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Natural Resource Condition Assessment for Cumberland Gap National Historical Park

Natural Resource Report NPS/CUGA/NRR—2013/620

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Natural Resource Condition Assessment for Cumberland Gap National Historical Park

Natural Resource Report NPS/CUGA/NRR—2013/620

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Contents

Page

Figures ... vii

Tables ... xi

Appendices ... xv

Executive Summary ... xvii

Acknowledgements ... xx

Prologue ... xx

Acronyms and Abbreviations: ... xxi

Purpose ... 1

Ranking Methodology ... 3

Data Description ... 7

Park Resources and Introduction ... 13

- Park Location and Significance ... 13
- Park Objectives ... 13
- Climate, Geology, and Soils ... 15
- Hydrology ... 16
- History and Park Significance ... 17
- Natural Resources and NPS Vital Signs ... 18
  - Vertebrate Assemblages ... 19
  - Vegetation Communities ... 19
  - Invasive Plants ... 20
  - Forest Pests ... 20

Natural Resource Conditions ... 21

- Air and Climate ... 21

Contents (continued)

Page

Ozone ... 21

Foliar Injury ... 25

Geology and Soils ... 30

Cave Meteorology ... 30

Water Quality ... 37

Overview and Parameters ... 37

Temperature ... 39

Specific Conductance ... 39

pH ... 40

Dissolved Oxygen ... 40

Acid-Neutralizing Capacity ... 40

Microorganisms ... 41

Hydrology ... 41

Summary ... 42

CUGA Historical Water Monitoring ... 42

Methodology ... 42

Temperature ... 43

Dissolved Oxygen ... 43

pH ... 43

Specific Conductance ... 45

Acid Neutralizing Capacity ... 45

Microorganisms ... 45

Hydrology ... 46

Contents (continued)

Page

Summary ... 46

Invasive Plants ... 55

Focal Species ... 55

Threat Ranking ... 59

Susceptible Areas ... 61

Summary ... 62

Infestations and Disease ... 64

Hemlock Woolly Adelgid ... 64

Focal Species and Communities ... 75

Vegetation Communities ... 75

Fish Communities ... 83

Bird Communities ... 91

Mammal Communities ... 99

Herpetofauna Communities ... 105

Cave Bats ... 113

At-Risk Plants ... 118

Rare Plants ... 118

Commercially Valuable Plants ... 124

Summary ... 125

Landscape Dynamics ... 125

Land Use ... 125

Conclusions ... 135

Summary ... 135

Contents (continued)

Page

Natural Resource Conditions ... 135

Ozone ... 135

Foliar injury ... 136

Cave Meteorology ... 136

Water Quality ... 137

Invasive Plants ... 137

Infestations and Disease ... 138

Vegetation Communities ... 139

Fish Communities ... 139

Bird Communities ... 140

Mammal Communities ... 140

Herpetofauna Communities ... 140

Cave Bats ... 141

At-Risk Plants ... 141

Landscape Dynamics ... 142

Natural Resource Synthesis ... 142

Literature Cited ... 145

Figures

Page

Figure 1. Summary of condition ranks and trends assigned to 16 ecological attributes from five broad categories in Cumberland Gap National Historical Park. xix

Figure 2**.** Cumberland Gap National Historical Park is located along the tri-state border of KY, VA, and TN. 14

Figure 3. Diagrams showing the Cumberland (left) and Powell (right) rivers and their creation of the Cumberland Gap through the Pine (left) and Cumberland (right) ranges (McFarlan 1943). 15

Figure 4. Cumberland Gap NHP straddles the Powell and Upper Cumberland hydrologic cataloging units, which in turn fall respectively in the Tennessee River and Ohio hydrologic regions. 17

Figure 5. Limestone caves in Cumberland Gap NHP are home to the endangered Indiana Bat (*Myotis sodalis*). 19

Figure 6. Passive ozone sampling took place at three locations in CUGA during 2005. 22

Figure 7. Daily mean 8-hr ozone concentrations from two POMS sites during peak summer monitoring periods. 24

Figure 8. Three-year mean 4th highest annual 8-hr concentrations from 2001-2009 at the Speedwell CASTNet site, which is located 9.8 km from the park in Clairborne County, TN. 24

Figure 9. Foliar injury summary metrics predicted by the Air Resources Division for 1995-1999, and as reported by the GPMP based on portable ozone monitoring data for 2007-2008. 26

Figure 10. Mean daily temperature from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park. 32

Figure 11. Mean temperature across years calculated using daily means from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park. 32

Figure 12. Mean daily relative humidity from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park. 33

Figure 13. Mean relative humidity across years calculated using daily means from 2002-2009 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park. 33

Figures (continued)

Page

Figure 14. Mean daily temperature collected 2001-2011 from data loggers placed in Cave A by the National Park Service and the Virginia Department of Inland Game and Fisheries. 34

Figure 15. Mean daily relative humidity from 2002-2011 from a data logger placed in Cave A, an Indiana bat hibernacula in Cumberland Gap National Historical Park. 34

Figure 16. Mean temperature across years of the mean daily temperatures recorded from a VDGIF datalogger placed near an Indiana bat hibernacula in Cave A. 35

Figure 17. Ten I&M water quality stations within CUGA were sampled monthly between 2006 and 2008. 38

Figure 18. Data from stations available in EPAStoret were used to assess historical monitoring at CUGA. 44

Figure 19. Box and whisker water quality data at CUGA during the first round of monthly I&M sampling ('06-'08): Davis Branch (DB10), Gap Creek (GC7), Martin's Fork (MF5), Railroad Creek (RR1), Shillalah Creek (SH10), Sugar Run (SRSR), Station Creek (ST9), Tunnel Creek (TC10), Upper Little Yellow Creek (YC1), and Little Yellow Creek (YC12). 48

Figure 20. Annual series of historical monitoring data at CUGA from EPAStoret (1990-2007) plotting mean with standard error. 51

Figure 21. *E. coli* concentrations were collected on Station Creek from 2003-2011, including the official I&M collections beginning in Oct. 2006. 54

Figure 22. Princesstree is a prolific seed-producer that can colonize hard-to-reach places. [Source: James H. Miller, USDA Forest Service, Bugwood.org] 56

Figure 23. Mimosa, a legume with a propensity for resprouting, is among the invasives treated at CUGA. [Source: James H. Miller, USDA Forest Service, Bugwood.org] 57

Figure 24. Kudzu can quickly invade and cover native vegetation. [Source: Kerry Britton, USDA Forest Service, Bugwood.org] 57

Figure 25. Crown vetch is another exotic legume that requires considerable management attention at CUGA. 58

Figure 26. Exotic treatment sites along Wilderness Rd. since 2005. 63

Figure 27. Treatments for hemlock woolly adelgid included pesticide drenches and predatory beetle releases from 2007 – 2011. 66

Figures (continued)

Page

Figure 28. As of 2011, 20 counties in NW KY and five counties in TN have been quarantined due to the presence of emerald ash-borer. 67

Figure 29. Since 2008, the invasion front of gypsy moth continues to spread southwest into Kentucky, though no counties surrounding CUGA have reported gypsy moth sightings to the Cooperative Agricultural Pest Survey (CAPS, NAPIS 2011). 69

Figure 30. Southern pine beetle risk map produced by Forest Health Technology Enterprise Team (Ellenwood and Krist 2007) shown for the CUGA area shows forest stands of highest risk in the north-central section of the park, which closely coincides with the Blue Ridge Table Mountain Pine-Pitch Pine Woodland forest type 71

Figure 31. The CUGA Fire Use Module prescribes periodic burns in each of the different burn units in the park. 72

Figure 32. As part of the recent NatureServe assessment by White (2006), 35 of 100 plots recorded one of four main disturbances: southern pine beetle damage, evidence of logging, erosion, or evidence of fire. 74

Figure 33. Using the NatureServe (2005) classification scheme, 33 vegetation community types were identified in CUGA [Source: CRMS]. 76

Figure 34. Four vegetation community types at CUGA are globally ranked as G2 or G1, representing globally imperiled and critically imperiled, respectively. 78

Figure 35. Walker and Ballinger (2007) conducted plant and lichen community surveys along the White Rocks cliff system at 12 transects. [Figure taken from White et al. (2007)] 80

Figure 36. Streams in and around Cumberland Gap National Historical Park, showing locations of fish samples collected in 2004 by Remley (2005). 84

Figure 37. Bird Community Index (BCI) scores for 49 individual point count bird lists (top figure) and for five-count bird lists (bottom figure), for bird counts taken during a 2003-2004 survey at Cumberland Gap National Historical Park (Monroe 2005). 96

Figure 38. Bird Community Index scores (O'Connell et al. 1998) for 0-10 stop BBS data collected from Cumberland Gap (bold series) and for nine other BBS routes within 100 km of Cumberland Gap National Historical Park over a 10-year period (Sauer et al. 2008). 97

Figure 39. Conservation value index scores (Nuttle et al. 2003) for 0-10 stop BBS data collected from Cumberland Gap (bold series) and for nine other BBS routes within 100 km of Cumberland Gap National Historical Park over a 10-year period (Sauer et al. 2008). 98

Figures (continued)

Page

Figure 40. Points sampled for mammals in the most recent CUGA mammal survey conducted by Gumbert et al. (2006). 100

Figure 41. Three pond clusters containing 16 ponds were monitored for breeding effort of wood frogs (*Rana sylvatica*) and spotted salamander (*Ambystoma maculatum*) since 1993... 108

Figure 42. Total egg masses of *Rana sylvatica* and *Ambystoma maculatum* counted annually at three clusters of ponds (south, middle, and north) in Cumberland Gap National Historical Site. 109

Figure 43. Total precipitation (cm) from November 1 of the previous year through April 30 of the current year and total egg masses of *Rana sylvatica* and *Ambystoma maculatum* counted at all sites from 2003-2010 at Cumberland Gap National Historical Park. 110

Figure 44. Total egg masses of *Rana sylvatica* and *Ambystoma maculatum* counted at constructed wetlands and at nearby reference ponds from 1993-2010 at Cumberland Gap National Historical Park. 111

Figure 45. Numbers of Indiana bats (*Myotis sodalis*) counted biennially, 1993-2011, in two winter hibernacula in Cumberland Gap National Historical Park. 115

Figure 46. With each successive buffer perspective, developed and grassland/shrub landcover increase at the expense of forest under both NLCD and GAP landcover datasets. 131

Figure 47. Mean species richness for each community type sampled by White (2006). Appalachian Oak-Hickory Forest was the most commonly sampled vegetation type (19 plots), while the Ridge and Valley Limestone Oak-Hickory Forest showed the highest average plant biodiversity (1 plot). 132

Tables

Page

Table 1. Hierarchical framework of ecological attributes assessed at Cumberland Gap National Historical Park for this Natural Resource Condition Assessment. 4

Table 2. Example condition assessments. 6

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park. 8

Table 4. The condition status for ozone at CUGA was ranked fair with an improving trend. The data quality for this assessment was good. 25

Table 5. Thirty-one species at CUGA were identified as sensitive to ozone by cross-referencing Porter's (2003) general sensitivity list with the NPSpecies list for CUGA. 27

Table 6. Set of foliar injury indices for CUGA (NPS ARD 2004). 28

Table 7. Palmer Z indices for Sum06 at CUGA (NPS ARD 2004). 29

Table 8. Palmer Z indices for W126 at CUGA (NPS ARD 2004). 29

Table 9. The condition status for foliar injury at CUGA was ranked fair with a stable trend. The data quality ranking for this attribute was poor. 30

Table 10. No rank was assigned to cave meteorology condition at Cumberland Gap National Historical Park.. 36

Table 11. The condition status for water quality is divided into three attributes: surface water, water chemistry, and microorganisms.. 47

Table 12. Thirty-one plant species at CUGA are considered significantly or severely invasive by the TN and KY Exotic Pest Plant Councils based on their ability to invade and displace native vegetation communities. 59

Table 13. CUGA was assigned a status of fair for invasive plants with no trend. Data quality was assigned a status a of good. 64

Table 14. The condition status for insect pests at CUGA was assigned a ranking of poor with a decreasing trend. The data quality was good. 75

Table 15. NatureServe conservation global status ranks are based on the rarity and risk of elimination for a vegetation community throughout its range (NatureServe 2011). 77

Table 16. Geographically disjunct lichen species identified by Walker and Ballinger (2007) at White Rocks in CUGA. 82

Tables (continued)

Page

Table 17. The condition status for vegetation communities at CUGA was not ranked. The data quality was good. communities at CUGA. 83

Table 18. Family and species of fishes reported from fish sampling efforts by Barbour et al. (1979), Stephens (2002a,b; 2007), and Remley (2005) in Cumberland Gap National Historical Park... 86

Table 19. Individuals sampled (N), species richness (S) with number native species in parentheses, Kentucky Index of Biotic Integrity (KIBI) score, and KIBI interpretation, for sampling efforts reported in three fish survey reports at Cumberland Gap National Historical Park (Stephens 2002a,b; Remley 2005; Stephens 2007). 90

