level 3 Category
Air and Climate	Air Quality	Sulfur deposition
		Nitrogen deposition
		Mercury deposition
		Ozone concentration
		$PM_{2.5}$ concentration
		Visibility/Haze
Soil & Geologic Resources	Soil Quality	Soil function and dynamics
Water	Water Quality	Hydrogen concentration and acid neutralizing capacity
		Stream water temperature
		Specific conductance
		Dissolved oxygen concentration
		Dissolved sulfate and nitrate concentration
		Dissolved aluminum concentration
		Metal concentrations
		Coliform bacteria

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

Level 1 Category	Level 2 Category	Level 3 Category
Biological Integrity	Invasive Species	Invasive/Exotic plants
	Infestations and Disease	Insect pests
		Plant diseases
	Focal Species or Communities	Wetland communities
		Forest/Woodland communities
		Fish diversity
		Macroinvertebrate species richness
		Amphibian and reptile species composition
		Avian species composition
		Mammal species composition
	At-risk Biota	Globally rare or uncommon species
Landscapes	Landscape Dynamics	Land use change/forest fragmentation

These proposed 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 is provided below while more detailed discussions are provided within each assessment section of chapter 4.

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 may be determined specifically for this NRCA or this effort can provide baseline information for future planning.

3.2.2. Reporting Areas

For the most part, resources were evaluated park-wide although with the exception of air quality and landscape conditions. Air quality monitoring data are available within the region but not specifically at CARL thus condition assessment is based upon this regional data. Human driven land use changes have occurred both adjacent to the park boundary and throughout the region and thus condition was based upon multi-scale assessments of LULC change (Table 3.2.1). Species inventory and monitoring data were collected from numerous sites within CARL and were evaluated in the context of the entire park's land use-land cover (LULC) (Table 3.2.1).

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

With 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). In addition, predicted surface water methylmercury concentrations at NPS Inventory & Monitoring units (USGS 2015). Estimates of annual average ozone concentrations were obtained from the Air Quality System (AQS) monitoring sites (EPA 2013). 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).

Particulate matter measures were obtained from a nearby site (AQS Monitor ID: 37-021-0034) located ~40 kilometers (25 miles) away in Asheville, NC (EPA 2013) while annual average measurements for visibility were obtained from Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring sites (IMPROVE 2013).

Water Quality

Five specific resource indicators were selected to evaluate water chemistry, including two parameters that allow for the characterization of stream water acidification (pH, acid neutralizing capacity) and three parameters that provide insights into the overall surface water quality at the historic site (dissolved oxygen, specific conductance, and water temperature). Monitoring for water quality has been conducted on-site at CARL every other year since 2002 and all of the 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).

Soil Quality

Data used for assessing soil resources came from four primary sources. 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 1980 (King 1980) and a custom report for CARL completed in 2015 (USDA NRCS 2015). Thornberry-Ehrlich (2012) performed a geological inventory of CARL and in their report included discussion of geologic properties that influenced soil characteristics. Woolsey and Walker (2008) examined soil development on granitic domes. Acid neutralizing capacity was not measured directly but was inferred from stream water pH monitoring.

Exotic Plants

Three key data sources were used to assess invasive exotic plants at CARL. First, the National Park Service maintains digital records for all plant species found in each park unit (NPSpecies 2015). A subset of this list including all exotic species currently found at CARL, with invasiveness rankings from the North Carolina Native Plant Society (2014), was used to provide an overview of exotic invasive species that are currently affecting park resources. An additional data set is derived from the Vegetation Monitoring Protocol for the Cumberland Piedmont Network (White et al. 2011) that provides a framework for monitoring invasive species already present in the park. Exotic species are monitored based on their occurrence in a network of 20 plots randomly distributed within the forest matrix throughout CARL. Third, CARL has adopted CUPN's Invasive Species Early Detection and Rapid Response Plan (ISEDRRP) (Keefer et al. 2014). This plan lists species that have the potential to affect park resources and provides strategies to detect these species through opportunistic observations.

Focal Species & Communities: Vegetation

The current condition and trend of CARL'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. We used four primary information and data sources for the assessment. NatureServe's vegetation inventory provided baseline information on species composition as well as identifying potential trends in certain communities (White 2003). Geographic locations and areal extent of the communities were mapped by the Center for Remote Sensing and Mapping Science at the University of Georgia (Jordan and Madden 2010). Current conditions of some of the communities were determined from CUPN's recently established long-term vegetation monitoring plots. Species composition and condition of the park's granitic dome communities were documented in a report by Woolsey and Walker 2008.

A vascular plant inventory was performed by NatureServe South between 2001 and 2003 (White 2003). In conjunction with this project, the Center for Remote Sensing and Mapping Science, Department of Geography, University of Georgia (Jordan and Madden 2010), mapped vegetation communities using aerial photograph interpretation (Figure 2.2.9). Fourteen distinct vegetation associations within eleven distinct ecogroups are found within the park's boundaries. Two of these vegetation associations, the Appalachian Low Elevation Granitic Domes and the Blue Ridge Table Mountain Pine – Pitch Pine Woodlands, have been assigned a G2 status and G3 status respectively. The Granitic Dome association is fairly common in patches within the park (Figure 2.2.9) but on a global scale, very rare. These exposed rock outcrops typically contain a diverse group of lichens, herbs, and woody species.

Focal Species & Communities: Vertebrates

Field inventories for terrestrial vertebrates were conducted at CARL between 2002 and 2006. The condition assessments presented here are based 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. In the case of reptiles and amphibians, the author's 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 (Reed and Gibbons 2005). 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 CARL and priority species occurring in the southern Blue Ridge.

Land Use: Land Cover Conditions

Land use-land cover conditions around CARL 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 CARL 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 CARL.

Reference Conditions

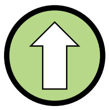
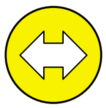
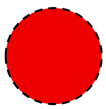
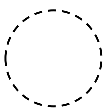
Where available, state, federal, and NPS specific standards and/or recommendations were used to establish reference conditions for evaluating resources including Air and Water Quality. In addition reference conditions were identified based upon the CUPN Vital Signs monitoring plan (NPS 2008). Where reference or target conditions have not been established the ideal condition is no impact (i.e., no trees exhibiting dogwood anthracnose or zero loss of natural vegetation cover over time), or researcher judgement.

Summary of Indicator Symbols

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 Resource Conditions

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). The Carl Sandburg Home National Historic Site is located in western 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. 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. 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 CARL. 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 (CUPN), which includes CARL, are shown in Figure 4.1.1.

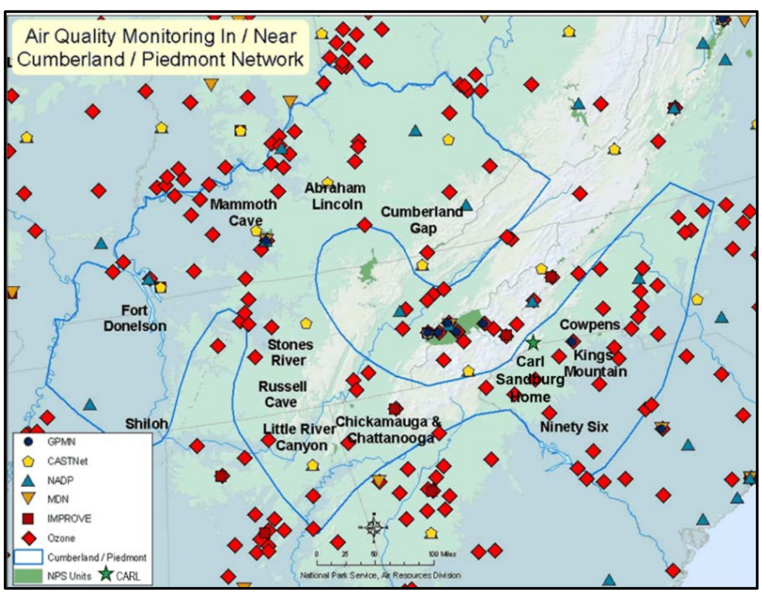


Figure 4.1.1. Map of air quality monitoring sites near CARL (Cumberland Piedmont Network, NPS ARD 2015c).

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 CARL. 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. Atmospheric 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 U.S. as a result of regulatory and emission standards imposed by the Clean Air Act (EPA 2013b).

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 5-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 method to estimate 5-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 CARL 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 CARL; 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 CARL (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 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 CARL, 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 2.7 kg/ha/yr (Figure 4.1.2) (NPS ARD 2014), a level that normally warrants moderate concern. However, the condition has been elevated to significant concern because ecosystems at CARL may be very highly sensitive to acidification effects relative to all Inventory & Monitoring parks (Sullivan et al. 2011a, Sullivan et al. 2011b). This ecosystem sensitivity rating was based on conditions such as steep slopes, high elevation, and the abundance of surface water and vegetation types expected to be the most sensitive to acidification. During that same period of time, estimated nitrogen wet deposition was 2.9 kg/ha/yr, which warrants moderate concern (Figure 4.1.2) (NPS ARD 2014). Ecosystems in the park were rated as having moderate 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).

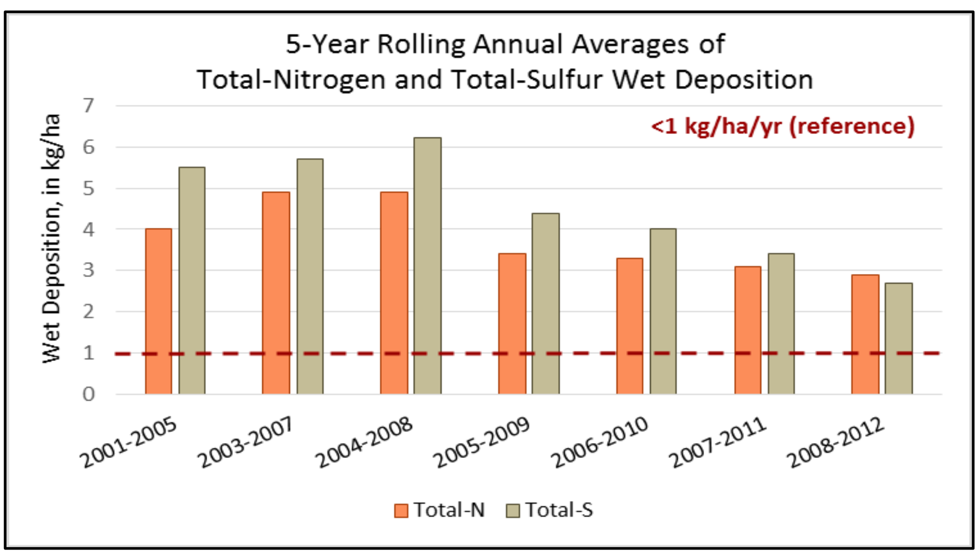


Figure 4.1.2. 5-year rolling annual averages of total-nitrogen and total-sulfur wet deposition for CARL (NPS ARD 2014).

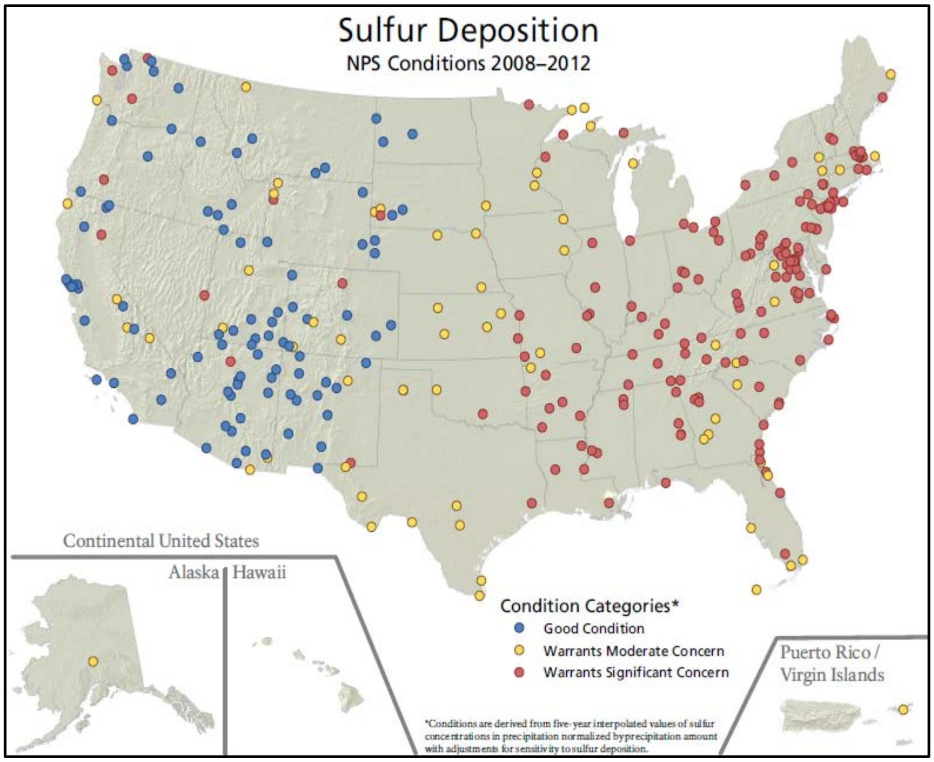


Figure 4.1.3. Map of sulfur deposition conditions in U.S. national parks, 2008-2012 (J. Renfro, NPS).

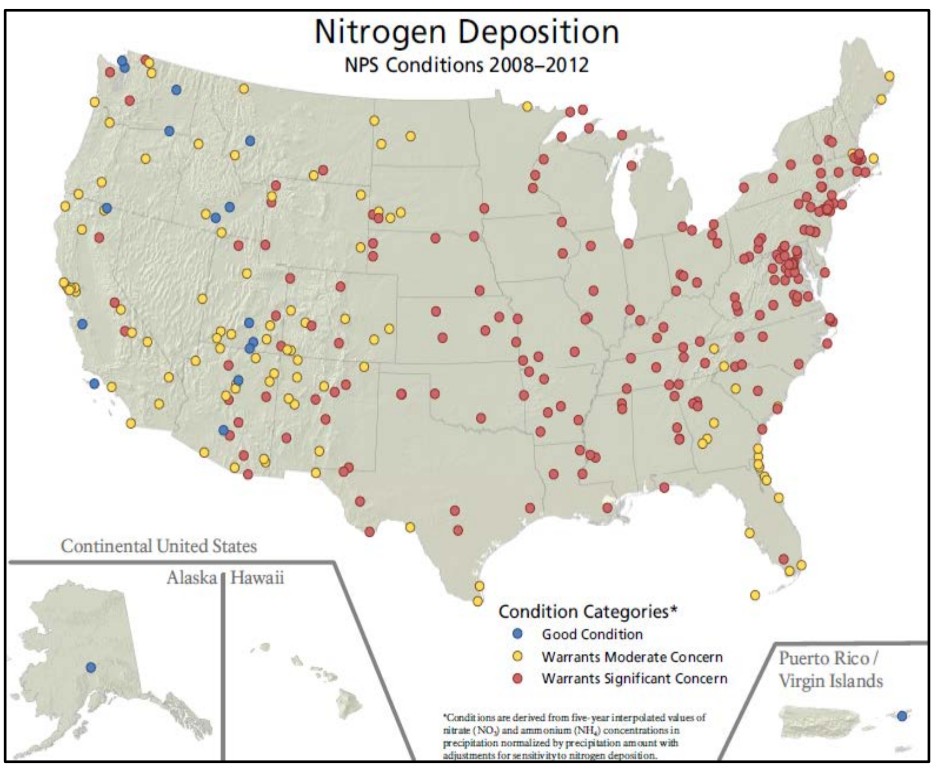


Figure 4.1.4. Map of nitrogen deposition conditions in U.S. national parks, 2008-2012 (J. Renfro, NPS).

The estimated maximum average for total nitrogen deposition for the 2010-2012 time period was 7.7 kg/ha/yr in the Eastern Temperate Forests ecoregion of CARL (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.

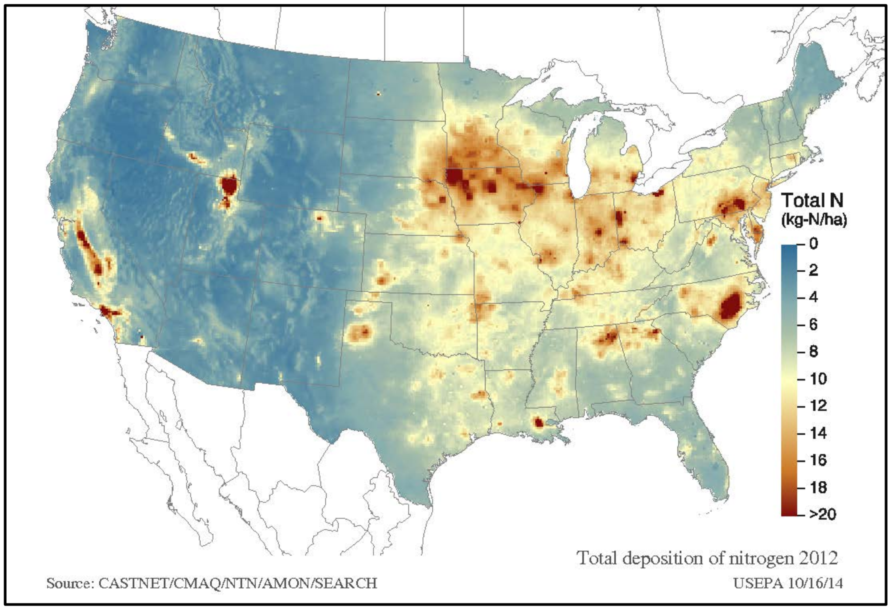


Figure 4.1.5. Map of total deposition of nitrogen in the contiguous U.S., 2012 (EPA 2014).

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).

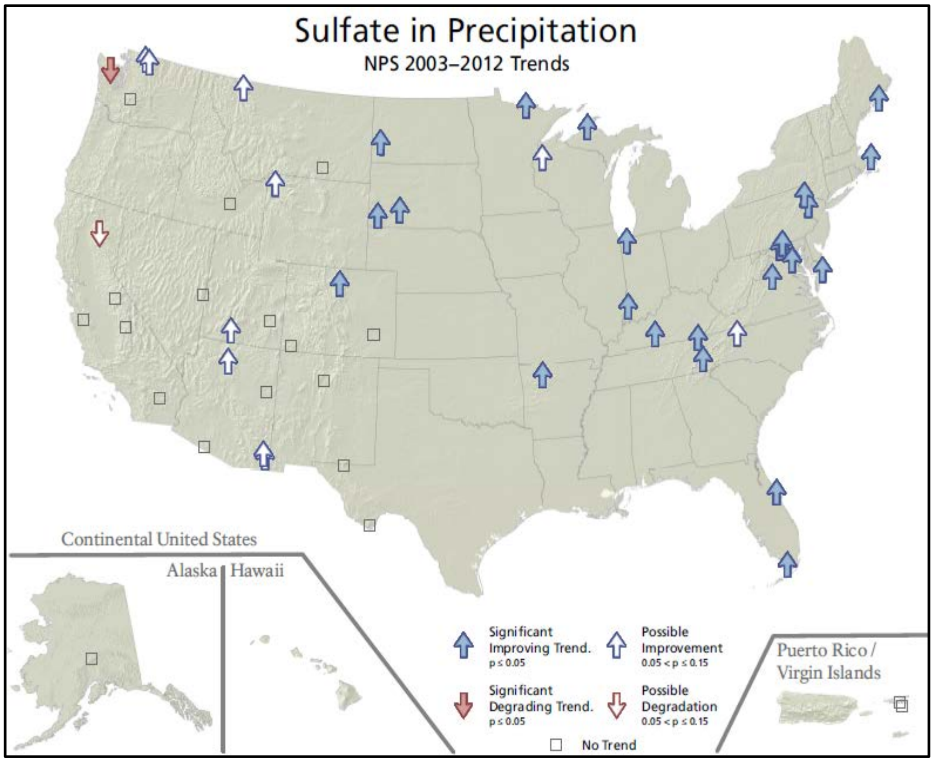


Figure 4.1.6. 10-year trends in sulfate in precipitation, 2003-2012 (J. Renfro, NPS).

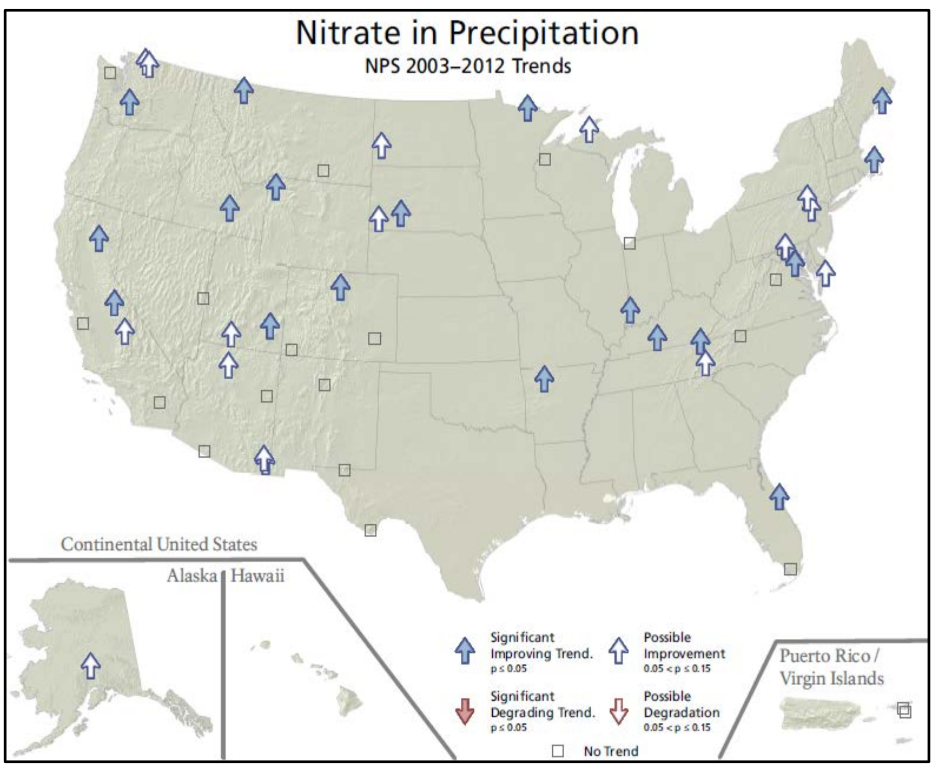


Figure 4.1.7. 10-year trends in nitrate in precipitation, 2003-2012 (J. Renfro, NPS).

Confidence and Data Gaps
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 CARL 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.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Total Sulfur (Wet deposition in kg/ha/yr)	Red circle	Estimated sulfur wet deposition was 2.7 kg/ha/yr (2008-12); condition elevated to significant concern due to sensitive ecosystems; 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)	Yellow circle	Estimated nitrogen wet deposition was 2.9 kg/ha/yr (2008-12); moderate sensitivity to nutrient-enrichment effects; NPS ARD advises against using interpolated values for trend (Data Source(s): NADP-NTN via AirAtlas)

Sources of Expertise

- Tamara Blett, Ecologist, National Park Service, Air Resources Division
- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, National Park Service, 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 CARL 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).

		Mercury (Hg) Wet Deposition Rating				
		Very Low	Low	Moderate	High	Very High
Predicted Methylmercury (MeHg) Concentration Rating	Very Low					
	Low					
	Moderate					
	High					
	Very High					

Conditions and Trends

As indicated above, no data were available to assess mercury deposition at or near CARL for this assessment, however, mercury deposition warrants moderate concern at CARL. 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 very high, estimated to be 15.13 µg/m²/yr (NADP-MDN 2015), however, predicted methylmercury concentrations in park surface waters at the park was very low, estimated to be 0.03 ng/L (USGS 2015). The combination of a very high rating for wet mercury deposition with a very low rating for predicted methylmercury concentrations yields a warrants moderate concern status (Table 4.1.3).

In addition, a study of mercury bioaccumulation in southern Appalachian birds found that mercury concentrations in feathers were highest at lower elevation sites near water (Keller et al. 2014). While no birds were sampled directly from CARL, the habitat is comparable. Elevated levels of mercury in biota, including insects and song birds, have been detected at the nearby Great Smoky Mountains National Park (Buchwalter et al. 2009, Simons and Keller 2009, Keller et al. 2014, Nelson and Flanagan Pritz 2014). CARL is currently assessing in-park mercury levels in water and dragonfly larvae samples via a citizen science project (Eagles-Smith et al. 2013). 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 2013).

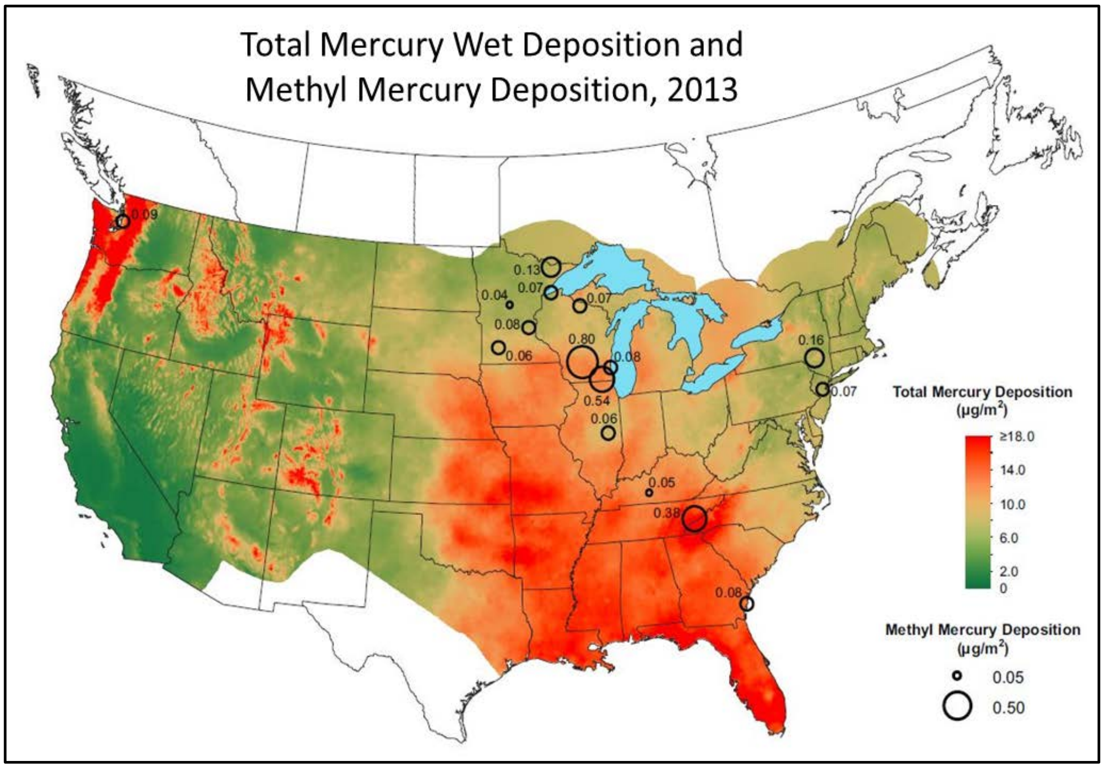


Figure 4.1.8. Interpolated values for total mercury wet deposition for the U.S. in 2013 using PRISM precipitation data. Circles represent 2013 annual methylmercury wet deposition (J. Renfro, NPS).

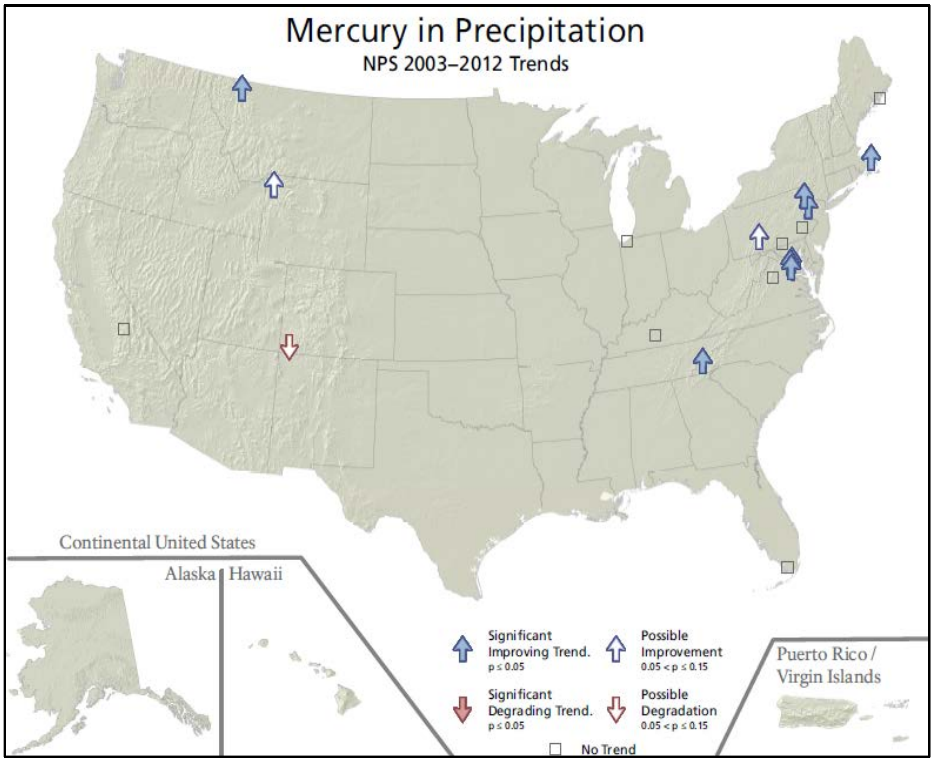


Figure 4.1.9. 10-year trends in mercury in precipitation, 2003-2012 (J. Renfro, NPS).

Confidence and Data Gaps

There are no monitors for measuring mercury wet deposition at or near CARL; thus, this represents a major data gap. Results from nationwide studies suggest moderate concern for mercury deposition at CARL, but the degree of confidence in the condition assessment for mercury deposition at CARL is low. Due to a lack of on-site or nearby monitoring data, there was no assessment of trend (Figure 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 15.13 µg/m2/yr; estimated methylmercury concentration in park surface waters was 0.03 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, National Park Service, Air Resources Division

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

- Ksienya Pugacheva, Natural Resource Specialist, National Park Service, 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 CARL were at moderate risk for ozone damage (Kohut 2004, Kohut 2007, Jernigan et al. 2014). There are at least 18 ozone-sensitive in the park, including spreading dogbane (*Apocynum androsaemifolium*) and Virginia pine (*Pinus virginiana*) (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 8-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 CARL 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 CARL; 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 three-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 CARL 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 are reported using monitoring data from across the U.S. to provide a national and regional context for current conditions reported at CARL (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:

- ≤7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species
- ≥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 CARL. This condition is based on NPS ARD benchmarks and the 2008-2012 estimated ozone of 69.5 ppb (Figure 4.1.10) (NPS ARD 2013b, NPS ARD 2014). Vegetation health risk from ground-level ozone also warrants moderate concern at CARL for this time period. This condition is based on NPS ARD benchmarks and the 2008-2012 estimated W126 metric of 8.9 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).

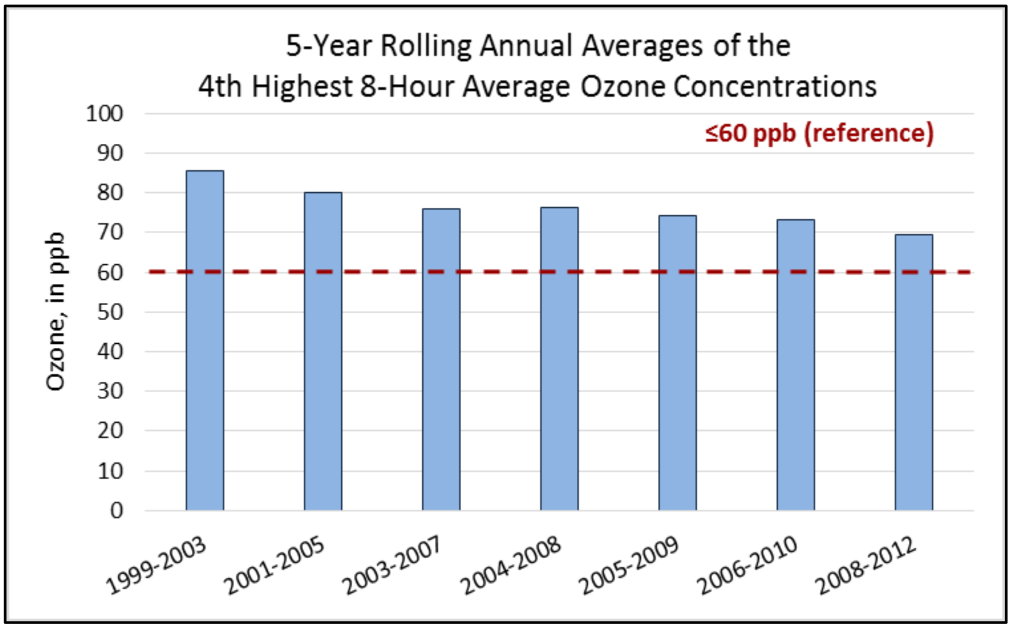


Figure 4.1.10. 5-year rolling annual averages of 4th highest 8-hour ozone concentration for CARL (NPS ARD 2014).

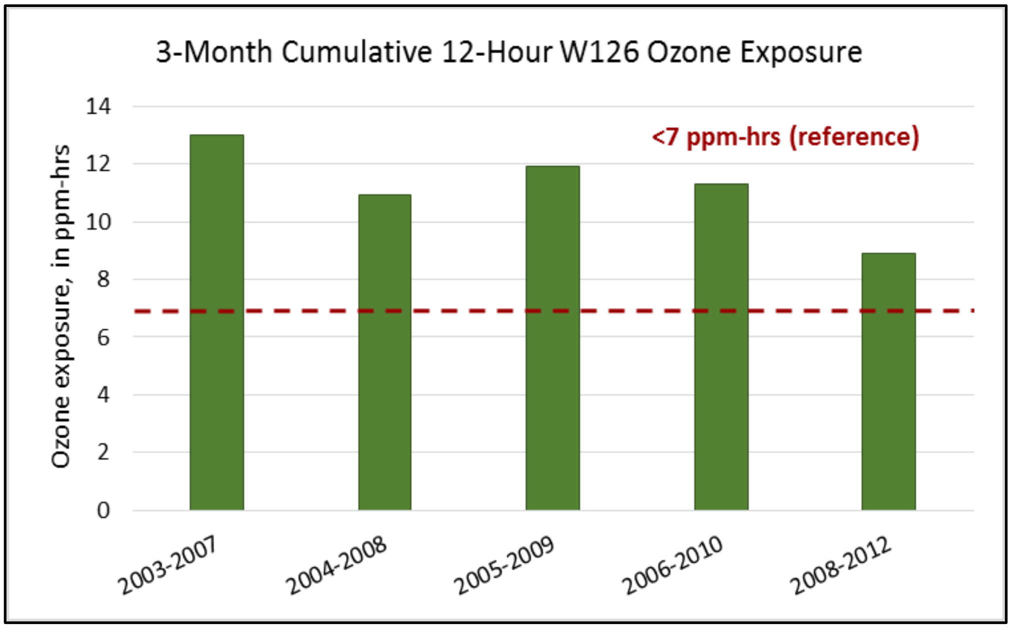


Figure 4.1.11. 5-year rolling annual averages of the W126 ozone metric for CARL (NPS ARD 2014).

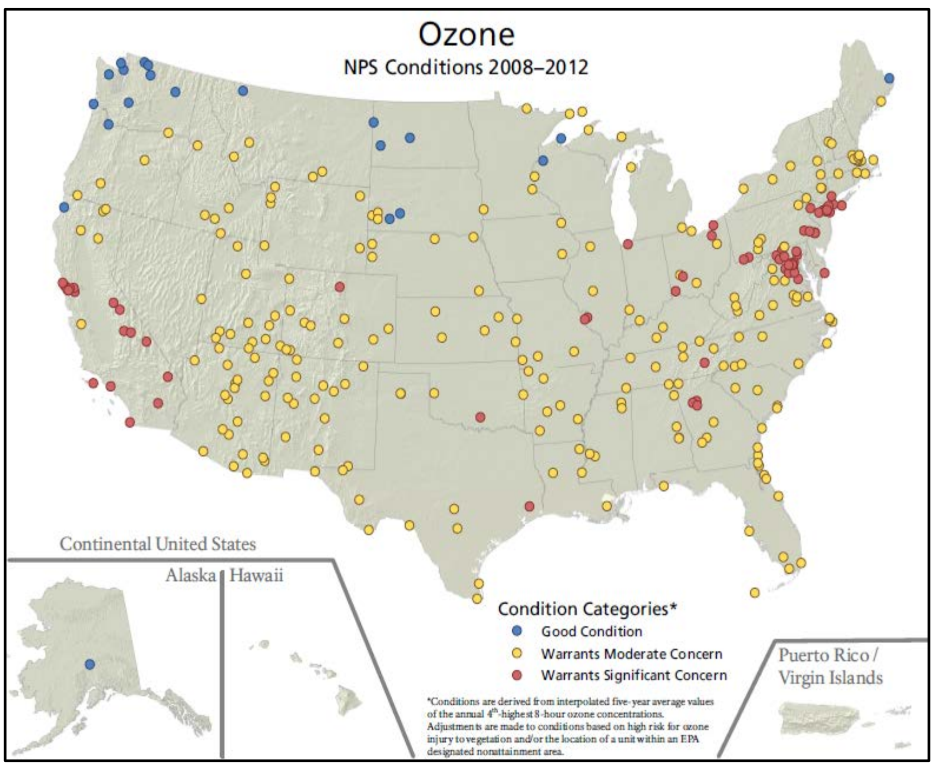


Figure 4.1.12. Map of ozone conditions in U.S. national parks, 2008-2012 (J. Renfro, NPS).

NPS ARD requires a monitor within ten kilometers (6 miles) of the park to calculate trends for ozone. As such, current trend information for ozone concentrations at CARL is not available (NPS ARD 2013b). However, 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.