Table 20. Physical habitat scores calculated by Remley (2005) based upon Environmental Protection Agency bioassessment techniques (Barbour et al. 1999). 91

Table 21. The quality of fish communities at Cumberland Gap National Historical Park was good.. 91

Table 22. Birds of conservation concern reported from CUGA during a 2003-2004 survey (Monroe 2005).. 93

Table 23. The condition of the bird community at Cumberland Gap National Historical Park was excellent... 99

Table 24. Mammals reported in Cumberland Gap National Historical Site by Barbour et al. (1979) and Gumbert et al. (2006)... 102

Table 25. Summary of trapping result for shrews, and native rats, mice, and voles for four studies in Kentucky and in the south and central Appalachian Mountains showing total species by category and number of species unique among the studies. 103

Table 26. Number of native species reported from a recent mammal inventory at CUGA, compared to number of native species expected (Gumbert et al. 2006)........................ 104

Table 27. The condition of the mammal community at Cumberland Gap NHP was good, with good data quality... 105

Table 28. Herpetofaunal species expected to occur in Cumberland Gap National Historical Park, and those actually reported from sampling in the park.................................... 106

Table 29. Number of expected herpetofaunal species and number and percentage of species actually reported during recent sampling efforts at CUGA. 107

Tables (continued)

Page

Table 30. The condition of the herpetofauna community at Cumberland Gap National Historical Park was good. 113

Table 31. Cave-hibernating bats captured in mist nets or harp traps in Cumberland Gap National Historical Park during a general mammal survey by Gumbert et al. (2006), the relative abundance (RA) of each species in the total sample of captured bats, and the number of cave entrances of three sampled, in which each species was reported...................... 114

Table 32. The condition of cave bats was good at Cumberland Gap National Historical Park. 117

Table 33. State or federally-listed and state-ranked plant species identified as Present in Park or Probably Present at CUGA. [table and definitions from Moore (2010); statuses current as of June 2008]. 119

Table 34. Rare plant species previously found at CUGA by Pounds et al. (1989) and other sources that were not located by White and Littlefield (2008) in 2008............................. 122

Table 35. Management Guideline for Rare Plants. (from White and Littlefield 2008)............. 123

Table 36. The condition status of rare plants at CUGA was ranked as good with a declining trend. The data quality was fair.. 125

Table 37. Comparison of park unit 2001 NLCD classifications, including Fern Lake watershed, with 400m and 1 km buffers (areas in ha). 126

Table 38. Comparison of park unit 2001 GAP classifications, including Fern Lake, with 400m and 1 km buffers (areas in ha). 127

Table 39. Of the 33 vegetation communities identified by White (2006), 27 were represented by one of the 101 survey plots established during 2002-2004. 129

Table 40. The condition status for landscape dynamics at CUGA was not ranked, but was assigned a stable trend. 133

Appendices

Page

Appendix A. NPS Ecological Monitoring Framework table, with highlighted categories representing relevant vital signs and features specifically selected for CUGA—‘*****’ denotes an official vital sign as identified by the CUPN for CUGA by the network monitoring plan 159

Appendix B. Bird species reported from Cumberland Gap National Historical Park during a 2003-2004 survey (Monroe 2005). 163

Appendix C. Certified species list of vascular plants listed as “Present” or “Probably Present” at CUGA........ 165

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xx) for more information.

Executive Summary

This report provides a comprehensive assessment of the state of natural resources at Cumberland Gap National Historical Park (CUGA). It also addresses sets of stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Cumberland/Piedmont Network, and other attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air and climate, geology and soils, water, biological integrity, and landscape dynamics.

Data used in the assessment includes I&M reports and bio-inventories, spatial information, park-commissioned reports, publicly-available data (EPA Storet, National Landcover Datasets), and personal communication. No new field data were collected for this report. When available, published criteria were used to derive a condition assessment based on available data, and when appropriate, we identify opportunities for improved data collection to allow for stronger assessment in the future.

Cumberland Gap National Historical Park is a 9,800 ha area of natural beauty that runs linearly along Cumberland Mountain in the Southern Appalachians. Roughly 5,700 ha of this area is currently proposed as wilderness. The park receives over 900,000 visitors each year, with highest rates of visitation during spring, summer, and fall. Virtually all (97%) of the park area is forested, which serves as habitat to a large variety of flora and fauna. A total of 970 vascular plants have been documented in the park, including 90 species considered rare or sensitive. The park also represents a major corridor and refuge for bird species, and 145 were reported from recent inventories. Mammals total 40 species, including several state-listed species and the federally-listed Indiana bat (*Myotis sodalis*) which depends on the extensive cave network found at the park. Over 100 km of streams flow through the park, virtually all of which also originate inside the park. Recent inventory efforts have reported 27 fish species including the federally-listed blackside dace (*Chrosomus cumberlandensis*). Reptiles and amphibians total 36 species reported from inventory and monitoring efforts. Overall, several broad classes of potential threats and stressors to natural resources are applicable to CUGA and are addressed in this report. They include:

Decreased air quality – High ozone concentrations pose human health risks and can cause foliar injury to sensitive vegetation.

Decreased water quality – High levels of bacterial contaminants and changes in water chemistry can pose human health risks, harm sensitive aquatic species, and can leave waters vulnerable to the effects of atmospheric deposition.

Exotic plant species – The presence and proliferation of exotic plants can cause loss of native plant diversity and can negatively alter habitat for animal communities.

Exotic/range-expanding/parasitic animal species – The presence and proliferation of exotic animal species, species outside of their native range, and parasitic species can cause loss of native animal diversity.

Animal disease – Several threats or potential threats to vertebrate populations are recognized for the park. These diseases could have impacts at the population level.

Animal damage – Habitat damage caused by beavers can negatively impact habitat for aquatic species, including species of concern.

Insect pests – Insect pests can cause loss of native plant diversity and negatively impact ecosystems and wildlife habitat.

Altered fire regimes – Loss of fire in an ecosystem can cause loss of plant and animal biodiversity and alter successional patterns.

Landscape change – An expansive category including negative impacts from development, human population increases, agricultural land uses, and habitat alteration and fragmentation.

Sixteen ecological attributes were assessed for this report (Figure 1). Of these, eight (50%) were ranked good or excellent, five (31%) were ranked as fair or poor, and three (19%) were not assigned a rank due to lack of appropriate data or lack of appropriate ranking protocols. Assessment method and data quality were both highly variable among assessed attributes. Therefore condition rankings are not necessarily directly comparable. Additional protocols are currently underway for vegetation and landscape dynamics monitoring (e.g. NPScape), which will aid future condition assessment efforts within CUPN parks.

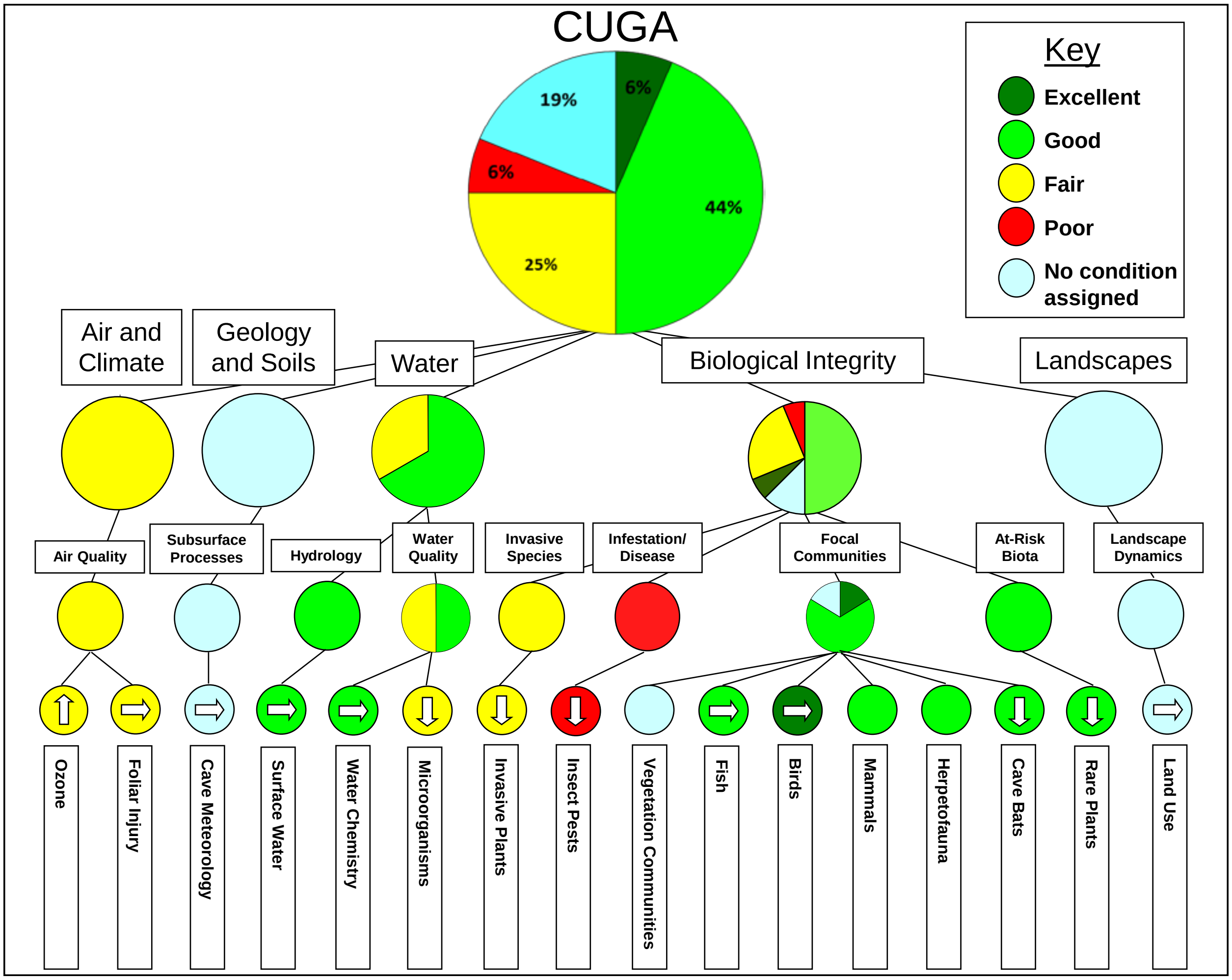

Figure 1. Summary of condition ranks and trends assigned to 16 ecological attributes from five broad categories in Cumberland Gap National Historical Park.

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Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Acronyms and Abbreviations:

ANC - Acid Neutralizing Capacity
ARD - National Park Service Air Resources Division
AVIP - Aviation Conservation Implementation Plan
BBS - Breeding Bird Survey
BCI - Bird Community Index
BOD - Biochemical Oxygen Demand
CASTNET - Clean Air Status and Trends Network
CERG - Cliff Face Ecology Research Group
COOP - Cooperative Observer Program
CRMS - Center for Remote Sensing and Mapping Science (UGA Department of Geography)
CUGA - Cumberland Gap National Historical Park
CUPN – Cumberland Piedmont Monitoring Network
DO - Dissolved Oxygen
EMF - Ecological Monitoring Framework
EPA - Environmental Protection Agency
FAA - Federal Aviation Administration
GRSM - Great Smoky Mountains National Park
HUC - Hydrologic Unit Code
I&M - Inventory and Monitoring
MRLC - Multi-Resolution Land Characteristics Consortium
NAAQS - National Ambient Air Quality Standards
NHP – National Historical Park
NLCD - National Landcover Dataset
NPS - National Park Service
NRCA - Natural Resource Condition Assessment
NRCS - Natural Resource Conservation Service
NTU - Nephelometric Turbidity Unit
NWS - National Weather Service
PIF - Partners in Flight
POMS - Portable Ozone Monitoring Station
PPM - Parts per million
RAWS - Remote Automated Weather Station
SAO - Surface Airways Observation Network
SSURGO - Soil Survey Geographic
UGA - University of Georgia
USGS - United States Geological Survey
VOC - Volatile Organic Compounds

Purpose

The objective of this Natural Resource Condition Assessment (NRCA) is to analyze existing data to provide an assessment of the current conditions of key ecological attributes at Cumberland Gap National Historical Park (CUGA). The National Park Service has initiated an Inventory and Monitoring (I&M) Program to collect and analyze data on park natural resources (NPS 2010a). Goals of this program include the collection of baseline inventory data on park resources, and the monitoring of key resource condition indicators (NPS 2010a). Based on location and natural resource characteristics, the NPS assigned park units to one of 32 ecoregional networks. Each network chose a subset of "vital signs" to represent "physical, chemical, and biological elements and processes of park ecosystems that…represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (NPS 2010a). Cumberland Gap National Historical Park is a member of the Cumberland Piedmont Network (CUPN), and the vital signs chosen by this Network (see Appendix A) received much of the focus of our efforts. This report will assist in establishing baseline conditions, will aid park personnel in future management decisions, and will serve as a summary of key biotic and abiotic ecological attributes.

The primary audience for our report includes park-level superintendents and resource managers, with a secondary focus on regional managers and coordinators. This report will be useful for several decision and management functions including near-term strategic planning, resource and budget allocation, General Management Plan (GMP) and Resource Stewardship Strategy development, and Desired Condition management objectives. In addition, this report will be a valuable contribution for broader directives including assessment of the Department of Interior's "land health goals," or the "resource condition scorecard" created by the Federal Office of Management and Budget (OMB).

Ranking Methodology

We based our ranking framework upon the National Park Service Ecological Monitoring Framework (EMF, Fancy et al. 2009, Table 1). The NPS framework divides monitoring into six general categories: air and climate, geology and soils, water, biological integrity, human use, and landscape pattern and processes (Fancy et al. 2009). Each of these general categories, referred to as level-one, is further subdivided into level-two and level-three categories (Appendix A). Identified NPS vital signs and other attributes assessed in this report were level-three categories. For example, the level-one category biological integrity is divided into four level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Invasive species, in turn, includes two level-three categories: invasive/exotic plants and invasive/exotic animals. Using this framework assisted us in selecting a meaningful subset of ecological attributes from a comprehensive list. It provided an organized system to discuss attributes and present findings. And because it is hierarchical, results could be summarized at multiple levels.

To assess park natural resources we considered the current condition of resources, the trend of the current condition, and the quality of the data available for each resource. We developed a list of ecological attributes suitable for condition assessment using 1) level-three category attributes from the monitoring framework described above, 2) the inventory and monitoring goals for the Cumberland Piedmont Network (CUPN, Leibfreid et al. 2005), and 3) input from CUGA staff. Methods used to assess the condition of each attribute are described in the appropriate sections of this report. When appropriate, we performed statistical comparisons using $a = 0.05$. The condition of each attribute was graphically represented with a colored circle where the color indicated the condition on a four-tiered scoring system of excellent (dark green), good (light green), fair (yellow), or poor (red). For several attributes, a condition was not assigned because available data were insufficient or because we lacked a defensible ranking method. These attributes are indicated with a blue circle.

Table 1. Hierarchical framework of ecological attributes assessed at Cumberland Gap National Historical Park for this Natural Resource Condition Assessment.

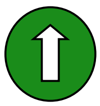
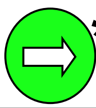
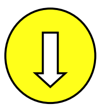
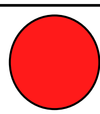
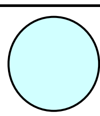
Ecological Monitoring Framework—CUGA			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Air and Climate	Air Quality	Ozone	Ozone levels
		Foliar Injury	Ozone impact on native plants
Geology and Soils	Subsurface Geologic Processes	Cave Meteorology	Air temperature, relative humidity
Water	Hydrology	Surface water dynamics	Discharge
	Water Quality	Water Chemistry	Temp, pH, specific conductivity, DO, ANC
		Microorganisms	*E. Coli* and fecal coliforms
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Presence/absence, distribution, invasibility
	Infestations and Disease	Forest Pests	Hemlock woolly adelgid, emerald ash borer, Gypsy moths, Asian long-horned beetle, southern pine beetle
	Focal Species and Communities	Vegetation Communities	Forest vegetation communities, cliffline vegetation communities, wetland vegetation communities, structure, composition, extent
		Fish Communities	Diversity, IBIs
		Bird Communities	IBIs, richness, abundance
		Mammal Communities	Observed vs. expected community, comparison with comparable efforts
		Reptile and Amphibian Communities	Reported vs. expected community, amphibian breeding effort
		Cave Bats	Cave use, relative abundance of cave obligates, reported vs. expected community,
	At-risk Plants	Rare Plants	Presence and distribution of rare plants and plant communities
Landscape	Landscape Dynamics	Land Cover and Land Use Change	Changes within CUGA vs. changes in surrounding landscape

When possible, we assigned a trend to the condition of each assessed attribute. We graphically presented condition trend using an arrow within the condition circle. Arrow orientation indicated improving condition (arrow points up), stable condition (arrow points right), or deteriorating condition (arrow points down). As with condition status, we did not assign a trend in cases where data were insufficient, or when we lacked a defensible method to determine a trend. In cases where no trend was assigned, the arrow-shaped trend graphic was omitted from the condition ranking.

For each assessed attribute, we also assessed the quality of the data used to determine the condition. This was done to provide context for the reliability of the rankings and to help identify areas where insufficient data exist. Specific data sources and characteristics are discussed within the narrative of each attribute section. Data quality was assessed using three pass-fail categories—thematic, spatial, and temporal—and was adopted from the data quality ranking utilized by Dorr et al. (2009). The "thematic" category refers to the relevance of the data used to make the assessment, such as whether the attribute of interest was measured directly or inferred from a secondary variable. The "spatial" requirement was met if the available data were spatially relevant for the assessment. The "temporal" requirement was met if the data were collected sufficiently recently to reflect the current condition at the time of publication. An overall data quality rank was assigned by summing the criteria that were met. Data quality was good (green bar) if all three criteria were met, fair (yellow bar) if two were met, or poor (red bar) if one was met. In rare cases where a good condition was assigned to an attribute for which data quality was poor, attention is drawn to the ranking with an asterisk. Data quality is graphically presented beside the condition and trend assessment of each attribute. Table 2 provides examples of the data quality graphics used in this report.

We have provided a comprehensive assessment of park condition with the caveat that our analysis is limited by the type and quality of data available, and by the availability of evaluation methods and reference conditions. Although we attempted to assess conditions using relevant and defensible metrics for each attribute, it is important to note that condition rankings are relative for each condition, and identical rankings for different attributes may hold separate meanings and implications. When possible, we used published metrics and established reference thresholds to assign rankings. In cases where no published quantitative metric or standard was available, we used our own judgment, often basing our decision on similar metrics available in the literature.

Table 2. Example condition assessments. Attribute condition is indicated by the color of the circle. Dark green=excellent, light green=good, yellow=fair, red=poor, blue=no condition assigned. Condition trend is indicated by the arrow within the circle. Pointing up=improving condition, pointing right=stable condition, pointing down=declining/deteriorating condition, no arrow=no trend assigned. Checkmarks indicate whether data met the thematic, spatial, and temporal criteria for data quality, as described in the text. The colored bar under the check marks indicates the overall data quality score. Green (good) = 3 checks, yellow (fair) = 2 checks, red (poor) = 1 check. An asterisk (*) brings additional attention when an attribute was ranked as good with data meeting only one quality criterion.

		Data Quality			
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**	**Interpretation**
Example 1:		✓	✓	✓	Condition: Excellent Trend: Improving Data Quality: Good
			3 of 3: Good		
Example 2:	 *			✓	Condition: Good Trend: Stable Data Quality: Poor
			1 of 3: Poor		
Example 3:		✓	✓		Condition: Fair Trend: Declining Data Quality: Fair
			2 of 3: Fair		
Example 4:				✓	Condition: Poor Trend: None assigned Data Quality: Poor
			1 of 3: Poor		
Example 5:		✓	✓	✓	Condition: None assigned Trend: None assigned Data Quality: Good
			3 of 3: Good		

Data Description

We used a variety of data sources in this report. Data collected pursuant of I&M program goals were our most important source of information about park resources. We also used other data provided by NPS staff at CUGA (e.g. personal communication, unpublished reports, management plans), and relevant data available from non-NPS sources. In some cases, raw data were available in electronic spreadsheets or databases. In other cases, data were taken from written documents. Other data were available for download in electronic form from online databases. Table 3 summarizes the data and sources that were used in the following condition assessments.

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	Portable Ozone Monitoring System (POMS) in CUGA	Hourly measurements of ozone concentration within CUGA	May-September, 2005-2010
		NPS Air Resources Division (ARD)	Model-interpolated ozone exposure maps using data from general region	1995-1999 period, 1999-2003 period, 2003-2007 period
		Gaseous Pollutant and Monitoring Program (GPMP) summaries, (Air Resource Specialists 2009 a,b)	Monthly summary reports	August and September 2009
		Clean Air Status and Trends Network (CASTNet), EPA monitoring station in Speedwell		1999-2008
	2nd highest 1-hr ozone concentration	Portable Ozone Monitoring System (POMS) in CUGA	Hourly measurements of ozone concentration within CUGA	May-September, 2005-2008
	Foliar injury risk predictions (3-metric index)	NPS report for the Cumberland Piedmont Monitoring Network (NPS ARD 2004)	Kriged predictions extracted from US-wide ozone models	1995-2003
Cave Meteorology	Air temperature and relative humidity	Data loggers placed in caves within CUGA (CUGA unpublished data; VDGIF unpublished data)	Measurements recorded regularly at several locations in two caves in CUGA	1998-2011
Surface Water Dynamics	Flow (l/sec)	NPStoret data for CUGA	Raw water quality monitoring data from sampling at 10 stations within CUGA	2006-2008
		NPS Water Quality Monitoring Report for CUGA (Meiman 2009)	Summarized water quality data for CUGA	2006-2008
		NPS Water Resources Division (WRD)	Historical and current monitoring conducted by park	1980-2008
Water Chemistry	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), ANC (mean)	NPStoret data for CUGA	Raw water quality monitoring data from sampling at 10 stations within CUGA	2006-2008
		NPS Water Quality Monitoring Report for CUGA (Meiman 2009)	Summarized water quality data for CUGA	2006-2008
		NPS Water Resourced Division (WRD)	Historical and current monitoring conducted by park	1980-2008

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park (continued).

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Microorganisms	E. Coli (mean colonies/100mL), fecal coliforms (mean colonies/100 mL)	NPStoret data for CUGA	Raw water quality monitoring data from sampling at 10 stations within CUGA	2006-2008
		NPS Water Quality Monitoring Report for CUGA (Meiman 2009)	Summarized water quality data for CUGA	2006-2008
		NPS Water Resourced Division (WRD)	Historical and current monitoring conducted by park	1980-2008
Invasive/Exotic Plants	Presence, relative predominance, and invasability of exotics	NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004
		NPS Exotic vegetation survey (Butler et al. 1981)	Survey of invasive woody vegetation at CUGA	1980
		CUGA records	Exotic plant treatment locations	2005-2009
Insect Pests	Presence and distribution of Hemlock woolly adelgid	NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004
		CUGA GIS data	Location of imidacloprid treatments, and predator beetle releases in CUGA	2007-2010
	Presence or absence of emerald ash borer	USDA/APHIS	Online insect pest distribution maps	2011
	Presence or absence of Gypsy moths	KY Cooperative Agricultural Pest Survey (CAPS)	Online summary of gypsy moth survey findings	2005-2011
		USDA Forest Service	Trapping records in park from 11-15 traps	2004-2010
	Presence or absence of Asian long-horned beetle	USDA Forest Service	Online Asian long-horned beetle pest report	2009
	Risk of infection by southern pine beetle	US Forest Service, Forest Health Technology Enterprise Team (Krist et al. 2007) (add to bib)	Southern pine beetle hazard maps for US at several resolutions	2007
		NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park (continued).

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Vegetation Communities	Presence of G1-G3 ranked forest communities	NatureServe and Center for Remote Sensing and Mapping Science at UGA	Spatially explicit description of CUGA vegetation communities	2002
		NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004
	Presence of G1-G3 ranked clifflline community assemblages	Walker and Ballinger (2007)) report: *Physical Variables and Community Structure of the White Rocks Cliff System*	Report of comprehensive survey conducted at White Rocks Outcrop in CUGA	2005-2006
		NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004
	Function and composition of wetland community assemblages	Wetland mitigation site function assessments (Petranka 2002, 2005)	Reports on assessments of the function of constructed mitigation wetlands in CUGA	1999-2005
Fish Communities	Kentucky Index of Biotic Integrity (KIBI), adapted macrohabitat assessment scores	Survey of CUGA vertebrate fauna (Barbour et al. 1979)	Final report including fish sampling data from 12 locations among eight streams	1978-1979
		Surveys of Davis Branch for blackside dace (Stephens 2002a; 2007)	Report on blackside dace survey of Davis Branch	2002, 2007
		Surveys of Gap Creek (Stephens 2002b)	Report on fish surveys of Gap Creek	1996-2002
		CUGA fish survey conducted by Third Rock Consultants (Remley 2005)	Final report of fish inventory of eight park streams using backpack electroshocking	2004
Bird Communities	Bird community index (BCI), conservation value index, richness, abundance over time	Survey of CUGA vertebrate fauna (Barbour et al. 1979)	Final report including bird sampling from walking surveys and incidental sightings	1978-1979
		CUGA bird inventory (Monroe 2005)	Final report and raw data for point count surveys and incidental sightings throughout the park	2003-2004
		USGS, breeding bird survey data (Sauer 2008)	Point count surveys at selected routes in CUGA and surrounding area	1993-2008

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park (continued).