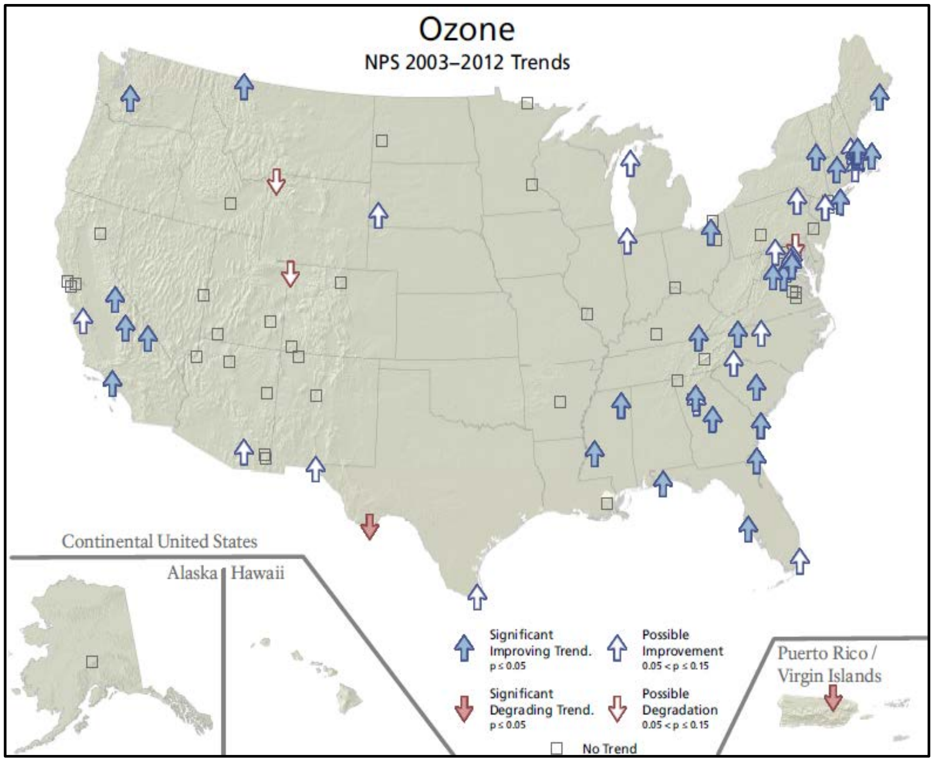


Figure 4.1.13. 10-year trends in annual 4th highest 8-hour ozone concentration (J. Renfro, NPS).

Confidence and Data Gaps

The degree of confidence at CARL is medium because estimates are based on interpolated data from more distant ozone monitors (Table 4.1.5). These AQS sites are located ~35 km (22 mi) away, and while this is not ideal, these data represent the best available for CARL. 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 mi) (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])	(yellow circle)	Estimated ozone concentration was 69.5 ppb and estimated W126 was 8.9 ppm-hrs (2008-12); warrants moderate concern; NPS ARD advises against using interpolated values for trends (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, National Park Service, 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 a nearby site (AQS Monitor ID: 37-021-0034) located ~40 km (25 mi) away in Asheville, NC (EPA 2013a). These air quality data are from monitors in the Environmental Protection Agency's Air Quality System (AQS). This site is a considerable distance away from CARL; however, it is considered representative of CARL because it is located in similar geographic terrain and elevation and there are few local sources (other than Duke Energy's coal-fired power plant which has maximum emissions controls). The Asheville monitor has a complete, long-term dataset with which to examine current conditions and assess trends over the past decade and thus, represents the best available data for this NPS site.

Reference Conditions

The reference condition for particulate matter concentrations is necessary to detect when concentrations reach levels of concern to human health, visibility, and park ecosystems. Natural background concentrations of particulate matter have been difficult to define; the EPA first established the National Ambient Air Quality Standard (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 µg/m^3 and ≤15 µg/m^3, respectively; the 24-hour (daily) primary and secondary standard is the same and is attained when the 3-year average of the annual 98th percentile is ≤35 µg/m^3 (EPA 2012). For this assessment, the annual primary standard of ≤12 µg/m^3 was used as reference condition (and ecological threshold) for particulate matter concentrations.

Conditions and Trends

The three-year rolling annual average $PM_{2.5}$ concentration (2010-2012) for the monitor location closest to CARL was 9.3 µg/m^3. This value is below the ecological threshold of ≤12 µg/m^3, and indicates minimal to moderate concern for particulate matter condition in the park (EPA 2013a). Particulate matter concentrations near CARL have steadily declined over the past decade, with values decreasing 37% from the fourteen-year high value of 14.8 µg/m^3 (1999-2001) to 9.3 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 2006-2008 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.

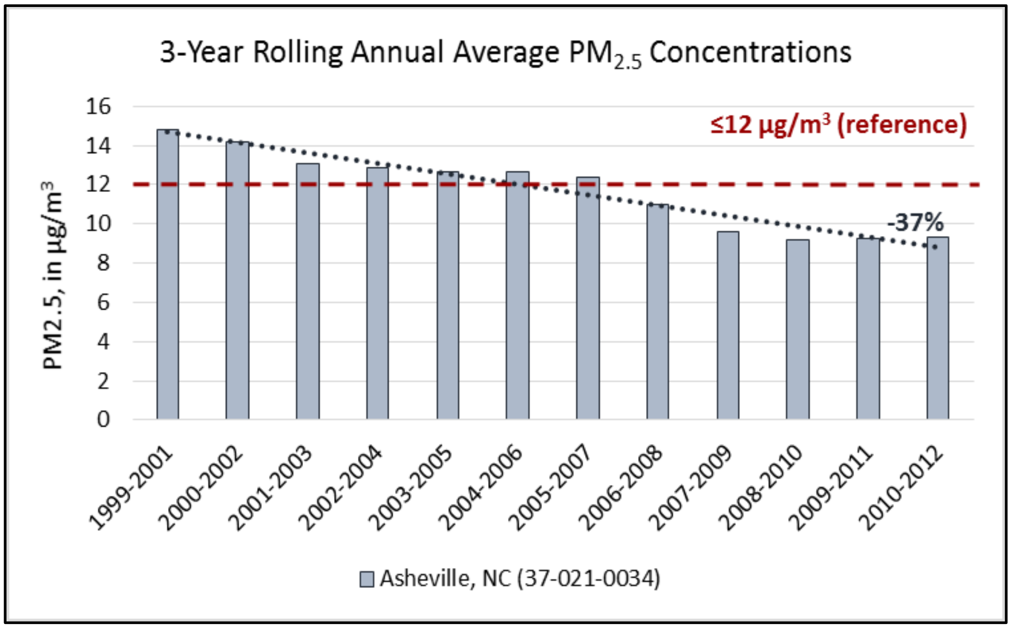


Figure 4.1.14. 3-year rolling annual average $PM_{2.5}$ concentrations for CARL (Author; EPA 2013a).

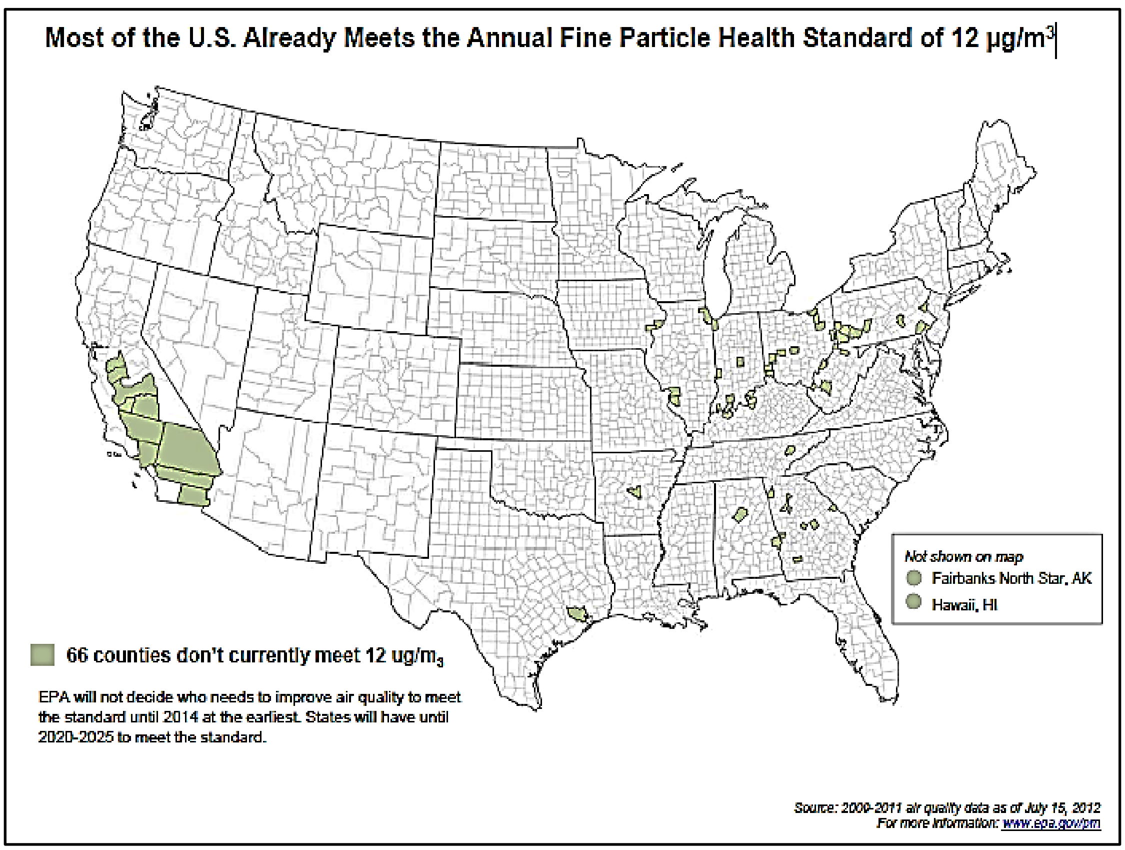


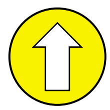
Figure 4.1.15. Nonattainment areas for the 2012 annual $PM_{2.5}$ NAAQS (J. Renfro, NPS).

Confidence and Data Gaps

Monitoring of $PM_{2.5}$ concentrations near CARL began in 1999 (at Asheville) as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE 2013) program. Continuous fine particle pollution monitoring has also taken place at other locations around, yet farther away from CARL since 1999. Therefore, 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 CARL (Table 4.1.6).

Summary Condition

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/m^3		$PM_{2.5}$ concentration was 9.3 μg/m^3 (2010-12); warrants moderate concern; values have declined since 1999; recent levels have fallen below threshold of ≤12 μg/m^3 (Data Source(s): EPA AQS and IMPROVE via EPA AirData)

Sources of Expertise

- Pat Brewer, Regulatory, Policy, Smoke Management, National Park Service, Air Resources Division
- Johnathan Jernigan, Physical Scientist, Air Resources Division and Cumberland Piedmont Network
- Ksienya Pugacheva, Natural Resource Specialist, National Park Service, 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 CARL, as viewing scenery is the top reason 10 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 40th through the 60th percentiles. Annual average measurements for visibility on mid-range days were averaged over five-year periods spanning the years 1999-2012 at all Interagency Monitoring of Protected Visual Environments (IMPROVE) 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 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 CARL is the value derived from this national analysis at the geographic center of the park. These sites are a considerable distance away from CARL; 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 CARL (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 Clean Air Act goal. Natural visibility conditions are those estimated to exist in a given area in the absence of human-caused visibility impairment (EPA 2003). 7NPS 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 CARL). This condition is based on NPS ARD benchmarks and the 2008-2012 estimated visibility on mid-range days of 8.3 dv above estimated natural conditions (6.9 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).

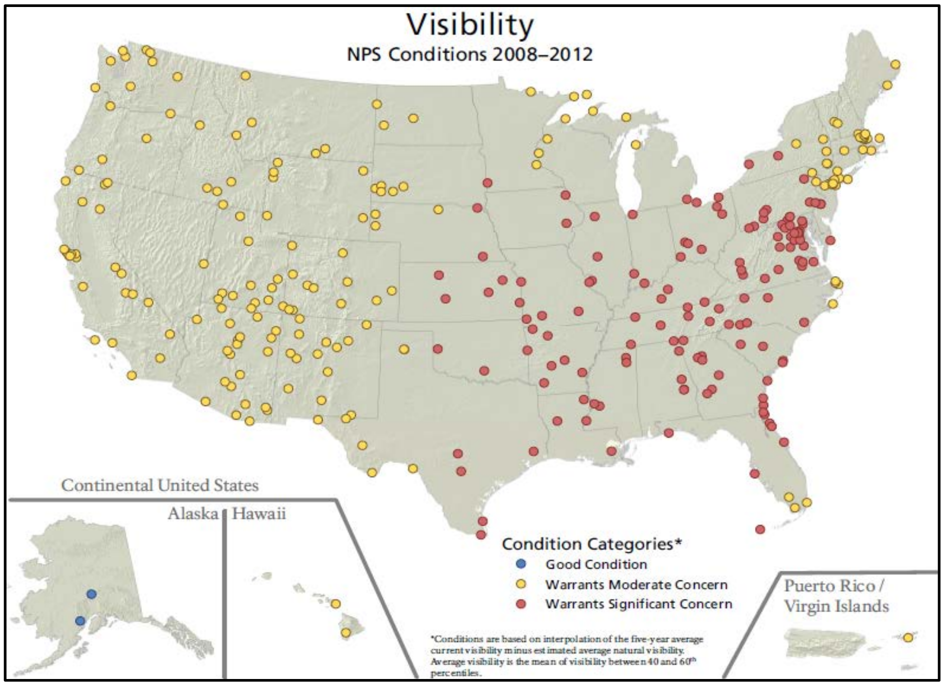


Figure 4.1.16. Map of visibility conditions in U.S. national parks, 2008-2012 (J. Renfro, NPS).

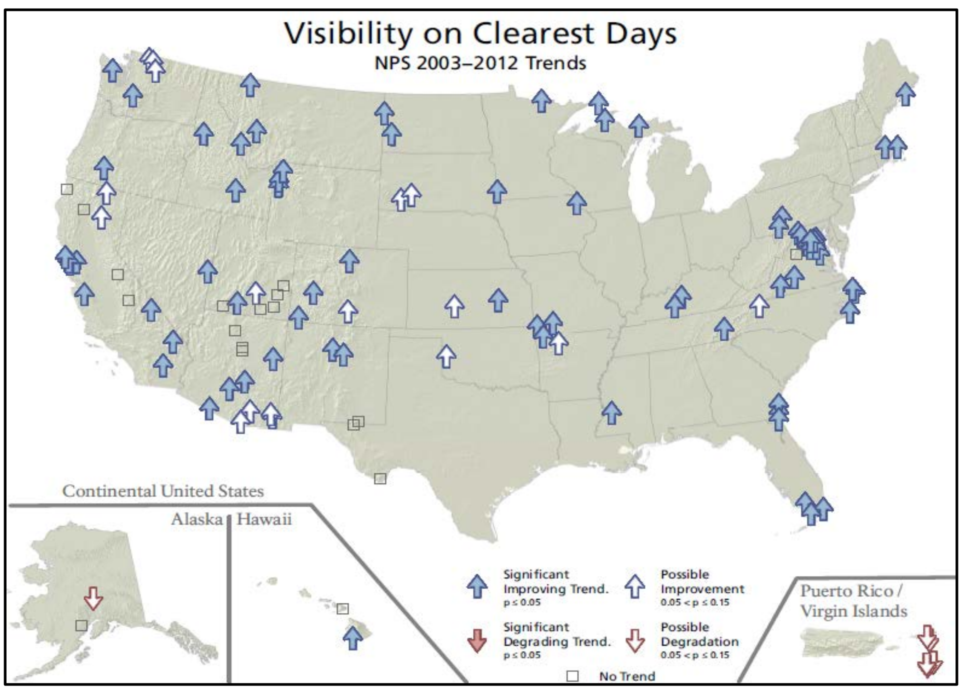


Figure 4.1.17. 10-year trends in visibility on clearest days, 2003-2012 (J. Renfro, NPS).

Haze is particularly an issue in the eastern U.S., and the region in which CARL is located has consistently experienced annual mean deciview values on the haziest days well in excess of estimated natural conditions. Five-year rolling annual averages of visibility values on clearest (best) days and haziest (worst) days for CARL are also shown in Figure 4.1.18. For 2003-2012, the trend in visibility at CARL improved on the 20% clearest days and improved on the 20% haziest days (IMPROVE Monitor ID: GRSM1, TN). These trends are consistent with improving trends in most parks across the U.S., which are likely due to tighter National Ambient Air Quality Standard (NAAQS) standards for $PM_{2.5}$ Best Available Retrofit Technology Rules, and Reasonable Progress measures under the Regional Haze Rule (Figures 4.1.17 and 4.1.19) (EPA 2012a, NPS ARD 2013). 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.

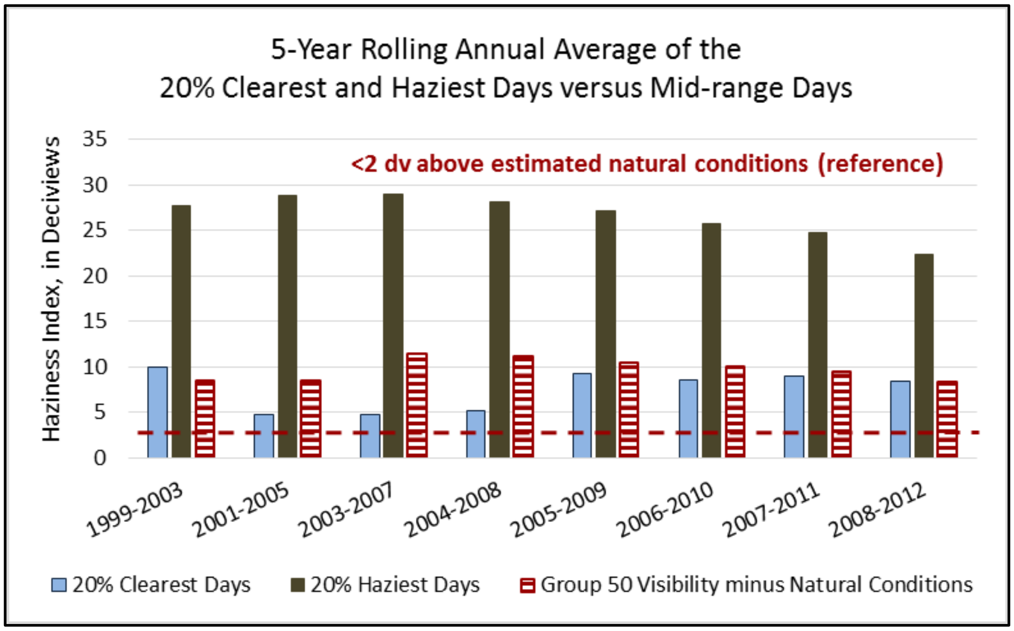


Figure 4.1.18. 5-year rolling annual averages of visibility values on haziest (worst) days, clearest (best) days, and mid-range days for CARL (NPS ARD 2014).

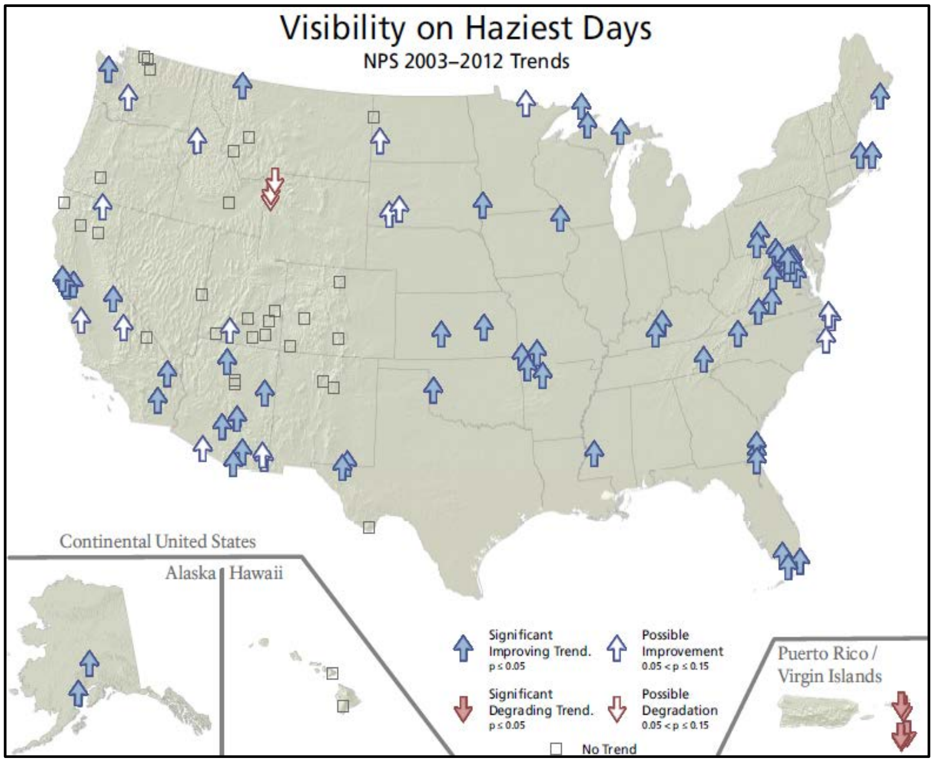


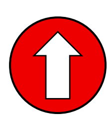
Figure 4.1.19. 10-year trends in visibility on haziest days, 2003-2012 (J. Renfro, NPS).

<u>Confidence and Data Gaps</u>

The degree of confidence at CARL is medium because estimates are based on interpolated data from more distant visibility monitors (Table 4.1.7). Three IMPROVE (2013) sites are located approximately 40, 90, and 140 kilometers (25, 56, and 87 miles) away, and while this is not ideal, these data represent the best available for CARL. However, haze tends to operate at a regional scale, and NPS ARD considers GRSM site (GRSM1; 140 km NW) representative of CARL. Their criteria for Class II parks is within 150 kilometers (93 miles), and an elevation criteria of 10% or 100 meters (328 feet) within the minimum and maximum park elevations.

<u>Summary Condition</u>

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 8.3 dv (2008-12); warrants significant concern; values have improved since 1999; exceeds significant concern level of <8 dv above estimated natural conditions (Data Source(s): IMPROVE via AirAtlas)

<u>Sources of Expertise</u>

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

- Ksienya Pugacheva, Natural Resource Specialist, National Park Service, Air Resources Division

- Jim Renfro, Air Quality Program Manager, Great Smoky Mountains National Park

4.2. Soil & Geologic Resources

4.2.1. Soil Quality

Relevance

Soils have a large impact on CARL 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 CARL formed in the Henderson Augen Gneiss. This type of parent material in combination with the regions warm, wet climate produces acidic soils due to leaching of the soluble bases. These soils have given rise to the characteristic vegetative communities found at CARL including pine woodlands, dry chestnut-oak forests, acidic cove forests, and montane oak-hickory forests (Thornberry-Ehrlich 2008). In addition, this geologic formation is characterized by domes of granitic gneiss that outcrop throughout the park (Figure 4.2.1). These domes are characterized by shallow, xeric soils that support some of the most unique vegetative communities in the park (Woolsey and Walker 2008, Thornberry-Ehrlich 2012).

Figure 4.2.1. Granitic dome in CARL (Woolsey and Walker 2008).

Reference Conditions

We defined the reference condition for soils to consist of soil properties sufficient to support the native vegetative communities found at CARL, and are also able to buffer surface waters from acidic deposition and other forms of anthropogenic pollution.

Data and Methods

Data used for assessing soil resources comes from four primary sources. 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 1980 (King 1980) and a custom report for CARL completed in 2015 (USDA NRCS 2015). Thornberry-Ehrlich (2012) performed a geological inventory of CARL and in their report included discussion of geologic properties that influenced soil characteristics. Woolsey and Walker (2008) examined soil development on granitic domes. They were particularly interested in the relationship between soil depth and soil age, and systematically sampled soil depth on soil islands of varying ages.

Current Conditions and Trends

Four primary soils series and seven soil map units were found at CARL (Table 4.2.1) (Figure 4.2.2) (USDA NRCS 2015).

Table 4.2.1. Soil map unit descriptions (USDA NRCS 2015).

Henderson County, North Carolina (NC089)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AhE	Ashe stony sandy loam, 15 to 25 percent slopes	89.7	33.3%
AhF	Ashe stony sandy loam, 25 to 45 percent slopes	59.0	21.9%
Co	Codorus loam (arkaqua)	1.3	0.5%
EdC	Edneyville (edneytown) fine sandy loam, 7 to 15 percent slopes	0.2	0.1%
EdE	Edneyville (edneytown) fine sandy loam, 15 to 25 percent slopes	83.9	31.2%
HyC	Hayesville loam, 7 to 15 percent slopes	20.7	7.7%
TeC	Tate fine sandy loam, 7 to 15 percent slopes	11.3	4.2%
W	Water	3.0	1.1%
Totals		**269.2**	**100.0%**

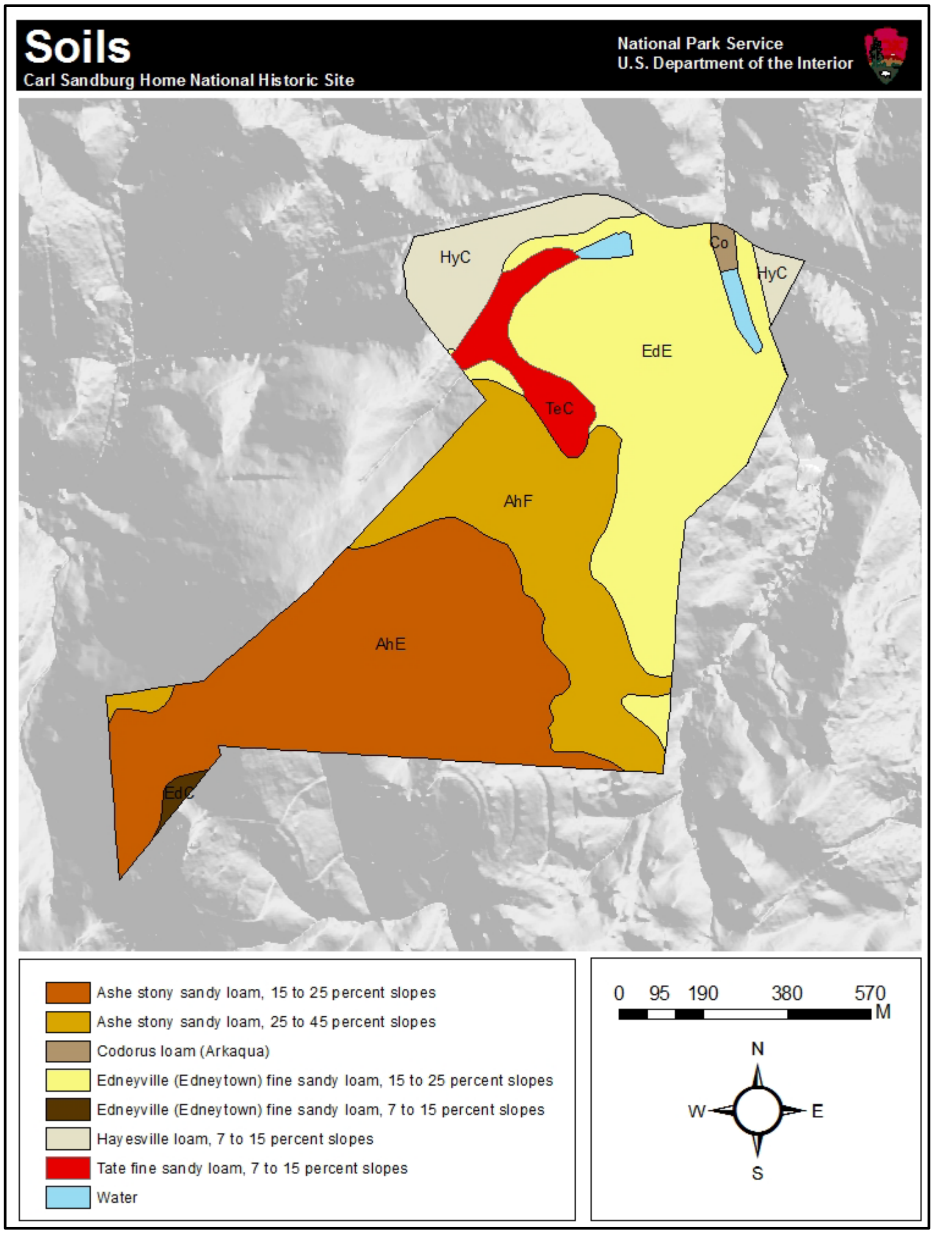


Figure 4.2.2. Soil map units at CARL (USDA NRCS 2015).

When evaluating the current conditions and trends of soil properties in CARL, there are three primary areas of focus. The first relates to the ability of soils to buffer acidic deposition. Reductions in this capacity can lead to increased acidification of surface waters, soil nutrient imbalances, and potentially Al toxicity in soils. The second focus area relates to soil conditions on granitic domes. The unique vegetative communities found on and adjacent to the domes are largely a function of the shallow, infertile, xeric soils that exist in those areas (Woolsey and Walker 2008). Changes to soil properties could significantly alter the existing plant communities. Finally, soil erosion and sedimentation, primarily from roads and trails causes soil to accumulate in downslope or depressional areas, severely impacting the native vegetation (Woolsey and Walker 2008, Thornberry-Ehrlich 2012).

Soil buffering capacity

There are no direct data for the buffering capacity of soils at CARL. However, stream water acidification data may provide a surrogate to assess soil buffering capacity. See section 4.3.1 of this document for a complete discussion, though a brief summary is presented here. Stream and lake water acidity was analyzed annually from 2002 to 2011 and water pH was found to vary throughout the park. Higher pH was observed in higher elevation streams and may be attributed to the higher amounts of precipitation and shallower soils that occur there. These factors may allow acids deposited with precipitation in these areas to pass quickly through soils and into streams. The median water pH value at CARL was 5.8, which is below the North Carolina Criteria. In addition, there were no systematic trends in water pH during this period despite reductions (improvements) in sulfate and nitrate deposition since 2008. These results may suggest that recovery of the acid buffering capacity of soils at CARL will require additional time.

Soil conditions on granitic domes

Woolsey and Walker (2008) found that soil formation occurs very slowly on granitic domes, and does not always mimic typical patterns of soil development. Instead, soils typically accumulate in cracks or shallow bedrock depressions where they lack a classic soil profile, but instead consist of weathered rock fragments and humus. They also found a significant relationship between increasing soil depth and both seral stage and vertical plant diversity. Maximum soil depths for different seral stages ranged from 18.4 cm (7.2 in) for annual and perennial forb communities to 48.6 cm (19.1 in) for a red cedar forest community (Figure 4.2.3) (Woolsey and Walker 2008). Though the rates of soil formation within and adjacent to granitic domes is slow, it is clear that as soils develop, vegetative community structure, and thus the legacy value of the domes, will change.

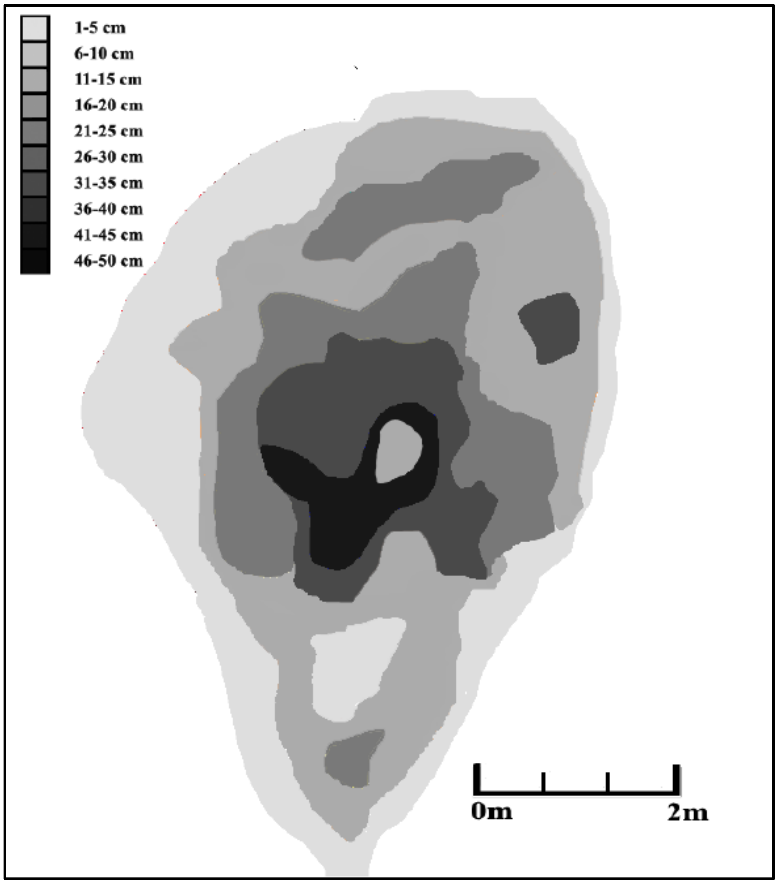


Figure 4.2.3. A map depicting soil depths on a soil island at CARL. The oldest tree located at the center of the island was estimated to be at least 250 years old (Woolsey and Walker 2008).

Soil erosion and sedimentation

Because soils form slowly, soils and the plant communities they support are sensitive to anthropogenic impacts. Two key impacts associated with visitor use are soil compaction and the movement and accumulation of sediment from eroding trails (Woolsey and Walker 2008, Thornberry-Ehrlich 2012). In addition to directly killing mosses, lichens and other plants, visitor trampling compacts soils, reducing soil infiltration capacity and increasing erosion rates. Erosion and the accumulation of sediment are most severe in high-use areas and trails (Figures 4.2.4 and 4.2.5).

Figure 4.2.4. Sediment from runoff along the Glassy Trail is deposited on a granitic dome (Woolsey and Walker 2008).

Figure 4.2.5. Sediment from runoff along the road adjacent to Duck Pond is deposited in and along the banks of the pond (Thornberry-Ehrlich 2012).

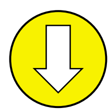
Accumulated sediment from runoff and erosion can accelerate plant succession in domes and can also facilitate the introduction of non-native invasive plants (Woolsey and Walker 2008, Thornberry-Ehrlich 2012).

Confidence and Data Gaps

We are moderately confident in this assessment. The park has direct observations of erosion and sedimentation in some areas, and while there are no direct data for soil buffering capacity at CARL, surface water chemistry data do suggest soil buffering may not be adequate. Soil development rates within dome communities are not known, but are likely very slow. A more extensive soil monitoring and inventory program would be a useful tool for documenting trends in soil quality.

Summary Condition and Graphic

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 Quality		Reference condition consists of soil properties sufficient to support the native vegetative communities found at CARL, and to buffer surface waters from acidic deposition and other forms of anthropogenic pollution. Stream water pH is often below NC State standards and accelerated erosion, soil compaction, and sedimentation are observed at some high visitor use areas and trails.

Sources of Expertise

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site

4.3. Water Quality

CARL is drained by small headwater streams, most of which originate within the historic site's boundary. Front Lake is an exception. It is fed by the axial channel of Meminger Creek, a stream that possesses tributaries that receive runoff from outside of the historic site, including drainage from the Ravenswood residential community (Figure 4.3.1). Given the nature of the drainage network, surface waters at CARL are not directly impacted by extensive human development or agriculture activities, a fact that has allowed the State of North Carolina to designate the majority of surface waters at the site as WSII, High Quality Waters (NPS 2011).

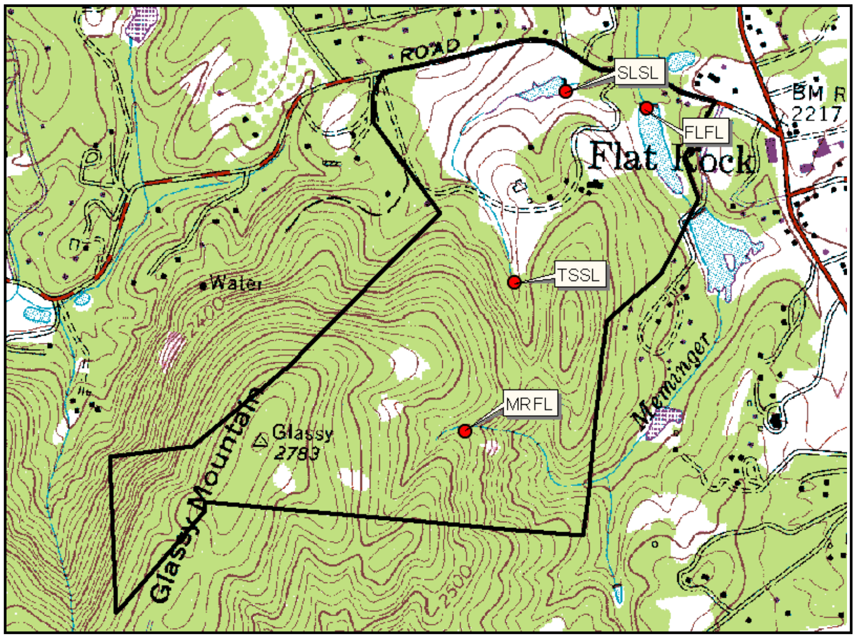


Figure 4.3.1. Map showing location of sampling sites (red dots) within CARL. MRFL – Mountain Reservoir; TSSL; Trout Spring; SLSL – Side Lake; FLFL – Front Lake (NPS 2011).

Although recreational use of these surface waters is prohibited, they are viewed as an aesthetic, interpretive and critical ecological resource. They also are a primary determinant of the site's overall resource condition. Water quality in particular is an important ecological indicator as poor water quality can act as a significant biotic stressor, lead to ecological system deterioration, and negatively affect the aesthetic value of the historic site (Deschu and Kavanagh 1986).

4.3.1. Water Chemistry

Five specific resource indicators were selected to evaluate water chemistry, including two parameters that allow for the characterization of stream water acidification (pH, acid neutralizing capacity) and three parameters that provide insights into the overall surface water quality at the historic site (dissolved oxygen, specific conductance, and water temperature).

Relevance

The primary threat, or stressor, of concern, with regards to water quality, is stream water acidification associated with the atmospheric deposition of acid pollutants in the form of sulfur (S) and nitrogen (N) compounds (discussed in Section 4.3.2, Toxics). Stream and lake water acidification, as measured by pH and acid neutralizing capacity (ANC), can be lethal or cause sublethal physiological stress to aquatic biota (Woodward et al. 1991, MacAvoy and Bulger 2004, Baldigo et al. 2007, Neff et al. 2009). In the case of CARL, and other areas of the eastern U.S., the lack of significant cation concentrations within the underlying bedrock (composed of the Henderson Augen Gneiss, Lemmon 1978) limits the ability of natural stream waters to buffer the input of acidic waters (Herlihy et al. 1996), making surface waters particularly sensitive to acidification.