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Mammal Communities	Comparisons of reported vs. expected	Survey of CUGA vertebrate fauna (Barbour et al. 1979)	Final report including mammal sampling from trapping and incidental sightings	1978-1979
		CUGA mammal inventory conducted by Copperhead Environmental Consulting (Gumbert et al. 2006)	Final report of trapping and incidental sightings; including bats	2005-2006
Reptile and Amphibian Communities	Comparisons of reported vs. expected; amphibian breeding effort; mitigation wetland function	Survey of CUGA vertebrate fauna (Barbour et al. 1979)	Final report including reptile/amphibian sampling from trapping and incidental sightings	1978-1979
		Long-term amphibian sampling program (Petranka et al. 2004; CUGA unpublished data)	Spring counts of focal amphibian species egg masses	1993-2009
		Herpetofauna survey of CUGA conducted by Third Rock Consultants (Meade 2003)	Final report of herpetofaunal sampling using searching and coverboards	2003
		RAWS data station for Cumberland Gap Visitor Center	Daily cumulative precipitation	2002-2011
Cave Bats	Cave bat diversity; occurrence at CUGA caves; presence of T&E sp.;	Indiana bat hibernacula sampling by VGDIF in CUGA (CUGA unpublished data)	Biennial counts of hibernating bats in two CUGA caves	1993-2007
		CUGA mammal inventory conducted by Copperhead Environmental Consulting (Gumbert et al. 2006)	Final report of mammal sampling including mist netting, harp trap sampling, Anabatt II acoustic sampling, and incidental sightings	2005-2006
		Data loggers placed in caves within CUGA (CUGA unpublished data)	Measurements recorded every 10 or 15 minutes at several locations in two caves in CUGA	1998-2009

Table 3. Summary of ecological attributes, assessment measures, and data sources used in a Natural Resource Condition Assessment of Cumberland Gap National Historical Park (continued).

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Rare Plants	Presence of G1/G2 plant communities; presence of state listed plants	NatureServe vegetation assessment (White 2006)	Report, and discussion from CUGA vegetation survey	2003-2004
		White and Littlefield (2008): *Update of KY Rare Plants in Cumberland Gap NHP*	Report of resurvey efforts for previous rare plant locations in KY portion of CUGA	2008
		Walker and Ballinger (2007)	Discussion of rare plants/lichens at White Rocks	2005-2006
Landscape Dynamics	Land use change	Multi-Resolution Land Characteristics Consortium (MRLC 2009)	Retrofitted landcover change maps to compare 1992 to 2001 NLCD layers	1992-2001
		National Land Cover Dataset	Nationwide landcover datasets	1992-2001
		CRMS	Land cover dataset	2002-2003

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xx) for more information.

Park Resources and Introduction

Park Location and Significance

Cumberland Gap National Historical Park (NHP) was designated in June 1940 and straddles the tri-state area that includes Kentucky, Virginia, and Tennessee, occupying a total of four different counties. Although the majority of the park is in Kentucky and Virginia, the closest metropolitan area is Knoxville, TN—about 60 km to the south. The park encompasses approximately 9,800 ha (24,000 acres), which includes 1,500 ha (3,700 acres) of the recent Fern Lake acquisition (Ehrlich 2008). This newly acquired area includes the drainage area of the Fern Lake reservoir, with the exception of the lake itself and the immediate vicinity. Currently, 5,700 ha (14,000 acres) of the park are designated as wilderness. The park stretches linearly from southwest to northeast for about 32 km along the Cumberland Mountain Range, with a variable width ranging from as narrow as ~1 km (<1 mile) near its center section to a greatest width of about 6 km (4 miles) in the northern and southern sections. The park unit is bounded by State Hwys 987 and 217 to the north and US Hwy 58 to the south (Figure 2). Elevation ranges from 335 to 1067 m (1100 to 3500 ft), while the Gap itself is located less than a mile north of the tri-state intersection of the KY, VA, and TN borders. The Tri-State Peak and The Pinnacle immediately surround the Gap to the south and north, respectively. Among many other geological attributes, the park features one of the largest natural breaks in the Appalachian range, which served as a major point of access for early American settlers travelling west into the Kentucky frontier. Native Americans had also used the Gap as a gateway through the mountains for many years before European settlers arrived (NPS 2009a).

One of the park's primary manmade features is the Wilderness Road Trail, which leads from Virginia through Cumberland Gap to central Kentucky. This trail, eventually widened by Daniel Boone in 1775, originally served as a passage for the Native Americans. Today, Cumberland Gap NHP is working with the Wilderness Trail Corridor Alliance to obtain a National Historic Trail designation for the route.

Park Objectives

Cumberland Gap NHP (CUGA) recently completed a general management plan that provides a framework for park managers to follow regarding management of environmental impacts and visitor use over the next 15 – 20 years (NPS 2010a). The park, in addition to its historical and cultural significance, is important due to its wealth of natural resources and features, and as such one of the main objectives of the park management is stewardship of these assets. Specifically, the park is involved in efforts to control invasive plant and animal populations via removal and integrated pest management. The park is also pursuing opportunities with research scientists to study aspects of the park environment and how it responds to environmental change.

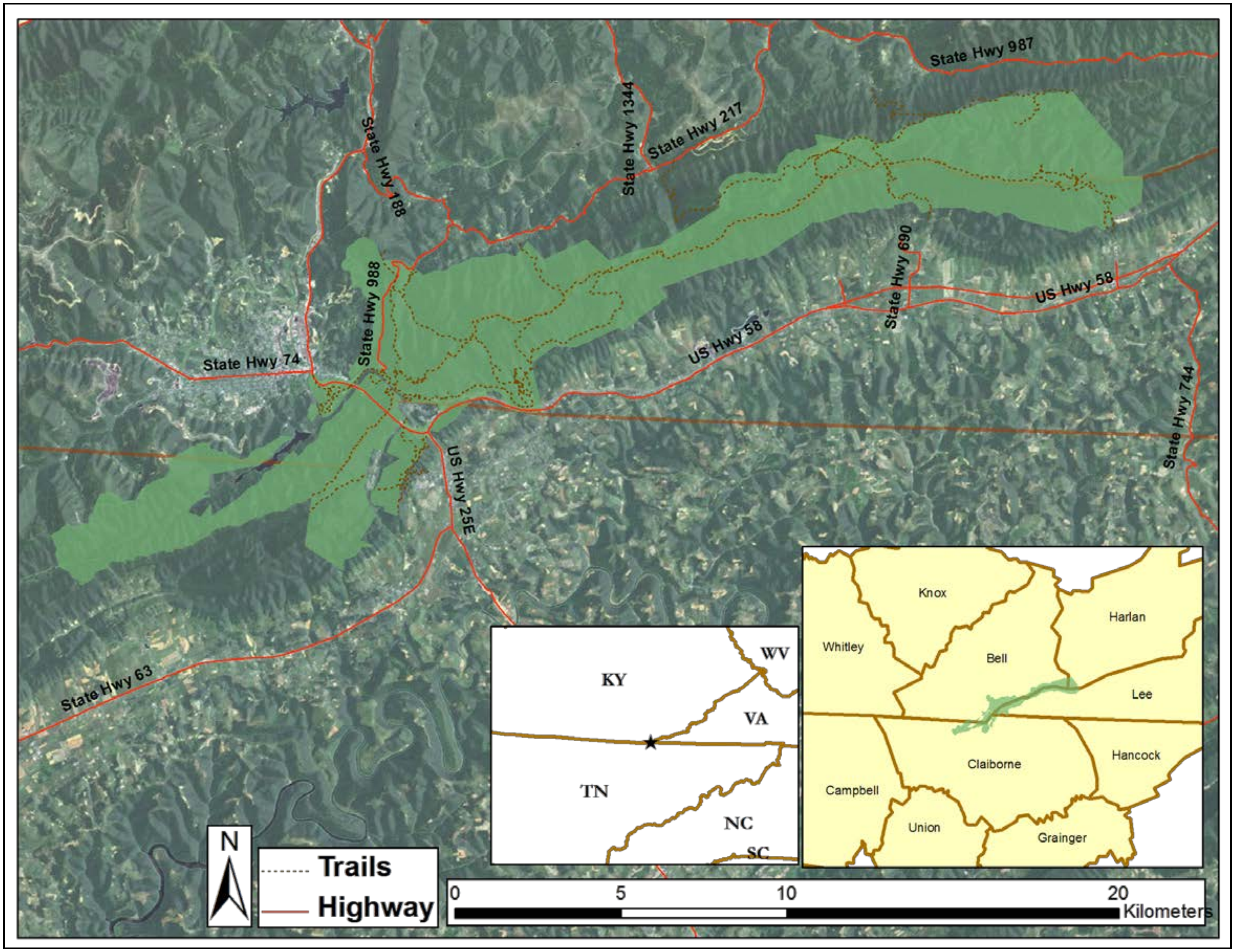


Figure 2. Cumberland Gap National Historical Park is located along the tri-state border of KY, VA, and TN.

Currently, the park is carrying out plans to acquire the remainder of the Fern Lake watershed, an 1800 ha area at the southwestern tip of the park. Although most of the land is now under care of the NPS, approximately 240 ha are still under negotiation.

Climate, Geology, and Soils

Cumberland Gap NHP falls within a region with a fairly mild climate, with hot and humid summers that have temperatures upwards of 32ºC (90ºF), while winters are generally mild with temperatures ranging from 0 – 10 ºC (32 - 50ºF). The average annual temperature is 13.8 ºC (57ºF), while average precipitation is 93.5 cm (37 in)—July and April are typically the wettest months.

Cumberland Gap NHP derives much of its historical and cultural significance from the unique geological history of the area. Out of only three east-west routes reported throughout the Appalachian chain, Cumberland Gap is the most famous, reportedly having served as passage for over 300,000 westbound settlers into Kentucky by 1810 (Luckett 1964). The Gap was formed as a result of a series of geological events. As the Pine Mountain thrust sheet shifted westward towards Cumberland Mountain, numerous local faults weakened and tilted the rock layers. One of these faults, the Rocky Face Fault, occurred perpendicularly to the Cumberland Gap area, thus weakening the area to weathering that eventually formed the Gap in Cumberland Mountain (Ehrlich 2008). To the west of the Pine Mountain thrust sheet, Pine and Cumberland mountains run parallel to each other, and were formed from Lee conglomerate material as part of the Middleboro syncline. The Cumberland River north of the syncline and a tributary to the Powell River south of the syncline were involved in carving the Cumberland Gap passageway through both ends of the syncline during the uplift period (Figure 3, McFarlan 1939). Cumberland Gap itself was formed as the Yellow Creek eroded away parts of Cumberland Mountain while the range was still being uplifted. Eventually, the creek changed direction, and ultimately ran dry before settlers began using the passage for migration.

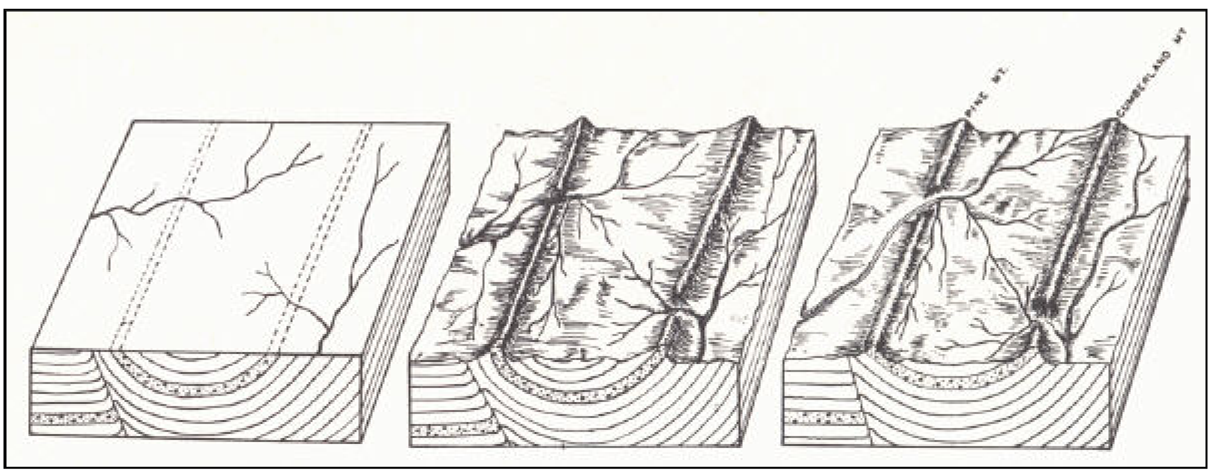


Figure 3. Diagrams showing the Cumberland (left) and Powell (right) rivers and their creation of the Cumberland Gap through the Pine (left) and Cumberland (right) ranges (McFarlan 1943).