Data and Methods

The five parameters selected to assess water chemistry have been collected at four locations (Figure 4.3.1) since December 2002. These sites include:

- Trout Pond Spring (TSSL): A perennial spring located approximately 100 m (328 ft) upstream of Trout Pond Spring within the headwaters of the Side Lake watershed;
- Side Lake (SLSL): A small man-made lake located within the Side Lake Watershed near the northern border of the historic site. The lake receives runoff from Trout Pond Spring and two small unnamed tributaries, including one that drains an area immediately outside and northwest of the historic site;
- Mountain Reservoir (MRFL): A small man-made pond located in the headwaters of the Front Lake watershed. It is fed by a stream that receives flow from a number of small springs located within and south of the historic site; and
- Front Lake (FLFL): A man-made lake located along the northeastern boarder of the historic site. It receives flow from Meminger Creek which drains areas both within and outside of the historic site, including Mountain Reservoir and the community of Ravenswood.

Sampling between December 2002 and September 2003 was conducted quarterly and included dissolved oxygen, pH, specific conductance, water temperature and discharge (Table 4.3.1). Sampling resumed following a one year hiatus (between October of 2003 and 2004) on a quarterly basis. Since August, 2005 sample collection has varied from one to four times per year. All of the 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).

Table 4.3.1. Summary of water quality data collection at CARL.

Year of Data Collection	ANC	Dissolved Oxygen	pH	SC	Water Temp	Discharge
2002	---	All Sites	All sites	All sites	All sites	All sites
2003	---	All Sites	All sites	All sites	All sites	All sites
2004	---	All Sites	All sites	All sites	All sites	MRFL
2005	---	All Sites	All sites	All sites	All sites	MRFL
2006	All Sites	All Sites	All sites	All sites	All sites	MRFL
2007	All Sites	All Sites	All sites	All sites	All sites	MRFL
2008	All Sites	All Sites	All sites	All sites	All sites	MRFL
2009	All Sites	All Sites	All sites	All sites	All sites	MRFL
2010	All Sites	All Sites	All sites	All sites	All sites	MRFL
2011	All Sites	All Sites	All sites	All sites	All sites	MRFL

Reference Conditions

Stream Water Acidification

Stream water acidification is assessed using two parameters: pH and ANC. The effects of pH on aquatic biota differ between species and life stages. Nonetheless, as illustrated by Table 4.3.2, the potential ecological effects of low pH waters on fish and other aquatic biota increase with increasing acidity. 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). Evidence provided by Alabaster and Lloyd (1980) suggests that the effects of lowered pH are time dependent, and found that brook trout (*Salvelinus fontinalis*) were able to survive episodic exposures to low pH waters (below 5) for short periods (< 24 hrs). Nevertheless, direct, lethal effects to fish can occur at pH values below about 5 (Neville and Campbell 1988), even when exposure times are limited. Macroinvertebrate and amphibian survival also decline in low pH waters (below ~5.0) (Cai et al. 2012a), and some evidence suggests that both amphibian and salmonid egg production begins to decline at pH values below 7.0 (Sadinski and Dunson 1992, Barnett 2003).

Table 4.3.2. 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

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 1986a). The acceptable, narrative standard set by North Carolina Department of Environment and Natural Resources is 6.0-9.0 (NCDENR 2007). The reference values used herein are set at 6 to 9 on the basis of the North Carolina standard.

Acid neutralizing capacity (ANC) is widely utilized to characterize the acid-base chemistry of surface- and groundwater. In general, ANC is the difference between proton acceptors and proton donors within a water body. 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).

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	2.5-9.98	Sensitive
>200	>9.98	Not Classified

Currently, state and federal standards for ANC do not exist. However, a reference value of 2.5 mg/l (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. 2012a), and 2) a default total maximum daily load (TMDL) management target of 2.50 mg/L (50 µeq/L) set by the Tennessee Department of Environment and Conservation for the 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 other chemical indicators of water quality were evaluated: specific conductance, temperature, and dissolved oxygen (DO). 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. For this reason, specific conductance is often used to assess the concentration of total dissolved solids, including pollutants, within water, and it provides an indicator of overall water quality.

Conductivity in natural (uncontaminated) rivers in the U.S. range from about 5 to 1,500 µS/cm. Due to the large natural variability in conductivity, no state or federal water quality criteria for specific conductance exist. However, uncontaminated stream water within the southern Appalachians is typically below 50 µS/cm. Miller (unpublished data), for example, found that specific conductance within the forested Allen Creek watershed in Haywood County ranged from 12 to 22 µS/cm between March 2007 and December 2011. Similarly, Webster et al. (2012) found that specific conductance within watersheds of the southern Appalachians, including the Coweeta Long-term Ecological Research Station (hereafter, also Coweeta), ranged between 9.3 and 63.5 µS/cm, and exhibited a strong, indirect relationship with forest land-cover and a number of other variables used to describe development. Given the noted ranges for specific conductance, 50 µS/cm is put forth here as a maximum reference value for predominantly forested watersheds.

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. Their health may be impacted above and below this range. In most instances, the primary concern is for increased water temperatures, particularly during the summer months, in response to the input of warm water from anthropogenic sources, or the alteration of aquatic and riparian habitat (e.g., the loss of shade associated with the removal of stream side vegetation).

For this NRCA, a temperature of 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 (37.0 °F) above the natural water temperature and in no case to exceed 29 °C (84.2 °F) for mountain and upper piedmont waters (NCDENR 2007)

Dissolved oxygen is essential to the metabolism of aquatic organisms, and is a requirement of high quality waters. DO also influences a host of other water quality parameters, such as water clarity, order, 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).

DO concentrations of at least 4-5 µg/L are required to support a diverse population of fish species; all factors being equal, cold water species generally require higher concentrations than do warm water species. State and federal water quality standards for DO in trout waters reflect these studies, although slight differences exist (Table 4.3.5). The more conservative North Carolina criteria of 5 mg/L (Table 4.3.5) is used as a reference for this NRCA.

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 1986a)

Conditions and Trends

Surface Water Acidification (pH, ANC)

Data collected and analyzed since 2002 for pH and since 2006 for ANC show that stream water acidity varies between the four monitoring sites within CARL, and exhibit, at some locations and times, values below the utilized reference criteria (6.0 pH units, 2.50 mg/L or 50 µeq/L) (Figure 4.3.2).

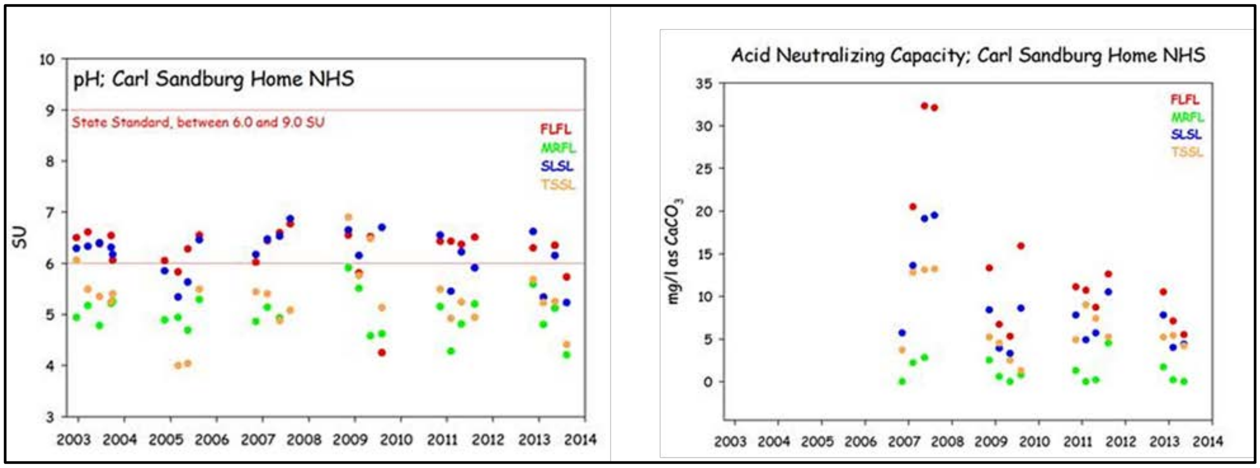


Figure 4.3.2. Park-wide changes in pH and ANC between 2002 and 2011.

In fact, site-wide median pH was 5.8 between 2002 and 2011, a value below the North Carolina State criteria utilized as a reference. The median ANC value for the combined data set for the period is 5.64 mg/L (113 µeq/L). While the median is above the 2.50 mg/L (50 µeq/L) value suggested as a threshold, measurements below 2.50 mg/L (50 µeq/L) were not uncommon (Figure 4.3.2).

On a site by site basis, surface waters collected at high elevation monitoring sites (i.e., Mountain Reservoir, Trout Pond Spring) exhibited relatively low pH and ANC values in comparison to the lower elevation sites (Figure 4.3.2). It is unclear why these higher elevation sites at CARL exhibited lower pH and ANC. However, studies within GRSM attributed similar spatial patterns to: 1) elevated levels of acid deposition and higher volumes of precipitation at higher elevations (Cai et al. 2012a, Neff et al. 2013), and 2) the presences of thin, highly conductive soils on steep slopes within small basins that allow acid inducing ions to pass quickly through the soils to the channel, particularly during rainfall events. The reduced contact time between the interflow waters and the soils limits ion absorption and consequent buffering, and affects the retention, mobility and chemical processing of sulfate and nitrate in the soil (Cai et al. 2012a, Neff et al. 2013). This argument is supported by the correlation of water chemistry to the hydraulic conductivity (Ksat) of the soil within GRSM watersheds, such that soils with higher hydraulic conductivities were linked to lower pH, ANC, and base cation concentrations and higher nitrate, sulfate, and aluminum concentrations.

The collection of data since 2002 has made it possible to examine temporal variations in surface water acidification. Data from all four sites show that systematic trends in pH have not occurred over the monitoring period (Figure 4.3.3). In contrast, temporal trends appear to vary between monitoring sites for ANC. At Front Lake and to a lesser degree Side Lake, ANC appears to have decreased between 2007 and 2009. This decreasing trend continues for Front Lake. No change is apparent for the other two sites. There is a lack of a systematic improvement in surface water acidification, in spite of the fact that sulfate (Figure 4.3.3) and nitrate (Figure 4.3.4) deposition within the region has decreased since about 2008. The trend, however, is consistent with modeling results by Zhou et al. (2014). They utilized a hydrochemical modeling approach (based on the PnET-BGC model) to assess the critical and dynamic critical loads that would be required for the recovery of stream waters to acidification, and found that it may take decades to centuries to occur in response to decreases in atmospheric deposition of acid inducing compounds.

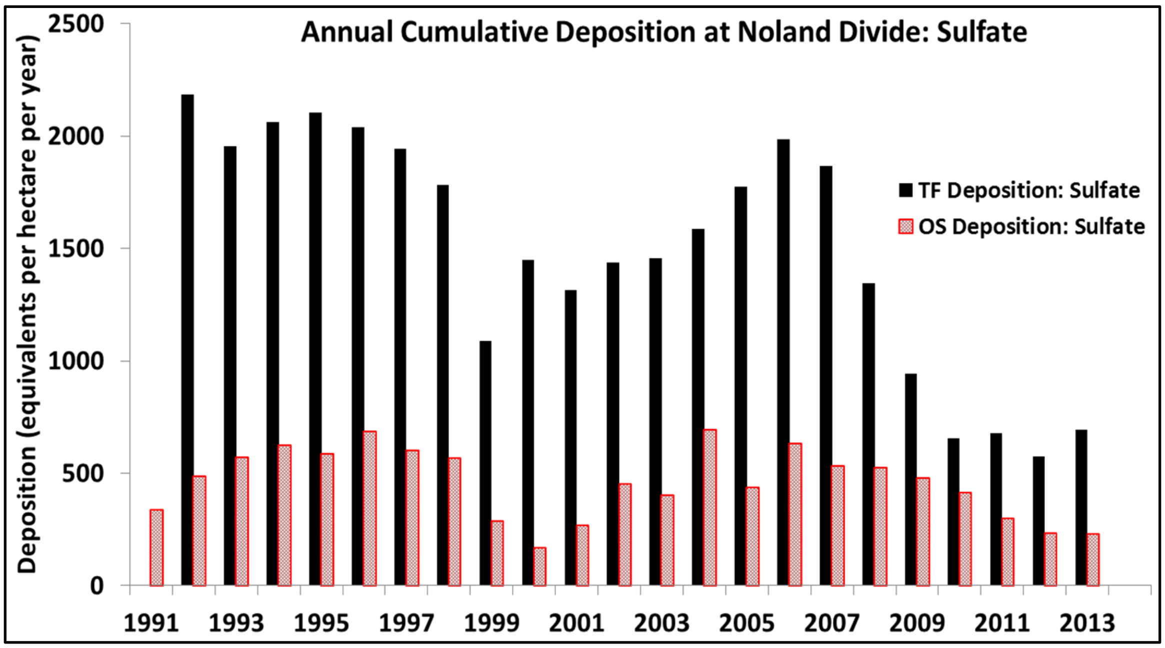


Figure 4.3.3. Total sulfate deposition measured in throughfall and precipitation at open sites within the Nolan Divide Watershed. Data for 1991 includes the latter part of the year only (Schwartz et al. 2014).

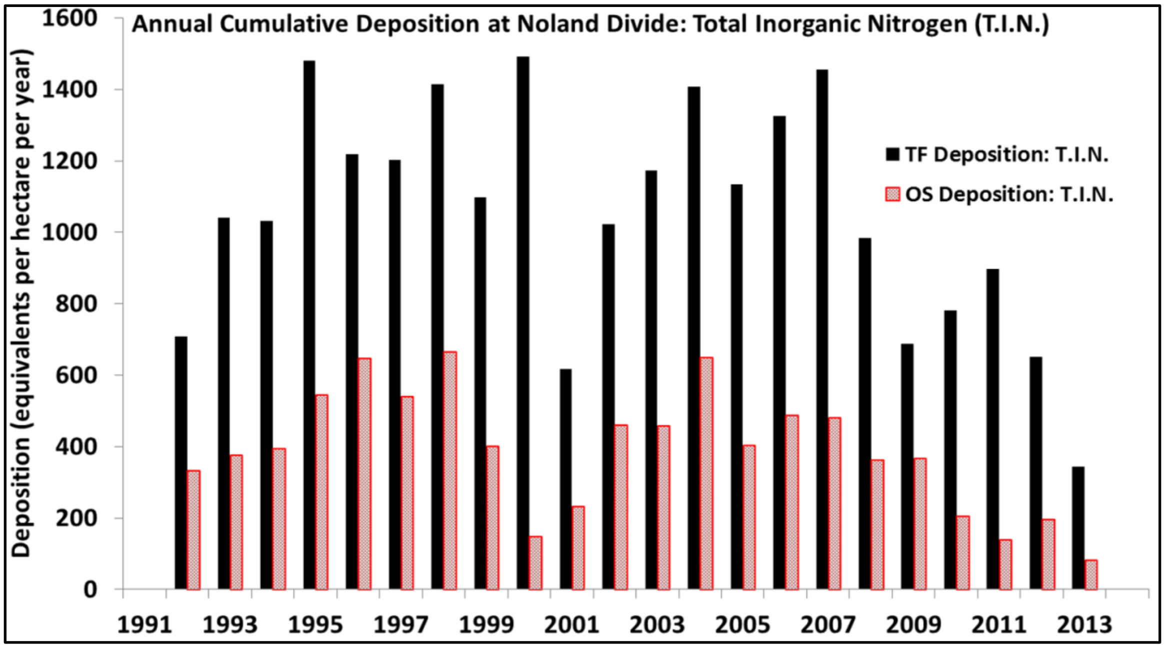


Figure 4.3.4. Total nitrogen deposition measured in throughfall and precipitation at open sites within the Nolan Divide Watershed. Data for 1991 includes the latter part of the year only (Schwartz et al. 2014).

Other Water Chemistry Parameters

In addition to pH and ANC, water quality also was assessed by examining the DO, specific conductance and temperature of surface waters within the historic site. While temperature is not a chemical parameter, it was included here because of its strong influence on solubility and other chemical processes.

The median and mean water temperatures for the entire data set and for the individual sites are generally well below the 29° C (84.2 °F) threshold set by the State of North Carolina for mountain and upper piedmont waters (NCDENR 2007) (Figure 4.3.5). Temperatures are Front Lake and Side Lake tend to approach the threshold during the summer, but only one measurement of 32.1° C (89.8 °F) taken from Front Lake during the summer of 2009 exceeds the threshold (Figure 4.3.5). With regard to temporal trends, yearly variations in annual and summer temperatures occur, but regression analyses show that temperature has not changed significantly over the monitoring period (Table 4.3.6).

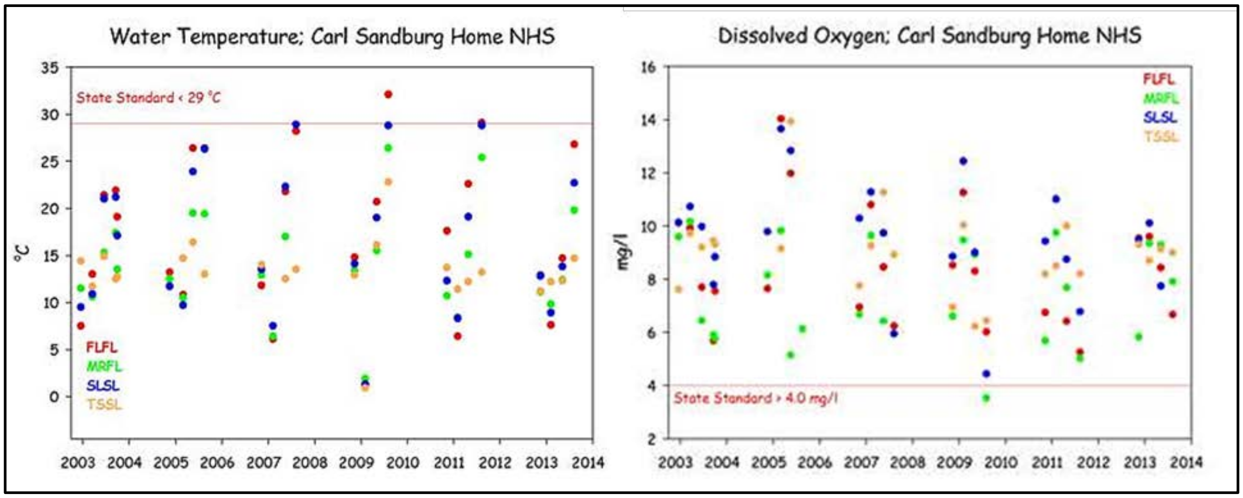


Figure 4.3.5. Changes in surface water temperatures at the four CARL monitoring sites between 2002 and 2014.

Table 4.3.6. Summary of time series regression analyses conducted for temperature and dissolved oxygen for the four sites at CARL.

Temperature					
Site	**n**	**r^2**	**p**	**Intercept**	**Slope**
Front Lake	**20**	**0.01**	**0.673**	**-6.9**	**0.001**
Mountain Reservoir	**21**	**0.008**	**0.699**	**-9.3**	**0.001**
Side Lake	**19**	**0.004**	**0.789**	**22.5**	**0.000**
Trout Pond Spring	**21**	**0.016**	**0.585**	**-22.0**	**0.001**
Dissolved Oxygen					
Front Lake	**20**	**0.0612**	**0.293**	**29.9**	**-0.0005**
Mountain Reservoir	**20**	**0.0222**	**0.531**	**17.9**	**-0.0003**
Side Lake	**20**	**0.0829**	**0.218**	**32.9**	**-0.0006**
Trout Pond Spring	19	0.0791	0.243	26.7	-0.0005

Similarly, median and mean DO concentrations are, with one exception, well above the 5 mg/L threshold set by North Carolina and used herein as a reference. Dissolved oxygen is inversely related to water temperatures; that is, cold water can hold more dissolved oxygen than warm water. Water at 1 °C (33.8 °F), for example, can hold 14.19 mg/L of dissolved oxygen, whereas water at 29 °C (84.2 °F) can hold only 7.67 mg/L. Data collected at the four CARL sites show that while DO occasionally approached the 5 mg/L threshold during the warm summer months in Slide Lake and Mountain Reservoir, the threshold is rarely crossed. Yearly variations in DO are also apparent in Figure 4.3.6, but regression analyses show DO concentrations have not changed significantly over the monitoring period for any of the monitored sites (Table 4.3.6). These data are consistent with DO values compiled by the NPS in 1998 (NPS 1998). They found that of the 283 measurements taken at 31 sites within and immediately adjacent to the historic site, a total of only 13 of the measurements were below 4 mg/L (the EPA standard) at Front Lake and Side Lake (NPS 1998).

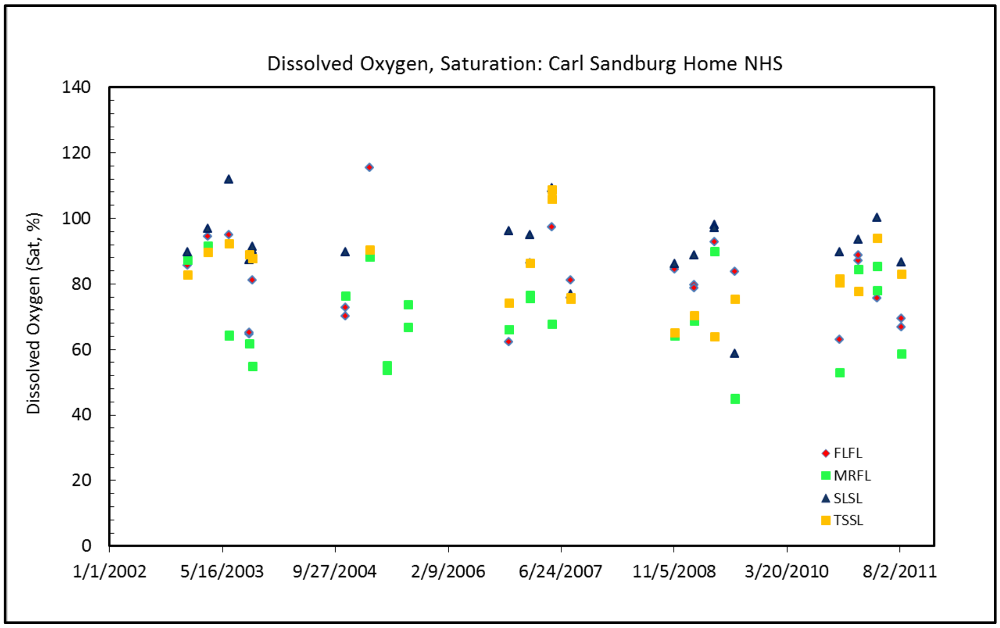


Figure 4.3.6. Changes in dissolved oxygen saturation at the four monitoring sites within CARL between 2002 and 2014.

Another way to examine DO concentrations is in terms of the degree to which the water is saturated at a specific temperature. Fish generally cannot survive in waters where DO saturation declines below about 30%, while a lack of oxygen, or hypoxia, may impact aquatic biota when saturation dips below approximately 50 to 60%. For cold water fish, "healthy" systems typically exhibit saturated DO values above 80% (Mallya 2007). The sites within CARL generally exhibited saturated DO values above 70%, although values below 70% were not uncommon at the Mountain Reservoir site where values between 55-60% were common during the warm summer months (Figure 4.3.6).

With regards to specific conductance, data collected from the four monitoring stations within the park between 2002 and 2013 exhibited maximum specific conductance values below 86.9 µS/cm. Less than 10% of the measurements exceeded 50 µS/cm, the utilized reference criterion. On a site by site basis, Front Lake exhibited significantly higher conductance values than the other three monitoring sites (Figure 4.3.7). The higher values at Front Lake are likely to reflect the input of dissolved constituents from developed areas outside of CARL which are then delivered to Front Lake via Meminger Creek (Figure 4.3.1). Measurements obtained since 2002 for all four sites show no systematic trend through time (although values were higher for all sites in 2009) (Figure 4.3.7). Thus, water quality is generally good with regards to specific conductance, and stable through time.

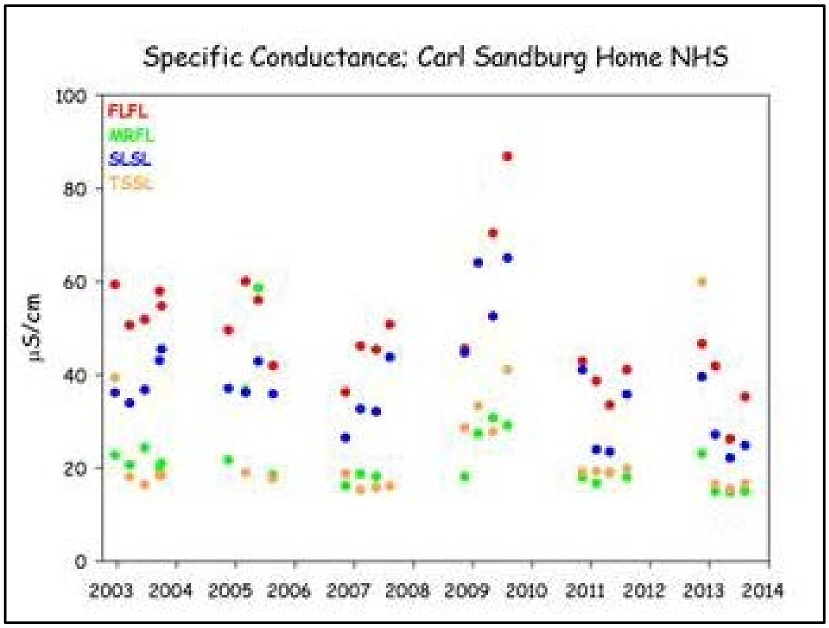


Figure 4.3.7. Specific conductivity measured at the four monitored sites within CARL between 2002 and 2014.

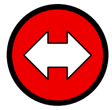
Confidence and Gaps

In general, there is a high degree of confidence in all five of the selected water quality parameters collected for analysis. Data have been collected for a period of more than ten years from four sites (within a relatively small area). One data gap that exists pertains to the collection of stream flow (discharge) data at the time of sample collection. Stream water chemistry is known to vary significantly as a function of stream flow (Miller et al. 2007, Neff et al. 2013). Moreover, contaminant load calculations require discharge (volumetric stream flow) data. At the present time, discharge data are collected for only one site (Mountain Reservoir), and sampling is conducted primarily during base flow. Thus, only general relationships can be assessed for the current condition of the surface waters, and changes in water quality parameters during floods cannot be determined. The collection of water quality and discharge data at additional sites and during storm events would enhance the analysis and interpretation of the water quality data within the historic site.

Summary Condition

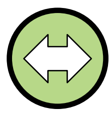
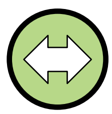
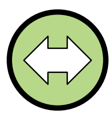
Stream water chemistry is summarized below with regards to surface water acidification and the general water quality within the historic site. With regards to the former, surface water acidification as represented by pH and ANC is a significant concern within CARL as values are frequently below the utilized reference criteria.

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

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Hydrogen (H^+) concentration (pH units)		Surface waters are often below a pH 6.0 and/or exhibit ANC values below 2.5 mg/l (50 μeq/L), Reference Condition: North Carolina Water Quality Standard for fish and aquatic life (Class C); Tennessee State ANC TMDL default target set for 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 park water quality, based on general water chemistry factions.

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)

4.3.2. Toxics

<u>Relevance</u>

The stream chemistry data provided above shows that the primary threat/stressor of concern, with regards to water quality, is surface water acidification. Acidification is closely linked to the atmospheric deposition of acid pollutants in the form of sulfur (S) and nitrogen (N) compounds. Air quality monitoring data collected since the 1980s have shown that the southern Appalachians and upper piedmont receive some of the highest levels of S and N deposition in the U.S. (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 GRSM at the Elkmont and Nolan Divide monitoring sites are well above those measured in other parks throughout the U.S. (Figure 4.3.8). 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).

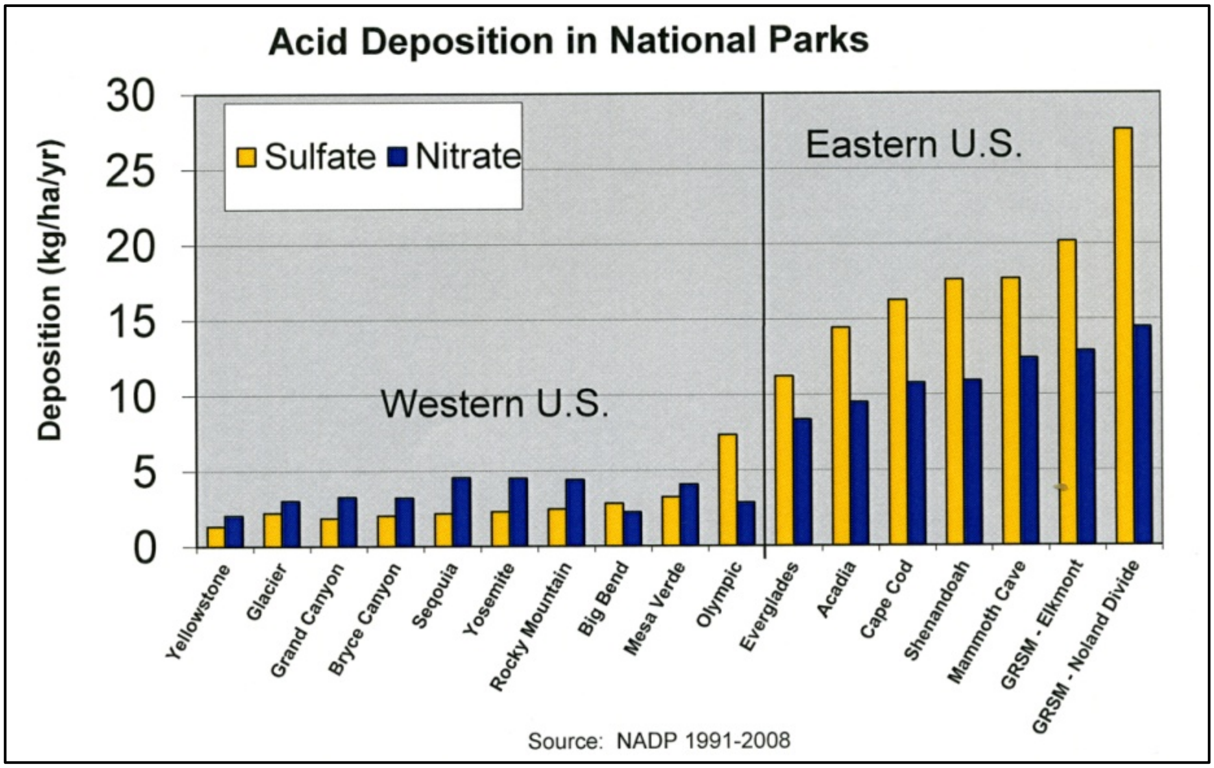


Figure 4.3.8. Average annual wet deposition of sulfate and nitrate in U.S. national parks (Vana-Miller et al. 2010).

A closely linked concern to both chronic and episodic surface water acidification is the potential mobilization of toxic metals (particularly, aluminum) 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). As discussed in more detail below, AlIM has been shown to disrupt fish gill ion transport, and lead to the loss of sodium, inhibiting ion regulation (Driscoll 1985, 2001).

Other toxic trace metals may also be of concern, particularly mercury (Hg). Although numerous Hg sources exist, the atmospheric deposition of Hg serves as an important, 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 show that the region, including CARL, is subjected to high rates of Hg deposition (Figure 4.3.9). In fact, Hg deposition rates within the Great Smoky Mountain National Park are some of the highest recorded for National Parks in the eastern U.S. (Figure 4.3.10) (NPS 2010a, Fisher and Wolfe 2012). Once released into the aquatic environment Hg is readily accumulated and biomagnified in biota, and poses a risk to both ecosystem and human health.

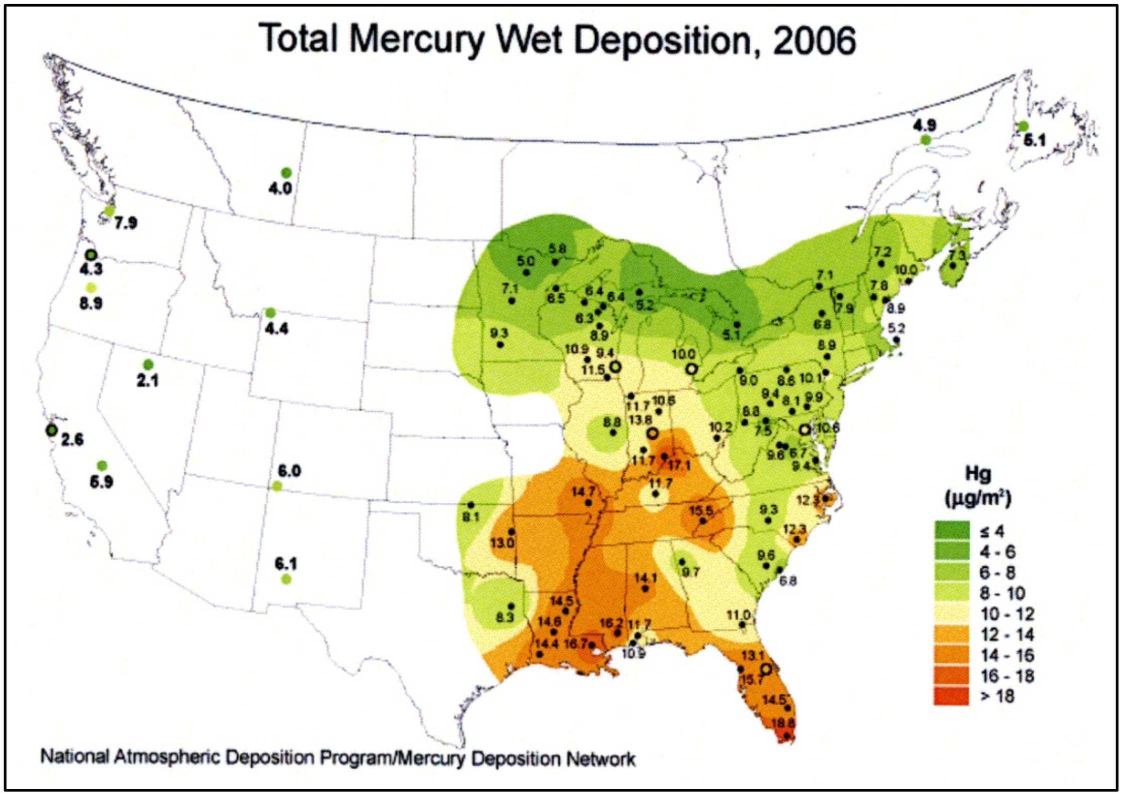


Figure 4.3.9. Map shown total wet mercury deposition in 2006 within the U.S. (Mercury Deposition Network 2006).

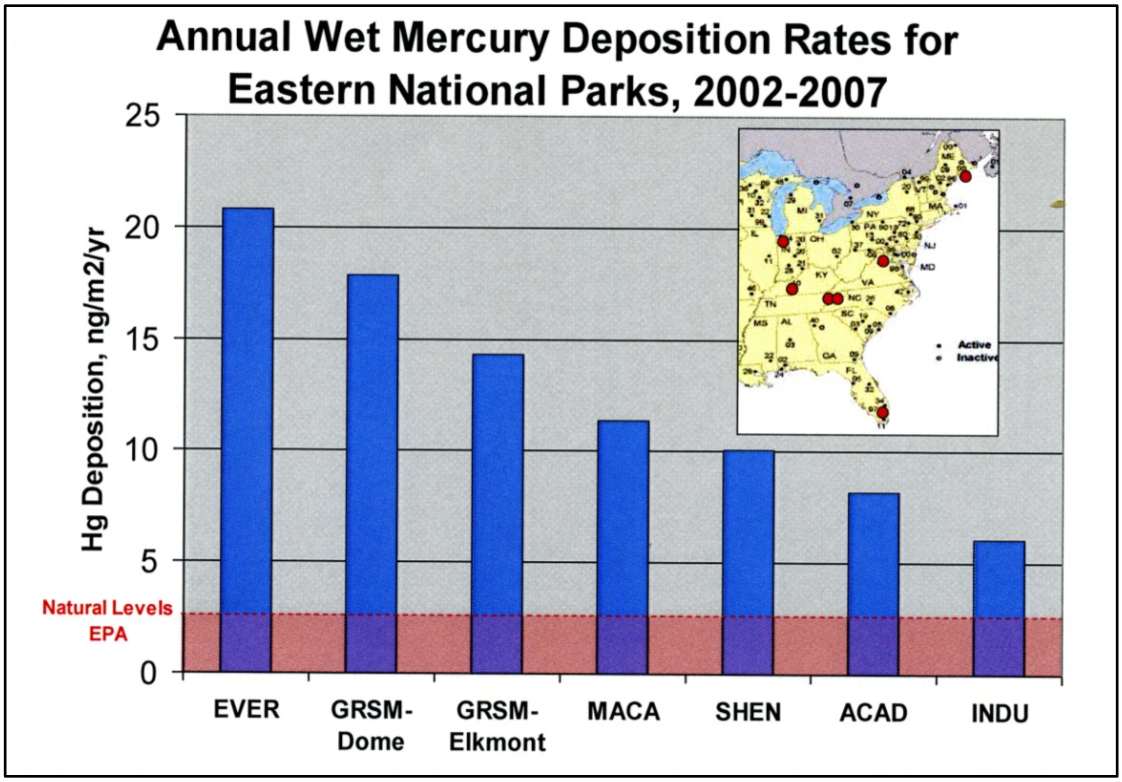


Figure 4.3.10. Comparison of annual wet mercury deposition rates measured in selected National Parks in the eastern U.S. between 2002 and 2007. Everglades National Park (EVER); Great Smoky Mountain National Park (GRSM); Mammoth Cave National Park (MACA); Shenandoah National Park (SHEN); Arcadia National Park (ACAD); Indiana Dunes National Lakeshore (INDU) (NPS 2010b).

Data and Methods

To date, dissolved Al data have not been collected for surface waters within CARL. However, data have been collected and interpreted for a number of sites within the region, including GRSM (Huckabee et al. 1975, Deyton et al. 2009, Neff et al. 2009, Cai et al. 2012, Neff et al. 2013). These external investigations are examined here to provide some insights into the potential risk of Al in surface waters of CARL to aquatic biota. Mercury and other trace metal data do not currently exist for the site.