Another important feature in the area, though not located in the park, is the 5km (3 mile) diameter Middlesboro impact crater located immediately adjacent to the park. This crater also served as a portion of the overall Cumberland passageway to Kentucky. Shatter cone patterned rock fragments, typical of impact events, are abundant around the Middlesboro crater, as well as concentric faults with brecciated and highly deformed material. Since the impact, the weakened material has eroded up to 300m (980 ft). Today, the town of Middlesboro, KY is located on the crater, and in 2003 the Kentucky Society of Professional Geologists designated Middlesboro as a Distinguished Geologic Site (Luckett 1964).

Other geologic features of note include the Greenbrier Limestone Formation, which occurs along the south face of Cumberland Mountain and contains a series of caves up to 26 km (16 miles) in length, including the well-known Gap and Sand Caves (NPS 2009a). These caves were formed from the dissolution of cherts and limestones deposited during the Mississippian period (Ehrlich 2008). On the east side of the park, the White Rocks are a formation of sandstone cliffs that run along the ridgeline forming the Virginia/Kentucky border, and also make up the highest part of the park. Upon seeing the White Rocks during his journey to widen the Gap trail into the Wilderness Trail, Daniel Boone offered the description that "the aspect of these cliffs is so wild and horrid, that it is impossible to behold them without terror." The 34 km (21 mile) Ridge Trail runs along this border southwest to the Pinnacle on the north side of the Gap (Luckett 1964).

The majority of the soils along the Cumberland Mountains are classified in either the Alticrest-Totz-Helechawa or the Helechawa-Varilla-Jefferson complexes, which are rocky soils characteristic of mountainsides and steep slopes. These complexes are composed mainly of extremely stony Inceptisols and Entisols, which are poorly-developed soils demonstrating only slight differentiation among subsurface horizons. Their poor development in the Cumberland Mountains may be due to both the high rate of erosion associated with the steep slopes, as well as the weather-resistant sandstone parent material on which these series mainly occur. Jefferson soils, as well as several other Alfisols and Ultisols, are characteristic of more well-developed locations and are typically found in rocky colluvial deposits on lesser slopes or areas associated with sandstone escarpments.

Hydrology

Cumberland Gap NHP is unique in that the ridge of the Cumberland Mountains straddles the boundary between the Ohio (Region 5) and Tennessee (Region 6) hydrologic regions (Figure 4). South of the Cumberlands is the Powell cataloging unit (HUC 06010206), which in turn is part of the Upper Tennessee accounting unit (HUC 060102). This portion of the park drains to the Powell River approximately 5 km (3 miles) below the park; while north of the ridge the drainage reaches the Cumberland River in about 16 km (10 miles). This northern portion falls within the Upper Cumberland cataloging unit (HUC 05130101), and the accounting unit of the same name (HUC 051301). In addition, with the exception of Little Yellow Creek, all streams occurring in the park, such as Sugar Run and Station Creek, originate inside the park (NPS 2009a).

According to current EPA data, none of the streams in the park qualify as 303(d) status, indicating impaired water quality conditions. Cumberland Gap NHP is classified as a Category One park (Meiman 2009), which means that the water resources in the park played a central role in its establishment and interpretation. It also acknowledges the existence of blackside dace populations and habitat—a rare fish species (Leibfreid et al. 2005). In order to monitor water quality and help protect aquatic habitat, CUGA has been monitoring water quality since the early 1990's, while the I&M program began regular monthly sampling in 2006.

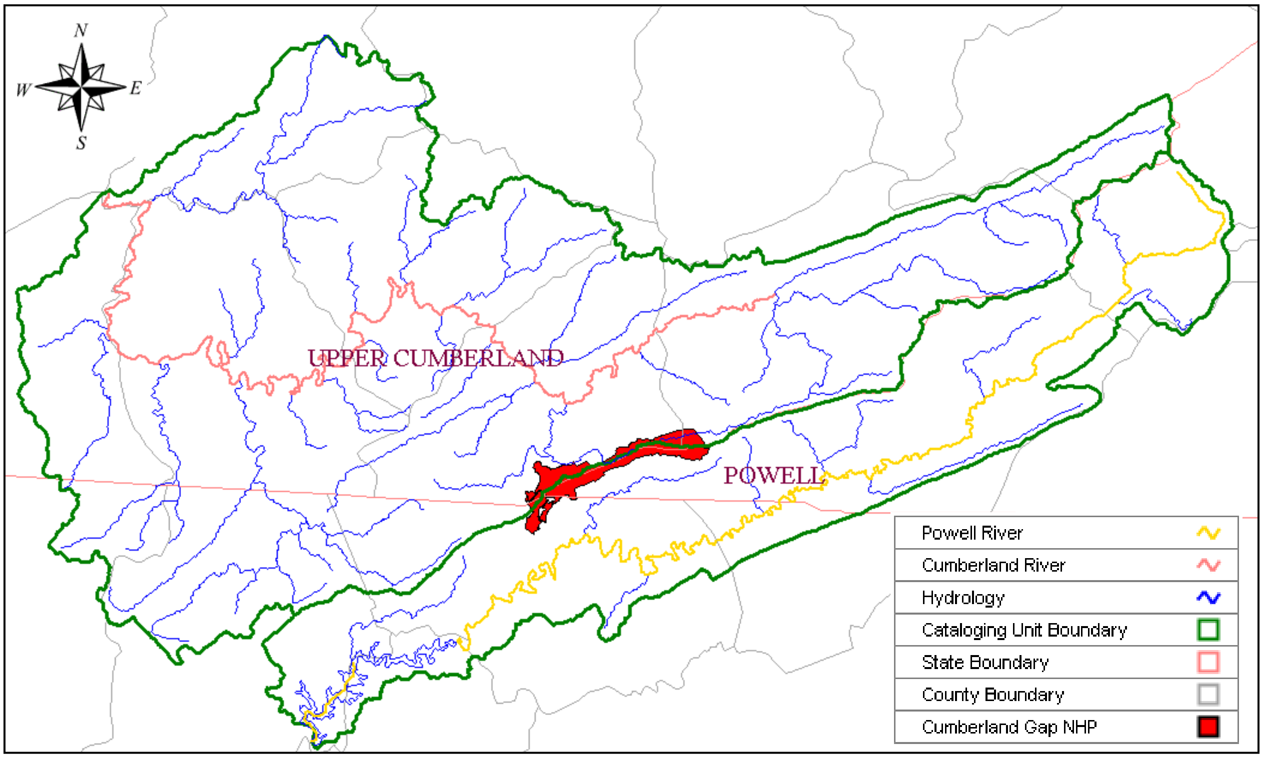


Figure 4. Cumberland Gap NHP straddles the Powell and Upper Cumberland hydrologic cataloging units, which in turn fall respectively in the Tennessee River and Ohio hydrologic regions.

History and Park Significance

Before settlers began using Cumberland Gap as a passage for westward migration, Native Americans used part of it as a hunting and trading route known as the Warrior's Path. The first recorded passage through the Gap by a European was in 1750, when Thomas Walker of the Loyal Land Company began an official expedition to search for a habitable area beyond the Appalachian Mountains. Speculators sponsored expeditions after Walker's journey, though permanent expansion was inhibited by frequent raids on settlers by the Shawnee and Cherokee tribes. This eventually led to a declaration of war on the Shawnee by Virginia's governor, Lord Dunmore, and subsequent defeat of the tribe four months later. A later agreement with the Cherokee resulted in the purchase of their land claim south of the Kentucky River, and Daniel Boone was soon hired to blaze a trail through the gap all the way to the river (Luckett 1964). Following Boone's lead, hundreds of thousands of settlers passed through the Gap along the Wilderness Road in the years between 1780 and 1810, when the Ohio River route became the safest and most direct route west.

During the Civil War, strategic possession of Cumberland Gap alternated between the Union and Confederates armies, as it was particularly valued for the vantage point that the Pinnacle offered as well as offering the most direct route between Union- and Confederate-held states. After the war ended in 1865, the spoiled landscape was mostly forgotten by outside interests until geological investigations in the 1880s sparked a renewed interest in the area due to its rich coal and iron deposits (Luckett 1964). Today, remnants of Civil War fortifications are still visible in the southeastern end of the park, including a crater near the Tri-State peak produced by detonation of powder kegs by retreating Union soldiers (Ehrlich 2008). Park staff also offer special tours of Hensley Settlement—an isolated settlement within the park and close to the Ridge Trail (NPS 2009a). The Hensley Settlement was occupied by the Hensley and Gibbons families from around the turn of the century until 1951.

In 1922, a proposal at the Appalachian Logging Conference in Cincinnati outlined the adoption of a "mountain park" centered on Fern Lake, though two bills by Kentucky Congressman John Robison for the creation of Lincoln National Park at the tri-state intersection were not passed the following year. Another effort by Robison was also unsuccessful in 1929, even though it took a slightly different approach by suggesting the creation of war memorials for participants in battles around Cumberland Gap. In 1938, the Cumberland Gap National Historical Park Association was created, the renewed attention of which spurred a new round of unsuccessful bills by Kentucky representatives. Virginia Congressman John Flanagan was finally successful in 1939, and President Franklin D. Roosevelt signed the bill authorizing Cumberland Gap NHP in 1940. Throughout 2008-2009, the park acquired around 1800 ha of additional land at its southern tip around Fern Lake.

Natural Resources and NPS Vital Signs

Just as the geology of the Cumberland Gap area played a large role in shaping its significant historical role, this naturally unique area also provides a wealth of resources that adds to its appeal. Based on recent inventories and review of extant data by taxonomic experts, over 1,200 vascular plants and vertebrate species were determined to be present in CUGA, making it one of the most species rich parks within the Cumberland Piedmont Network (CUPN, Moore 2010). As part of the I&M monitoring plan, NatureServe established 36 sampling plots throughout the park on a 1.5 km^2 grid plus an additional 24 plots in unique habitats off of the grid to help complete a vegetation inventory (White 2006).

Cave Ecosystems—One of the most distinctive features at CUGA is its cave system. A vital sign selected by the CUPN Inventory and Monitoring (I&M) network, cave meteorology, is relevant to cave related natural resources at CUGA. Cave meteorology addresses how environmental properties such as air temperature, humidity, and airflow can affect species communities found inside the caves, in addition to the cave formations (speleothems) that attract many visitors.

Caves within the park provide habitat for the Allegheny woodrat (*Neotoma magister*)—a species of management concern that is a candidate for federal listing, and listed by Tennessee as "deemed in need of management" (TDEC 2009, USFWS 2011). Allegheny woodrats play an important and unique role in the nutrient cycling of cave ecosystems through transport of organic material from outside the caves. Due to their sensitivity to resource condition and availability, Allegheny woodrats are often regarded as indicators of health for terrestrial ecosystems outside the cave. At the time of publication, detailed data were not available about the distribution and abundance of woodrats in CUGA.

Cumberland Gap NHP is home to nine species of bats, including the endangered Indiana Bat (*Myotis sodalis*, Figure 5), which lives in several of the limestone cave formations within the park and probably uses surrounding forested habitat for summer and pre-hibernation roosting and foraging. Cave bats are a CUPN Vital Sign. Like Allegheny woodrats, cave bats are vital to the cave ecosystem because of their dual role in importing nutrients and serving as an indicator species (NPS 2008).

Figure 5. Limestone caves in Cumberland Gap NHP are home to the endangered Indiana Bat (*Myotis sodalis*).

Vertebrate Assemblages

Fishes, birds, mammals, reptiles, and amphibians have been inventoried in CUGA in recent years. Around 27 species of fish have been reported from stream inventories conducted since 2002 (Stephens 2002a,b, Stephens 2007,Remley 2005). Fishes reported from the park include the federally threatened blackside dace (*Chrosomuss cumberlandensis*). Blackside dace habitat in the park has been negatively impacted by beaver activity, therefore while beaver are not currently managed in CUGA, it may be important in the future. The park contains a rich bird assemblage dominated by interior forest specialist species. A recent inventory reported 145 species, including several species of management concern such as the Cerulean Warbler (*Dendroica cerulea*), and Worm-eating Warbler (*Helmitheros vermivorum*) (Monroe 2005). A rich assemblage of mammals occurs in CUGA, and 40 species were reported from a recent inventory (Monroe 2005). Bats are an especially important resource in the park, and CUGA has many caves providing habitat for cave roosting and hibernating bats. The endangered Indiana bat hibernates in the park and is discussed above. From recent inventory and monitoring efforts, 36 species of reptiles and amphibians have been reported from CUGA (Meade 2003, Petranka 2005). Breeding effort of spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Rana sylvatica*) has been monitored in the park since 1993, as part of a long-term amphibian monitoring program (Petranka 2005). Three small mitigation wetlands were constructed in 1998, and have been included in the monitoring. These ponds have proven to provide habitat for at least 11 species (Petranka 2005).

Vegetation Communities

Cumberland Gap NHP also contains many unique vegetation community types. From low elevation wetlands to mountain bogs, recent classification work by White (2006) found 33 vegetation communities present in the park. These communities were also mapped by the Center for Remote Sensing and Mapping Science at the University of Georgia, which resulted in a total of 37 vegetation classes throughout the park (Jordan and Madden 2008). The steep cliff faces and alcoves such as those present at White Rocks also provide important habitat. A recent survey by Appalachian State University (Walker and Ballinger 2007) documented at least 14 species of vascular plants in these areas. In addition, 48 species of lichen are known to live in the White Rock area, a few of which represent disjunct populations not previously known to occur in the region (Walker and Ballinger 2007).

Invasive Plants

Disturbance and historic development in areas of the park have also led to the introduction of invasive exotic species, and park staff are continually trying to reduce populations of the highest priority invasives. Many of these invasive species can interrupt ecological processes at multiple spatial scales and threaten the presence of sensitive species. In some highly disturbed areas of the park, invasive species such as autumn olive (*Elaeagnus umbellata*), Japanese stiltgrass (*Microstegium vimineum*), multiflora rose (*Rosa multiflora*), and privet (*Ligustrum* sp.) are outcompeting native species (White 2006).

Forest Pests

The gypsy moth (*Lymantria dispar*) is another exotic species that, though not yet throughout the park, is spreading towards the park and poses an imminent threat. Even more significant, the invasive hemlock woolly adelgid (*Adelges tsugae*) was recently discovered in the park in 2006 and is very destructive to both eastern (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*) species. The southern pine beetle (*Dendroctonus frontalis*), a native southeastern forest pest, has also already killed hundreds of acres of pines within the park (NPS 2009a). Preliminary monitoring objectives for these species dictate the collection of additional information on infestation levels with a focus on early detection followed by appropriate management responses (NPS 2008).

Natural Resource Conditions

Air and Climate

Ozone

Ozone is one of the main air quality considerations in the CUPN; the National Ambient Air Quality Standards (NAAQS) set by the EPA include two thresholds for primary and secondary pollutant limits. Primary limits are set with human health factors in mind, while secondary standards pertain to considerations relating to visibility, vegetation health, and building integrity. In the case of ozone, the NAAQS primary and secondary standard concentrations were lowered starting on May 27, 2008 from 0.080 ppm to 0.075 ppm for ozone over 8-hr periods. As a result, violations of this standard are defined as 3-year averages of the 4th highest daily maximum 8-hour average ozone concentration (4th Hi Max 8-hr means) that exceed 0.075 ppm (NPS 2006a).

<u>Portable Ozone Monitoring Stations</u>

Ozone concentrations were collected using a Portable Ozone Monitoring Stations (POMS) at the Hensley Settlement in the northeast portion of the park beginning in 2006 and at the Pinnacle Overlook near highway 25E in 2005 (Figure 7). Monitoring continues at the Hensley Settlement, though the Pinnacle Overlook site was discontinued after only a few weeks. These stations collected hourly ozone concentrations during the summer ozone season (May-September), and as a result, CUGA meets the EPA data standards for 3-yr averages during 2007- 2010, which respectively had average 3-yr 4th Hi Max 8-hr means of 0.071, 0.075, 0.072, and 0.067 ppm. Since the EPA decreased the NAAQS in 2008, these final 3-yr averages fall barely inside the threshold of compliance. Monitoring was completed for the full 5-month ozone season during 2006-2010, during which only five days in 2007 recorded means greater than the threshold (Figure 7). In addition to these full seasons, Gaseous Pollutant and Monitoring Program (GPMP) summaries are available for the park in August and September 2009, which report 4th highest daily 8-hour maximum concentrations of 0.053 and 0.050 ppm, respectively. Neither of these months recorded any measurements greater than the NAAQS limit (Air Resource Specialists 2009a,b). The 2nd highest 1-hr concentration (another measure of ozone used to indicate variability) was 0.086, 0.092, and 0.093 ppm for 2006, 2007, and 2008, respectively.

<u>Passive Ozone Samplers</u>

During 2005, three passive ozone collectors recorded concentrations at Hensley Settlement, Pinnacle Overlook, and Civic Park in CUGA (Figure 6). The former two stations showed fairly comparable concentrations, which were higher than concentrations from Civic Park, though none of the stations approached the NAAQS limit. Of all the passive monitors in CUPN parks that year, those at Hensley Settlement and Pinnacle Overlook recorded the highest values.

<u>NPS Air Resources Division</u>

Another source of air quality information pertinent to CUGA is available from the Air Resources Division (ARD) of the NPS. The ARD used existing data from NPS, EPA, state tribal, and local monitoring stations to produce interpolated exposure maps of the US for different air quality related variables, including ozone (NPS 2007). At CUGA, these predictions resulted in a mean 4th highest 8-hr daily concentration of 0.087 ppm for the five-year period from 1995-1999, 0.086

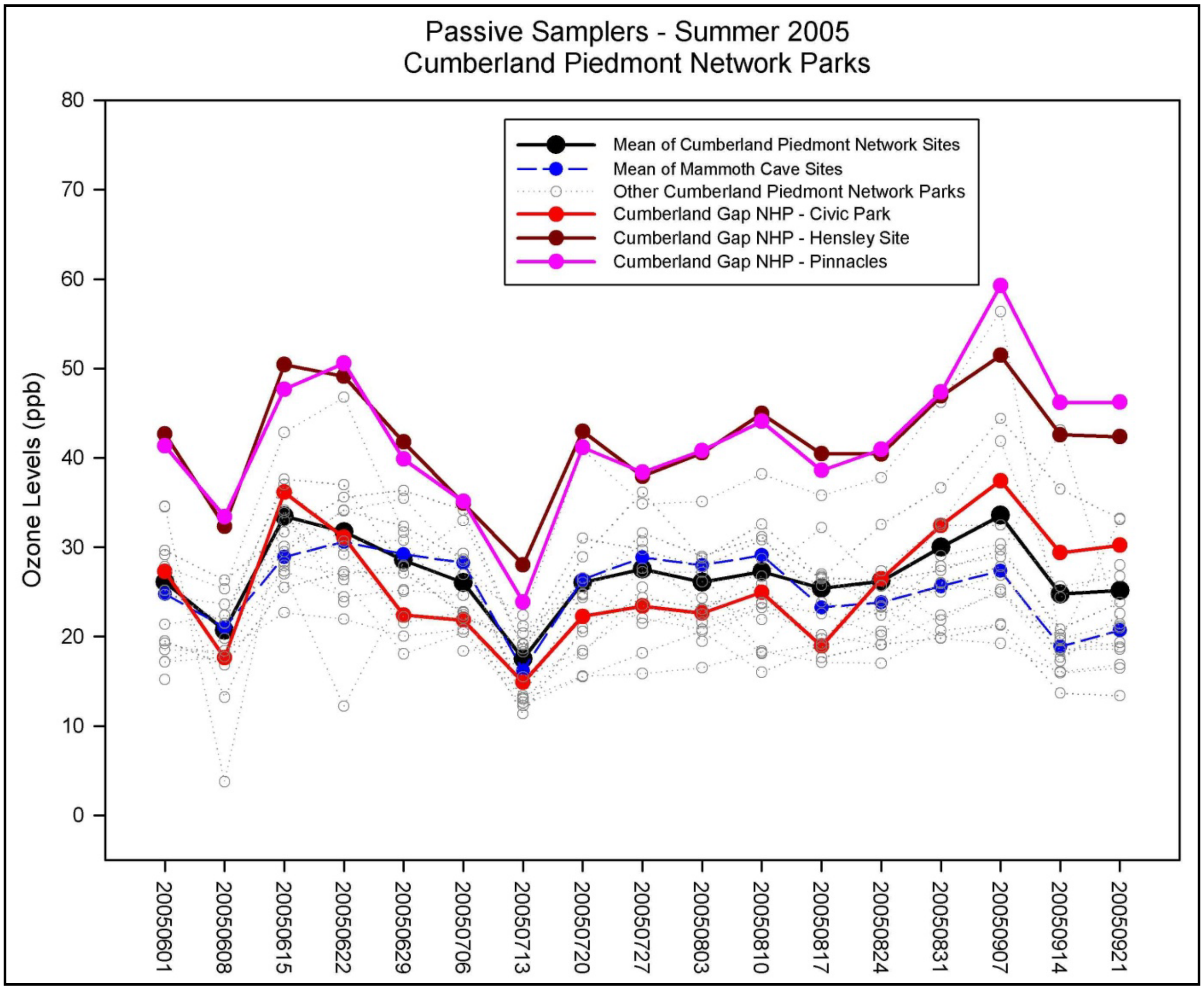


Figure 6. Passive ozone sampling took place at three locations in CUGA during 2005.

ppm for 1999-2003, 0.080 ppm for 2001-2005, and 0.076 ppm for 2003-2007 with respective predicted mean daily concentrations of 0.033-0.036, 0.031, and 0.029 ppm for the first three 5-year periods. The first two 4th highest 8-hr daily concentrations exceed the NAAQS limit, although it is difficult to assess the accuracy of these estimates.

Clean Air Status and Trends Network

One of the sources of data for the ARD interpolations comes from the series of Clean Air Status and Trends Network (CASTNet) sites monitored by the EPA. These sites collect data on an hourly basis for various parameters including atmospheric deposition and ozone. The ARD uses ozone monitors within 16.1 km (10 miles) of the park boundary for interpolations, and at CUGA, the Speedwell CASTNet station, located 9.8 km from the park near Speedwell, TN, has monitored ozone since 1999. Because of the longevity of this record, data from this station may be used to gauge the adherence of CUGA to the ozone section of NPS Goal 1a3, which dictates the examination of an ozone concentration trend using 10-yr moving windows where at least six years of data are available. It is important to note, however, that the differences in elevation between the POMS location at Hensley Settlement (1,013 m) and the CASTNet site in Speedwell, TN (361 m) may affect the ozone measurements.

Because data from this CASTNet station extends from 1999-2009, calculating 3-yr averages of 4th highest annual 8-hr concentrations results in 2001 as the earliest year included in the trend. This trend, shown with fitted regression in Figure 7 shows a significant decrease ($p = 0.0004$, adjusted-$R^2 = 0.83$) in average ozone concentration of 0.003 ppm/yr, though seven of the nine 3-yr means exceed the NAAQS limit, including the final 3-yr mean of 0.076 ppm in 2009. In addition, NPS park units typically report ozone trends using Theil regressions for 3-yr averages over 10-yr moving windows (NPS ARD 2006). Theil regression is a non-parametric technique that is less sensitive to outlier points than typical least-squares linear regression. Using data from 2001-2009, Theil regression also yielded a significantly decreasing trend of approximately 0.002 ppm/yr ($p < 0.0001$).

Summary

Overall, CUGA demonstrates a continued risk of elevated ozone concentration levels. Beginning in 2005, passive ozone samplers in two main areas of CUGA recorded higher concentrations compared to other CUPN park units. CASTNet monitoring showed a significant trend of improving concentrations for both linear and Theil regression fits, though the recent decrease in the EPA standard has resulted in the most recent 3-yr average (2007-2009) remaining above the limit as observed from the CASTNet station. Three-year averages from the POMS in the park also continue to decrease, and the most recent 3-yr mean (2008-2010) was the lowest since monitoring began, though still only slightly below the NAAQS.

Because of the short history of borderline measurements from the POMS, the historic elevated estimates from the NPS ARD interpolations, and the history of levels above the NAAQS limit at the Speedwell CASTNet station, including the most recent monitoring period, CUGA is assigned an ozone condition status of fair.

CASTNet observations at Speedwell represent the only dataset extensive enough to assess a trend, which is found to be significantly decreasing, and therefore the condition is listed as improving. This trend is supported by the decrease of 3-yr 4th highest annual 8-hr concentrations observed at the CUGA POMS from 2007 – 2010. Continued monitoring will be required to determine whether ozone concentrations continue to decline and remain at levels below the new NAAQS threshold.