Reference Conditions

Sulfate and Nitrate

The drinking water standards for sulfate and nitrate are 161 μeq/L (10 mg/L) and 5,205 μeq/L (250 mg/L), respectively. However, the primary concern within the historic site is the effect of sulfate and nitrate on stream water acidification. 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); thus, freshwater standards at the state or federal level are not directly applicable to this assessment. Thus, a reference condition is proposed here on the basis of the concentrations observed on a local and regional scale.

Regionally, Argue et al. (2011) characterized water chemistry, including nitrate and sulfate concentrations, within headwater streams along the Appalachian Trail (from Maine to Georgia). Median sulfate and nitrate concentrations for nine separate ecoregions vary from 49.76 to 233.18 µeq/L and 1.02 to 6.71 µeq/L, respectively. Sullivan et al. (2007) compiled nitrate and sulfate data from 66 watersheds in North Carolina, Tennessee, and South Carolina to calibrate a model used to assess stream water acidification. 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 Coweeta were ~12 µeq/L and < 5 µeq/L throughout the year, respectively (Hartman et al. 2009). These values are on the low end of the concentration range cited by Sullivan et al. (2007) and the Argue et al. (2011).

Zhou et al. (2014) estimated the mean, pre-industrial sulfate and nitrate concentration within12 watersheds in GRSM to be 9.5 + 7.1 µeq/L and 1.2 + 0.7 µeq/L, respectively, both within the range found at Coweeta. Thus, a concentration of 12 µeq/L for sulfate and <5 µeq/L for nitrate (as found at Coweta and estimated as a pre-industrial – 1850 - value) is used as a general reference concentration here.

Aluminum, Mercury, and Other 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 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 DOC content of the water. Calcium (Ca) concentrations are also important as Ca 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 between monitoring stations at the historic site as a result of their overall water chemistry.

The EPA Water Quality chronic and acute exposure criteria is 87 µg/L and 750 µg/L, respectively for freshwaters with a pH range of 6.5 to 9.0 (EPA 1986, 2013). The chronic exposure criteria is used here as a reference value. It is important to recognize that the criterion applies to the total recoverable Al within the waters, rather than the dissolved Al concentration. A potential constraint on using this reference is that surface waters within CARL exhibit pH values that are often below 6.4, and therefore fall outside of the pH range for which the EPA criteria apply. Moreover, a number of investigators have argued that the impacts of Al on trout occur at dissolved (rather than total) concentrations above 0.2 mg/L (200 µg/L) for both total dissolved Al and Al_{IM} (Neff et al. 2009, Cai et al. 2012).

The geochemistry of mercury is also 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 mono 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 ingested organic mercury is absorbed, 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.

With regards to other potentially toxic metals, Table 4.3.9 provides a comparison of the various water quality criteria that have been put forth for North Carolina and the EPA for selected metals. The utilized reference values are based on the maximum and continuous water quality criterion provided for fish and aquatic life by the State of North Carolina.

Table 4.3.9. Comparison of state and federal water quality standards for selected metals. Criteria used are for freshwater and/or the protection of fish and aquatic life.

Metal	North Carolina1 (total recoverable) (µg/L)	EPA3 (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)	1000	1000
Lead (Pb)	25	65 (acute); 2.5 (chronic); for hardness of 100 mg/L
Manganese (Mn)	—	---

Table 4.3.9 (continued). Comparison of state and federal water quality standards for selected metals. Criteria used are for freshwater and/or the protection of fish and aquatic life.

Metal	North Carolina1 (total recoverable) (µg/L)	EPA3 (µg/L)
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

Acid Causing Compounds

Stream water acidification within CARL is likely to result from high sulfate and nitrate concentrations associated with the deposition of S and N compounds from the atmosphere, and a lack of base cations to buffer the effects of acidification. While sulfate and nitrate data have not been collected for CARL, insights into their potential effects on water quality within the historic site can be gained by examining data the detailed studies conducted over the past 2.5 decades within GRSM. These investigations have shown that in comparison to many regions of the U.S. stream waters within the park (are presumably the region) exhibit a relatively high mean base flow sulfate concentration of 35.5 + 16.1 µeq/L (Zhou et al. 2014). This mean concentration is about three times higher than that measured at Coweeta and used as general reference level. Similarly, a mean volume weighted nitrate concentrations of 23.2 +12.2 µeq/L was calculated for the park by Zhou et al. (2014), a value that is an order of magnitude above the proposed reference concentration. While sulfate concentrations did not systematically vary between sites within the park, nitrate concentrations were generally higher in high elevation basins (Cai et al. 2012, Neff et al. 2013), presumably reflecting more precipitation and higher rates of atmospheric N deposition. Soil characteristics were also found to influence nitrate concentrations; higher stream water nitrate concentrations are found in basins with thin, steep soils characterized by high hydraulic conductivities (Ksat values), reduced interflow contact time, and relatively high soil organic matter percentages (Driscoll et al. 1995, Neff et al. 2013). In addition, watersheds dominated by high-elevation forests exhibit relatively high nitrate concentrations as a result of higher rates of nitrification and mineralization (Neff et al. 2013). Neither sulfate nor nitrate appear to be declining with recent decreases in the atmospheric deposition of N and S compounds, suggesting that sulfate and nitrate concentrations within surface waters of the park are controlled by a suite of complex biogeochemical processes and that the recovery of stream water acidification as a result of S and N deposition is a long-term process.

Dissolved Aluminum

As noted above, Al contamination is often associated with surface water acidification. Data pertaining to Al have not been collected for surface waters within CARL. However, a number of investigations have examined the concentration of dissolved Al and its potential effects on aquatic biota within GRSM (Huckabee et al. 1975, Deyton et al. 2009, Neff et al. 2009, Cai et al. 2012, Neff et al. 2013). As was the case of sulfate and nitrate, these Al data provide insights into the potential impacts of Al on surface waters within CARL.

On a Park-wide basis, Cai et al. (2012) found that mean dissolved Al concentrations with GRSM streams for both base flow and storm flow were below 0.2 mg/L (which they used as a criteria for biotic impacts). Nonetheless, significant variations in dissolved Al concentrations were observed both spatially within GRSM and temporally at any given monitoring site. On some occasions and localities, dissolved Al reached values in excess of 0.4 mg/L at monitoring sites within the park. The observed variability in Al concentrations correlated strongly with pH and ANC, presumably because the solubility of Al increases with decreasing pH. Thus, higher dissolved Al concentrations were generally found within higher elevation watersheds that tend to be characterized by higher rates of acid deposition, and lower pH and ANC. Cai et al. (2012), for example, demonstrated for GRSM that the toxicological impacts of pH, ANC, and dissolved Al primarily exceed toxicological thresholds within higher elevation streams. Temporally, higher dissolved Al concentrations were observed at a given site during storm flow events when pH and ANC episodically declined (Deyton et al. 2009, Neff et al. 2009, 2013), occasionally reaching values that represented toxic levels of dissolved Al for trout.

Confidence and Gaps

At the current time there is insufficient data to determine the current surface water quality condition in the historic site for sulfate, nitrate, and Al. Given their potential effects on aquatic biota, their strong correlation to pH and ANC, and studies conducted within GRSM (summarized above), there is a need to collect date on all three of these parameters. Similarly, Hg concentration data in water, sediments, or biota from CARL are currently unavailable, and should be obtained. Data for other metals (e.g., Cd, Cu, Pb, and Zn) are also lacking for the site and should be obtained.

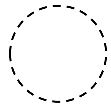
Summary Condition

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 for park water quality, based on the concentration of dissolved aluminum, nitrate, sulfate, and trace metals.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Sulfate, Nitrate Total dissolved concentration (mg/L)	(dashed circle)	Data within the park are limited. Reference Condition: Based on local and regional conditions
Water Quality	Dissolved Aluminum Concentration, Aluminum in water passing through 0.45 µm filter (µg/L)	(dashed circle)	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)

Table 4.3.10 (continued). Graphical summary of status and trends for park water quality, based on the concentration of dissolved aluminum, nitrate, sulfate, and trace metals.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
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

4.3.3. Microorganisms (Coliform)

<u>Relevance</u>

Pathogens leading to gastroenteritis affect 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 are a poor indicator 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).

<u>Data and Methods</u>

Data were obtained for fecal coliform in 2002, whereas total coliform was measured at the four sampling sites from 2003 to 2005. From 2006 to 2013 sampling has focused on *E. coli*.

<u>Reference Conditions</u>

For this evaluation, we use 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 utilize the EPA recommendation (576 cfu/100 mL, MPN**)** for waters in which there is infrequent swimming.

Table 4.3.11. Fecal coliform and *E. coli* criteria set by North Carolina and EPA, respectively.

Parameter	North Carolina (Fecal Coliform)	EPA (*E. coli*)
Bacteria	Organisms of the coliform group: fecal coliforms shall not exceed a geometric mean of 200/100 mL (MF count) based upon at least five consecutive samples examined during any 30 day period, nor exceed 400/100 mL in more than 20% 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 cfu/100 mL with no one value over 235 cfu/100 mL; 235 to 576 cfu/100 mL for instantaneous measurement of freshwaters depending on use; 576 cfu/100 mL for waters designated as "infrequent swimming."

Conditions and Trends

Data were obtained for total coliform between 2002 and 2005. Meiman (2007) found that total coliform levels were high (600 – 2,400 colonies per 100 mL), but noted that total coliform is a rather poor indicator of bacterial contamination. More recent data show that levels of *E. coli*, which is a better indicator of contamination, are relatively low. On a Site-wide basis, only one measurement of 980.4 cfu/100 mL at Trout Pond Spring in 2009 was above the EPA recommendations of 576 cfu/100 mL (Figure 4.3.11). Figure 4.3.11 shows that *E. coli* is consistently higher in Front Lake, most likely reflecting the input of coliform to Meminger Creek in areas outside of the historic site.

The two highest values of 387.3 and 980.4 cfu/100 mL water were both measured in 2009 from Front Lake and Trout Pond Spring, respectively. *E. coli* values are known to vary widely with hydrologic conditions; thus, the high values are likely to reflect the low flow conditions associated with the drought in 2009. In general, there is no notable change in *E. coli* values over the monitoring period.

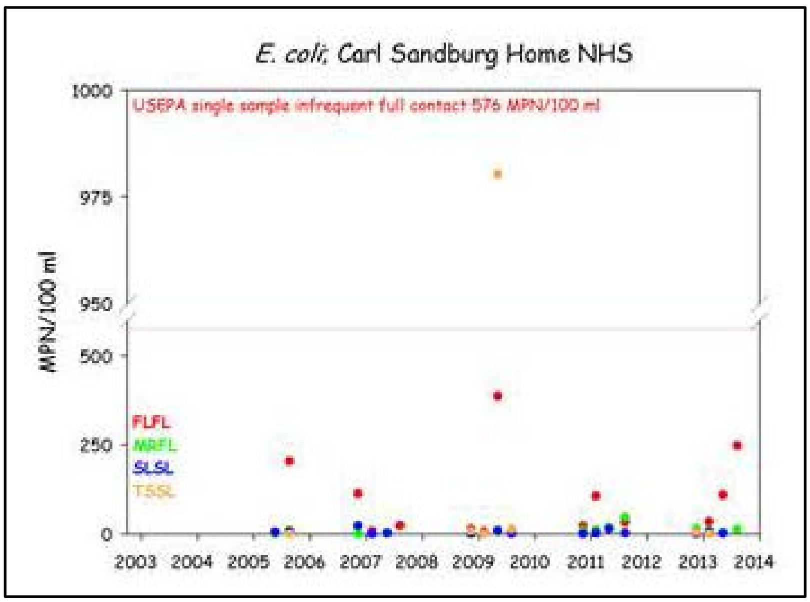


Figure 4.3.11. Site-wide variations in *E. coli* from 2005 to 2014.

Confidence and Gaps

In general, there is a high degree of confidence in the described *E. coli* conditions for surface waters within the historic site. Data are available for four sites within a relatively small area, and data have now been collected for nearly a decade.

Summary Condition

In light of the fact that *E. coli* values are generally below the EPA threshold value of 576 cfu/100 mL for waters infrequently used for swimming over the past eight years, water quality with respect to bacteria is thought to be stable and good.

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

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Water Quality	Coliform Bacteria (MPN/100 mL)		With one exception, measured values are below reference values. North Carolina standard for fecal coliform (200 cfu/100 mL of water); EPA Criteria for *E.Coli* (576 MPN/100 mL)

4.4. Invasive Species

4.4.1. Invasive Exotic Plants

Relevance

Exotic invasive plant species (also referred to as non-native species) are a major stressor that affects vegetation communities and are ranked highly among a core set of vital signs in the CUPN Parks. Although many exotic species remain relatively innocuous in the landscape, some exotic 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 CUPN parks, exotic invasive species tend to become established in disturbed areas, floodplains, high visitor-use areas, and along park boundaries (CUPN 2013).

While some exotic species are inadvertently introduced, in some cases they are purposely planted. For example, at CARL, where the cultural landscape is of particular importance, some plants including English ivy (*Hedera helix*) were planted by owners predating the Sandburgs (Figure 4.4.1). The English ivy is likely attributable to the Smyth period. When buying the estate, the ivy spilling over various rock walls was one of the selling points for Mrs. Sandburg (Hart 1993). Such plantings pose a management challenge to staff as these areas need to be preserved as part of the historical landscape yet constantly kept in check for spread into adjacent plant communities.

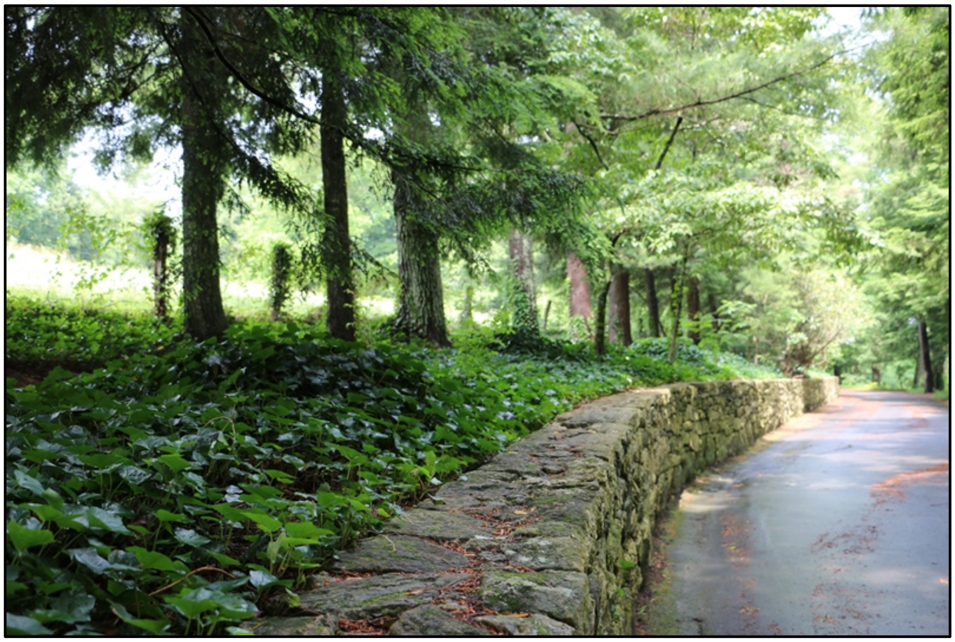


Figure 4.4.1. English ivy planted along the allée. Note the ivy growth on the hemlock trunks and fence posts in the background. Resource managers must manage some invasive species as part of the cultural landscape while simultaneously preventing invasion into adjacent areas.

Invasive/exotic plant species occur throughout the park, and primarily in areas most accessed by visitors, such as roadways and trails, pastures, rock outcrops, park land that boarders public roads and residences, the two small lakes (Front Lake and Side Lake) and the stream leaving Side Lake. In locations that are not commonly visited, such as areas away from trails, exotic plant species are infrequent. Remote rock outcrops are the exception where sweet vernal grass (*Anthoxanthum odoratum*), Asiatic dayflower, and a number of other potentially disruptive non-natives have begun to invade.

Non-native invasive flora of the grassland/pasture community experiences frequent shifts in species composition, where non-native species appear due to seed dispersal from adjacent sites or from further afield via bird dispersal. All locations must be monitored annually for the appearance of new invasive exotic species and for sudden upsurges in population and infestation expansion.

Data and Methods

Three key data sources were used to assess invasive exotic plants at CARL. First, the National Park Service maintains digital records for all plant species found in each park unit (NPSpecies 2015). A subset of this list including all exotic species currently found at CARL, with invasiveness rankings from the North Carolina Plant Society (2014), was used to provide an overview of exotic invasive species that are currently affecting park resources.

A second data set is derived from the Vegetation Monitoring Protocol for the Cumberland Piedmont Network (White et al. 2011) that provides a framework for monitoring invasive species already present in the park. Exotic species are monitored based on their occurrence in a network of 20 plots located in various vegetation communities throughout CARL. Plots are revisited every five years.

“High priority” species are determined based upon state Exotic Plant Pest Council lists for Kentucky, Tennessee, South Carolina, North Carolina, Alabama, and Virginia.

Third, CARL has adopted CUPN’s Invasive Species Early Detection and Rapid Response Plan (ISEDRRP) (Keefer et al. 2014). This plan lists species that have the potential to affect park resources and provides strategies to detect these species through opportunistic observations. Habitat-specific treatment recommendations are presented based on each species’ regional status, impact, trends, and dispersal dynamics. The goal is to eradicate incipient populations of invasive species before they become widely established. Identifying high priority species, or species that “occur in localized areas of parks, are extremely rare, or are not currently within a park, but have the potential to cause major ecological, cultural, or economic problems if they were to become established,” is a main objective of the plan (Keefer et al. 2014).

Reference Conditions

Given that it would likely be impossible to eliminate all invasive exotic plants from CARL, we consider a more logical reference condition to be maintaining or reducing invasive exotic species to levels where they do not threaten the ecological integrity of plant communities. By this we mean the ecological structure (biotic and abiotic components) and processes remain intact for each native community type.

Current Conditions and Trends

There are currently 118 non-native vascular plant species in CARL (NPSpecies 2015). Of these, 42 are ranked for their invasiveness by the NC Native Plant Society (2014) (Table 4.4.1). The invasiveness ranking is expressed on a scale of one to three, with one representing species that have the most invasive characteristics and spread readily into native plant communities where they displace native vegetation, and three representing species that are presently considered a low threat to native communities. Fourteen species are ranked one, 19 as two, and 9 as three.

Table 4.4.1. Exotic species at CARL ranked by their invasiveness (NPSpecies 2015). Rankings from 1 (most invasive) to 3 (least invasive) (NC Native Plant Society 2014).

Scientific Name	Common Names	NC Rank
Ailanthus altissima	Tree of Heaven	1
Celastrus orbiculatus	Oriental bittersweet	1
Elaeagnus umbellata var. parvifolia	Autumn olive, oleaster	1
Euonymus alata	Burning bush	1
Euonymus fortunei var. *radicans*	Winter creeper	1
Hedera helix	English ivy	1
Lespedeza cuneata	Chinese lespedeza	1
Ligustrum sinense	Chinese privet	1
Lonicera japonica	Japanese honeysuckle	1
Microstegium vimineum	Japanese stiltgrass	1

Table 4.4.1 (continued). Exotic species at CARL ranked by their invasiveness (NPSpecies 2015). Rankings from 1 (most invasive) to 3 (least invasive) (NC Native Plant Society 2014).

Scientific Name	Common Names	NC Rank
Murdannia keisak	Aneilima	1
Paulownia tomentosa	Princess tree	1
Polygonum cuspidatum	Japanese knotweed	1
Rosa multiflora	Multiflora rose	1
Ampelopsis brevipedunculata	Porcelainberry	2
Arthraxon hispidus	Hairy jointgrass	2
Berberis thunbergii	Japanese barberry	2
Conium maculatum	Poison hemlock	2
Dioscorea oppositifolia	Chinese yam	2
Glechoma hederacea	Groundivy	2
Ligustrum vulgare	European privet	2
Lonicera morrowii	Morrow's honeysuckle	2
Mahonia bealei	Beale's Oregon grape	2
Miscanthus sinensis	Chinese silvergrass	2
Morus alba	White mulberry	2
Myriophyllum spicatum	Eurasian watermilfoil	2
Polygonum caespitosum	Bristled knotweed, bunchy knotweed, oriental lady's thumb, oriental ladysthumb	2
Spiraea japonica	Japanese spiraea	2
Stellaria media	Common chickweed	2
Veronica hederifolia	Ivyleaf speedwell	2
Vinca major	Greater periwinkle	2
Vinca minor	Lesser periwinkle	2
Wisteria floribunda	Japanese wisteria	2
Allium vineale ssp. *vineale*	Wild garlic	3
Artemisia vulgaris var. vulgaris	Common wormwood	3
Bromus catharticus	Rescue brome	3
Cirsium vulgare	Bull thistle	3
Daucus carota	Queen Anne's lace	3
Leucanthemum vulgare	Oxeye daisy	3
Perilla frutescens	Beefsteakplant	3
Populus alba	White poplar	3
Vicia sativa	Common vetch	3

Each year the list of invasive exotic plants at CARL is reviewed as part of the ISEDRRP process. During this review process, new invasive species threats are evaluated for possible inclusion and the prior year's list of species are evaluated for removal from the list. The purpose of the review is to ensure the list of invasive species threats is current and includes high priority species. Keefer et al. (2014) suggests the threat from invasive exotic plants is increasing in CARL. In 2013, 13 species were given early detection status and another seven were being considered for early detection status (Table 4.4.2).

Table 4.4.2. Early detection invasive plant species at CARL. ED=early detection plant species; P=already present in the park; PP=probably present in the park; ? =considering adding to 2013 early detection list; L=low priority (Keefer et al. 2014).

Scientific Name	Common Name	Status
Alternanthera philoxeroides	Alligatorweed	ED
Hydrilla verticillata	Waterthyme/hydrilla	ED
Myriophyllum aquaticum	Brazillian watermilfoil	P
Myriophyllum spicatum	Eurasian watermilfoil	P
Acer platanoides	Norway maple	?
Aegilops cylindrica	Jointed goatgrass	L
Ailanthus altissima	Tree of heaven	P
Akebia quinata	Chocolate vine	L
Albizia julibrissin	Silktree	PP
Alliaria petiolata	Garlic mustard	ED
Ampelopsis brevipedunculata	Amur peppervine	P
Anthoxanthum odoratum	Sweet vernalgrass	P
Arctium minus	Lesser burdock	P
Arthraxon hispidus	Small carpgrass	P
Berberis thunbergii	Japanese barberry	P
Cayratia japonica	Bushkiller	?
Celastrus orbiculatus	Oriental bittersweet	P
Commelina benghalensis	Tropical spiderwort	L
Cirsium arvense	Canada thistle	ED
Cirsium vulgare	Bull thistle	P
Commelina communis	Asiatic dayflower	P
Conium maculatum	Poison hemlock	P
Cuscuta japonica	Japanese dodder	L
Dioscorea oppositifolia/polystachia	Chinese yam	P
Elaeagnus umbellata	Autumn olive	P
Euphorbia cyparissias	Cypress spurge	L
Eleusine indica	Indian goosegrass	P
Euonymus alatus	Burningbush	P
Euonymus fortunei	Winter creeper	P

Table 4.4.2 (continued). Early detection invasive plant species at CARL. ED=early detection plant species; P=already present in the park; PP=probably present in the park; ? =considering adding to 2013 early detection list; L=low priority (Keefer et al. 2014).

Scientific Name	Common Name	Status
Hedera helix	English ivy	P
Heracleum mantegazzianum	Giant hogweed	L
Humulus japonicus	Japanese hop	L
Imperata cylindrica	Cogongrass	ED
Ligustrum amurense	Amur privet	?
Ligustrum japonicum	Japanese privet	PP/?
Ligustrum lucidum	Glossy privet	?
Lonicera spp.	Bush honeysuckles	?
Lygodium japonicum	Japanese climbing fern	ED
Lythrum salicaria	Purple loosestrife	ED
Melia azedarach	Chinaberrytree	ED
Metha x piperita	Peppermint	P
Miscanthus sinensis	Chinese silvergrass	P
Morus alba	White mulberry	P
Mudannia keisak	Watremoving herb	P
Nandina domestica	Sacred bamboo	PP/L
Nasturtium offiniale	Watercress	L
Nymphoides cristata	Crested floatingheart	L
Oplismenus hirtellus spp. undulatifolius	Wavyleaf basketgrass, basketgrass	ED
Paederia foetida	Skunk-vine	L
Paulownia tomentosa	Princesstree	P
Phragmites autralis	Phragmites, common reed	ED
Polygonum cuspidatum/P. sachalinense	Japanese knotweed/giant knotweed	P
Polygonum perfoliatum (=Persicaria perfoliata)	Asiatic tearthumb, mile-a-minute	ED
Poncirus trifoliata	Hardy orange	L
Pueraria montana	Kudzu	ED
Quercus acutissima	Sawtooth oak	L
Rhodotypos scandes	Jetbead	L
Rhubus phoenicolasius	Wine rasberry	L
Salvinia molesta	Kariba-weed	L
Solanum viarum	Tropical soda apple	ED
Spiraea japonica	Japanese meadowsweet	P
Striga asiatica	Asiatic witchweed	L

Table 4.4.2 (continued). Early detection invasive plant species at CARL. ED=early detection plant species; P=already present in the park; PP=probably present in the park; ? =considering adding to 2013 early detection list; L=low priority (Keefer et al. 2014).

Scientific Name	Common Name	Status
Triadica sebifera	Chinese tallow	?
Viburnum dilatatum	Linden arrowwood	L
Vinca major	Bigleaf periwinkle	P
Wisteria spp. (floribunda, sinensis)	Wisteria	P

A total of 14 exotic species were documented in the 20 CUPN long-term vegetation monitoring plots (unpublished CUPN). Eleven of those species are considered "High Priority" (Table 4.4.3). The highest number of exotic species (12) was found in a plot located in vegetation that had been heavily influenced by human activity. Two plots, which are located near a private residential area, had two occurrences each, and one plot, located in a hardwood successional forest, had one occurrence.

Table 4.4.3. Exotic species found in the 20 CUPN long-term vegetation monitoring plots at CARL and their priority (unpublished CUPN).

Scientific name	Common name	# plots	High priority
Spiraea japonica	Japanese meadowsweet	4	Y
Lonicera japonica	Japanese honeysuckle	3	Y
Microstegium vimineum	Japanese stiltgrass	2	Y
Hedera helix	English ivy	2	Y
Rosa multiflora	Multiflora rose	1	Y
Prunus cerasus	Sour cherry	1	
Polygonum caespitosum	Bristled knotweed	1	Y
Mahonia bealei	Beale's barberry	1	
Ligustrum sinense	Chinese privet	1	Y
Ilex crenata	Japanese holly	1	
Euonymus alata	Burning bush	1	Y
Celastrus orbiculatus	Asian bittersweet	1	Y
Berberis thunbergii	Japanese barberry	1	Y
Ailanthus altissima	Ailanthus	1	Y

Based on the monitoring data, CARL has one of the lowest incidences of exotic plant species within CUPN with an average of one species per plot (Figure 4.4.2). Only four other parks in the CUPN have lower incidences. The relative low number of exotic species may be attributed in part to CARL's geology, which creates dry, infertile sites that are much less susceptible to exotic species (Bill Moore, personal communication 2015).

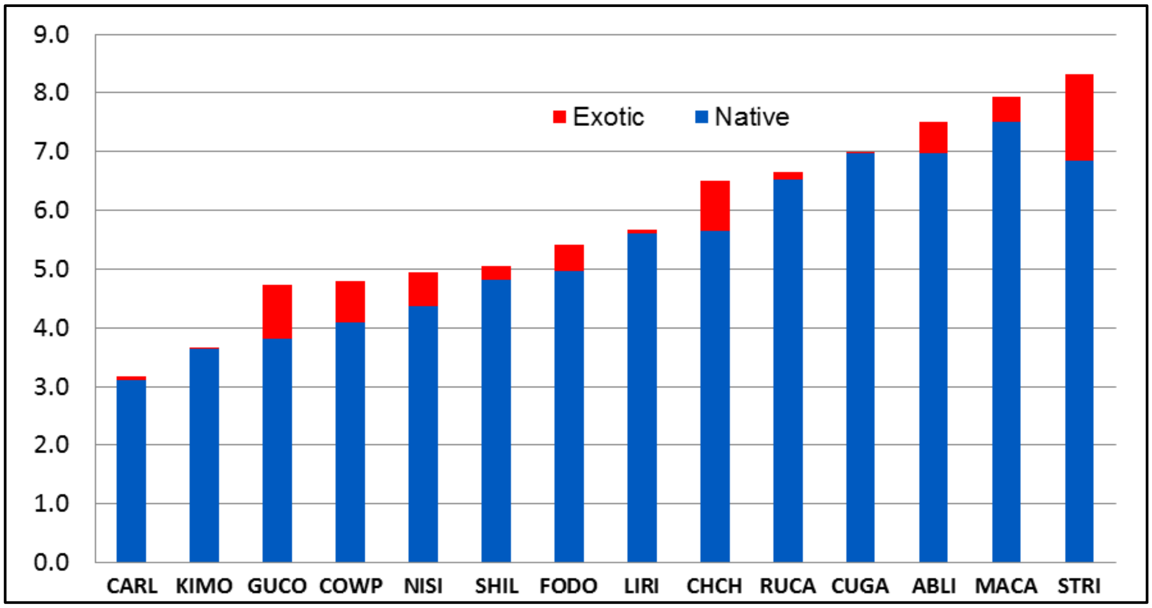


Figure 4.4.2. Average number of native and exotic plant species per 1 m^2 subplot in the CUPN parks (CUPN 2013).

Granitic Domes

Of particular concern are invasive species that threaten the granitic domes in the park. Since native species that are typically associated with granitic domes are very slow to recover after disturbance, aggressive exotic species may quickly take over and prevent native vegetation cover from re-establishing. White (2003) reports that wherever visitors have strayed from trails in CARL, exotic species and common field weeds have replaced delicate granitic dome species. A botanical survey performed from 2006-2007 identified 20 exotic plant species on and around the granitic dome communities. Using the Alien Plant Ranking System (APRS) Woolsey (2010) prioritized 10 of the most frequently occurring plant species by separating innocuous exotic species from those that are invasive as well as identifying species that have a high potential to affect the granitic dome communities in the future (Table 4.4.4). Woolsey found that exotic species were present on all the park's granitic domes. Six of the seven highest ranking species in the APRS are categorized as Rank 1 invasive exotics in the state of North Carolina. At this time, there are no strategies in place to reduce or prevent visitor impacts on the granitic dome communities. However, the park staff give occasional interpretive programs about these communities, with the intention of educating and raising awareness of the impacts they have on the domes (Irene Van Hoff, personal communication 2015).

Table 4.4.4. APRS and NC ranks for the ten most common exotic species found on the granitic domes at CARL (Woolsey 2010).

APRS Rank	Scientific Name	Common Name	State Rank	# Outcrops Species Found
1	*Ligustrum sinense*	Chinese privet	Rank 1	9
2	*Lonicera japonica*	Japanese honeysuckle	Rank 1	3
3	*Hedera helix*	English ivy	Rank 1	3
4	*Rosa multiflora*	Multi-flora rose	Rank 1	3
5	*Microstegium vimineum*	Japanese stilt grass	Rank 1	4
6	*Commelina communis*	Asiatic dayflower	SNR	9
7	*Ailanthus altissima*	Tree-of-heaven	Rank 1	2
8	*Rumex acetosella*	Sheep sorrel	SNR	3
9	*Anthoxanthum odoratum*	Sweet vernal grass	SNR	10
10	*Polygonum caespitosum*	Oriental smartweed	SNR	3

Monitoring for invasive species is performed on both an opportunistic (ISEDRRP) and project funded basis. Project funded monitoring occurs roughly every two years. Additionally, the NPS Southeast Exotic Plant Management Team assists park resource managers on an annual basis by providing additional information and monitoring for new species in locations that are undergoing treatment (Irene Van Hoff, personal communication 2015). Under the ISEDRRP and funded projects, exotic invasive species are monitored and treated year-round, except for a few months over the winter. Park staff and volunteers incorporate integrated pest management. Control methods depend on what species is being treated and include hand-pulling, foliar and stump herbicide treatments, bark herbicide applications, and girdling with herbicide application to the cambium on undesirable trees. Some species are particularly difficult to control due to seedbanks that continually add new propagules every year. Such species, including Japanese stiltgrass (*Microstegium vimineum*) (Figure 4.4.3), Asiatic dayflower, parrot feather watermilfoil (*Myriophyllum aquaticum*), among others, require constant monitoring and control efforts.

Figure 4.4.3. Japanese stiltgrass infestation on trailhead at CARL.

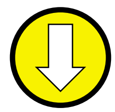
Invasive plant species are a serious threat to the plant communities at CARL. There are eleven high-priority invasive plant species found in CARL's CUPN long-term vegetation monitoring plots and 14 species across the entire park that are Rank 1 species and considered highly invasive by various state EPPC lists. Many of these species tend to be concentrated in the open fields that were previously grazed, as well as in areas along public roads. Invasive species are also found on and around all granitic dome communities, which are a critical resource at CARL. Monitoring and treatment is labor intensive and requires many hours from both paid staff and volunteers. The vectors by which species infest the park are numerous and varied. While nothing can be done to completely eradicate certain species, the park works diligently to control and treat existing populations. However, the entry of these species will always be a problem, either from adjacent private property, park visitors, or a myriad of other human- or natural entry ways. Through the park's efforts, some progress has been made; however, most invasive exotic species are not under control (Irene Van Hoff, personal communication 2015). A continuing and vigilant monitoring program is necessary for the effective management of exotic invasive species in the park. Monitoring efforts document that invasive exotic plants have been found in CARL, and the number of species appears to be increasing. However, in most cases exotic plants are limited to highly trafficked areas and have not significantly impacted large areas of native plant communities. Therefore, we assign a moderate level of concern with a deteriorating condition.

<u>Confidence and Data Gaps</u>

CUPN monitoring plots were established and monitored beginning in 2011, giving only a small time-frame in which to determine longer term trends in invasive species plant populations and their spread. However, with park resource managers' intimate and long-running knowledge of problematic exotic invasive species in the park, we assign a high confidence level to this assessment.

Summary Condition and Graphic

Table 4.4.5. Graphical summary of status and trends for invasive exotic plants.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Invasive Species	Invasive Exotic Plants		Reference condition is maintaining or reducing invasive exotic species to levels where they do not threaten the ecological integrity of plant communities. Monitoring efforts document that invasive exotic plants have been found in CARL, and the number of species appears to be increasing. However in most cases exotic plants are limited to highly trafficked areas and have not significantly impacted large areas of native plant communities.

Sources of Expertise

- Kurt Helf, Ecologist, Cumberland Piedmont Network
- Teresa Leibfreid, Network Program Manager, Cumberland Piedmont Network
- Shepard McAninch, Ecologist, Cumberland Piedmont Network
- Bill Moore, Data Manager/Ecologist, Cumberland Piedmont Network
- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site
- NPS-EPMT (National Park Service, Exotic Plant Management Team)
- NatureServe
- Appalachian State University

4.5. Infestations and Disease

4.5.1. Insect Pests

Relevance

Invasive forest pests and pathogens (IFP's) can greatly impact forest systems. Just a few years after invasion, IFPs can alter forest light regimes, microclimate, and nutrient cycling; and within a few decades, they can alter species composition and forest structure at both the ecosystem and landscape scale (CUPN 2009). Roughly 80% of CARL is forested, which makes the park susceptible to IFP's. Non-native pests can be particularly damaging due to the lack of natural defense mechanisms to control their spread.

Data and Methods

The monitoring of exotic invasive forest pests and pathogens (IFPs) is an important part of CUPN's monitoring protocols. Numerous federal and state agencies, research institutions, and non-governmental agencies compile data on IFP characteristics and model future outbreaks and major pathways. CUPN uses these data to monitor the network parks. Resource managers monitor for several non-native forest pests and pathogens at CARL. Data used in this assessment came from the CUPN's forest monitoring plots located at CARL and from observations from park staff. Twenty plots located across the park's forests are surveyed every five years by CUPN staff for key stressors, including forest pests. For this assessment, the presence/absence of hemlock woolly adelgid (HWA) (*Adelges tsugae*) and treatment efficacy were used to assess the current condition of insect pests. Level of concern was derived from the presence/absence of HWA in and around the park, and the availability of continued resources for treatments.

<u>Reference Conditions</u>
Hemlock woolly adelgid is not causing mortality and individual hemlock trees are healthy and able to live and grow to their full size and life span.

<u>Current Conditions and Trends</u>
Forests within the park have experienced tree mortality as a result of southern pine beetle, Asian ambrosia beetle, and turpentine beetle. However, the primary pest threat to the park is the hemlock woolly adelgid (HWA). HWA is one of the most serious invasive pests to the region's hemlock trees. This pest initially invaded the southern Appalachians in the early 2000s and is now well-established throughout the Blue Ridge Mountains. HWA is a native to Japan and preys upon both eastern hemlock (*Tsuga canadensis*) and Carolina hemlock. Left untreated, hemlocks usually die within five to seven years after infestation.

Figure 4.5.1. White woolly wax, with which the hemlock woolly adelgid protects itself and eggs, are apparent on this hemlock at CARL (Carey Burda).

CARL has several areas where eastern hemlock occur. Eastern hemlock is co-dominant with white pines (*Pinus strobus*), white oak, or black oak (*Quercus velutina*) in the park's White Pine Successional Forest association. This association occurs in the far northwestern corner of the park (adjacent to park administration facilities), the far northeastern corner of the park bordering Little River Road, and just south of the Carl Sandburg house. Several hemlocks of great importance to CARL's cultural and natural landscape are part of the landscaping along front entry drive. In 1950, following years of white pine decline and mortality from disease and storms the Sandburgs planted approximately 100 eastern hemlock along the allée. The 1993 cultural landscape report for the park recommended following the Sandburgs' example by replacing any remaining white pines with hemlocks as the white pines declined. In 2004, hurricanes Ivan and Francis passed through the park. The storms damaged some of the hemlocks along the front entry drive. Following the storm, the damaged hemlocks were carefully pruned by an arborist to encourage clean healing of the wounds.

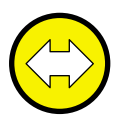
Resources managers treat all large hemlocks within park boundaries. The 420 mature trees are treated with soil injections and younger trees are treated with insecticidal soap. Hemlocks are in good condition under the current treatment regime and their health appears to be stable and unchanging. However, spot infestations of HWA will be a continual problem on small untreated shrub- and sapling-sized trees. A regular treatment regime, which is dependent upon dedicated resources, both financially and through park staff labor, is required for the trees' future. Since HWA causes the eventual mortality of its host, and resources are tenuous at best, we assign a medium level of concern to this assessment.