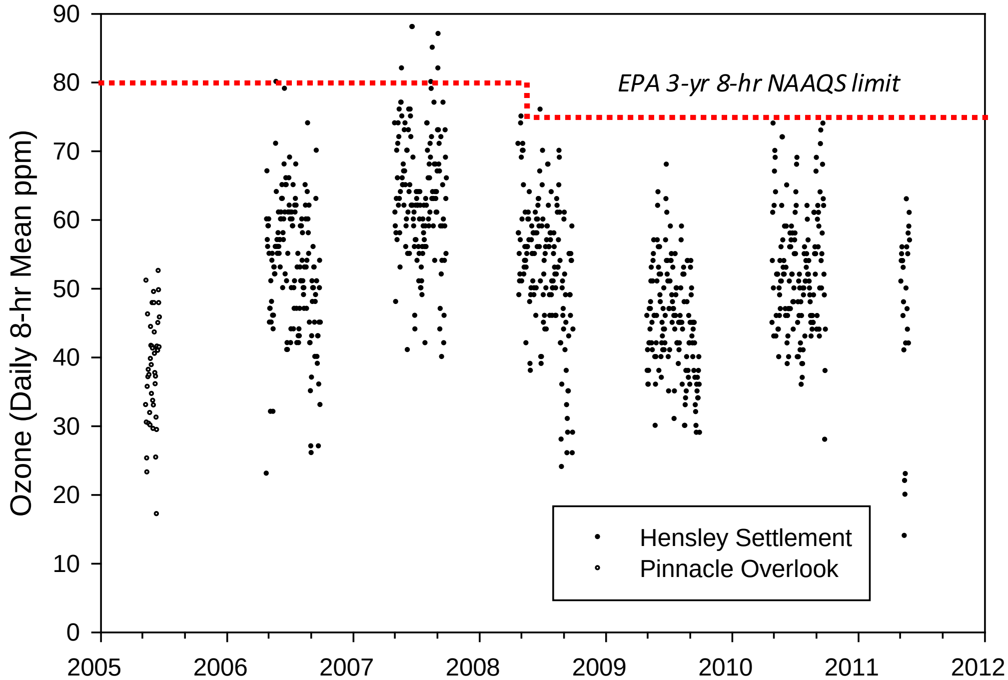


Figure 7. Daily mean 8-hr ozone concentrations from two POMS sites during peak summer monitoring periods.

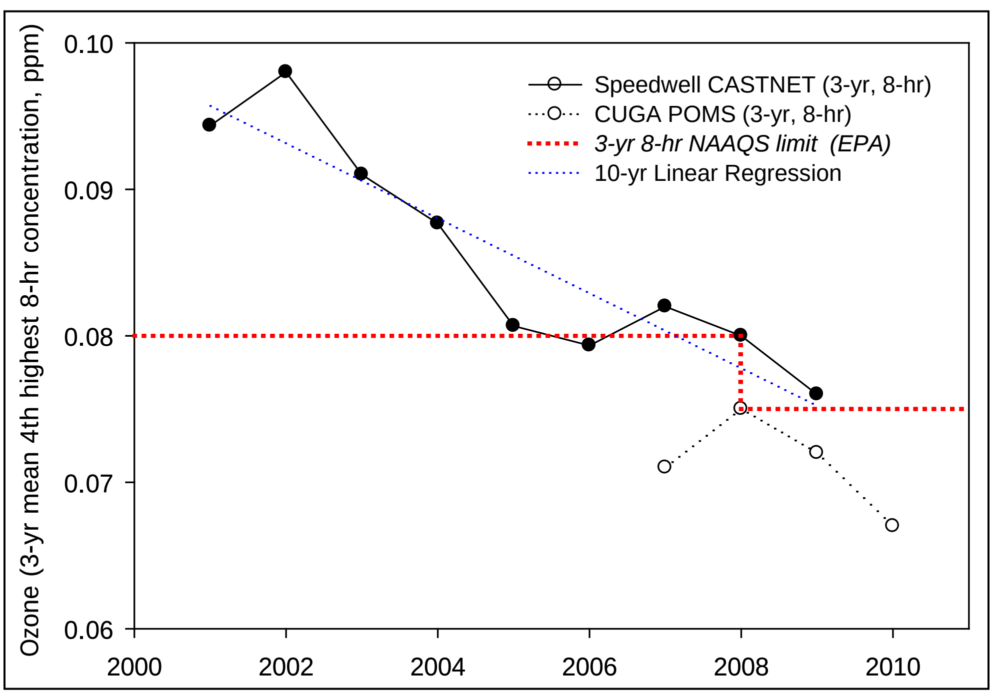
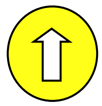


Figure 8. Three-year mean 4th highest annual 8-hr concentrations from 2001-2009 at the Speedwell CASTNet site, which is located 9.8 km from the park in Clairborne County, TN. Each data point represents an average of ozone data from that year and the two previous years (e.g. 2001 includes 1999-2001). The Theil regression, though significantly decreasing ($p < 0.001$), is not included because the y-intercept is variable.

Table 4. The condition status for ozone at CUGA was ranked fair with an improving trend. The data quality for this assessment was good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Ozone		✓	✓	✓
		3 of 3: Good		

Foliar Injury

Ozone concentrations have been linked with deleterious growth or physiological effects in certain sensitive plant species (Ollinger et al. 1997, Lefohn and Runeckles 1987). The NPS ARD has also developed foliar injury maps to predict potential harm to vegetation in each of the I&M parks included. Of the 14 parks in the CUPN, CUGA was one of ten parks to receive a high risk rating for ozone foliar injury (NPS ARD 2004). Ozone foliar injury metrics developed for CUGA are not measurements, but are kriged (interpolated) predictions extracted from ozone models for the entire US. These metrics are available as yearly predictions from 1995-1999 as part of a 2004 foliar injury assessment report for the CUPN, though predictions are only available as a single average over the period 1999-2003. In addition, two metrics are available as part of GPMP reports for 2007 and 2008 (Figure 9).

<u>Ozone Sensitive Species</u>

A list of ozone sensitive species was determined for CUGA from a general list developed by NPS and the US Fish and Wildlife Service (FWS, Porter 2003). This list was cross-referenced with NPSpecies to determine which species were present at CUGA, the results of which are presented in Table 5. These sensitive species are described by Porter (2003) as species that “typically exhibit foliar injury at or near ambient ozone concentrations and for which ozone foliar injury symptoms have been documented in the field.”

<u>Sum06</u>

The first foliar injury metric, Sum06, is an index representing the maximum of the sum of ozone concentrations ≥ 0.060 ppm between 8 AM and PM over a 90-day period from June - August. The NPS Air Resources Division classifies 8 cumulative ppm-hours as the threshold for foliar injury, with the potential for growth reduction starting at 10 cumulative ppm-hr (NPS 2004). At CUGA, Sum06 prediction values averaged 23 cumulative hours > 0.060 ppm for 1995-1999, 27 hours for the period from 1999-2003, and 38hours for 2007-2008, all of which are well above the threshold for foliar injury.

<u>W126</u>

The second index, W126, is a twofold description that includes the sum of hourly concentrations from April through October, and also considers the number of hours where the concentration was ≥ 0.010 ppm for the same period (LeFohn et al. 1997). For the hourly sum, this index weights the values using a sigmoidal function where higher ozone concentrations are weighted disproportionately greater because they present more of a threat for foliar injury (LeFohn and

Runeckles 1987). For W126, highly-sensitive species are affected beginning at 5.9 cumulative ppm-hr, and moderately sensitive at 23.8 ppm-hr. Predictions at CUGA for this metric place it between the threshold affecting moderately and marginally sensitive species (Table 6) for each year between 1995 and 1999, as well as the average over 1999-2003 and 2007-2008.

<u>N-value</u>

The final index is an N-value which corresponds to the number of hours that exceed 0.060, 0.080, and 0.100 ppm. Although these thresholds are relatively arbitrary, ozone concentrations above 0.080 and 0.100 ppm are typically associated with risk for foliar injury (NPS 2004). Like the W126 metric, this one is also separated into three categories for N100 based on plant sensitivity: highly sensitive—6 cumulative ppm-hr, moderately sensitive—51 ppm-hr, and marginally sensitive—135 ppm-hr. Average predicted indices fell into the region affecting highly sensitive species for each year between 1995 and 1999 as well as the overall period from 1999-2003 (Table 6).

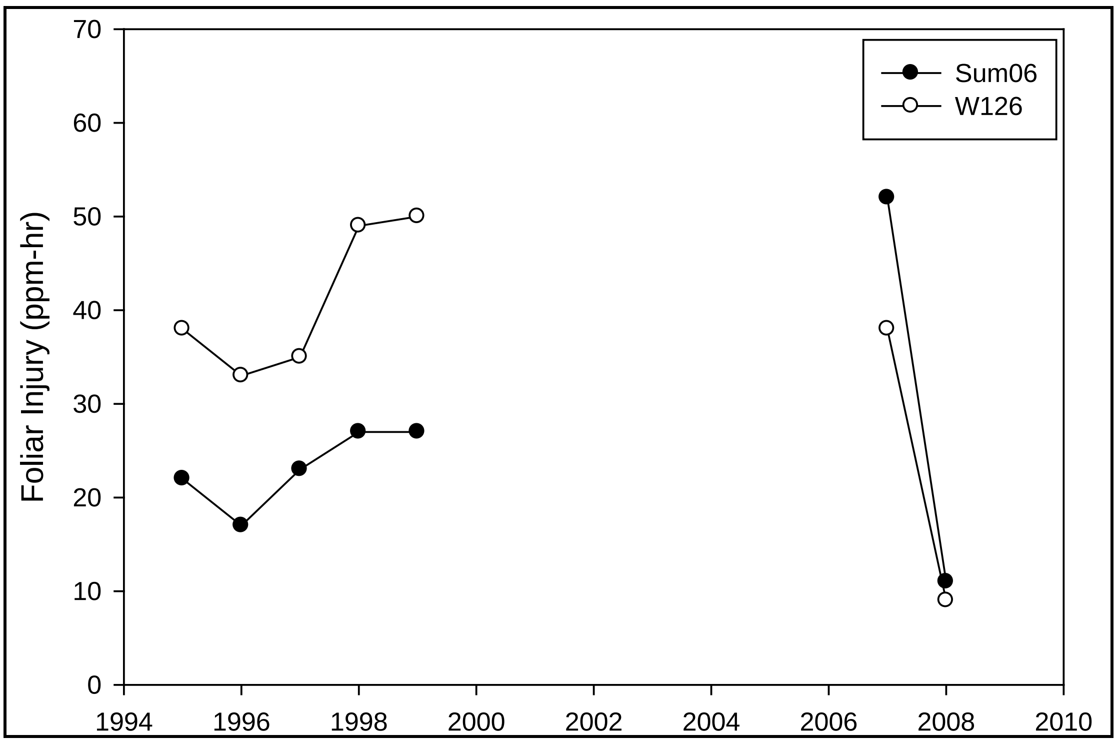


Figure 9. Foliar injury summary metrics predicted by the Air Resources Division for 1995-1999, and as reported by the GPMP based on portable ozone monitoring data for 2007-2008.

Table 5. Thirty-one species at CUGA were identified as sensitive to ozone by cross-referencing Porter's (2003) general sensitivity list with the NPSpecies list for CUGA.

Species		**Family**
Ailanthus altissima	Tree-of-heaven	Simaroubaceae
Apios americana	Groundnut	Fabaceae
Apocynum cannabinum	Dogbane	Apocynaceae
Asclepias exaltata	Poke milkweed	Asclepiadaceae
Asclepias incarnata	Swamp milkweed	Asclepiadaceae
Asclepias syriaca	Common milkweed	Asclepiadaceae
Aster acuminatus	Whorled wood aster	Asteraceae
Cercis canadensis	Redbud	Fabaceae
Clematis virginiana	Devil's darning needles	Ranunculaceae
Corylus americana	American hazelnut	Betulaceae
Fraxinus americana	White ash	Fraxinaceae
Fraxinus pennsylvanica	Green ash	Fraxinaceae
Gaylussacia baccata	Black huckleberry	Ericaceae
Liquidambar styraciflua	Sweetgum	Hamamelidaceae
Liriodendron tulipifera	Tulip-poplar	Magnoliaceae
Lyonia ligustrina	Maleberry	Ericaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Pinus rigida	Pitch pine	Pinaceae
Pinus virginiana	Virginia pine	Pinaceae
Platanus occidentalis	Sycamore	Platanaceae
Prunus serotina	Black cherry	Rosaceae
Robinia pseudoacacia	Black locust	Fabaceae
Rubus allegheniensis	Allegheny blackberry	Rosaceae
Rubus canadensis	Smooth blackberry	Rosaceae
Rubus cuneifolius	Sand blackberry	Rosaceae
Rudbeckia laciniata	Cutleaf coneflower	Asteraceae
Sambucus canadensis	Elderberry	Adoxaceae
Sambucus racemosa	Red elderberry	Adoxaceae
Sassafras albidum	Sassafras	Lauraceae
Solidago altissima	Tall goldenrod	Asteraceae
Verbesina occidentalis	Yellow crownbeard	Asteraceae

Table 6. Set of foliar injury indices for CUGA (NPS ARD 2004).