Confidence and Data Gaps

We assign a high level of confidence to this assessment as the threat of HWA to hemlocks is well-understood, park staff have located all hemlock trees in the park, and each mature tree is treated for HWA and monitored on a regular basis.

Summary Condition and Graphic

Table 4.5.1. Graphical summary of status and trends for insect pests.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Infestations and Diseases	Insect Pests		The presence/absence of hemlock woolly adelgid and treatment efficacy were used to assess the current condition of insect pests. The reference condition consists of HWA not causing mortality or preventing individual hemlock trees to live and grow to their full size and life span. Hemlocks are in good condition under the current treatment regime and their health appears to be stable and unchanging.

Sources of Expertise

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site
- Teresa Leibfreid, Network Program Manager, Cumberland Piedmont Network
- Kurt Helf, Ecologist, Cumberland Piedmont Network
- Bill Moore, Data Manager/Ecologist, Cumberland Piedmont Network
- Shepard McAninch, Ecologist, Cumberland Piedmont Network

4.5.2. Plant Diseases

Relevance

The monitoring of exotic invasive forest pests and pathogens (IFP) is an important part of CUPN's monitoring protocols. Roughly 80% of CARL is forested, which makes monitoring for IFPs particularly important in the park. In the span of a few years after invasion, IFPs can "alter forest light regimes, microclimate, and nutrient cycling. In the long-term, (i.e., decades) they can alter tree species composition and so their effects may ramify through the entire forest ecosystem and beyond." (CUPN 2009). Numerous federal and state agencies, research institutions, and non-governmental agencies compile data on IFP characteristics and model future outbreaks and major pathways. CUPN uses these existing data to monitor the network parks. CARL monitors for several non-native forest pathogens. The primary forest pathogen threat to the park is dogwood anthracnose (*Discula destructive*).

Dogwood Anthracnose

Flowering dogwood (*Cornus florida*) is an important understory tree species in second-growth stands at CARL. It is sometimes described as a calcium "pump" because the tree draws the mineral from deeper mineral soil and enriches surface soil horizons with its foliar biomass. The foliage contains significantly higher amounts of calcium than almost any other forest species (Jenkins et al. 2007) making it a major soil builder in forests and a significant component to calcium cycling. Its high protein fruit is important food for migratory birds in the fall and the twigs and leaves are a favored browse for herbivores.

Figure 4.5.2. Foliar symptoms of dogwood anthracnose (bugwood.org).

Dogwood anthracnose is an introduced pathogen that entered the United States in 1977. The fungus creates scattered mortality in landscape settings; however, it is most severe in cool, moist areas, especially in the understory. Wet, cool spring-time conditions create ideal conditions under which flowering dogwoods may be infected by the *Discula* fungus. The impacts of dogwood anthracnose and associated diseases on flowering dogwoods have the potential to affect forest stand structure and composition.

Data and Methods
Data used in this assessment came from two sources. Twenty forest monitoring plots established by CUPN are located across the park's forests are surveyed every five years for key components and stressors, including forest diseases. Additionally, as part of larger projects covering the Southeast, U.S. Forest Service scientists look for and document the presence of diseases. CARL was used for sampling transect plots a few years ago to measure overall dogwood decline in Henderson County. The presence/absence of dogwood anthracnose and dogwood decline in the park and in the Henderson County was used to determine the condition and level of concern.

Reference Conditions
Flowering dogwood tree populations are healthy and disease free, and individual trees live to their full size and life span ranges.

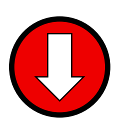
Condition and Trend
Although dogwood anthracnose has not been detected in the long-term monitoring plots, U.S. Forest Service scientists have documented the disease along research transects both within CARL, as well as, outside the park in Henderson County. County data show a 70.7% decline in the number of dogwoods trees (15.5 million to 4.2 million trees) from 1984 to 2002. Further, the average DBH of dogwood has dropped from 6 inches in 1984 to 4 inches 2002, indicating the trees are not regenerating at a rate to sustain populations. The 2015 estimates for dogwoods inside the park suggest there are no more than 18.3 trees per acre, a 82.8% decrease since pre-disease values in 1984 (William E. Jones, personal communication 2015).

The overall condition of the park's dogwoods is poor and the population is declining. We assign a high level of concern due to the presence of the disease in the park and in Henderson County.

Confidence and Data Gaps
Based on regular monitoring of forest plots and observations by U.S. Forest Service plant pathologists, we assign a high confidence to this assessment.

Summary Condition and Graphic

Table 4.5.2. Graphical summary of status and trends for plant diseases.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Infestations and Diseases	Plant Diseases - Dogwood Anthracnose		Reference condition is healthy flowering dogwood tree populations are health with individual trees living to their full size and life span. The overall condition of the park's dogwoods is poor and the population is declining.

Sources of Expertise

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site
- William E. Jones, Plant Pathologist, United States Forest Service
- Teresa Leibfreid, Network Program Manager, Cumberland Piedmont Network

- Bill Moore, Data Manager/Ecologist, Cumberland Piedmont Network
- Kurt Helf, Ecologist, Cumberland Piedmont Network
- Shepard McAninch, Ecologist, Cumberland Piedmont Network

4.6. Focal Species or Communities

4.6.1. 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 critical breeding grounds for amphibians. Additionally, wetlands may provide baseline data for monitoring climate change, as they are highly sensitive to shifts in precipitation, temperature, and weather events. Because of the value of wetlands, The NPS has a "no net loss" wetlands policy. Thirteen small wetlands occur at CARL.

Data and Methods

Roberts and Morgan (2006) note that most, if not all, of the wetlands at CARL are man-made and were created by occupants in the 19th and 20th centuries (Figure 4.6.1). A wetlands inventory and classification for CARL was performed in 2004 (Roberts and Morgan 2006). The two man-made ponds, Front and Side lakes, were not included as wetlands in this report. The authors used methodology to identify wetlands outlined in the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual despite the fact that man-made wetlands may not fully exhibit the characteristics of naturally occurring wetlands. Wetland hydrology, hydric soils, dominant wetland plant species, locations, wetland type, and size were recorded for each wetland found. Wetland functions, including surface water storage, groundwater discharge to streams, carbon/nutrient export, provision of wildlife habitat, and support of wetland plants, were also documented. Values included cultural importance, research and scientific value, and economic value. White (2003) documented two wetland ecogroups, one of which included the park's two ponds. Conditions and trends were based on the species composition noted by White (2003), the documented wetland functions and values documented by Roberts and Morgan (2006), and input from park staff.

Figure 4.6.1. Example of a man-made depression wetland at CARL (Roberts and Morgan 2006).

Reference Conditions

The reference condition for wetlands was established as their ability to perform key wetland functions including, surface water storage, groundwater discharge to streams, carbon/nutrient export, provision of wildlife habitat, support of wetland plants.

Current Conditions

White (2003) identified two wetland ecogroups at CARL. The Eastern Emergent Marshes ecogroup exists as a narrow band within a field which is mowed regularly. There are no species of special concern in this ecogroup. The second ecogroup is the Eastern Open Marshes and Ponds ecogroup. There are no species of special concern in this group. However, White noted that the community supported plants that are considered disjunct in the mountains and are extremely rare in the region. Examples included little floating bladderwort (*Utricularia radiata*) and American white waterlily (*Nymphaea odorata*). According to park resource managers, the Front Lake previously harbored a healthy population of little floating bladderwort. However, around 2005, the species disappeared from the lake. The reasons for its disappearance are unknown (Irene Van Hoff, personal communication 2014). There is currently a very small population of American white waterlily in the northeastern portion of Front Lake.

In 2004 a total of 13 wetlands, averaging 0.02 hectares (0.05 acres) in size, were documented throughout the park and characterized (Table 4.6.1). The primary functions performed by the park wetlands were to maintain discharge to streams, export carbon and nutrients to streams and rivers, and to provide habitat for wetland plants and animals. Four of the 13 wetlands were located near or adjacent to trails and have interpretive and educational potential. The researchers note that since the original plant communities in the park have been altered, none of the sites are considered pristine. However, the hydrology and soils of most have not been substantially altered resulting in wetlands that are generally in good condition. For this reason, at least one site was rated highly as serving as a reference site because its hydrology and soils are in good condition. All of the sites rated low (dominated by facultative wetland species) to medium (dominated by facultative species) in their capacity to support wetland plants. Economic value of the park's wetlands as defined by the researchers for CARL included whether a wetland served as an attraction to park visitors and if it is valued for reducing flood damage. None of the wetlands met these criteria. Three of the 13 wetlands were free of exotic invasive species.

Table 4.6.1. Functions and other characteristics of the 13 wetlands found at CARL (Roberts and Morgan 2006).

Site ID	Acreage	Surface Water Storage	Groundwater Discharge (to streams)	Carbon/Nutrient Export	Wildlife Habitat Value	Support Wetland Plants	Cultural Values	Research/Scientific	Economic Value	Exotics Present
CS1	0.030	low	low	low	medium	low	yes-near trail	no	no	yes-common privet
CS2	0.008	low	n/a	low	low	low	yes-near trail	no	no	yes-common privet
CS3	0.140	high	n/a	n/a	high	medium	yes-near trail	yes-above average size	no	yes-common privet, Japanese honeysuckle
CS4	0.050	low	high	high	low	low	yes-near trail	no	no	no
CS5	0.030	low	high	low	low	low	no	no	no	yes-common privet, Japanese honeysuckle
CS6	0.020	low	low	low	low	low	no	no	no	yes-common privet, Japanese honeysuckle
CS7	0.280	high	n/a	n/a	high	medium	no	yes-above average size	no	yes-common privet, Japanese honeysuckle
CS8	0.001	high	n/a	n/a	high	medium	no	no	no	yes-fescue
CS9	0.020	low	low	low	low	medium	no	no	no	yes-fescue
CS10	0.060	n/a	low	low	low	low	no	yes-above average size	no	yes-fescue
CS11	0.040	low	low	low	low	low	no	no	no	yes-Japanese honeysuckle
CS12	0.020	low	high	high	medium	low	no	no	no	no
CS13	0.010	low	n/a	low	low	low	no	no	no	no

The park's wetlands provide some level of ecological services, and will continue to contribute a small amount of flood attenuation, groundwater discharge maintenance, and other beneficial functions characteristic to wetlands. The presence of invasive species in the wetlands necessitates monitoring and treatment to maintain ecological integrity. Based on the most current data, the condition of park's wetlands appear to be unchanging and their condition is of moderate concern.

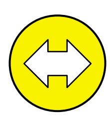
Confidence and Data Gaps

Roberts and Morgan (2006) recommended that the wetlands at CARL needed to be investigated further because some units likely provide breeding habitats for amphibians and the inventory did not allow time for documentation for uses by other vertebrate groups. They also noted that because the park's wetlands exist as unique patches within a mostly upland landscape, their value as water sources for other groups of wildlife should be investigated, especially during prolonged dry periods.

The wetlands inventory used in this assessment is now eleven years old. While significant changes to these wetlands since the publication of the report are unlikely, current park management activities including exotic invasive species management, trail maintenance, farming, and other administrative management tasks, may have changed or altered some wetland characteristics since the 2004 inventory. An updated survey, including the data mentioned in the previous paragraph needs to be conducted in order to provide an assessment that is informed by the latest conditions of the park's wetlands. Of particular interest are the wetland species, little floating bladderwort and American white lily, that are considered disjunct species in the area. Further investigation is needed to confirm the presence the former species. Therefore, we assign a medium level of confidence to this assessment.

Condition and Graphic

Table 4.6.2. Graphical summary of status and trends for wetland communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Wetland Communities		The reference condition for wetlands was established as their ability to perform key wetland functions including, surface water storage, groundwater discharge to streams, carbon/nutrient export, provision of wildlife habitat, support of wetland plants. The park's wetlands provide some level of ecological services, and will continue to contribute a small amount of flood attenuation, groundwater discharge maintenance, and other beneficial functions characteristic to wetlands. The presence of invasive species in the wetlands necessitates monitoring and treatment to maintain ecological integrity.

Sources of Expertise

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site Summary

4.6.2. Forest/Woodland Communities

Relevance

CARL's geographic proximity to the Piedmont and its location within the Blue Ridge ecoregion gives rise to diverse vegetation communities. Additionally, the park's exposed granitic domes, forest and woodlands, farm fields adjacent to forests, and ponds, contribute to its relatively high plant diversity for a park of its small size.

The Appalachian Highlands Granitic Domes Ecogroup and Blue Ridge Table Mountain Pine-Pitch Pine Woodland, both of which occur in CARL, are significant natural communities of interest and warrant active monitoring due to their globally imperiled (G2) and globally vulnerable (G3) statuses, respectively. Although Appalachian Highlands Hemlock-Hardwood Forests are stable throughout the region (G5), there is a small tract located in CARL that contains the oldest trees in the park.

Data and Methods

The current condition and trend of CARL'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. We used four primary information/data sources for the assessment. NatureServe's vegetation inventory provided baseline information on species composition as well as identifying potential trends in certain communities (White 2003). Geographic locations and areal extent of the communities were mapped by the Center for Remote Sensing and Mapping Science at the University of Georgia (Jordan and Madden 2010). Current conditions of some of the communities were determined from CUPN's recently established long-term vegetation monitoring plots (CUPN 2014). Species composition and condition of the park's granitic dome communities were documented in a report by Woolsey and Walker (2008).

The parks comprising the Cumberland Piedmont Network identified forest communities as one of the highest priority vital signs across the network because their components provide information on the overall health of the forest ecosystem. NatureServe led the initial effort to monitor the forest communities in CARL, and established 20 plots across the park for the purposes of inventorying and documenting plant species and ecological communities (White 2003). NatureServe identified fourteen distinct vegetation associations within eleven distinct ecogroups as defined by the United States National Vegetation Classification (Grossman et. al. 1998) (Table 4.6.3). Additionally, the inventory added over 135 species to a list of 375 species for a total of 510 species in the park. The current count for vascular plant species stands at 611 (NPSpecies online database 2015).

Table 4.6.3. Common names of vegetation communities found at CARL (White 2003).

Vegetation Community	Global Rank[1]	CEGL#[2]
Water Lily Aquatic Vegetation	G4G5	2386
Rush Marsh	G5	4112
Cultivated Meadow/Old Field	GW	4048
Appalachian Low Elevation Granitic Dome	G2	7690
Blue Ridge Table Mountain Pine—Pitch Pine Woodland (Typic Type)	G3	7097
Appalachian White Pine—Xeric Oak Forest	G3	7519
Eastern White Pine Successional Forest	GD	7944
Southern Appalachian Acid Cove Forest (Typic Type)	G5	7543
Appalachian Shortleaf Pine—Mesic Oak Forest	G3G4	8427
Chestnut Oak Forest (Xeric Ridge Type)	G5	6271
Appalachian Montane Oak Hickory Forest (Typic Acidic Type)	G5	7230
Chestnut Oak Forest (Mesic Slope Heath Type)	G4	6286
Appalachian Montane Oak—Hickory Forest (Red Oak Type)	G4?	6192
Appalachian Montane Oak—Hickory Forest (Chestnut Oak Type)	G4G5	7267

[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

In 2003, in conjunction with the NatureServe 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. Overall, 15 mapping units as well as infrastructure, ponds, and other anthropogenic land covers, were mapped (Figure 4.6.2). Of these vegetation communities, eleven are naturally occurring while four are man-made.

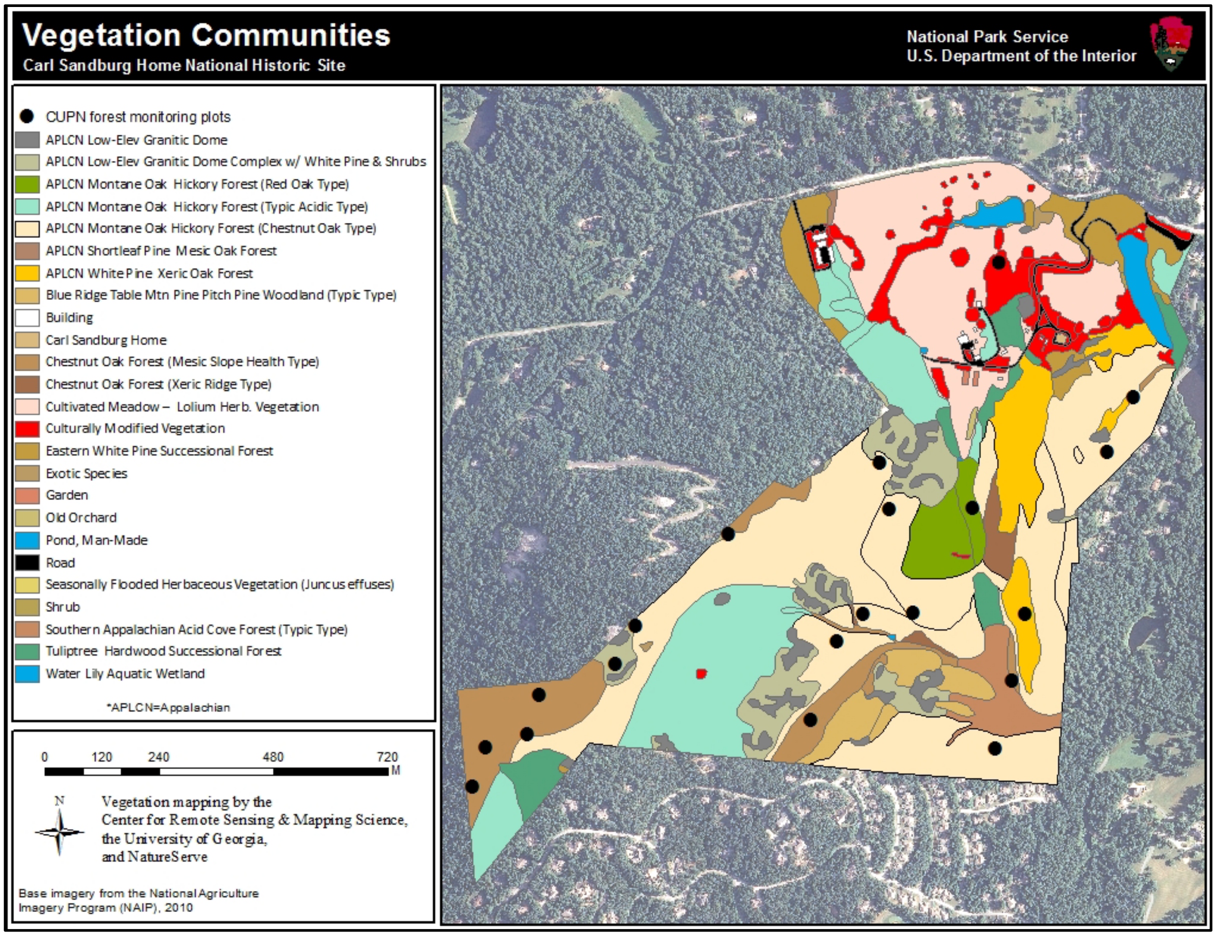


Figure 4.6.2. Map of vegetation communities at CARL. There are eighteen distinct mapping units within CARL, making it remarkably diverse for a park of its size (Jordan and Madden 2010).

In addition to mapping vegetation communities, CUPN and NatureServe developed and implemented a vegetation monitoring protocol that addresses most aspects of monitoring vegetation communities (White et al. 2011). The document addresses both network-wide and park-specific vegetation concerns with one primary goal and two objectives:

- Primary Monitoring Goal: Assess status and trends of ecological health for park-wide vegetation communities, including key communities of management concern.
- Primary Objective: Detect 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" every two to four years.
- Secondary Objective: Determine ecological health of key communities of importance to parks with respect to that community's reference condition.

CUPN has established a minimum of twenty, 20 x 20 meter (65.6 x 65.6 feet) plots in each park in the network, including CARL. Species presence, frequency, cover, tree canopy cover, tree growth and health, evidence of forest pests, snags, coarse wood debris, and community characterization, are recorded in each plot every five years. These data enable scientists and managers to look at quantitative change over time and general health within forest communities.

In addition to the above data, a report on the granitic domes in the park was used for assessing the condition of these communities in the park. Woolsey and Walker (2008) assessed the condition and species composition of granitic rock outcrop communities which are a critical vegetation community within CARL. Unlike the NatureServe plant inventory, this report includes non-vascular plants found on and around the granitic domes in CARL.

Reference Conditions

The vegetation communities at CARL are undoubtedly very different than they were before Euro-American settlement. Invasive species were introduced after settlement. A low-intensity naturally occurring fire regime likely maintained open forest floors and created ideal reproductive conditions for Table Mountain pine on the ridge in the northern portion of the park. The granitic dome communities were also likely maintained with these fires, limiting woody species encroachment on the margins of these communities. Therefore, we will use perceived pre- Euro-Settlement conditions for the park's focal communities as our reference conditions. Such conditions existed under a natural fire regime, were free from visitor use impacts, and existed without competition from exotic invasive plant species.

Current Conditions and Trends

Following is a discussion of the park's three most significant forest/woodland communities and their conditions and trends.

Low Elevation Granitic Dome Communities

The Appalachian Highlands Granitic Domes ecogroup is very rare on a global scale but fairly common in patches within the park. Within the Southern Appalachian Granitic Dome ecological group, Low-Elevation Granitic Dome communities are generally found below 914 meters (3,000 feet) on large, smooth, exfoliation surfaces with few cracks (Schafale 2012). These communities have been identified as both a cultural and natural critical resource within CARL (Hart 1993, White 2003, Johnson 2003). Jordan and Madden (2010) determined that the granitic domes encompass approximately 8.5 hectares (21 acres) inside the park (Figure 4.6.2).

The granitic dome outcrops possess some of the harshest environments in the park. Soils occur primarily at the margins of exposed bedrock, and are thin, strongly acidic, and infertile. The combination of thin soils, rock outcrops, and rugged topography creates an arid to xeric microclimate that support unique communities of lichens, bryophytes, and vascular plants adapted to these conditions (Woolsey and Walker 2008). The domes occur most frequently within the Ashe stony sandy loam soil type in the park. Table 4.6.4 lists components of granitic dome communities and major threats associated with them.

Table 4.6.4. Critical components and processes in granitic dome communities and their key roles and major threats associated with them (Woolsey and Walker 2008).

Component	Key Roles	Associated Threats
Xeric soils	Severe conditions support xeric plant species that contribute to site diversity	Disturbance, erosion and sedimentation from trails, compaction from visitors
Seeps	Seeps support mesophytic and wetland species, moss, and lichen communities	Disturbance, erosion and sedimentation from trails, vegetative spalling
Lichen and moss communities	Affect seedlings, water, and nutrient relations. Relic communities reported on many outcrop systems	Trampling from visitors, atmospheric deposition
Vascular plant community	Unique suite of habitat specific and regionally uncommon species. Contributes substantially to regional biodiversity.	Trampling from visitors, exotic invasions, disturbance to soil substrates, over-collection.
Disturbance	Maintains granitic domes as open. Controls vegetation structure. Determines spatial heterogeneity and specie abundances.	Frequency. Response lag and legacy effects from anthropogenic throughputs, particularly disruption of fire regime.
Landscape pattern	Affects meta-population dynamics, gene flow.	Increasing regional development and associated impacts. Greater insularity of outcrop communities.

Woolsey and Walker (2008) identified the floral composition, present and future threats, and characteristics of the current forest matrix surrounding the domes in the park. They noted that the outcrops are of significant interest to the cultural and natural landscape of CARL. One outcrop, which lies behind the Main House, was a favorite place for Carl Sandburg to write and was used as a family recreation area and a place to entertain guests (Figure 4.6.3). Currently, this location is the second most visited feature in the park. A small outcrop next to Side Lake was also used as a family picnic area and the outcrop at the top of Big Glassy was likely visited by the Sandburg family on a regular basis. These outcrops are also popular destination points for visitors.

Figure 4.6.3. Interpretive sign providing visitors with information about Carl Sandburg's favorite outdoor writing spot on a granite dome. This dome is one of the most visited areas in the park.

Woolsey and Walker (2008) systematically compiled species lists for 19 of the 21 granitic domes. Overall, NatureServe documented 519 vascular species within the park's boundaries. The granitic dome assessment project found that about 38% of all known vascular species at CARL were located on the domes. Forbs and herbaceous species accounted for 40%, followed by trees (23%) and graminoid species (16%). Additionally, the researchers identified 33 lichen species and 16 moss species. The authors recorded conservation status ranks, developed by NatureServe and the Natural Heritage Network, for each species found on the domes. For a complete listing of granitic dome species, see Woolsey and Walker (2008).

Figure 4.6.4. St. John's wort (*Hypericum* spp.) is a common plant of the granitic dome communities at CARL (Woolsey and Walker 2008).

Woolsey and Walker (2008) concluded that trampling by park visitors off of park-designated trails or non-sanctioned trails, negatively impacted dome communities. Park resource managers confirm that the vegetation communities on the five domes along trails are degraded due to visitor impacts. Domes where vegetative communities were most intact were located almost exclusively in areas devoid of trails. Lichens growing on outcrop faces were most sensitive to human disturbances, whereas bryophytes and vascular plants were not significantly affected (Woolsey and Walker 2008). Severe erosion and deposition from adjacent trails has also negatively impacted the park's outcrops. Sedimentation build-up on the outcrops has the potential to accelerate the process of succession thereby eliminating sensitive lichen and moss communities.

Forests occupying the edge of the park's granitic domes were primarily associated with the Appalachian Highlands Pitch and Table Mountain Pine Woodlands Ecogroup and Appalachian Highlands Upland White Pine Forests (Schafale and Weakley 1990). White pine and oak were dominant overstory species at the edges. Pitch pine was also important but was almost absent in the understory and regeneration layers. The authors indicate that the heavy recruitment of fire intolerant species such as white pine is likely the result of decades of fire suppression. The historical fire regime encouraged open, sunny and dry conditions which, in turn, maintained the characteristic granitic dome plant species. With the absence of fire, mesophytic woody species are now encroaching upon dome areas and creating shady moist microclimates in which dome communities cannot sustain themselves.

Figure 4.6.5. White pine and other fire intolerant tree species encroaching on a granitic dome at CARL.

A total of 20 exotic species were identified on granitic dome study sites. Exotic species were found on all domes but were more frequent on sites that were accessed by trails. The most common exotic invasive species were categorized using either the NC Native Plant Society's ranking system (2014) or Alien Plant Ranking System (APRS 2000) (Table 4.6.5). Seven of these species are categorized as Rank 1 invasive exotics in the State of North Carolina and are considered a severe threat to ecosystem function because of their ability to spread readily into native-plant communities, displacing native vegetation. The APRS prioritizes management for exotic plants by separating innocuous exotic species from those that are invasive, and also by identifying those species that currently impact a site or have a high potential to do so in the future as illustrated in Figure 4.6.6 (Woolsey and Walker 2008).

Table 4.6.5. Ten most abundant exotic plants found on the granitic domes at CARL (Woolsey and Walker 2008).

Scientific Name	Common Name	Abbreviation	NC State Rank*
Anthoxanthum odoratum	Sweet vernal grass	AO	SNR
Commelina communis	Asiatic dayflower	CC	SNR
Ligustrum sinense	Chinese privet	LS	Rank 1
Microstegium vimineum	Japanese stilt grass	MV	Rank 1
Rosa multiflora	Multi-flora rose	RM	Rank 1
Hedera helix	English ivy	HH	Rank 1
Rumex acetosella	Sheep sorrel	RA	SNR
Lonicera japonica	Japanese honeysuckle	LJ	Rank 1
Polygonum caespitosum	Oriental smartweed	PC	SNR
Ailanthus altissima	Tree of Heaven	AA	Rank 1
Miscanthus sinensis	Chinese silvergrass	MS	Rank 2
Paulowinia tomentosa	Princess tree	PT	Rank 1

*Based on the NC Native Plant Society's ranking system. SNR=not ranked

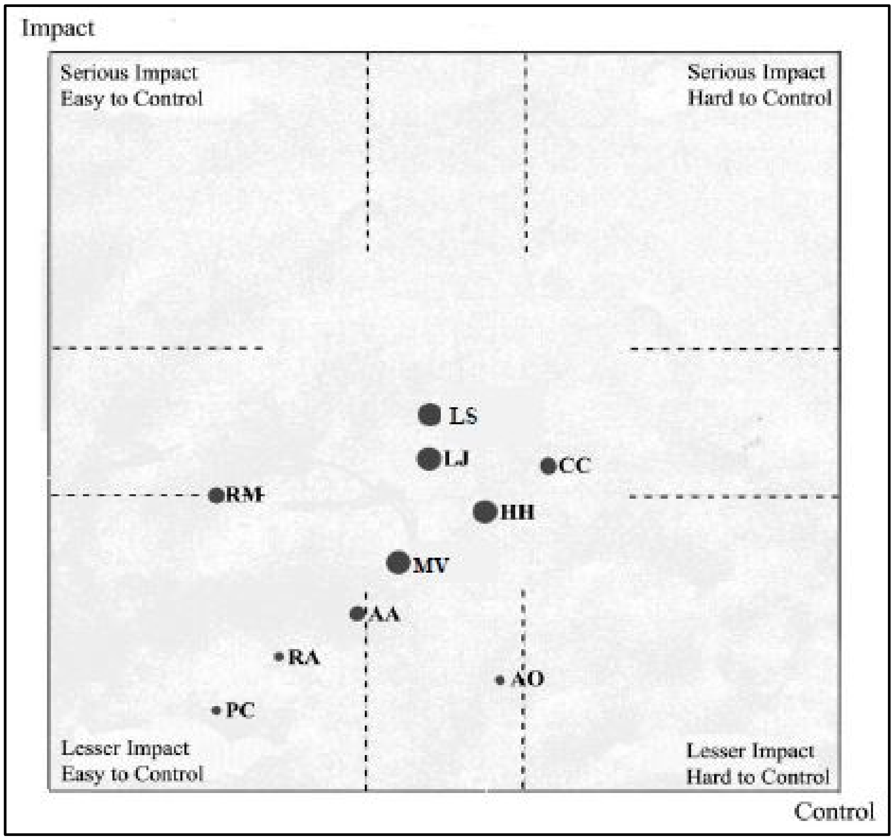


Figure 4.6.6. APRS graphic showing impact, potential to be invasive, and feasibility of control for the ten most abundant exotic plants on the granitic domes at CARL. Pest scores are indicated by size of dot (Woolsey and Walker 2008).

The granitic dome communities contribute significantly to the biodiversity at CARL. Species characteristic to domes are inherently sensitive to disturbance and slow to recover. Visitor use impacts, fire suppression and resulting hardwood forest encroachment, and invasive species continue to negatively impact these communities. While resource managers hold interpretive programs to raise visitor awareness, resources are insufficient to effectively protect the domes. Since the park does not currently have a prescribed burn program, woody species will continue to encroach on the domes unless mechanical removal of woody plants is initiated. Along with other areas in the park, resource managers and volunteers are committed to monitoring and treating invasive species on and around the domes year-round and these efforts are managing the species effectively. However, new infestations will continue as seed banks provide continual propagules, visitors transport seeds onto the domes, along with other natural- and man-caused vectors. When assessing the granitic dome communities we assign a decreasing trend that warrants significant concern. These vegetation communities have been well-documented and studied in the park and the stressors are known. Therefore, we assign a high level of confidence to this assessment.

Blue Ridge Table Mountain Pine-Pitch Pine Woodland

The Blue Ridge Table Mountain Pine-Pitch Pine Woodland, which occurs on the exposed dry ridge tops and adjacent slopes in the southeastern corner of the park (Figures 4.6.2 and 4.6.7). This community has a G3 global status indicating that the community is regionally abundant but restricted to only the Southern Appalachians. This group is uncommon in the park and occupies exposed, dry, nutrient-poor sites (White 2003). Jordan and Madden (2010), determined the park contains approximately 2.8 hectares (7 acres) of this community (Figure 4.6.2).

Figure 4.6.7. Various pine species on the margins of a dome at CARL.

Within the park, this community is severely compromised by years of fire suppression that have allowed hardwood species including scarlet oak, chestnut oak, and red maple to out-compete the pines (White 2003). Woolsey and Walker (2008) calculated importance values for individual species in different canopy layers based on the relative frequency, density, and basal area of each species. They found that white pine, and oaks (*Quercus* spp.) had higher importance values in the overstory. Pitch pine also had a high importance value in the overstory but its importance value declined in the midstory and was nearly absent in the regeneration layer. By contrast, the importance value of red maple was high in the understory. The authors suggest that the heavy recruitment of less fire tolerant species, such as red maple, is likely the result of fire suppression. Recent data collected in long-term forest monitoring plots by CUPN confirms this pattern (Figure 4.6.8). Park-wide, more fire-tolerant species, such as oaks and hickories still dominate the upper canopy. However, fire-tolerant species are less common in the sapling and seedling layers. Fire-intolerant maple species are relatively rare in the canopy but more common in the seedling and sapling layers. Pine species are found in the canopy layer, and to a slightly lesser extent, in the sapling layer. However, they are virtually absent in the seedling layer.

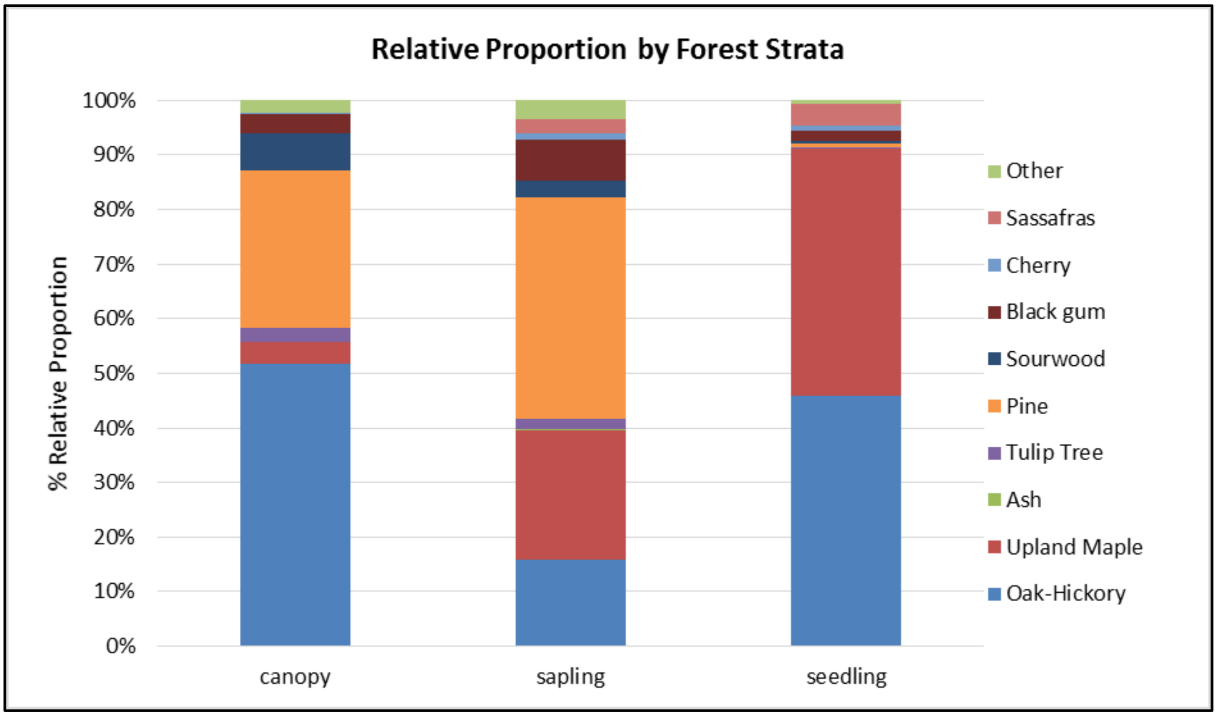


Figure 4.6.8. Tree species composition (10≥ cm DBH) based on basal area and sapling/seedling composition based on counts within 20 forest plots at CARL (CUPN 2013).

Active fire suppression has allowed these forest canopies to close, which has created more shaded conditions. This creates a situation where shade-intolerant species, such as table mountain pine are unable to regenerate and are replaced by more shade tolerant species. White (2003) states that the canopy of this group in CARL is now closed due to heavy recruitment of more shade tolerant species; as a result, very little regeneration of pitch pine has occurred in the past few decades. Furthermore, although this association is technically classified as a woodland, White (2003) states that the sites at CARL are now effectively closed forests with a heavy understory of mountain laurel (*Kalmia latifolia*). Since part of the park's wildland fire management goals include suppressing all wildland fire (CARL Fire Management Plan, Gorder 2004), this vegetation group is at risk of disappearing from the park at some point in the future. Therefore, we believe the condition warrants significant concern with a decreasing trend. Based on regional historical forest trends, recent data collected in forest monitoring plots at CARL, and species composition data collected by White (2003) we assign a high confidence level to this assessment.

Appalachian Highlands Hemlock-Hardwood Forest

The Appalachian Highlands Hemlock-Hardwood Forest ecogroup (Figure 4.6.9) is usually found adjacent to small creeks within coves White (2003). It typically consists of a tall, diverse canopy with hemlock, tulip poplar (*Liriodendron tulipifera*), birch (*Betula* spp.), and many other species. The shrub layer is composed of rhododendron (*rhododendron maximum*) and sometimes mountain laurel, with a poorly developed herb layer due to dense shade produced by substantial amounts of dog hobble (*Leucothoe fontanesiana*).

Figure 4.6.9. An example of the Appalachian Highlands Hemlock-Hardwood Forest at CARL.

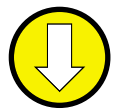
While this ecogroup is secure within its range, it is significant in CARL because it represents and older stand of trees and is the only example of a mesic forest inside the park. Jordan and Madden (2010) determined there are approximately 2.2 hectares (5.5 acres) in the far southeastern portion of the park along the narrow creek corridor and the adjacent steep slopes (Figure 4.6.2.1). The canopy consists of birches, white oaks, tulip poplars, black gum (*Nyssa sylvatica*), red maple, and fraser magnolia (*Magnolia fraseri*). The hemlock trees are regularly treated for hemlock wooly adelgid and remain in good health. The shrub layer consists of very tall rhododendron with some mountain laurel while the herb layer is very sparsely populated with small amounts of galax (*Galax urceolata*), striped prince's pine (*Chimaphila maculata*), and Biltmore's carrionflower. According to White (2003) this community appears stable within the park. However, it occurs near the edge of the park's boundary and should be monitored for human activities that are incompatible with the forest's long-term health. Based on the current health of this community we believe its condition is good with a stable trend. Input from park resource managers coupled with high quality data allow for high confidence in this assessment.

Confidence and Data Gaps

CUPN and CARL monitoring efforts provide solid data for these assessments. We have high confidence and are not aware of any significant data gaps.

Summary Conditions and Graphics

Table 4.6.6. Graphical summary of status and trends for woodland/forest communities.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Forest / Woodland Communities		Reference condition is the perceived pre- Euro-settlement conditions that existed under a natural fire regime, were free from visitor use impacts, and existed without competition from exotic invasive plant species. Granitic Dome and Table Mountain Pine-Pitch Pine community conditions warrant significant concern because of changes attributed to fire suppression, visitor impacts, and exotic species introduction. These are the most unique forest and woodland communities in CARL. Highlands Hemlock-Hardwood forest are in good condition due to continual treatment of hemlock woolly adelgid, but those treatments will need to continue indefinitely and these forests will need to be monitored for exotic plants.

Sources of Expertise

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site
- Teresa Leibfreid, Cumberland Piedmont Network
- Bill Moore, Cumberland Piedmont Network

4.6.3. Aquatic Communities

Relevance

Aquatic macroinvertebrate and fish assemblages are often used as integral components of water quality monitoring because they integrate over seasonal fluctuations (macroinvertebrates) or even years (fish). CARL contains a variety of aquatic habitats (Figure 4.6.10): a section of Meminger Creek flows through the northeastern portion of the park, including an impounded reach, Front Lake. A small, unnamed tributary to Meminger Creek that also has an impounded reach, Side Lake, drains the northern and central portions of the park. The headwaters of Meminger Creek drain most of the southern portion of the park and exits from its southeastern boundary. In addition to these habitats, Scott (2006) mentions small ponds and a spring.

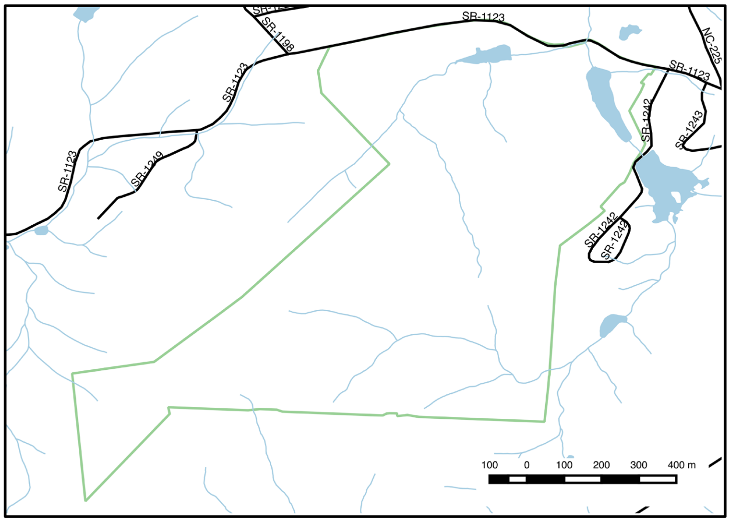


Figure 4.6.10. Map of the streams and impoundments present at CARL.

<u>Data and Methods</u>

For this report, data and analyses presented in Scott (2006) and Parker et al. (2012) will be compared to fish and benthos samples collected from two nearby watersheds as part of the periodic monitoring conducted by the North Carolina Department of Environment and Natural Resources (NCDENR).

Parameter Criteria

Scott (2006) sampled the section of Meminger Creek between Front Lake and the park boundary, and the section of the unnamed tributary from Side Lake to its confluence with Meminger Creek using a backpack electrofisher. He also sampled Front Lake and Side Lake by seining and/or boat-mounted electrofisher. He also sampled other smaller bodies of water but either found no fish or only a single species. From the data he presented, Shannon Diversity was calculated which ranges from a low of 0 to a maximum of log (species richness). NCDENR provides similar data for their long-term assessment sites (Figure 4.6.11) (NCDENR 2015) from which species richness and Shannon diversity was calculated.

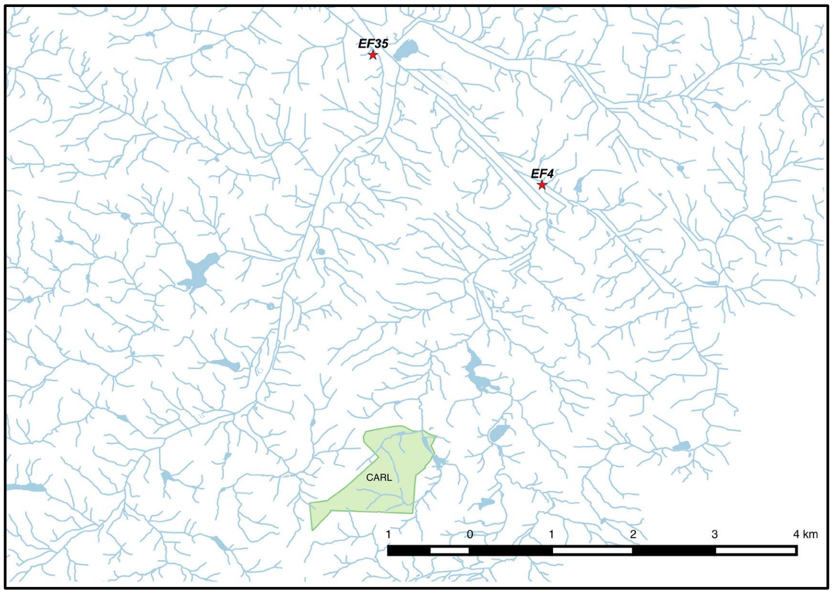


Figure 4.6.11. Map of NCDENR periodic, long-term sample sites, EF35 (Mud Creek) and EF4 (Bat Fork) relative to the streams at CARL.

Reference Conditions

Scott (2006) sampled a total of 566 individuals representing 14 species. The fish assemblage structure and diversity from his stream samples was very similar to that found in NCDENR samples from adjacent watersheds near the same time period (Table 4.6.7). The biggest differences are the absence of two common to abundant species, northern hogsuckers (*Hypentelium nigricans*) and bluehead chubs (*Nocomis leptocephalus*). Scott did find an abundant *Nocomis*, but identified it as river chub.

Table 4.6.7. Numbers of fish sampled by Scott (2006) compared to NCDENR collections from adjacent watersheds (Figure 4.6.11).

	Bat Fork (EF4)		Mud Creek (EF 35)		Scott (2006)			
Scientific Name	**1997**	**2002**	**1997**	**2002**	**CARL1**	**CARL2**	**Side Lake**	**Front Lake**
Ambloplites rupestris				1				
Ameiurus platycephalus			2	6	10	14		
Campostoma anomalum	71	1	1	19	11	1		
Catostomus commersonii	8	4	5	4		1		
Cottus bairdii					1			
Cyprinella galactura			2	1				
Erimystax insignis	10							
Etheostoma fusiforme		1						
Esox niger	3	5	2	1				
Hypentelium nigricans	3	3	18	20				

Table 4.6.7 (continued). Numbers of fish sampled by Scott (2006) compared to NCDENR collections from adjacent watersheds (Figure 4.6.11).

	Bat Fork (EF4)		Mud Creek (EF 35)		Scott (2006)			
Scientific Name	**1997**	**2002**	**1997**	**2002**	**CARL1**	**CARL2**	**Side Lake**	**Front Lake**
Lepomis auritus	6	20	30	17	4	20	1	23
Lepomis cyanellus			1					
Lepomis gulosus			1		2			
Lepomis macrochirus	34	6	14	3	69	19	40	71
Lepomis microlophus							1	12
Luxilus coccogenis	10		1	7	6	2		
Micropterus salmoides	3			1			16	26
Nocomis leptocephalus	188	73	70	94				
Nocomis micropogon					51	74		
Notemigonus crysoleucas					2			
Notropis rubricroceus	3							
Percina evides			1	4				
Pomoxis nigromaculatus					3			
Semotilus atromaculatus	38	17	5	2	1	55		
Species Richness (S)	12	9	14	14	11	8	4	4
Shannon Diversity (H')	0.696	0.614	0.741	0.732	0.672	0.651	0.326	0.511

Parker et al. (2012) reported that 139 species of aquatic macroinvertebrates were collected from CARL. When compared to species richness of other parks within the Appalachian Highland and Cumberland Piedmont monitoring networks (Figure 4.6.12), CARL's aquatic macroinvertebrate species richness is an outlier, with much higher richness that would be expected based on the size of the park, even after correction for the number of sample events.

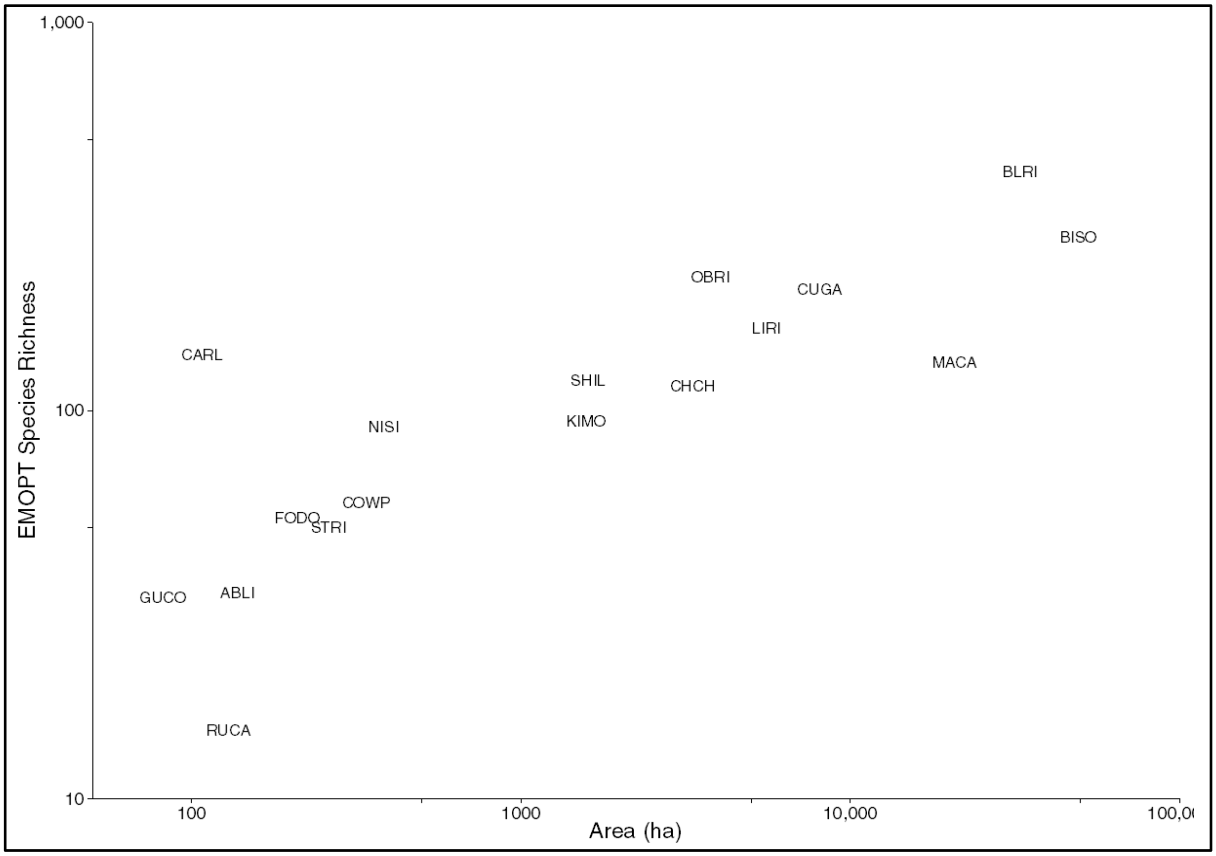


Figure 4.6.12. Species richness of aquatic macroinvertebrates (Ephemeroptera, Megaloptera, Odonata, Plecoptera, and Trichoptera) reported by Parker et al. (2012) for parks of the Appalachian Highland and Cumberland Piedmont monitoring networks.

Conditions and Trends

Current conditions of the fish assemblage are unknown, and given the lack of periodic monitoring, trends are impossible to assess for either fish or macroinvertebrate assemblages.

Confidence and Data Gaps

Given there has been no recent monitoring of the fish assemblages, there is little confidence in the current condition of the fish assemblage within the park and it is impossible to determine any trends. There is no available data on macroinvertebrate assemblages from previous decades, so recent trends are impossible to assess. Further, the USGS samples were collected five years ago, and confidence in the assessment is weakened as time passes.

Summary Condition

Table 4.6.8. Graphical summary of status and trends for fish and aquatic macroinvertebrate diversity.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Fish Diversity		2006 sampling identified 12 species from stream samples (Scott 2006). But, there are no data available after 2006.
	Macro-invertebrate Species Richness		Sampling from 2010-2011 identified 139 aquatic macroinvertebrate species from the park (Parker et al. 2012).

4.6.4. Amphibians and Reptiles

Relevance

The composition of species found within a particular area can provide direct information about the quality of available habitat resources and 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). Amphibians and reptiles are often selected as taxonomic indicators due to their sensitivity to environmental degradation (Smith et al. 2009). For example, species assemblages have been studied in the Appalachians in order to evaluate the role of forest management in determining habitat conditions for herpetofauna (Greenberg and Waldrop 2008).

Data and Methods

Given the lack of baseline information for major terrestrial vertebrate groups, field studies were conducted at CARL between 2002 and 2006. Amphibians and reptiles 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). While we considered each species individually, overall condition estimates were based upon comparison of the composition of species encountered during field surveys to those reasonably expected to be found within the park.

Reference Conditions

Patterns of species and community composition observed within non-disturbed ecosystems would represent the most ideal reference condition, yet such baseline information is very seldom available, particularly for animal taxa. Managers often must rely upon the use of indirect comparisons (i.e., with data from similar ecosystems), surrogate variables, or selection of ecologic indicator species or species guilds (Lambeck 1997, Lindenmayer et al. 2002). While these approaches are not without cautions or critics (Landres et al. 1988), the limited data for assessing individual species often makes the use of surrogates a necessity (Rodrigues and Brooks 2007). Based upon species distribution information provided by the report authors, relevant scientific literature, and regional species atlases, we compared survey results to species reasonably expected to occur within the park (Table 4.6.9).

Table 4.6.9. Reptile and amphibian species documented or possible within CARL during 2004-5 surveys by Reed and Gibbons (2005).

Species Group	Common Name	Not Observed	Observed
Frogs & Toads	American toad		X
	Bullfrog		X
	Eastern spadefoot toad	X	
	Gray/Cope's gray tree frog	X	
	Green frog		X
	Pickerel frog	X	
	Shovelnose salamander	X	
	Southern toad	X	
	Spring peeper		X
	Wood frog	X	
	Woodhouse toad	X	
Salamanders	Black-bellied salamander		X
	Blue ridge two-lined salamander		X
	Four-toed salamander	X	
	Green salamander		X
	Hellbender	X	
	Jordan's salamander	X	
	Long-tailed salamander	X	
	Mole salamander	X	
	Mud salamander	X	
	Mudpuppy	X	
	Ocoee salamander		X
	Red salamander		X
	Red spotted newt		X
	Seal salamander		X
	Southern two-lined salamander	X	
	Spring salamander	X	
	Three-lined salamander		X
Lizards	Coal skink	X	
	Fence Lizard		X
	Five-lined skink		X
	Ground skink	X	
Turtle	Bog turtle	X	
	Common musk turtle		X
	Eastern box turtle		X

Table 4.6.9 (continued). Reptile and amphibian species documented or possible within CARL during 2004-5 surveys by Reed and Gibbons (2005).

Species Group	Common Name	Not Observed	Observed
Snakes	Black racer		X
	Canebrake rattlesnake		X
	Copperhead	X	
	Eastern kingsnake	X	
	Garter snake		X
	Northern banded water snake		X
	Queen snake		X
	Rat snake		X
	Redbelly snake	X	
	Ringneck snake		X
	Scarlet kingsnake or milksnake	X	
	Scarlet snake	X	

Resource Conditions

Twenty eight of the approximately 53 species expected at CARL were documented. Of those not encountered, 17 of 25 were amphibians with several considered common in the area (Table 4.6.9). This many species not encountered seems severe yet several factors likely contribute to this. Since the survey by Reed and Gibbons (2005), a green salamander population was documented in the park during 2007 (NPSpecies 2015), bringing the total number of species to 29.

Because of CARL's proximity to diverse ecosystems the list of 'expected' species may have been too inclusive (Tuberville et al. 2005). While some species are widespread throughout the region, some require very specific habitat conditions and are much patchier in their local distribution. For example, bog turtles have been documented nearby yet CARL has very limited suitable habitat and thus it is not very surprising that it wasn't found (Reed and Gibbons 2005). CARL could also be expected to have somewhat less diversity given its size relative to the diversity of habitat conditions found in the region. In a study of other national parks in the southeast, park size seemed to be most associated with herpetofauna diversity although smaller parks with a diversity of habitat conditions and available freshwater habitats did exhibit high levels of diversity (Tuberville et al. 2005).

Ultimately, historic land disturbances and the long term maintenance of non-forest conditions (pastures, orchards) at CARL likely has contributed to lower diversity in herpetofauna (Reed and Gibbons 2005). Further, several studies have shown that reptiles and amphibians do not respond similarly to disturbance. In the case of some forest management methods, amphibians may not be negatively affected and reptile species may well benefit (Greenberg and Waldrop 2008). Where human disturbance is more severe (i.e., urban sprawl) reptiles appear to be more tolerant whereas amphibian diversity can drop dramatically (Barret and Guyer 2008).

Fortunately CARL has experienced less adjacent development than other protected areas of the region and while no amount of fragmentation is without some impact, it may be that more micro-scale conditions such as coarse woody debris will need to be assessed. In the central Appalachians, Mitchel et al. (1997) found a higher diversity of amphibians where more diverse microhabitat conditions existed including surface and subsurface retreats nearby wetlands.

Summary Condition

Table 4.6.10. Graphical summary of status and trends for herpetofauna.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Reptiles and Amphibian Species Composition (Actual vs. Expected)		While some species that commonly occur within the region were not observed at CARL, species richness was still relatively high.

4.6.5. Birds

Relevance

Highly mobile groups such as birds 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 can provide direct 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. Multiple studies have evaluated the use of habitat guilds in evaluating forest conditions for birds (O'Connell et al. 2000, Lichstein et al. 2002). 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).

Data and Methods

Breeding birds were sampled between 2003-2005 using fixed radius point count plots placed at existing vegetation sampling points within the park between May and late June. Point counts were conducted twice per year and species abundance was estimated using the maximum number of individuals counted within 100 m (328 ft) 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 (Pearson and Smith 2006).

While valuable, such single point surveys don't 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 birds was assessed based upon the overall suite of species encountered. Since species richness was much greater for birds (compared to other vertebrate taxa at CARL) 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. 2007): 1) Open, species requiring or preferring non-forest type conditions such as pasture/grassland, 2) Forest, representing both interior obligates and species generally associated with forest habitat, and 3) Edge/Generalist, including both forest edge species and overall habitat generalists (Table 4.6.11).

Table 4.6.11. General habitat guilds for bird species encountered at CARL during 2003-2005.

Open	Forest	Edge/Generalists
American goldfinch	Acadian flycatcher	American crow
American kestrel	American redstart	Blue jay
American robin	Black-and-white warbler	Blue-winder warbler
Barn swallow	Black-throated blue warbler	Carolina chickadee
Belted kingfisher	Blue-gray gnatcatcher	Chipping sparrow
Blue grosbeak	Broad-winged hawk	Downy woodpecker
Brown thrasher	Brown creeper	Eastern towhee
Brown-headed cowbird	Canada warbler	Great crested flycatcher
Canada goose	Cape may warbler	Red-bellied woodpecker
Carolina wren	Cooper's hawk	Red-eyed vireo
Cedar waxwing	Dark-eyed junco	Red-tailed hawk
Chimney swift	Fox sparrow	Tufted titmouse
Common grackle	Golden-crowned kinglet	Turkey vulture
Eastern bluebird	Hairy woodpecker	White-breasted nuthatch
Eastern kingbird	Hermit thrush	White-throated sparrow
Eastern phoebe	Hooded warbler	Yellow-bellied sapsucker
Gray catbird	Ovenbird	Yellow-billed cuckoo
Great blue heron	Pileated woodpecker	
House finch	Pine warbler	
House wren	Red-headed woodpecker	
Indigo bunting	Ruby-crowned kinglet	
Mallard	Scarlet tanager	
Mourning dove	Solitary vireo	
Northern cardinal	Swainson's thrush	
Northern flicker	Winter wren	
Northern mockingbird	Wood thrush	
Orchard oriole	Worm-eating warbler	
Purple martin	Yellow warbler	
Red-winged blackbird	Yellow-rumped warbler	
Song sparrow	Yellow-throated warbler	
Swamp sparrow		
White-eyed vireo		
Yellow-breasted chat		
Yellow-throated vireo		

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.

Reference Conditions

Patterns of species and community composition observed within non-disturbed ecosystems would represent the most ideal reference condition, yet such baseline information is very seldom available, particularly for animal taxa. Managers often must rely upon the use of indirect comparisons (i.e., with data from similar ecosystems), surrogate variables, or selection of ecologic indicator species or species guilds (Lambeck 1997, Lindenmayer et al. 2002). While these approaches are not without cautions or critics, data needed to assess individual species is often lacking thus making the use of surrogates a necessity (Rodrigues and Brooks 2007). Based upon species distribution information provided by the report authors, relevant scientific literature, and regional species atlases, we compared survey results to species reasonably expected to occur within the park.

Resource Conditions

Surveys detected 371 individuals of 53 species during the breeding season and 533 individuals across 40 species during the winter surveys. The greatest diversity of species were found in the northern portions of the park (Pearson and Smith 2006). This pattern makes sense in that the most common breeding and winter season birds were associated with edge and forest habitats (Table 4.6.12) and these habitat types are dominant in the northern portion of CARL.

Table 4.6.12. Total individuals counted within major habitat guilds at CARL for both breeding and winter season bird surveys at CARL.

Guild	Number of Species	Individuals Counted	
		Summer	Winter
Forest	28	104	122
Edge/Generalist	17	164	204
Open	36	103	207

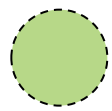
Given that forest dominates the land cover at CARL it is somewhat surprising more forest interior species were not encountered in surveys. However, considering the presence of non-forest habitat along some parts of the park boundary, the proportions of bird species would seem to match the general composition of the landscape. Given the historical purpose of maintaining open habitats at CARL conditions for birds seem to be good. The fact that so few Brown-Headed Cowbirds (*Molothrus ater*) were encountered could indicate that maintaining open habitats hasn't caused a significant increase of nest parasites. It is also likely that the species occurring in and around open habitats at CARL are better adapted to cowbird presence. Both possibilities would require field validation and avian condition may change if the surrounding landscape sees increased development, however, it seems the avian resources at CARL are in good condition.

Data Gaps

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.

Summary Condition

Table 4.6.13. Graphical summary of status and trends for birds.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Avian Species Composition (Actual vs. Expected and Response Guild Abundance)		Species composition and abundance seem to reflect the available habitats at CARL and avian resources appear in good condition.

4.6.6. Mammals

Relevance

The complexity of species-habitat interactions means detailed knowledge of individual species-habitat requirements is often lacking (Morrison 2001). 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). For example, species assemblages have been studied in the Appalachians in order to evaluate the role of forest management in determining habitat conditions for numerous species including small mammals and bats (Kaminski et al. 2007, Loeb et al. 2009). 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 (Rodriguez and Brooks 2007). Although data available for vertebrate taxa are limited, they do provide information useful in evaluating ecological conditions at CARL.

Data and Methods

Non-volant mammals were sampled during 2004-2006 using a combination of live traps, pitfall traps, remote cameras and visual encounters at 19 sites placed within a variety habitats throughout the park (Pivorun and Fulton 2007). Bats were sampled during 2005-2007 using mist nets, acoustic detectors, and building searches for the presence of bats or guano (Loeb 2007).

Reference Conditions

Patterns of species and community composition observed within non-disturbed ecosystems would represent the most ideal reference condition, yet such baseline information is very seldom available, particularly for animal taxa. Managers often must rely upon the use of indirect comparisons (i.e., with data from similar ecosystems), surrogate variables, or selection of ecologic indicator species or species guilds (Lambeck 1997, Lindenmayer et al. 2002). While these approaches are not without cautions or critics (Landres et al. 1988), the limited data for assessing individual species often makes the use of surrogates a necessity (Rodriguez and Brooks 2007). Based upon species distribution information provided by the report authors, relevant scientific literature, and regional species atlases, we compared survey results to species reasonably expected to occur within the park. For reptiles, amphibians, and mammals (including bats) we considered species individually whereas for birds (where species richness was much greater) we evaluated abundance within three major habitat guilds (e.g., O'Connell et al. 2000).

Resource Condition

Non-Volant Species

Eighteen species of non-volant terrestrial mammals (of 34 expected) were documented in the park via trapping (24 individuals from 5 species) and visual observations (108 individuals from 13 species) Pivorun and Fulton (2007). The most numerous species from woodland plots included the white-footed mouse (*Peromyscus leucopus*), raccoons, opossums, gray squirrels and chipmunks, and 2) the most numerous species in the pastures were the short-tailed shrew (*Blarina brevicauda*), the meadow vole (*Microtus pennsylvanicus*) and the cotton rat (*Sigmodon hispidus*). Numerous is a relative term, since so few animals were live trapped. However, these species are the species that one would expect in these habitats in this part of the U.S. Of the species documented most were either forest-edge, or open habitat species (Tables 4.6.14 and 4.6.15). While the distinctions among these groups are relative approximations it would suggest that the composition of mammal species at CARL reflects the general habitat composition of the park. Additional species not documented but common in this part of the Southeastern United States include the norther flying squirrel (*Glaucomys volans*), pine vole (*Microtus pinetorum*), striped skunk (*Mephitis mephitis*), white-tailed deer (*Odocoileus virginianus*), and red fox (*Vulpes vulpes*) (Table 4.6.16).

Table 4.6.14. Non-volant mammal species caught in live and pitfall traps at CARL during 2004-2006.

Common Name	Woodland	Pasture	Total
Short-tailed shrew	0	3	**3**
White-footed mouse	9	3	**12**
Meadow vole	0	2	**2**
Hispid cotton mouse	0	5	**5**
Golden mouse	2	0	**2**
Total	**11**	**23**	**34**

Table 4.6.15. Non-volant mammal species documented by visual encounter, camera and sign at CARL during 2004-2006.

Common Name	Visual	Camera	Sign	Dead	Total
Virginia opossum	0	19	0	0	**19**
Short-tailed shrew	0	1	0	0	**1**
Eastern mole	0	0	0	1	**1**
Eastern cottontail	2	0	0	0	**2**

Table 4.6.15 (continued). Non-volant mammal species documented by visual encounter, camera and sign at CARL during 2004-2006.

Common Name	Visual	Camera	Sign	Dead	Total
Eastern chipmunk	6	0	0	0	**6**
Woodchuck	1	0	0	0	**1**
Gray squirrel	5	3	0	0	**8**
Coyote	0	4	0	0	**4**
Gray fox	0	10	0	0	**10**
Raccoon	0	54	0	0	**54**
Beaver	0	0	1	0	**1**
Bear	0	0	1	0	**1**
Bobcat	0	3	0	0	**3**

Table 4.6.16. Non-volant mammal species expected at CARL but not observed along with comments about status and distribution.

Common Name	Status/Distribution
Nine-banded armadillo	Rare, Increasing
Woodland jumping mouse	Higher elevations?
Red squirrel	High elevations? Declining
Woodland vole	Common but varied
Common muskrat	Common
Southern red-backed vole	High elevations
North American deer mouse	Common at higher elevations
Star-nosed mole	Locally common
North American least shrew	Open habitats
Red fox	Common
Long-tailed weasel	Uncommon
Least weasel	Uncommon, NC-S2
Striped skunk	Common
Eastern spotted skunk	Rare
White-tailed deer	Increasing

The apparent absence of more common but not documented species (see Table 4.6.16) was a concern expressed by the authors and they attributed some of this to the increased presence of domestic dogs and cats associated with human residential development outside of the park. The presence of domestic animals like cats have been shown to negatively impact wildlife populations (Baker et al. 2003) and the authors did observe cats on wildlife cameras in pasture and forest habitats at CARL so this is a potential concern for managing mammal populations in the park. It has also been shown that increased trail use and road traffic associated with human residential development will impact the occurrence of larger mammals within protected areas (Erb et al. 2012) and may be of concern in CARL.

Overall, the literature documenting responses of small mammals to various types of habitat disturbance is varied to say the least with some studies suggesting negative impacts of forest disturbance and the presence of edge while others suggest no effects or positive impacts (Bowman et al. 2001, Osbourne et al. 2005, Kamiski et al. 2007). Microhabitat factors such as leaf litter depth, herbaceous vegetation have been found to influence small mammal abundance across studies and may suggest that microhabitat conditions may help offset the presumably negative impacts of landscape disturbance (Kaminski et al. 2007).

Bats

Mist netting documented five species (Table 4.6.18) and according to Loeb (2007), three of the species captured via mist-netting were expected to occur in the park whereas the small-footed bat and the evening bat were classified as a "possible inhabitants." The capture of a small-footed bat at CARL was particularly noted as these are quite rare. The northern long-eared bat (*Myotis septentrionalis*) (federally listed as threatened) was the most frequently captured species (4 of 6 sites surveyed) while other relatively common species included the little brown bat (*Myotis lucifugus*) and the big brown bat (*Eptesicus fuscus*) (Table 4.6.18).

Table 4.6.17. Acronyms, scientific and common name of bat species occurring at CARL during 2006-2007 surveys. Used in Tables 4.6.18 and 4.6.19.

Acronym	Scientific name	Common name
EPFU	*Eptisicus fuscus*	Big brown bat
LABO	*Lasiurus borealis*	Red bat
LANO	*Lasionycteris noctivagans*	Silver-haired bat
MYLE	*Myotis leibii*	Small-footed myotis
MYLU	*Myotis lucifigus*	Little brown myotis
MYSE	*Myotis septentrionalis*	Norther long-eared myotis
NYHU	*Nycticeius humeralis*	Evening bat
PISU	*Pipistrellus subflavus*	Tricolored bat

Table 4.6.18. Bat species captured at mist-netting sites for CARL during 2005 and 2006 (Loeb 2007).

Site	Habitat Type	EPFU	MYLE	MYLU	MYSE	NYHU	PISU
Front Lake	Hemlock-hardwood bottomland; Riparian habitat	3		6	4		
Glassy Trail Reservoir	Rhododendron, Pine-Oak; Riparian				4		
Goat Barn	Oak-pine forest; Pasture						
Main House	Hemlock, Rhododendron	1					
Five Points	Mixed hardwood		1		8		
Historic Entrance	Bottomland hardwood				1	1	
Total		**4**	**1**	**6**	**17**	**1**	**0**

Eight species were documented with bat detectors which included three additional species: eastern red bats (*Lasiurus borealis*), silver-haired bats (*Lasionycteris noctivagans*), and eastern pipistrelles (*Perimyotis subflavus*), all of which were expected (Loeb 2007). Based upon acoustic samples several sites are highly used by foraging bats (Table 4.6.19).

Table 4.6.19. Bat species detected in 2005 and 2006 by acoustic sampling in several habitat types at CARL (Loeb 2007).

Sample Plot	Habitat Type	EPFU	LABO	LANO	MYLE	MYLU	MYSE	NYHU	PISU	Total Spp.
CARL01	Montane Oak-Hickory	+				+	+		+	**4**
CARL02	Flat Rock Community	+		+						**2**
CARL03	Granite Flat Rock Community		+			+	+		+	**4**
CARL05	Chestnut-Oak/Mountain Laurel	+								**1**
CARL06	Chestnut-Oak Forest		+							**1**
CARL07	Agriculture/Tulip Poplar Successional	+	+	+		+			+	**5**
CARL08	Old Field	+	+	+		+			+	**5**
CARL09	Old Field	+								**1**
CARL10	White Pine-Hemlock Successional	+								**1**
CARL11	Chestnut-Oak Slope									**0**
CARL13	Pitch Pine-Mountain Laurel									**0**
CARL15	Red-Oak Maple (Near trout pond)	+	+		+	+	+	+	+	**7**
Front Lake	Hemlock-Hardwood, Bottomland Riparian	+	+		+	+			+	**5**
Mtn. Reservoir	Rhododendron, Pine-Oak Riparian	+	+	+			+			**4**
Side Lake	Riparian, Open Field	+	+	+	+	+	+	+	+	**8**
Total Sites		**11**	**8**	**5**	**3**	**7**	**5**	**2**	**7**	

Of particular note was the presence of lactating and pregnant females among northern long-eared bats, little brown bat, and big brown bats suggesting the presence of maternity colonies within or nearby CARL. As with other species, the proximity of CARL to both blue-ridge and piedmont type ecosystems likely influences the diversity occurring within the park. Species diversity measured for bats at CARL was higher than in other parks which may be due in part to the proximity of different physiographic regions but also the lesser degree of adjacent urbanization compared to other parks in the southeast (Loeb et al. 2009).

Given the variability in mammal response to habitat, it is somewhat difficult to make a definitive assessment of the condition of mammal populations at CARL. While the absence of numerous 16 expected species would seem severe, a portion of this could be attributed to poor trapping conditions (drought) as well as the cryptic nature, trap shyness, or overall rarity of some species (Pivorun and Fulton 2007). Additional monitoring data are sorely needed but in general the suite of mammal species found at CARL would seem to reflect the distribution of vegetation habitat types although the potential impacts from surrounding land use changes will likely be an ongoing concern if future studies show a decrease or continued absence of common species.

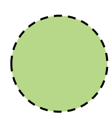
The condition of bat populations at CARL appears to be quite good as of 2007. As urbanization continues in the southeast, the park will likely become a very important resource for conserving bat populations. The most pressing unknown in the effort to conserve bats is the spread and ultimate impacts from white-nose syndrome. Although this analysis lacks the data to evaluate trajectories in bat populations at CARL, the potential impacts of this disease will be a major concern of managers in years to come (Flory et al. 2012).

Data Gaps

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.

Summary Conditions

Table 4.6.20. Graphical summary of status and trends for small mammals.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Mammal Species Composition (Actual vs. Expected)		Although several expected species were not encountered, Overall species composition among non-volant mammals seems to generally reflect the distribution of habitat (vegetation) conditions at CARL. Bats exhibited high diversity and all expected species were encountered. The spread of white nose syndrome will be a major concern with all bat species in this region.

4.7. At-risk Biota

4.7.1. Globally Rare or Uncommon Species

Relevance

Several plant species in the park are either globally rare or locally uncommon. Some of these species are regionally endemic and are not found anywhere else in the world while others are regionally disjunct at the park. Monitoring and protecting these species is critical to preserving both individual species' genetic diversity and overall ecological diversity. The CUPN monitoring program assists network parks with ongoing monitoring, development of protocols, and assists with project statements to fund future monitoring efforts (CUPN 2007). However, there is currently no formal monitoring program at CARL focused on rare and/or uncommon species. Park resource managers monitor certain species on an informal basis status (i.e., secure, improving, declining); however, the status of some species of interest are unknown.

Data and Methods

Data and resources used in this assessment include a vegetation assessment of the park's granitic domes (Woolsey and Walker 2008), a park vascular plant inventory (White 2003), and information gathered from personal communication with key park and CUPN staff. Global ranks for each species were based on NatureServe's global ranking system (NatureServe 2013b). A qualitative evaluation of the current trends in the populations of rare and uncommon species in the park was used to assess the condition and trend of this resource. Table 4.7.1 lists significant plant species found at CARL that will be summarized in the following paragraphs.

Table 4.7.1. Significant plant species found at CARL.

Species**	Common Name	Habitat	Global Rank	NC State Rank*
Packera millefolia	Piedmont ragwort	Rock	G2	S2
Hexastylis rhombiformis	North Fork heartleaf	Hardwood ravine	G3	S3
Scleria reticularis	Netted nutrush	Rock edge	G4	S2

* North Carolina Ranks: S2=imperiled; S3=vulnerable

** Plant species in table based on species of interest from White 2003.

Global and NC rankings from NatureServe Explorer online database, http://explorer.natureserve.org/ Accessed 2/5/2014

Table 4.7.1 (continued). Significant plant species found at CARL.

Species**	Common Name	Habitat	Global Rank	NC State Rank*
Talinum teretifolium	Quill fameflower	Rock	G4	S3
Dichanthelium leucothrix	Rough panicgrass	Rock	G4	S3
Nymphaea odorata	American white waterlily	Wetlands	G5	S4
Utricularia radiata	Little floating bladderwort	Wetlands	G4	S3
Smilax biltmoreana	Biltmore's carrionflower	Xeric Chestnut Oak	G4	S3
Thermopsis mollis	Alleghany mountain golden-banner	Dry woods	G3G4	S2
Tsuga caroliniana	Carolina hemlock	Acid Cove and Hemlock Forests	G3	S3

* North Carolina Ranks: S2=imperiled; S3=vulnerable; S4= apparently secure

** Plant species in table based on species of interest from White 2003.

Global and NC rankings from NatureServe Explorer online database, http://explorer.natureserve.org/ Accessed 2/5/2014

Reference Condition

Reference conditions for rare and uncommon plant species include conserved and protected habitats in which they occur, and sustainable populations with potential for long-term viability.

Current Conditions and Trends

Piedmont Ragwort

The Piedmont ragwort is a globally rare granitic dome specialist. Within North Carolina it is an imperiled species. According to the NatureServe plant database (2013a), the Piedmont ragwort is regionally endemic with fewer than 50 known populations. It can hybridize with the common Small's ragwort and may be in some danger of genetic deterioration. In general, granitic domes are uncommon, and the future of this species is dependent upon the continued good health of the granitic domes. This species was found on one outcrop near the park's southern boundary in 2001 (White 2003) but has not been documented since then (Woolsey and Walker 2008). Further searches are needed to determine the exact status of this species in the park. Its highly restrictive habitat, the documented presence of the species in the park over a decade ago, and a subsequent lack of observations and surveys since its initial documentation, warrants a significant concern for this resource. Since its status is uncertain, we assign an unknown trend and a high confidence level to this assessment.

North Fork Heartleaf

The North Fork heartleaf (Figure 4.7.1) is a globally and state-level vulnerable species. It is endemic to the southern Blue Ridge and found in four North Carolina counties and one county in South Carolina. It occurs in hardwood forests and woodlands and is commonly associated with rhododendron, mountain laurel, mayflower (*Epigaea repens*), and *Chimaphila maculate* shrub and herb layers. Threats include certain forest management practices, land use conversion, and habitat fragmentation. Inside the park, this species is secure with an expanding population (Irene Van Hoff, personal communication 2015). Based on long-term observations by park management staff, we assign a high level of confidence to this assessment.

Figure 4.7.1. North Fork heartleaf (*Hexastylis rhombiformis*).

Netted Nutrush

The netted nutrush, which has a widespread but spotty distribution, was found on a granitic outcrop edge in 2001 at CARL (White 2003). Although it is globally secure, the species is listed as imperiled in North Carolina. Further searches are needed to determine the exact status of this species in the park. The documented presence of the species in the park over a decade ago, and a subsequent lack of observations and surveys since its initial documentation, warrants a significant concern for this resource. Since its status is uncertain, we assign an unknown trend and a high confidence level to this assessment.

Quill Fameflower

The quill fameflower (*Talinum teretifolium*) is a characteristic species of granitic dome outcrops. It is secure in North Carolina; however it is a threatened species in some other states because of its restricted habitat on granitic domes, which are ranked as G2 communities. Although it is widespread, it is not a common species. Within the park, the quill fameflower has been documented in a granitic dome community near the southern boundary, and on a dome within the Appalachian Montane Oak Hickory Forest community in the center of the park (White 2003). Park resource managers report that this species is secure and populations appear to be stable. However, there is no formal monitoring program for this species; therefore, we assign a low confidence in this assessment.

Rough Panicgrass

Rough panicgrass (*Dichanthelium leucothrix*) is ranked as G4 species; however, it is considered vulnerable in North Carolina. Within the park, this species is considered a coastal disjunct (White 2003) and has been documented on a granitic dome community near the southern boundary, and within the Appalachian Montane Oak Hickory Forest community in the center of the park. Since it is considered vulnerable in North Carolina, contributes disproportionately to the park's biodiversity, and has previously been documented in the park but currently has an unknown status, we assign a condition that warrants significant concern with an unknown trend. There is no formal monitoring of this species; therefore, we assign a low confidence level to this assessment.

American White Waterlily

While it is not a plant of special concern, the American white waterlily (Figure 4.7.2) is very rare in the mountains and is considered a piedmont disjunct. There is a very small population in the northeastern portion of Side Lake. Further investigation is necessary to confirm its presence in other areas of Side Lake and its presence in Front Lake. Since this species contributes disproportionately to the park's biodiversity and it is not monitored regularly, we assign a condition that warrants significant concern with an unknown trend. There is no formal monitoring of this species; therefore, we assign a low confidence level to this assessment.

Figure 4.7.2. American white lily population located on Front Lake.

Little Floating Bladderwort

A carnivorous wetland plant, the little floating bladderwort is apparently secure world-wide but vulnerable in North Carolina. The park formerly had a healthy population in Front Lake (White 2003). Its location in the park is highly unusual because it is a disjunct species from the South Carolina piedmont. However, it has not been observed in over a decade. The reasons for its disappearance are unknown. Since this species contributes disproportionately to the park's biodiversity and has previously been documented in the park but currently has an unknown status, we assign a condition that warrants significant concern with an unknown trend and a high confidence in this assessment.

Biltmore's Carrionflower

Biltmore's carrionflower is restricted in its range to a small portion of the Blue Ridge. White (2003) reported this species was found throughout the Oak Hickory forests in healthy numbers at CARL and appeared to be secure within the park's boundaries. Since this species is a regional endemic restricted in its range, and the last population status was reported nearly 15 years ago, we assign a condition that warrants moderate concern with an unknown trend. Due to data currency we assign a low confidence level to this assessment.

Allegheny Mountain Golden-Banner

The Allegheny mountain golden-banner is rare throughout its range and is threatened by land-use conversion, fire suppression, and habitat fragmentation. This species needs open woodlands and deep soils to thrive and bloom. White (2003) speculates that this plant probably existed in the Pitch and Table Mountain Pine Woodlands group when the canopy was more open and permitted an herbaceous layer. Historic records from the UNC Herbarium show Edward Meminger, the son of the original occupant of Connemara, documented the species in Flat Rock in “open mountainsides” in 1886 (UNC Herbarium 2015). Park resource managers report a few known plants in one location inside the park. Since of its vulnerability, due to extremely low numbers in a single location we assign a condition that warrants significant concern. Its trend is unknown as there is no formal monitoring program. We assign a medium confidence level to this assessment because park resource managers informally but regularly monitor its status.

Carolina Hemlock

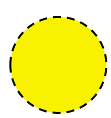
Carolina hemlock occurs in western areas of Virginia, and North and South Carolina, and parts of Georgia and Tennessee. Its habitat is confined to rocky stream beds and lower slopes within this range. Due to the exotic hemlock woolly adelgid decimating populations, the Carolina hemlock is a globally and North Carolina state-ranked vulnerable species. The species is currently secure and in good condition within CARL, as park staff regularly treat the trees for HWA using a variety of methods. We assign a high level of confidence to this assessment as the condition of the hemlocks is regularly monitored and treatments continue to sustain the tree’s populations in the park.

<u>Confidence and Data Gaps</u>

The lack of formal monitoring of many of these species is a significant data gap that leads to uncertainty about both the current condition and trend for these species.

<u>Summary Conditions and Graphics</u>

Table 4.7.2. Graphical summary of status and trends for at-risk biota.

Resource	Indicator	Status and Trend	Rationale and Reference Conditions
At-risk Biota	Globally rare or uncommon species		Reference conditions for rare and uncommon plant species include conserved and protected habitats in which they occur, and sustainable populations with potential for long-term viability. Lack of current observations for many species may suggest those species have already declined and warrant significant concern. Lack of formal monitoring programs makes it difficult to identify trends.

<u>Sources of Expertise</u>

- Irene Van Hoff, Biological Science Technician, Carl Sandburg Home National Historic Site
- Teresa Leibfreid, Network Program Manager, Cumberland Piedmont Network

4.8. Landscape Dynamics

4.8.1. Land Cover and Use

Relevance

The southern Appalachians contain some of the most biodiverse forest ecosystems in the world yet rural housing development in recent years has fragmented forests throughout this region (SAMAB 1996, Turner et al. 2003). In the case of CARL, the level of impact immediately adjacent to the park has been less severe than other areas of the region but such lower intensity 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 (Hansen et al. 2005).

Data and Methods

Land use-land cover conditions around CARL 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 in an effort to improve comparisons. Modified classes are shown in Table 4.8.1 and 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 5) Non-Vegetation (barren, rock, water). We then compared the proportion of area occupied by each class for CARL and a series of distance bands outside of the park boundary (400m, 1km, and 5km).

Table 4.8.1. Classification developed from NLCD data to evaluate landscape conditions at CARL.

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	Low Intensity Residential	Developed-Low Intensity
Developed-Med/High	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

NLCD layers are most suitable for assessing regional and national patterns thus we did not attempt to evaluate LULC changes within CARL but more to compare patterns at various distances away from the boundary.

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 CARL for each year.

In evaluating overall land cover we left "developed-low intensity" separate in our classification system (Table 4.8.2) because this has been the predominant land use change in the area around CARL. In evaluating landscape pattern we combined all development into a single class along with other non-forest. While many areas classified as low intensity development still have a forest component we were intending to focus on the changes in areas considered to be only forest.

Table 4.8.2. Percent (of total area) change within NLCD derived land cover classes from 1992-2011.

Year	Distance	Non-veg	Developed-low	Dev-Med/High	Non-Forest Veg	Forest
1992	CARL	0.00	0.74	2.39	9.88	86.99
	400m	0.27	1.13	13.15	3.80	81.65
	1,000m	1.25	0.97	10.09	11.71	75.97
	5,000m	0.63	5.58	11.35	19.68	62.75
2001	CARL	0.00	0.00	15.57	3.62	80.81
	400m	0.53	0.47	42.94	2.07	53.99
	1,000m	1.04	0.20	51.52	6.27	40.98
	5,000m	0.52	3.04	37.98	12.97	45.50
2006	CARL	0.00	0.00	15.57	3.62	80.81
	400m	0.53	0.80	42.61	2.07	53.99
	1,000m	1.04	0.53	51.19	6.27	40.98
	5,000m	0.52	3.80	37.91	12.49	45.29
2011	CARL	0.00	0.00	15.57	3.62	80.81
	400m	0.53	0.90	42.51	2.07	53.99
	1,000m	1.04	0.71	52.26	5.06	40.93
	5,000m	0.51	4.34	37.82	12.65	44.68

Reference Conditions

An ideal standard for evaluation of LULC changes, fragmentation and connectivity would be zero (or some established minimum) loss of natural vegetation cover over time. In the case of CARL as in so many landscapes there are few such reference conditions available by which to compare. Since the landscape at CARL 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 CARL.

Current Conditions and Trend

Some values changed within CARL and or between years because the 1992 classification combined some rock outcrop areas with forest classes whereas by 2001 these were somewhat more distinct although in general the NLCD resolution isn't particularly suitable for assessing specific changes within a relatively small area such as CARL.

The most dramatic changes in LULC at all distances from CARL occurred between 1992 and 2001 and indicated marked loss of forest and an increase in medium and high levels of development (Table 4.8.1). This trend reflects similar patterns reported for the Southern Appalachian region (Turner et al. 2003) as much of the western portion of North Carolina, for example, experienced population growth rates roughly two times the national average during the 1980s and 1990s (Pollard 2005).

The most dramatic changes occurred within 1 km (0.62 mi) of CARL although slight increases in low intensity development and losses in forest were seen within 5 km (3.1 mi) between 2001 and 2011 (Table 4.8.2). The majority of the forest loss in the region occurred toward the more urban areas north and east of the park although the most severe changes immediately adjacent to the park fall to the south (Figure 4.8.1).

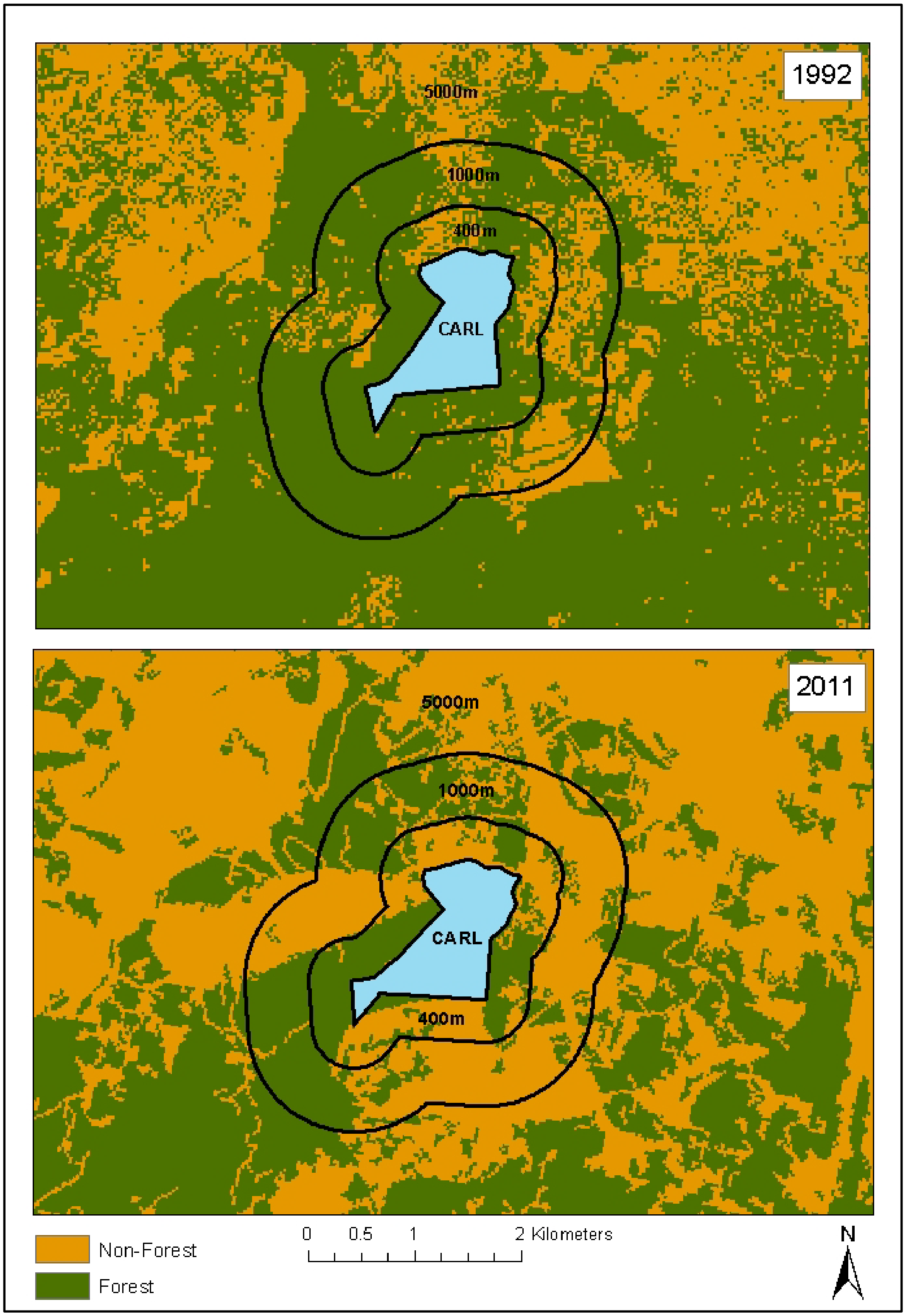


Figure 4.8.1. Loss of contiguous forest land cover around CARL between 1992 and 2011 as derived from the National Land Cover Database. Much of the area immediately adjacent to CARL is low intensity residential development thus a substantial forest component remains but has been fragmented to some degree by residential development.

Average distance to the nearest edge followed similar patterns to the general land cover but also would suggest that the areas within 1 km (0.62 mi) of CARL were somewhat more severely impacted whereas nearer to the boundary this is less so (Table 4.8.3). Conditions adjacent to CARL have fragmented forests and thus reduced the average distance to human impacted forest or non-forest by half between 1992 and 2001 (Table 4.8.3, Figure 4.8.1). This trend seems to be continuing within 5 km (3.1 mi) of CARL but has apparently leveled off elsewhere by measures used here.

Table 4.8.3. Average distance (meters) to the nearest non-forest edge within and adjacent to CARL between 1992 and 2011.

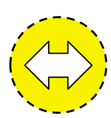
Distance	1992	2001	2006	2011
CARL	96.24	116.90	116.90	116.90
400m	100.51	53.67	53.67	53.67
1,000m	101.67	40.08	40.08	40.06
5,000m	81.02	48.57	48.50	45.76

Confidence and Data Gaps

The 30 meter resolution of the NLCD data sets necessitates an over-simplification of land cover at smaller extents and thus very local and quantitative measures of land use change aren't practical. This is further complicated by the variation in NLCD classifications over time. Even so, the difficulty in assigning condition in this case stems more from not knowing how much specific impact there has been or will be to the condition of forest resources at CARL (and thus whether current conditions warrant moderate concern). Lower density residential development has existed near CARL for years and the park itself was established to preserve several non-forest land cover features as well as the forests. Thus, while human land use around CARL has increased, how much specific impact this has had on the ecosystems at CARL is not clear. On one hand most terrestrial vertebrate communities seem to be in good condition yet the presence of adjacent residential development has likely increased the risk of invasive species occurrence, the level of trail use in the park and introduced a greater number of domestic dogs and cats which are likely impacting some wildlife inside the park (Pivorun and Fulton 2007).

Summary Condition

Table 4.8.4. 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 (Pattern of change since 1992)		Trends seem to be stable but conversion of adjacent forests to residential development has the potential to continue to negatively impact ecosystems within CARL

4.9. Viewscape

4.9.1. Night Skies

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). Ecological impacts on wildlife include habitat quality for birds, terrestrial and marine mammals, fish, and sea turtles, nocturnal wildlife activity and behavior, migration patterns, and predator-prey interactions (Longcore and Rich 2004).

Data and Methods

Data are unavailable.

Reference Conditions

A cited reference condition for natural sky brightness is based upon "true-dark" sites where the sky brightness is less than half a magnitude brighter than natural (at the zenith) or about 21.5 magnitudes/square arc second or fainter (Garstang 1989, Skiff 2001).

Resource Conditions

While land use changes around CARL have no doubt increased non-natural light conditions, no data exist with which to evaluate the night sky conditions or their impacts.

Chapter 5. Natural Resource Conditions Summary

5.1. NRCA Overview

The Carl Sandburg Home National Historic Site covers approximately 106 ha (264 ac) on the edge of the southern Appalachian Mountains in North Carolina. CARL is located in the Broad Basins ecoregion, which is a transitional zone between the Blue Ridge Mountains and the Southern Piedmont. It is characterized by moderate relief with elevations ranging from 658 to 848 meters (2,160 to 2,783 feet). The property is primarily forested, but also contains pastures, ponds, two small streams, and contains nearly 50 structures including the Sandburgs' former residence and goat barn complex. CARL faces a number of resource related issues, many of which are related to surrounding population growth and land use. The park lies within the Flat Rock, NC municipality and is located approximately 4.8 km (3 mi) from Hendersonville, NC. Increased development reduces wildlife habitat availability in areas outside of the park and further encourages invasive exotic species encroachment inside the park boundaries. Furthermore, as the surrounding population continues to grow, visitor rates to the park will increase, placing added stress on the park's natural resources.

This NRCA describes the current conditions and trends for CARL's natural resources. The resource assessments were largely based on summarizing existing data in combination with expert judgement 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

CARL is tasked with conserving both natural and cultural values. As a unit of the National Park System, CARL 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, the Carl Sandburg Home is fundamentally a cultural park under the historic sites Act of 1935 (16 U.S.C sec. 461-467). This NRCA identified 3 areas where management and monitoring will be particularly important to achieve its mission of conserving the park's natural resources. Recognizing that there is some overlap between them, these include: 1) protecting and restoring unique vegetative communities found on the property, 2) monitoring and managing the impacts of non-native plants, insects, and diseases, and 3) monitoring the effects of acidic deposition on soils, water quality, terrestrial communities, and aquatic communities.

CARL contains two unique natural communities including the globally imperiled (G2) Appalachian Low Elevation Granitic Dome Communities and the globally vulnerable (G3) Blue Ridge Table Mountain Pine-Pitch Pine Woodland. The Granitic Dome communities are suffering from trampling by park visitors and the introduction of non-native invasive plants. The fragile native vegetation found on the domes is very slow to recover following such disturbances. In addition, both the Granitic Domes and Table Mountain Pine-Pitch Pine woodlands contain a number of fire-adapted species that are being displaced by fire-intolerant species in response to the exclusion of fire from these sites since the mid-1900s. This has led to increased dominance of eastern white pine in the Granitic Domes and increased dominance of fire-intolerant hardwoods, such as, red maple in the Table Mountain Pine-Pitch Pine woodlands.

Current monitoring efforts have identified 118 non-native plants species in the park. Forty-two of these have been ranked for their invasiveness, with 33 of those considered to be a threat to natural vegetation in the park. Invasive non-native plants threaten all native plant communities within CARL, and will likely be an increasing challenge in the future. The number of non-native insects and diseases in the region continues to grow and pose a serious threat to CARL's natural communities. In most cases, there are no effective treatments to combat non-native insects and diseases once they become established. This is illustrated by dogwood anthracnose disease, which is currently widespread throughout the park and has led to an 83% decrease in flowering dogwood trees since its introduction. In some cases there are effective treatments, such as those used to treat hemlocks for hemlock woolly adelgid. However, a large number of hemlocks died before treatments were implemented, and saving the remaining 400 trees will require continuing the current treatments indefinitely unless an effective biological control mechanism is developed.

Atmospheric deposition of acid pollutants, primarily in the form of nitrogen and sulfur compounds, is the greatest threat to water quality in the park, and also impacts soils and vegetation. Soils in CARL are inherently low in bases and have little capacity to buffer the effects of acidic deposition. Soil acidification causes leaching of nutrients from soils, making them less fertile, and can potentially mobilize toxins, such as aluminum and other metals. CARL has little information on soil properties, though water acidification data show little improvement despite recent reductions in atmospheric deposition of acid pollutants. This suggests it may take at least several decades for systems to recover from past acid deposition.

5.3. Compiled Resource Assessment Summary Condition Tables

The following sections contain the resource condition summary tables for each Level 3 resource assessed in this NRCA. These provide a snapshot of the current condition and trend for park resources.

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

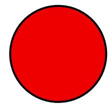
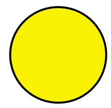
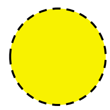
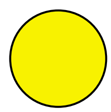
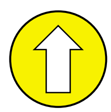
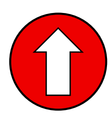
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Air Quality	Total Sulfur (Wet deposition in kg/ha/yr)		Estimated sulfur wet deposition was 2.7 kg/ha/yr (2008-12); condition elevated to significant concern due to sensitive ecosystems; NPS ARD advises against using interpolated values for trends (Data Source(s): NADP-NTN via AirAtlas)
Air Quality	Total Nitrogen (Wet deposition in kg/ha/yr)		Estimated nitrogen wet deposition was 2.9 kg/ha/yr (2008-12); moderate sensitivity to nutrient-enrichment effects; NPS ARD advises against using interpolated values for trend (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 15.13 µg/m2/yr; estimated methylmercury concentration in park surface waters was 0.03 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 69.5 ppb and estimated W126 was 8.9 ppm-hrs (2008-12); warrants moderate concern; NPS ARD advises against using interpolated values for trends (Data Source(s): EPA AQS via AirAtlas)
Air Quality	$PM_{2.5}$ Concentration in $µg/m^3$		$PM_{2.5}$ concentration was 9.3 $µg/m^3$ (2010-12); warrants moderate concern; values have declined since 1999; recent levels have fallen below threshold of ≤12 $µg/m^3$ (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 8.3 dv (2008-12); warrants significant concern; values have improved since 1999; exceeds significant concern level of <8 dv above estimated natural conditions (Data Source(s): IMPROVE via AirAtlas)

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

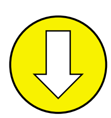
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Soil & Geologic Resources	Soil Quality		Reference condition consists of soil properties sufficient to support the native vegetative communities found at CARL, and to buffer surface waters from acidic deposition and other forms of anthropogenic pollution. Stream water pH is often below NC State standards and accelerated erosion, soil compaction, and sedimentation are observed at some high visitor use areas and trails.

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 are often below a pH 6.0 and/or exhibit ANC values below 2.5 mg/l (50 µeq/L), Reference Condition: North Carolina Water Quality Standard for fish and aquatic life (Class C); Tennessee State ANC TMDL default target set for 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;
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. Reference Condition: Based on local and 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/100 mL)		With one exception, measured values are below reference values. North Carolina standard for fecal coliform (200 cfu/100 mL of water); EPA Criteria for E.coli (576 MPN/100 mL)

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

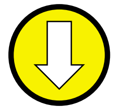
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Invasive Species	Invasive Exotic Plants		Reference condition is maintaining or reducing invasive exotic species to levels where they do not threaten the ecological integrity of plant communities. Monitoring efforts document that invasive exotic plants have been found in CARL, and the number of species appears to be increasing. However in most cases exotic plants are limited to highly trafficked areas and have not significantly impacted large areas of native plant communities.

Table 5.3.5. Graphical summary of status and trends for infestations and diseases.

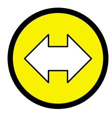
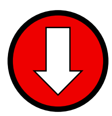
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Infestations and Diseases	Insect Pests		The presence/absence of hemlock woolly adelgid and treatment efficacy were used to assess the current condition of insect pests. The reference condition consists of HWA not causing mortality or preventing individual hemlock trees to live and grow to their full size and life span. Hemlocks are in good condition under the current treatment regime and their health appears to be stable and unchanging.
Infestations and Diseases	Plant Diseases - Dogwood Anthracnose		Reference condition is healthy flowering dogwood tree populations are health with individual trees living to their full size and life span. The overall condition of the park's dogwoods is poor and the population is declining.

Table 5.3.6. Graphical summary of status and trends for focal species and communities.

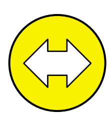
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Wetland Communities		The reference condition for wetlands was established as their ability to perform key wetland functions including, surface water storage, groundwater discharge to streams, carbon/nutrient export, provision of wildlife habitat, support of wetland plants. The park's wetlands provide some level of ecological services, and will continue to contribute a small amount of flood attenuation, groundwater discharge maintenance, and other beneficial functions characteristic to wetlands. The presence of invasive species in the wetlands necessitates monitoring and treatment to maintain ecological integrity.

Table 5.3.6 (continued). Graphical summary of status and trends for focal species and communities.

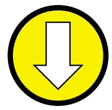
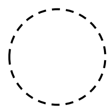
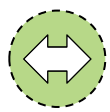
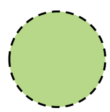
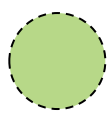
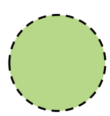
Resource	Indicator	Status and Trend	Rationale and Reference Conditions
Focal Species & Communities	Forest / Woodland Communities		Reference condition is the perceived pre- Euro-settlement conditions that existed under a natural fire regime, were free from visitor use impacts, and existed without competition from exotic invasive plant species. Granitic Dome and Table Mountain Pine-Pitch Pine community conditions warrant significant concern because of changes attributed to fire suppression, visitor impacts, and exotic species introduction. These are the most unique forest and woodland communities in CARL. Highlands Hemlock-Hardwood forest are in good condition due to continual treatment of hemlock woolly adelgid, but those treatments will need to continue indefinitely and these forests will need to be monitored for exotic plants.
Focal Species & Communities	Fish Diversity		2006 sampling identified 12 species from stream samples (Scott 2006). But, there are no data available after 2006.
	Macro-invertebrate Species Richness		Sampling from 2010-2011 identified 139 aquatic macroinvertebrate species from the park (Parker et al. 2012).
Focal Species & Communities	Reptiles and Amphibian Species Composition (Actual vs. Expected)		While some commonly occurring within the region species were not observed at CARL. Species richness was still relatively high.
Focal Species & Communities	Avian Species Composition (Actual vs. Expected and Response Guild Abundance)		Species composition and abundance seem to reflect the available habitats at CARL and avian resources appear in good condition.
Focal Species & Communities	Mammal Species Composition (Actual vs. Expected)		Although several expected species were not encountered, Overall species composition among non-volant mammals seems to generally reflect the distribution of habitat (vegetation) conditions at CARL. Bats exhibited high diversity and all expected species were encountered. The spread of white nose syndrome will be a major concern with all bat species in this region.

Table 5.3.7. Graphical summary of status and trends for at-risk biota.

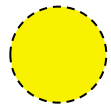
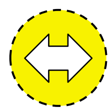
Resource	Indicator	Status & Trend	Rationale and Reference Conditions
At-risk Biota	Globally rare or uncommon species		Reference conditions for rare and uncommon plant species include conserved and protected habitats in which they occur, and sustainable populations with potential for long-term viability. Lack of current observations for many species may suggest those species have already declined and warrant significant concern. Lack of formal monitoring programs makes it difficult to identify trends.

Table 5.3.8. 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 (Pattern of change since 1992)		Trends seem to be stable but conversion of adjacent forests to residential development has the potential to continue to negatively impact ecosystems within CARL

Literature Cited

Alabaster, J.S. and R. Lloyd**.** 1980. Water Quality Criteria for Freshwater Fish. London-Boston: Butterworth.

Altshuller, A.P. and A.S. Lefohn. 1996. Background ozone in the planetary boundary layer over the United States. *Journal of the Air and Waste Management Association* 46: 134-141.

AMAP/UNEP (Arctic Monitoring and Assessment Programme/United Nations Environmental Programme). 2008. Technical background report to the Global Atmospheric Mercury Assessment. Arctic Monitoring and Assessment Programme/UNEP Chemicals Branch. Available at: http://www.unep.org/chemicalsandwaste/Portals/9/Mercury/Documents/Publications/Technical_background_report.pdf.

Ambrose, S. and S. Burson. 2004. Soundscape studies in National Parks. *The George Wright Forum* 21(1): 29-38.

Aneja, V.P., C.S. Clalborn, Z. Liu, and A. Murthy. 1990. Exceedances of the national ambient air quality standard for ozone occurring at a pristine area site. *Journal of the Air and Waste Management Association* 40: 217-220.

Argue, D.M., J.P. Pope, and F. Dieffenback. 2011. Characterization of major-on chemistry and nutrients in headwater streams along the Appalachian National Scenic Trail and within adjacent watersheds, Maine to Georgia. U.S. Geological Survey Scientific Investigations Report 2011-5151.

ATSDR (U.S. Agency for Toxic Substances and Disease Registry). 1999. Toxicological profile for mercury. Report No. CAS# 7439-97-6. Atlanta, GA.

Baker, J., J. Van Sickle, C. Gagen, D. DeWalle, W. Sharpe, R. Carline, B. Baldigo, P. Murdoch, D. Bath, W. Drester, H. Simonin, and P. Winington, Jr. 1996. Episodic acidification of small streams in the northeastern United States: effects on fish populations. *Ecological Applications* 6(2): 422-437.

Baker, P.J., R.J. Ansell, P.A.A. Dodds, C.E. Webber, and S. Harris. 2003. Factors affecting the distribution of small mammals in an urban area. *Mammal Review* 33: 95-100

Baldigo, B.P. and P.S. Murdoch. 1997. Effect of stream acidification and inorganic aluminum on mortality of brook trout (*Salvelinus fontinalis*) in the Catskill Mountains, New York. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 603-615.

Baldigo, B.P., G. Lawrence, and H. Simonin. 2007. Persistent mortality of brook trout in episodically acidified streams of the southwestern Adirondack Mountains, New York. *Transactions of the American Fisheries Society* 136(1): 121–134.

Barnett, T.W. 2003. Stream water quality modeling in the Great Smoky Mountains National Park. Master Thesis. University of Tennessee. Knoxville, TN.

Barrett, K. and C. Guyer. 2008. Differential responses of amphibians and reptiles in riparian and stream habitats to land use disturbances in western Georgia, USA. *Biological Conservation* 141: 2290-2300.

Bobbink, R., K. Hicks, J. Galloway, T. Spranger, R. Alkemade, M. Ashmore, M. Bustamante, S. Cinderby, E. Davidson, F. Dentener, B. Emmett, J-W. Erisman, M. Fenn, F. Gilliam, A. Nordin, L. Pardo, and W. De Vries. 2010. Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis. *Ecological Applications* 20: 30-59.

Boening, D.W. 2000. Ecological effects, transport, and fate of mercury: a general review. *Chemosphere* 40(12): 1335-1351.

Bowman, J., G. Forbes, and T. Dilworth. 2001. Landscape context and small-mammal abundance in a managed forest. *Forest Ecology and Management* 140: 249-255.

Buchwalter, D.B., L. Xie, and Y. Arai. 2009. Final report: assessing mercury contamination and bioavailability in Great Smoky Mountains National Park aquatic habitats. Prepared for: Great Smoky Mountains Conservation Association James Tanner Fellowship Committee and Great Smoky Mountains National Park, National Park Service

Buerhmann, E. n.d. Image of Carl Sandburg. Available at: http://www.poets.org/poetsorg/poet/carl-sandburg (Accessed 29 September 2014).

Cai, M. and J.S. Schwartz. 2012. Biological effects of stream water quality on aquatic macroinvertebrates and fish communities within Great Smoky Mountains National Park. Unpublished Report.

Chappelka, A.H. and L.J. Samuelson. 1998. Ambient ozone effects on forest trees of the eastern United States: A review. *New Phytologist* 139: 91-108.

Chestnut, L.G. and D.M. Mills. 2005. A fresh look at the benefits and costs of the U.S. Acid Rain Program. *Journal of Environmental Management* 77(3): 252-266.

Cinzano, P., F. Falchi1, and C. D. Elvidge. 2001. The first world atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society* 328: 689-707.

Clarkson, T.W. and L. Magos. 2006. The toxicology of mercury and its chemical compounds. *Critical Reviews in Toxicology* 36(8): 609-662.

Cornell Lab of Ornithology. n.d. Image of eastern towhee. Available at: http://www.allaboutbirds.org/guide/Eastern_towhee/id (Accessed 29 September 2014).

CUPN (Cumberland Piedmont Inventory and Monitoring Network) 2009. Monitoring of Native and Exotic Invasive Forest Pests and Pathogens. Available at: http://science.nature.nps.gov/im/units/cupn/publications.cfm (Accessed 5 May 2014).

CUPN (Cumberland Piedmont Network). 2007. Resource Brief: Rare Plant Monitoring in Cumberland Piedmont Parks.

CUPN (Cumberland Piedmont Network). 2013. Forest Vegetation 2013 Resource Brief. Carl Sandburg Home National Historic Site.

CUPN (Cumberland Piedmont Network). 2014. Long term forest vegetation monitoring plot data. Unpublished raw data.

De Schrijver, A., P. De Frenne, E. Ampoorter, L. Van Nevel, A. Demey, K. Wuyts, and K. Verheyen. 2011. Cumulative nitrogen inputs drive species loss in terrestrial ecosystems. *Global Ecology and Biogeography* 20: 803-816.

Deschu, N. and R. Kavanagh. 1986. Water quality and the effects of mining activities in the Kantishna Hills, Denali National Park, 1983, National Park Service, Anchorage, Alaska.

Deyton, E.B., J.S. Schwartz, R.B. Robinson, K.J. Neff, S.E. Moore, and M.A. Kulp. 2009. Characterizing episodic stream acidity during stormflows in the Great Smoky Mountains National Park. *Water, Air, and Soil Pollution* 196: 3-18.

Diem, J.E. 2003. A critical examination of ozone mapping from a spatial-scale perspective. *Environmental Pollution* 125: 369-383.

Driscoll, C.T. 1985. Aluminum in acidic surface waters: chemistry, transport, and effects. *Environmental Health Perspectives* 63: 93-104.

Driscoll, C.T. and K.M. Postek. 1995. The chemistry of aluminum in surface waters. Pages 363-418 *in* G. Sposito, Editor. The Environmental Chemistry of Aluminum. Lewis, Chelsea, MI.

Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51(3): 180-198.

Driscoll, C.T., J.P. Baker, J.J. Bisogni, and C.L. Schofield. 1980. Effect of aluminum speciation on fish in dilute acidified waters. *Nature* 284: 161-164.

Eagles-Smith, C., S.J. Nelson, D. Krabbenhoft, R. Haro, and C. Chen. 2013. Linking freshwater mercury concentrations in parks to risk factors and bio-sentinels: a national-scale research and citizen science partnership. NPS/USGS Water Quality Partnership proposal.

EPA (U.S. Environmental Protection Agency). 1986. Quality Criteria for Water 1986. EPA Redbook.

EPA (U.S. Environmental Protection Agency). 1996. Air quality criteria for ozone and related photochemical oxidants. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, Report No. EPA 600/P-93/004bF.

EPA (U.S. Environmental Protection Agency). 1997. Mercury Study Report to Congress. Vol. VI.

EPA (U.S. Environmental Protection Agency). 1999. Smog – Who does it hurt? What you need to know about ozone and your health. EPA Office of Air and Radiation, Washington, D.C., Report No. EPA 452/K-99-001.

EPA (U.S. Environmental Protection Agency). 2001. Protocols for developing pathogen TMDLs, first edition. EPA 841-R-00-002.

EPA (U.S. Environmental Protection Agency). 2002. Water Quality Standards: Regulations and Resources. May 2002. Available at: www.epa.gov/ost/standards/bacteria/bacteria.pdf.

EPA (U.S. Environmental Protection Agency). 2002b. Water Quality Conditions in the United States: 2000 National Water Quality Inventory. EPA-841-R-02-001. August 2002

EPA (U.S. Environmental Protection Agency). 2003. Guidance for estimating natural visibility conditions under the regional haze program. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, Report No. EPA-454/B-03-005.

EPA (U.S. Environmental Protection Agency). 2004. Air quality criteria for particulate matter. EPA Office of Air and Radiation, Washington, D.C., Report No. EPA 600/P-99/002aF-bF.

EPA (U.S. Environmental Protection Agency). 2005. Evaluating ozone control programs in the Eastern United States: focus on the NO_X budget trading program, 2004. EPA Office of Air and Radiation, Washington, D.C., Report No. EPA 454-K-05-001.

EPA (U.S. Environmental Protection Agency). 2012. Mercury and Air Toxics Standards (MATS): Basic Information. Available at: https://www.epa.gov/mats (Accessed 19 May 2015).

EPA (U.S. Environmental Protection Agency). 2012. National Ambient Air Quality Standards (NAAQS). Available at: https://www.epa.gov/criteria-air-pollutants/naaqs-table (Accessed 20 May 2015).

EPA (U.S. Environmental Protection Agency). 2012b. Visibility and Regional Haze. Available at: http://www.epa.gov/visibility/ (Accessed 22 May 2015).

EPA (U.S. Environmental Protection Agency). 2013. Air Data – Air Quality System (AQS) Data Mart. Available at: http://www.epa.gov/airdata/ (Accessed 21 May 2015).

EPA (U.S. Environmental Protection Agency). 2013. Mercury in Your Environment. Available at: http://epa.gov/mercury/about.htm (Accessed 19 May 2015).

EPA (U.S. Environmental Protection Agency). 2013. National Recommended Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm.

EPA (U.S. Environmental Protection Agency). 2013. Overview of the Clear Air Act and Air Pollution. Available at: http://www.epa.gov/air/caa/ (Accessed 18 May 2015).

EPA (U.S. Environmental Protection Agency). 2013a. Air Data – Air Quality System (AQS) Data Mart. Available at: http://www.epa.gov/airdata/ (Accessed 21 May 2015).

EPA (U.S. Environmental Protection Agency). 2013a. Level III and IV Ecoregions of the Continental United States. Available at: https://archive.epa.gov/wed/ecoregions/web/htmL/level_iii_iv-2.htmL.

EPA (U.S. Environmental Protection Agency). 2013b. Particulate Matter (PM). Available at: https://www.epa.gov/pm-pollution (Accessed 11 June 2015).

EPA (U.S. Environmental Protection Agency). 2013c. Particulate Matter (PM2.5) Map of Nonattainment Areas. Available at: http://www.epa.gov/pmdesignations/1997standards/documents/Apr05/greenmap.htm (Accessed 21 May 2015).

EPA (U.S. Environmental Protection Agency). 2014. National Atmospheric Deposition Program Total Deposition Maps. Available at: http://nadp.sws.uiuc.edu/committees/tdep/tdepmaps/ (Accessed 6 August 2015).

EPA (U.S. Environmental Protection Agency). 2014. Policy assessment for the review of the ozone National Ambient Air Quality Standards. EPA Office of Air and Radiation, Research Triangle Park, NC, Report No. EPA-452/R-14-006.

EPA (U.S. Environmental Protection Agency). 2015. Air Emission Sources. Available at: http://www.epa.gov/air/emissions/index.htm (Accessed 10 May 2015).

Erb, P.L., W.J. McShea, and R.P. Guralnick. 2012. Anthropogenic influences on macro-level mammal occupancy in the Appalachian Trail corridor. *PLoS ONE* 7(8): e42574.doi: 10.1371/journal.pone.0042574

Exley, C., J.S. Chappell, and J.D. Birchall. 1991. A mechanism for acute aluminum toxicity in fish. *Journal of Theoretical Biology* 151: 417-428.

Fancy, S.G., J.E. Gross, and S.L. Carter. 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* 151(1): 161-174.

Fisher, L.S. and M.H. Wolfe. 2012. Examination of mercury inputs by throughfall and litterfall in the Great Smoky Mountains National Park. *Atmospheric Environment* 47: 554-559.

Flory, A.R., S. Kumar, T.J. Stohlgren, and P.M. Cryan. 2012. Environmental conditions associated with bat white-nose syndrome mortality in the eastern United States. *Journal of Applied Ecology* 49: 680-689.

Fowler, D., J.A. Pyle, J.A. Raven, and M.A. Sutton. 2013. The global nitrogen cycle in the twenty-first century: introduction. *Philosophical Transactions of the Royal Society B: Biological Sciences* 368(1621). Available at: http://dx.doi.org/10.1098/rstb.2013.0165.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the conterminous United States, *Photogrammetric Engineering & Remote Sensing* 77(9): 858-864.

Fry, J.A., M.J. Coan, C.G. Homer, D.K. Meyer, and J.D. Wickham. 2009. Completion of the National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit product: U.S. Geological Survey Open-File Report 2008–1379

Gagen, C.J. and W.E. Sharpe. 1987. Net sodium loss and mortality of three salmonid species exposed to a stream acidified by atmospheric deposition. *Bulletin of Environmental Contamination and Toxicology* 39: 7-14.

Garstang, R.H. 1989. The status and prospects for ground-based observatory sites. *Annual Review of Astronomy and Astrophysics* 27: 19-40.

Gorder, J. 2004. Carl Sandburg Home National Historic Site: Fire Management Plan & Environmental Assessment. Prepared by Mangi Environmental Group for the National Park Service.

Gramann, J. 1999. The effects of mechanical noise and natural sound on visitor experiences in units of the National Park System. *NPS Social Science Research Review* 1: 1–16.

Grantz, D.A., J.H.B. Garner, and D.W. Johnson. 2003. Ecological effects of particulate matter. *Environment International* 29(2-3): 213-239.

Greaver, T.L., T.J. Sullivan, J.D. Herrick, M.C. Barber, J.S. Baron, B.J. Cosby, M.E. Deerhake, R.L. Dennis, J-J.B. Dubois, C.L. Goodale, A.T. Herlihy, G.B. Lawrence, L. Liu, J.A. Lynch, and K.J. Novak. 2012. Ecological effects of nitrogen and sulfur air pollution in the US: what do we know? *Frontiers in Ecology and Environment* 10(7): 365-372.

Greenberg, C.H. and T.A. Waldrop. 2008. Short-term response of reptiles and amphibians to prescribed fire and mechanical fuel reduction in a southern Appalachian upland hardwood forest. *Forest Ecology and Management* 255: 2883-2893.

Greenberg, C.H., A.L. Tomcho, J.D. Lanham, T.A. Waldrop, J. Tomcho, R.J. Phillips, and D. Simon. 2007. Short-term effects of fire and other fuel reduction techniques on breeding birds in a southern Appalachian upland hardwood forest. *Journal of Wildlife Management* 71: 1906–1916

Griffith, G., J. Omernik, and J. Comstock. 2002. Ecoregions of North Carolina-Regional Descriptions. Available at: https://archive.epa.gov/wed/ecoregions/web/htmL/ncsc_eco.htmL (Accessed 1 April 2002).

Griffith, G.E., J.M. Omernik, and M. McGinley. 2008. Ecoregions of North Carolina and South Carolina. *In:* Cleveland, C.J., editor. Encyclopedia of earth, environmental information coalition. National Council for Science and the Environment, Washington, DC. Pearson, S.M. and A.B. Smith. 2006. Bird Inventory of Carl Sandburg Home 2003-2004. Prepared for the National Park Service Inventory and Monitoring Program.

Grippo R.S. and W.A. Dunson. 1996. The body ion loss biomarker. 1. Interactions between trace metals and low pH in reconstructed coal mine-polluted water. *Environmental Toxicology Chemistry* 15(11): 1955–1963.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume 1. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, Virginia, USA.

Grulke, N.E. 2003. The physiological basis of ozone injury assessment attributes in Sierran conifers. Pages 55-81 *in* A. Bytnerowicz, M.J. Arbaugh, and R. Alonso, Editors. Ozone Air Pollution in the Sierra Nevada: Distribution and Effects on Forests. New York, NY: Elsevier Science, Ltd

Hansen, A.J., R.L. Knight, J.M. Marzluff, S. Powell, K. Brown, P.H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications* 15: 1893-1905.

Hart, S. 1993. Carl Sandburg Home National Historic Site: Cultural Landscape Report. NPS Southeast Regional Office. Southeast Regional Office. Published Report-2188251.

Heck, W.W. and E.B. Cowling. 1997. The need for a long term cumulative secondary ozone standard – an ecological perspective. Environmental Management, January 1997, pages 23-33. Available at: http://pubs.awma.org/gsearch/em/1997/1/heck.pdf.

Hemond, H.F. 1990. Wetlands and the source of dissolved organic carbon to surface waters. Pages 301-313 *in* E.M. Perdue and E.T. Gjessing, Editors, Organic Acids in Aquatic Ecosystems. John Wiley and Sons, New York

Henderson County Government. 2014. Parcel Map. Available at: http://henderson.roktech.net/ParcelMap/# (Accessed 23 September 2014).

Herlihy, A., P. Kaufmann, J. Stoddard, K. Eshleman, and A. Bulger. 1996. Effects of acid deposition on aquatic resources in the southern Appalachians with a special focus on Class I Wilderness areas. Report to the Southern Appalachian Mountains Initiative (SAMI).

Hermann, J., E. Degerman, A. Gerhardt, C. Johansson, P. Lingdell, and I.P. Muniz. 1993. Acid stress effects on stream biology. *Ambio: A Journal of the Human Environment* 22(5): 298-306.

Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity, and invasion: implications for conservation. *Conservation Biology* 6(3): 324-337.

Homer, C., J. Dewitz, J. Fry, M. Coan, N. Hossain, C. Larson, N. Herold, A. McKerrow, J.N. VanDriel, and J. Wickham. 2007. Completion of the 2001 National Land Cover Database for the conterminous United States. *Photogrammetric Engineering and Remote Sensing* 73(4): 337-341.

Homer, C.G., J.A. Dewitz, L. Yang, S. Jin, P. Danielson, G. Xian, J. Coulston, N.D. Herold, J.D. Wickham, and K. Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing* 81(5): 345-354.

Howells, G.D., D.J.A. Brown, and K. Sadler. 1983. Effects of acidity, calcium, and aluminum on fish survival and productivity – A review. *Journal of the Science of Food and Agriculture* 34: 559-570.

Huckabee, J.W., C.P. Goodyear, and R.D. Jones. 1975. Acid rock in the Great Smokies: Unanticipated impact on aquatic biota of road construction in regions of sulfide mineralization. *Transactions of the American Fisheries Society* 104(4): 677-684.

IMPROVE (Interagency Monitoring of Protected Visual Environments). 2013. Available at: http://vista.cira.colostate.edu/improve/Default.htm (Accessed 21 May 2015).

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer, editors]. IPCC, Geneva, Switzerland.

Jenkins, M.A., S. Jose, and P.S. White. 2007. Impacts of an exotic disease and vegetation change on foliar calcium cycling in Appalachian forests. *Ecological Applications* 17: 869-881.

Jernigan, J.W., B. Carson, and T. Leibfreid. 2014. Cumberland Piedmont Network ozone and foliar Injury report – Carl Sandburg Home NHS, Guilford Courthouse NMP and Mammoth Cave NP: Annual report 2012. Natural Resource Data Series NPS/CUPN/NRDS-2014/676. National Park Service, Fort Collins, Colorado. Available at: http://irmafiles.nps.gov/reference/holding/496279 (Accessed 20 May 2015).

Johnson, J.E. 2003. Forest Management Plan for the Carl Sandburg Home National Historic Site, Flat Rock, North Carolina. Dept. of Forestry, College of Natural Resources, Virginia Tech, Blacksburg, Virginia.

Jordan, T.R. and M. Madden, 2010. Digital Vegetation Maps for the NPS Cumberland-Piedmont I&M Network: Final Report November 1, 2010. Natural Resource Technical Report NPS/CUPN/NRTR—2010/406. National Park Service, Fort Collins, Colorado.

Kamiski, J.A., M.L. Davis, and M. Kelley. 2007. Disturbance effects on small mammals in a managed Appalachian forest. *American Midland Naturalist* 157: 385-397.

Keefer, J.S., K.L. Helf, T. Leibfreid, and M.W. Kaye. 2014. Invasive species early detection and rapid response plan for the Cumberland Piedmont Network. Natural Resource Report NPS/CUPN/NRR—2014/795. National Park Service, Fort Collins, Colorado.

Keller, R.H., L. Xie, D.B. Buchwalter, K.E. Franzreb, and T.R. Simons. 2014. Mercury bioaccumulation in southern Appalachian birds, assessed through feather concentrations. *Ecotoxicology* 23(2): 304-16.

Kentucky Bat Working Group. n.d. Image of small-footed bat. Available at: http://biology.eku.edu/bats/myotisleibii.htm (Accessed 29 September 29, 2014).

King, J.K. 1980. Soil Survey of Henderson County, North Carolina. USDA Soil Conservation Service. Raleigh, NC.

Kohut, R.J. 2004. Ozone risk assessment for Cumberland Piedmont Network. National Park Service. Fort Collins, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=441686&file=cupnO3RiskOct04.pdf (Accessed 26 June 2015).

Kohut, R.J. 2007. Ozone risk assessment for Vital Signs Monitoring Networks, Appalachian National Scenic Trail, and Natchez Trace National Scenic Trail. NPS/NRPC/ARD/NRTR-2007/001. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=152846&file=OzoneRiskAssessment_NRTR2007_001.pdf (Accessed 26 June 2015).

Kourtev, P.S., J.G. Ehrenfeld, and M. Haggblom. 2002. Nonnative plant species alter the microbial community structure and function in the soil. *Ecology* 83(11): 3152-3166.

Lambeck, R.J. 1997. Focal species: A multi-species umbrella for nature conservation. *Conservation Biology* 11: 849-856.

Landres, P.B., J. Verner, and J.W. Thomas. 1988. Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* 2(4): 316-328

Lefohn, A.S., S. Oltmans, T. Dann, and H. Singh. 2001. Present day variability of background ozone in the lower troposphere. *Journal of Geophysical Research* 106: 9945-9958.

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

Lemmon, R.E. 1978. Manuscript Geologic Map of the Hendersonville Quadrangle, North Carolina (scale 1:24,000), unpublished, North Carolina Geological Survey.

Lichstein, J.W., T.R. Simons, and K.E. Franzreb. 2002. Landscape effects on breeding songbird abundance in managed forests. *Ecological Applications* 12: 836-857.

Likens, G.E. and F.H Bormann. 1974. Acid rain: a serious regional environmental problem. *Science* 184(4142): 1176-1179.

Lindenmayer D., J. Pierson, P. Barton, M. Beger, C. Branquinho, A. Calhoun, T. Caro, H. Greig, J. Gross, J. Heino, M. Hunter, P. Lane, C. Longo, K. Martin, W.H. McDowell, C. Mellin, H. Salo, A. Tulloch, and M. Westgate. 2015. A new framework for selecting environmental surrogates. *Science of the Total Environment* 538: 1029-1038.

Lindenmayer, D.B., A.D. Manning, P.L. Smith, H.P. Possingham, J. Fischer, I. Oliver, and M.A. McCarthy. 2002. The focal-species approach and landscape restoration: a critique. *Conservation Biology* 16: 338-345.

Loeb, S. 2007. Bats of Carl Sandburg Home National Historic Site, Cowpens National Battlefield, Guilford Courthouse National Military Park, Kings Mountain National Military Park, Ninety Six National Historic Site. USDA Forest Service, Southern Research Station, Department of Forestry & Natural Resources, Clemson University.

Loeb, S.C., C.J. Post, and S.T. Hall. 2009. Relationship between urbanization and bat community structure in national parks of the southeastern U.S. *Urban Ecosystems* 12: 197-214.

Long, J.M. 2004. Management Plan for Side Lake Creek Riparian Vegetation at Carl Sandburg Home National Historic Site: Balancing Natural and Cultural Values. Southeast Region, Division of Science and Natural Resources Management, National Park Service. Atlanta, Georgia.

Longcore, T. and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2(4): 191-198.

MacAvoy, S.E. and A.J. Bulger. 1995. Survival of brook trout (*Salvelinus fontinalis*) embryos and fry in streams of different acid sensitivity in Shenandoah National Park, USA. *Water, Air, Soil Pollution* 85(2): 445–450.

McLaughlin, S.B. and D.J. Downing. 1995. Interactive effects of ambient ozone and climate measured on growth of mature forest trees. *Nature* 374: 252-254.

Meiman, J. 2007. Cumberland Piedmont Water Quality Report: Carl Sandburg Home National Historic Site NPS/SER/CUPN/NRTR—2007/001. National Park Service, Atlanta, Georgia.

Miller, D.A.W., L.L. Bailey, E.H. Campbell Grant, B.T. McClintock, L.A. Weir, and T.R. Simons. 2015. Performance of species occurrence estimators when basic assumptions are not met: a test using field data where true occupancy status is known. *Methods in Ecology and Evolution* 6: 557-565.

Miller, J.R. and L.F. Villarroel. 2011, Case studies, Bolivia: Mining, river contamination and human health. *In* J. Nriagu, editor. Encyclopedia of Environmental Health. Elsevier, Amsterdam.

Miller, J.R. and S.M. Orbock Miller. 2007. Contaminated Rivers: A Geomorphological-Geochemical Approach to Site Assessment and Remediation. Springer Publishers.

Mitchel, J.C., S.C. Rhinehart, J.F. Pagels, and K.A. Buhlmann. 1997. Factors influencing amphibian and small mammal assemblages in central Appalachian forests. *Forest Ecology and Management* 96: 65-76

Monahan, B. and N. Fisichelli. 2014. Recent Climate Change Exposure of Carl Sandburg Home National Historic Site. Resource Brief: Climate Change. Available at: http://irmafiles.nps.gov/reference/holding/497254 (Accessed 11 June 2015).

Morrison, M.L. 2001. A proposed research emphasis to overcome the limits of wildlife-habitat relationship studies. *Journal of Wildlife Management* 65: 613–623.

NADP (National Atmospheric Deposition Program). 2006. National Atmospheric Deposition Program 2006 Annual Summary. Illinois State Water Survey, NADP Data Report 2006-01. Champaign, Illinois.

NADP (National Atmospheric Deposition Program). 2012. About NADP. Available at: http://nadp.sws.uiuc.edu/nadp/ (Accessed 18 May 2015).

NADP-MDN (National Atmospheric Deposition Program – Mercury Deposition Network). 2015. Annual data, All MDN Sites. Available at: http://nadp.isws.illinois.edu/data/MDN/annual.aspx (Accessed by K. Pugacheva at NPS ARD on 26 June 2015).

NADP-NTN (National Atmospheric Deposition Program, National Trends Network). 2014. National Trends Network. Available at: http://nadp.sws.uiuc.edu/ntn/ (Accessed 18 May 2015).

NADP-TDEP (National Atmospheric Deposition Program, Total Deposition Science Committee). 2014. Total Deposition Maps, v2014.02. Available at: http://nadp.sws.uiuc.edu/committees/tdep/tdepmaps (Accessed 26 June 2015).

NatureServe. 2013. NatureServe Conservation Status webpage. Available at: http://explorer.natureserve.org/ranking.htm (Accessed 2 April 2013).

NatureServe. 2013a. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: http://www.natureserve.org/explorer (Accessed 14 February 2014).

NatureServe. 2013b. NatureServe Conservation Status webpage. Available at: http://www.natureserve.org/explorer/ranking.htm (Accessed 2 April 2013).

NC Native Plant Society. 2014. Available at: http://www.ncwildflower.org/index.php/plant_galleries/invasives_list (Accessed 8 August 2014).

NC Native Plant Society. 2015. Available at: http://www.ncwildflower.org/index.php/plant_galleries/invasives_list (Accessed 8 August 2014).

NCDENR (North Carolina Department of Environment and Natural Resources). 2007. North Carolina Department of Environment and Natural Resources – Division of Water Quality "Redbook", Surface Waters and Wetlands Standards, NC Administrative Code 15A NCAC 02B.0100, .0200 and .0300.

NCDENR (North Carolina Department of Natural Resources). 2015. Stream fish community assessment Program: Fish community data by river basin. French Broad Basin. Available at: http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=1360230&name=DLFE-114452.xlsx.

NCDOT (NC Department of Transportation). 2013. Geographic Information Systems Unit. Permanent GIS dataset. Municipal Boundaries – 2012 Powell Bill. Available at: http://www.nconemap.com/ (Accessed 11 January 2013).

NCSS (National Cooperative Soil Survey). 2001a. Ashe Soil Series. Available at: https://soilseries.sc.egov.usda.gov/OSD_Docs/A/ASHE.htmL (Accessed 29 September 2014).

NCSS (National Cooperative Soil Survey). 2001b. Hayesville Soil Series. Available at: https://soilseries.sc.egov.usda.gov/OSD_Docs/H/HAYESVILLE.htmL (Accessed 30 September 2014).

NCSS (National Cooperative Soil Survey). 2004. Tate Soil Series. Available at: https://soilseries.sc.egov.usda.gov/OSD_Docs/T/TATE.htmL (Accessed 29 September 2014).

NCSS (National Cooperative Soil Survey). 2013. Edneyville Soil Series. Available at: https://soilseries.sc.egov.usda.gov/OSD_Docs/E/EDNEYVILLE.htmL (Accessed 29 September 29, 2014).

Neff, K.J., J.S. Schwartz, S.E. Moore, and M.A. Kulp. 2013. Influence of basin characteristics on baseflow and stormflow chemistry in the Great Smoky Mountains National Parks, USA. *Hydrologic Processes* 27: 2061-2074.

Neff, K.J., J.S. Schwartz, T.B. Henry, R.B. Robbinson, S.E. Moore, and M.A. Kulp. 2009. Physiological stress in native southern brook trout during episodic stream acidification in the Great Smoky Mountains National Park. *Archives of Environmental Contamination and Toxicology* 57: 366-376.

Nelson, S.J. and C.M. Flanagan Pritz. 2014. The Dragonfly Mercury Project: 2013 Results. Six-legged Scouts fact sheet. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=510865&file=DragonflyMercury_2013-DataSummary.pdf (Accessed 26 June 2015).

Neufeld, H.S., J.R. Renfro, W.D. Hacker, and D. Silsbee. 1992. Ozone in Great Smoky Mountains National Park: dynamics and effects on plants. Pages 594-617 *in* R.L. Berglund, Editor. Transactions: Tropospheric Ozone and the Environment II. Pittsburgh, PA: Air and Waste Management Association

Neville, C.M. and P.G.C. Campbell. 1988. Possible mechanisms of aluminum toxicity in a dilute, acidic environment to fingerlings and older life stages of salmonids. *Water Air Soil Pollution* 42: 311–327.

NOAA-NCDC (National Oceanic and Atmospheric Administration, National Climatic Data Center). 2010. Data Tools: 1981-2010 Normals (Hendersonville, NC). Available at: http://www.ncdc.noaa.gov/cdo-web/datatools/normals (Accessed 23 September 2014).

Nodvin, S.C., H. Van Miegroet, S.E. Lindberg, N.S. Nicholas, and D.W. Johnson. 1995. Acidic deposition, ecosystem processes, and nitrogen saturation in a high elevation Southern Appalachian watershed. *Water, Air, and Soil Pollution* 85: 1647-1652.

NPCA (National Parks Conservation Association). 2009. State of the parks: Carl Sandburg Home National Historic Site. Available at: https://www.npca.org/resources/1940-center-for-state-of-the-parks-carl-sandburg-home-national-historic-site (Accessed 23 September 2014).

NPS (National Park Service) 2013. Permanent GIS dataset. NPS Land Resources Division geospatial dataset, Current Administrative Boundaries of National Park System Units. Available at: https://irma.nps.gov/App/Reference/Profile/2192761?lnv=true (Accessed 1 January 2013).

NPS (National Park Service). 1998. Baseline water quality data, inventory and analysis, Carl Sandburg Home National Historic Site. Water Resources Division and Servicewide Inventory and Monitoring Program, U.S. Park Service.

NPS (National Park Service). 2000. Management Policies 2001. National Park Service, Washington, D.C.

NPS (National Park Service). 2003. General Management Plan and Final Environmental Impact Statement for Carl Sandburg Home National Historic Site, North Carolina.

NPS (National Park Service). 2006. Management Policies. Available at: https://www.nps.gov/policy/MP2006.pdf.

NPS (National Park Service). 2008. The Cumberland Piedmont Vital Signs Network (CUPN). Available at: http://www.nature.nps.gov/air/permits/aris/networks/cupn.cfm (Accessed 11 June 2015).

NPS (National Park Service). 2010a. Physical resources information and issues overview report, Great Smoky Mountains National Park. National Resource Report NPS/NRPC/WRD/NRR-2010.

NPS (National Park Service). 2010b. Great Smoky Mountains National Park 2010 Water Quality Annual Report. U.S. Department of Interior, National Park Service, Great Smoky Mountains National Park in cooperation with the University of Tennessee, Knoxville, Department of Civil and Environmental Engineering.

NPS (National Park Service). 2011. Carl Sandburg Home National Historic Site water quality summery fiscal year 2011. Cumberland Piedmont Network, Resource Brief, Inventory and Monitoring, Southeast Region, National Park Service.

NPS (National Park Service). 2012. National Park Service Visitation Statistics. Available at: https://irma.nps.gov/Stats/ (Accessed 11 January 2013).

NPS (National Park Service). 2014a. History & Culture. Available at: http://www.nps.gov/carl/historyculture/index.htm (Accessed 16 September 2014).

NPS (National Park Service). 2014b. Recreation Visitors by Month: Carl Sandburg Home NHS. Available at: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Recreation%20Visitors%20By%20Month%20%281979%20-%20Last%20Calendar%20Year%29?Park=CARL (Accessed 16 September 2014).

NPS (National Park Service). 2014c. Image of Carl Sandburg National Historic Site. Available at: http://www.nps.gov/carl/index.htm (Accessed 29 September 2014).

NPS (National Park Service). 2016. Lightscape/Night Sky. Available at: https://www.nps.gov/grba/learn/nature/lightscape.htm (Accessed 25 July 2016).

NPS (National Park Service). 2016a. Plants of Carl Sandburg Home National Historic Site. Available at: https://www.nps.gov/carl/learn/nature/plants.htm (Accessed 10 June 2016).

NPS (National Park Service). 2016b. Update Park Fire Management Plan (FMP). Available at: https://parkplanning.nps.gov/projectHome.cfm?projectID=30291 (Accessed 15 June 2016).

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

NPS ARD (National Park Service, Air Resources Division). 2013a. Air quality in national parks trends (2000-2009) and conditions (2005-2009). Natural Resource Report NPS/NRSS/ARD/NRR-2013/683. National Park Service, Denver, Colorado.

NPS ARD (National Park Service, Air Resources Division). 2013b. Methods for Determining Air Quality Conditions and Trends for Park Planning and Assessments. Available at:

http://www.nature.nps.gov/air/planniµg/docs/AQ_ConditionsTrends_Methods_2013.pdf (Accessed 18 May 2015).

NPS ARD (National Park Service, Air Resources Division). 2014. AirAtlas. Available at: http://www.nature.nps.gov/air/Maps/AirAtlas/ (Accessed 18 May 2015).

NPS ARD (National Park Service, Air Resources Division). 2015a. Air Quality Related Values (AQRV) Inventory: Resources sensitive to air quality. Available at: http://www.nature.nps.gov/air/Permits/ARIS/networks/index.cfm (Accessed 11 June 2015).

NPS ARD (National Park Service, Air Resources Division). 2015b. Air Quality Monitoring & Access to Data. Available at: http://www.nature.nps.gov/air/monitoring/index.cfm (Accessed 10 May 2015).

NPS ARD (National Park Service, Air Resources Division). 2015c. The Cumberland Piedmont Network. Available at: http://www.nature.nps.gov/air/permits/aris/networks/cupn.cfm (Accessed 10 May 2015).

NPSpecies online database. 2015. Available at: https://irma.nps.gov/NPSpecies/Search/SpeciesList/CARL (Accessed 12 September 2015).

NPSpecies, Information of Species in National Parks. 2015. Carl Sandburg Home National Historic Site (CARL). IRMA Portal version. National Park Service. Available at: https://irma.nps.gov/NPSpecies/Reports/Systemwide/Ozone-Sensitive%20Species%20in%20a%20Park.

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10: 1706–1721.

O'Driscoll, M. and T. Shear. 2009. Nonnative plant management plan for Guilford Courthouse National Military Park. North Carolina State University Department of Forest Resources. Unpublished Report, Greensboro, NC.

Osbourne, J.D., J.T. Anderson, and A.B. Spurgeon. 2005. Effects of habitat on small-mammal diversity and abundance in West Virginia. *Wildlife Society Bulletin* 33: 814-822.

Pardo, L.D., M.J. Robin-Abbott, and C.T. Driscoll, editors. 2011. Assessment of nitrogen deposition effects and empirical critical loads of nitrogen for ecoregions of the United States. General Technical Report NRS-80. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA.

Parker, C.R., J.L. Robinson, B.C. Kondratieff, D.A. Etnier, and D.R. Lenat. 2012. The Ephemeroptera, Megaloptera, Odonata, Plecoptera, and Trichoptera of the Blue Ridge Parkway, North Carolina and Virginia. Unpublished Report.

Pearson, S.M. and A.B. Smith. 2006. Bird Inventory of Carl Sandburg Home 2003-2004. Mars Hill College. Mars Hill, North Carolina. Unpublished report.

Pivorun, E. and L. Fulton. 2007. Terrestrial mammals of Carl Sandburg Home National Historic Site, Flat Rock, North Carolina. Prepared for the National Park Service, Carl Sandburg Home National Historic Site.

Pollard, K.M. 2005. Population growth and distribution in Appalachia: new realities. Appalachian Regional Commission. Demographic and Socioeconomic Change in Appalachia, Population Reference Bureau.

Porter, E. and K. Morris. 2007. Wet deposition monitoring protocol: monitoring atmospheric pollutants in wet deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR-2007/004. National Park Service, Fort Collins, Colorado.

Reed, R. and W.H. Gibbons. 2005. Results of herpetofaunal surveys of five national park units in North and South Carolina. Savannah River Ecology Laboratory. Aiken, South Carolina. Unpublished Report-591789.

Reid, N. 2007. A review of background ozone in the troposphere. Transboundary Science Unit, Ontario Ministry of the Environment, Report No. PIBS: 6424e. Available at: https://archive.org/stream/std01079168.ome/std01079168_djvu.txt.

Roberts T.H. and K.L. Morgan. 2006. Inventory and classification of wetlands at Carl Sandburg Home, National Historic Site, Flat Rock, North Carolina. Center for the Management, Utilization, and Protection of Water Resources, Tennessee Technological University. Unpublished Report, Cookeville, TN.

Rodrigues, A.S.L and T.M. Brooks. 2007. Shortcuts for biodiversity conservation planning: the effectiveness of surrogates. *Annual Review of Ecology, Evolution, and Systematics* 38: 713-737.

Sadinski, W.J. and W.A. Dunson. 1992. A multilevel study of effects of low pH on amphibians of temporary ponds. *Journal of Herpetology* 26: 413-422.

SAMAB (Southern Appalachian Man and the Biosphere). 1996. The Southern Appalachian Assessment Summary Report. Report 2 of 5, USDA Forest Service, Southern Region, Atlanta, Georgia.

Schafale, M.P. 2012. Guide to the classification of the natural communities of North Carolina. 4th Approximation. North Carolina Natural Heritage Program, Division of Parks and Recreation, NC Department of Environment, Health, and Natural Resources. Raleigh, NC.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the natural communities of North Carolina, third approximation. North Carolina National Heritage Program, Division of Parks and Recreation, Department of Environment and Natural Resources. Raleigh, NC.

Scheuhammer, A.M., M.W. Meyer, M.B. Sandheinrich, and M.W. Murray. 2007. Effects of environmental methylmercury on the health of wild birds, mammals, and fish. *Ambio: A Journal of the Human Environment* 36(1): 12-19.

Schofield, E.K. 1989. Effects of introduced plants and animals on island vegetation: examples from the Galapagos archipelago. *Conservation Biology* 3: 227-238.

Schwartz, J.S., A. Gonzalez, M. Alprin, S.E. Moore, and M.A. Kulp. 2014. Great Smoky Mountains National Park 2013 water quality annual report. Natural Resource Data Series NPS/GRSM/NRDS-2014/701. National Park Service, Fort Collins, Colorado.

Scott, M.C. 2006. Inventory of Fishes in Carl Sandburg Home National Historic Site. South Carolina Department of Natural Resources. Available at: http://science.nature.nps.gov/im/units/cupn/parks/carl.cfm?tab=1#products (Accessed 23 September 2014).

Scott, M.C. 2006. Inventory of fishes in Carl Sandburg Home National Historic Site. Unpublished report.

Shafer, S.R. and A.S. Heagle. 1989. Growth responses of field-grown loblolly pine to chronic doses of ozone during multiple growing seasons. *Canadian Journal of Forest Research* 19: 821-831.

Shubzda, J., S.E. Lindberg, C.T. Garten, and S.C. Nodvin. 1995. Elevational trends in the fluxes of sulfur and nitrogen in throughfall in the southern Appalachian Mountains: some surprising results. *Water, Air, and Soil Pollution* 85: 2265-2270.

Simons, T.R. and B. Keller. 2009. Effects of atmospheric pollution on high elevation fauna in Great Smoky Mountains National Park: Progress Report. U.S. Geological Survey. Raleigh, North Carolina.

Skiff, B. 2001. How dark can the night sky get? Available at: http://www.astropix.com/HTML/L_STORY/SKYBRITE.HTM.

Smith, W.H. and L.J. Rissler, 2009. Quantifying disturbance in terrestrial communities: abundance–biomass comparisons of herpetofauna closely track forest succession. *Restoration Ecology* 18: 195-204.

Smoot, J., B. Robinson, M. McCann, G. Harwell, and J. Shubzda. 2000. Assessment of stream water quality and atmospheric deposition rates at selected sites in the Great Smoky Mountains National Park, 1991-1998. Report prepared for the National Park Service, Cooperative Agreement No. 1443- CA-5460-98-006.

Somers, G.L., J.R. Renfro, and A.H. Chappelka. 1998. Empirical evidence of growth decline related to visible ozone injury. *Forest Ecology and Management* 104: 129-137.

Spry, D.J. and J.G. Wiener. 1991. Metal bioavailability and toxicity to fish in low-alkalinity lakes: A critical review. *Environmental Pollution* 71: 243-304.

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR-2011/349. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=428429&file=main_acidification-eval_2011-05.pdf (Accessed 26 June 2015).

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Cumberland Piedmont Network. Natural Resource Report NPS/NRPC/ARD/NRR-2011/354. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=428433&file=cupn_acidification-eval_2011-05.pdf. (Accessed 26 June 2015).

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011c. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR-2011/313. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=427566&file=main_n_sensitivity_2011-02_updated.pdf (Accessed 26 June 2015).

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011d. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Cumberland Piedmont Network. Natural Resource Report NPS/NRPC/ARD/NRR-2011/306. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=425334&file=cupn_n_sensitivity_2011-02.pdf (Accessed 26 June 2015).

Sullivan, T.J., J.R. Webb, K.U. Synder, A.T. Herlihy, and B.J. Cosby. 2007. Spatial distribution of acid-sensitive and acid-impacted streams in relation to watershed features in the southern Appalachian Mountains. *Water, Air, and Soil Pollution* 182: 57-71.

Swenson, H.A. and H.L. Baldwin. 1965. A primer on water quality: U.S. Geological Survey, Washington, D.C.

TDEC (Tennessee Department of Environment and Conservation). 2010. Proposed total maximum daily load (TMDL) for low pH in the Great Smoky Mountains National Park located in the Pigeon River (HUC 06010106), Lower French Broad River and Watershed (HUC06010107), Ft. Loudoun Lake Watershed (HUC06010201), Coce and Sevier County, Tennessee. Final report, Tennessee Department of Environment and Conservations, Division of Water Pollution Control, Nashville, TN.

Thornberry-Ehrlich, T. 2008. Great Smoky Mountain National Park, Geologic Resource Evaluation Report. Natural Resource Report NPS/NRPC/GRD/NRR - 2008/048.

Thornberry-Ehrlich, T. 2012. Carl Sandburg Home National Historic Site: geologic resources inventory report. Natural Resource Report NPS/NRSS/GRD/NRR-2012/501. National Park Service, Fort Collins, Colorado.

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

Turner, M.G., S.M. Pearson, and D.N. Wear. 2003. Effects of land-cover change on spatial patterns of forest communities in the southern Appalachian Mountains (USA). *Landscape Ecology* 18: 449-464.

U.S. Census Bureau. 2010. American FactFinder." Available at: http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtmL (Accessed 11 January 2013).

UNC (University of North Carolina) Herbarium. 2015. Website. Available at: http://www.herbarium.unc.edu/9-10-02.pdf (Accessed 14 September 2015).

USDA NRCS (U.S. Department of Agriculture, Natural Resource Conservation Service). 2015. Custom soil resource report for Henderson County, North Carolina, Carl Sandburg NP.

USGS (U.S. Geological Survey). 2015. Predicted surface water methylmercury concentrations in National Park Service Inventory and Monitoring Program Parks. U.S. Geological Survey, Wisconsin Water Science Center, Middleton, WI. Available at: http://wi.water.usgs.gov/mercury/NPSHgMap.htmL (Accessed by K. Pugacheva at NPS ARD on 26 June 2015).

USGS (United States Geological Survey). 2012. Land Cover Trends Project. Available at: http://landcovertrends.usgs.gov/east/regionalSummary.htmL (Accessed 1 June 2012).

Vana-Miller, D., D.P. Weeks, J.R. Renfro, and N. Lyons. 2010. Physical resources information and issues overview report: Great Smoky Mountains National Park. Natural Resource Report NPS/NRPC/WRD/NRR—2010/xxx. National Park Service, Fort Collins, Colorado.

Vogelmann, J.E., S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and J.N. Van Driel. 2001. Completion of the 1990's National Land Cover Data Set for the conterminous United States, *Photogrammetric Engineering and Remote Sensing* 67:650-662.

Watson, J. 2005. Avian conservation implementation plan Guilford Courthouse National Military Park. National Park Service Southeast Region. U.S. Fish and Wildlife Service in cooperation with GUCO Resource Management Staff, National Park Service and Bird Conservation Partners.

Webb, J.R., B.J. Cosby, J.N. Galloway, and G.M. Hornberger. 1989. Acidification of native brook trout streams in Virginia. *Water Resources Research*, 25: 1367-1377.

Webster, J.R., E.F. Benfield, K.K. Cecala, J.F. Chamblee, C.A. Dehring, T. Gragson, J.H. Cymerman, C.R. Jackon, J.D. Knoepp, D.S. Leigh, J.C. Maerz, and C. Pringle. 2012. Water quality and exurbanization in southern Appalachian Streams. Pages 91-106 *In* P.J. Boon and P.J. Raven, Editors. River Conservation and Management, John Wiley and Sons Ltd.

White Jr., R.D. 2003. Vascular Plant Inventory and Plant Community Classification for Carl Sandburg Home National Historic Site. NatureServe: Durham, North Carolina. Available at: http://www.nps.gov/carl/learn/nature/upload/CARL%20plant%20inventory.pdf.

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation monitoring protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado.

Wiener, J.G., M.B. Sandheinrich, S.P. Bhavsar, J.R. Bohr, D.C. Evers, B.A. Monson, and C.S. Schrank. 2012. Toxicological significance of mercury in yellow perch in the Laurentian Great Lakes region. *Environmental Pollution* 161: 350-357.

Wiken, E, F., J. Nava, and G. Griffith. 2011. North American Terrestrial Ecoregions—Level III. Commission for Environmental Cooperation, Montreal, Canada.

Woodward, D.F., A.M. Farag, E.E. Little, B. Steadman, and R. Yancik. 1991. Sensitivity of greenback cutthroat trout to acidic pH and elevated aluminum. *Transactions of the American Fisheries Society* 120(1): 34–42.

Woolsey, J. and G. Walker. 2008. A vegetational assessment of the granitic rock outcrop communities at Carl Sandburg Home National Historic Site. Appalachian State University.

Woolsey, J.A. 2010. Maintaining the integrity of the low-elevation granitic-dome communities of Carl Sandburg National Historic Site. Thesis. Appalachian State University, Boone, North Carolina.

Zhou, Q., C.T. Driscoll, S.E. Moore, M.A. Kulp, J.R. Renfro, J.S. Schwartz, and M. Cai. 2014. Developing critical loads of nitrate and sulfate deposition to watersheds of Great Smoky Mountains National Park, United States. Natural Resources Technical Report NPS/GRSM/NRTR-2014/896. U.S. National Park Service, Fort Collins, Colorado.

Appendix A: Summary of Ambient Air Quality Data Collected in and near CARL

Source* (Parameters Measured)	Location	Site #
NADP-NTN (At Dep)	Mt. Mitchell, NC 60 km N	NC45
	Otto, NC 90 km SW	NC25
AQS (O_3, $PM_{2.5}$)	Asheville, NC 35 km NW	370210030
	Asheville, NC 40 km NW	370210034
CASTNet (O_3)	Otto, NC 90 km SW	COW137
	Cranberry, NC 105 km NE	PNF126
IMPROVE ($PM_{2.5}$, Vis)	Shining Rock W A, NC 40 km NW	SHRO1
	Linville Gorge W A, NC 90 km NE	LIGO1
	Great Smoky Mtn NP, TN 140 km NW	GRSM1

*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).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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