CUGA Ozone Foliar Injury Indices					
	Sum06	W126	N60	N80	N100
	-----ppm-hr-----			-----hr-----	
1995	22	38	682	117	15
1996	17	33	595	104	9
1997	23	35	627	105	9
1998	27	49	842	200	38
1999	27	50	903	184	20
2007	52	38	-	-	-
2008	23‡	9	-	-	-
1995-1999 Mean	**23**	**41**	**730**	**142**	**18**
1999-2003 Mean†	**27**	**41**	**NA***	**NA***	**12**
1995-2003 Mean	**25**	**41**	**NA***	**NA***	**15**
2007-2008 Mean†	**38**	**24**	**-**	**-**	**-**

* Not available
†Foliar injury indices are provided as a mean prediction from 1999-2003 and 2007-2008 based on NPS ARD interpolations.
‡Two differing Sum06 metrics were offered for CUGA in 2008—one from Jernigan et al. (2008) and one from Ray (2009), the former from a partial dataset. These values were averaged for the table.
Sum06 (ppm-hr): 8-10 (low), 11-15 (mid), 16+ (high)
W126 (ppm-hr): 5.9-23.7 (low), 23.8-66.5 (mid), 66.6+ (high)
N100 (hr): 6-50 (low), 51-134 (mid), 135+ (high)

Soil Moisture

In addition to these exposure indices, soil moisture conditions play a large role in mitigating or exacerbating the potential for foliar injury. During periods of higher soil moisture, injury risk is typically increased as leaf stomates open for gas exchange, thus increasing the chance of ozone uptake (Kohut 2007). Often, the danger of ozone to plants is less than what may be apparent from ozone conditions alone, as environmental conditions that facilitate the production of ozone such as a clear sky, high temperatures, and high UV levels also tend to reduce atmospheric gas exchange in plants. The Palmer Z index (Palmer 1965) attempts to describe soil moisture and its departure from long-term averages for a given month and location by assigning a number in the range ±4.0 based on temperature, precipitation, and available soil water content, with ±0.9 representing the typical range for soil moisture (NPS ARD 2004, Wager 2003). This method was used to calculate drought indices for the same time periods used to calculate both the Sum06 and W126 metrics (Table 7, Table 8) from 1995-1999. As the 2004 foliar injury report for the CUPN points out, soil moisture values were generally high when the Sum06 and W126 metrics were low, thus mitigating the overall risk of foliar injury. The only year without drought conditions during the Sum06 assessment period (1996) had the lowest foliar injury index values, while the years with the highest values, 1998-1999, had drought conditions during each of the three months of the assessment period. A similar pattern was observed during the period for W126, whereby 1997-1999 had the most number of drought months and the highest values, while 1996 had no drought periods and the lowest value.

Field Studies

As part of Kohut's (2007) general assessment of foliar injury in NPS units nationwide, field surveys were conducted for foliar injury in five NPS units, including CUGA, where damage was assessed from milkweed populations at eight different sites during the summer of 2006. Five of the populations showed damage, including two sites where all plants displayed injury. Overall, 96 of 221 plants (43%) showed some damage.

Another field survey was conducted in August 2008 by CUPN at two CUGA locations—along the Daniel Boone Trail and at the Hensley Settlement (Jernigan et al. 2008). Out of a total of ten plant species and 227 individual plants inspected at CUGA, two specimens, both sassafras, were confirmed for foliar injury. Jernigan et al. (2009) suggested that more foliar injury may have been apparent had the survey at CUGA not been in a moderate drought at the time of the survey. This seems likely given the difference in injury rates between the 2006 and 2008 surveys.

Summary

Overall, every year for which there is an ozone metric shows some degree of elevated exposure with the potential for foliar injury. This would seem to support the high injury risk rating assigned to CUGA by the NPS ARD. However, this fact is mitigated slightly by the predominance of drought years during high ozone exposure periods, which mitigates plant gas exchange and risk for injury. Independent field surveys conducted by Kohut (2007) and Jernigan et al. (2009) also showed direct evidence of ozone foliar injury, the former much more than the latter, affirming that ozone does have an effect on vegetation at CUGA. As a result, the condition for foliar injury at CUGA is assigned a ranking of "fair" (Table 9). Because none of the metrics display a positive or negative tendency, the condition status is also assigned a stable trend. Continued ozone monitoring by the POMS at the Hensley Settlement Site will allow direct calculation of these metrics, as well as a reliable trend assessment. Foliar injury field surveys are scheduled to continue at CUPN parks on a six-year rotating schedule.

Table 7. Palmer Z indices for Sum06 at CUGA (NPS ARD 2004).

Sum06	June	July	August
1995	0.54	-2.95	-1.97
1996	2.73	1.04	0.35
1997	-1.33	0.35	-0.03
1998	-0.54	-1.49	-2.85
1999	-0.84	-3.26	-1.42

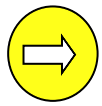
Palmer Z drought index: -1.00 to -1.99 (mild), -2.00 to -2.99 (moderate), -3.00 and below (severe)
1.00 to 1.99 (low wetness), 2.00 to 2.99 (mid wetness), 3.00 and above (high wetness)

Table 8. Palmer Z indices for W126 at CUGA (NPS ARD 2004).

W126	A	M	J	J	A	S	O
1995	-0.39	4.43	0.54	-2.95	-1.97	0.29	1.85
1996	1.39	2.73	1.04	2.03	0.46	3.08	1.33
1997	-1.65	1.41	4.17	-1.33	0.35	-0.03	-0.83
1998	5.46	1.07	4.96	-0.54	-1.49	-2.85	-1.62
1999	-0.97	-1.87	-0.84	-3.26	-1.42	-2.31	-0.23

Palmer Z drought index: -1.00 to -1.99 (mild), -2.00 to -2.99 (moderate), -3.00 and below (severe)
1.00 to 1.99 (low wetness), 2.00 to 2.99 (mid wetness), 3.00 and above (high wetness)

Table 9. The condition status for foliar injury at CUGA was ranked fair with a stable trend. The data quality ranking for this attribute was good.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
Foliar Injury		✓	✓	✓
		3 of 3: Good		

Geology and Soils

Cave Meteorology

The geology of the region containing Cumberland Gap National Historical Park promotes the formation of caves and other karst features (Thornberry-Ehrlich 2008). The park contains at least 30 caves and includes large, interlinking cave networks (Thornberry-Ehrlich 2008). Cave habitats are uniquely fragile and face multiple anthropogenic threats. A suite of threats is broadly related to land use and hydrologic alterations in regions surrounding caves, and another class of threats results from direct human disturbances within caves (Elliot 1998). Negative impacts may result from vandalism, looting of archaeological artifacts, or breaking or theft of cave formations (Thornberry-Ehrlich 2007). Most large caves in CUGA have experienced vandalism and are gated to prevent unauthorized entrance (Thornberry-Ehrlich 2007). The location of caves in the park is considered sensitive information. The caves of CUGA had not been exhaustively inventoried or monitored for climate conditions at the time of this report. Ongoing monitoring efforts included recording climate data from two caves.

Temperature and humidity monitoring were conducted by NPS at two caves in CUGA beginning in 1998. Monitoring was consistently conducted at five locations within Gap Cave. In order of closest to farthest from cave openings, the names of these locations were: Exit, Entrance, Upstream, Overlook, and Big Room. All stations were within 150 meters of a cave opening. Gap Cave, part of an extensive cave network, has a relatively greater rate of human visitation than other CUGA caves and is the only park cave where formal, supervised public tours are conducted. A second cave, reported here as Cave A, was monitored over a similar time period. Cave A is a hibernaculum for Indiana bats. Data were recorded every 10 to 30 minutes with data loggers placed at fixed positions within the caves. Campbell Scientific data loggers were originally placed at all stations. In 2002, HOBO® data loggers were placed at all stations, and the Campbell Scientific units were removed from all except two stations, where they were allowed to record concurrently with the new units. In 2008, all HOBO® units were replaced with newer HOBO® data logger models. To provide maximum consistency and interpretability, we used only data collected from HOBO® data loggers from 2002-2011 in this report. The Virginia Department of Game and Inland Fisheries (VDGIF) also conducted monitoring with HOBO® loggers in Cave A from late 2001 through late 2006. This monitoring was conducted near the Indiana bat hibernaculum in the cave, and only temperature data were available from the received data.

Environmental measuring devices are not perfectly accurate, and accuracy varies with time and across environmental conditions. Both models of HOBO® loggers used to collect the data analyzed in this report were constantly deployed within the temperature range reported by the manufacturer to provide maximum temperature accuracy for the units (Onset 2002, 2010). However, the units were frequently subjected to very high humidity outside the range of maximum accuracy for the units (Onset 2002, 2010). The models used from 2002 to mid-2008 often reported relative humidities (RH) > 100%, indicating a condensing environment and high, though inaccurately measured, relative humidity (Onset 2002). The models used from mid-2008 to 2011 were more robust to high humidity, but were still subject to errors in accuracy of > 4% in environments with RH > 90%, and often reported 100% humidity for long periods (Onset 2010). These issues resulted in relative humidity datasets showing artificially high or otherwise potentially inaccurate values during parts of the year, and an artificial drop in maximum relative humidity corresponding to the change in data logger models in 2008. Despite these significant caveats about the relative humidity data, we presented it in this report because it is useful for indicating that humidity is often "high", for showing seasonal fluctuations in humidity, and for showing some relative differences among recording locations.

We calculated the mean daily temperature and mean daily relative humidity at each station for each date, and the mean of these daily means across years. Where extreme data outliers were obviously associated with the changing and servicing of the units, we removed these outliers. Relative humidity measurements from the Big Room of Gap Cave showed an unprecedented decrease followed by unseasonal irregularity starting in August 2010. Because these data did not correspond with the stable temperature regime otherwise observed at the site during the period, and because no human-caused explanation was readily available, we believe these data were likely the result of equipment malfunction and removed them from the dataset. Because Indiana bats are of particular importance in CUGA, we examined mean temperature profiles at a selected cave location relative to the timing of hibernation and environmental requirements of the species.

The five monitored stations in Gap Cave had differing temperature profiles from 2002-2011 (Figure 10; Figure 11). Mean daily temperature at all stations remained above freezing during the monitored time period (Figure 10). The warmest temperatures occurred at the Exit location, which was the closest location to a cave opening. The coldest temperatures occurred at the Entrance location, which was the second closest station to a cave opening and consistently fell below 5ºC (41°F) during the winter (Figure 10). The most stable temperature regime occurred at the Big Room location which was the farthest from a cave opening. Relative humidity remained high within Gap Cave at all monitored locations from 2002-2011 (Figure 12, Figure 13). Mean relative humidity at all sites generally stayed above 80% and was highest from early summer through early autumn. The monitoring locations closest to cave openings, Exit and Entrance, experienced the most variability, although much of the reported variability was within the range of error for the units in highly humid environments. Furthermore, the continuously high readings observed throughout portions of the time period, and change in maximum reported RH in 2008 reflect limitations of the equipment, as discussed above (Onset 2002, 2010).

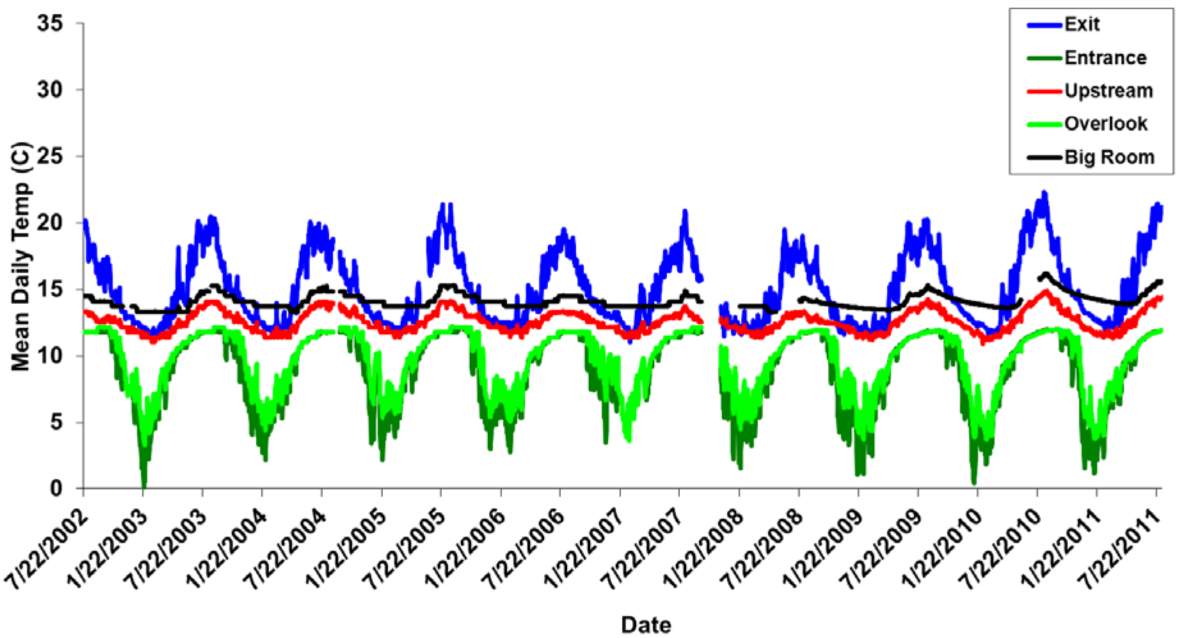


Figure 10. Mean daily temperature from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park.

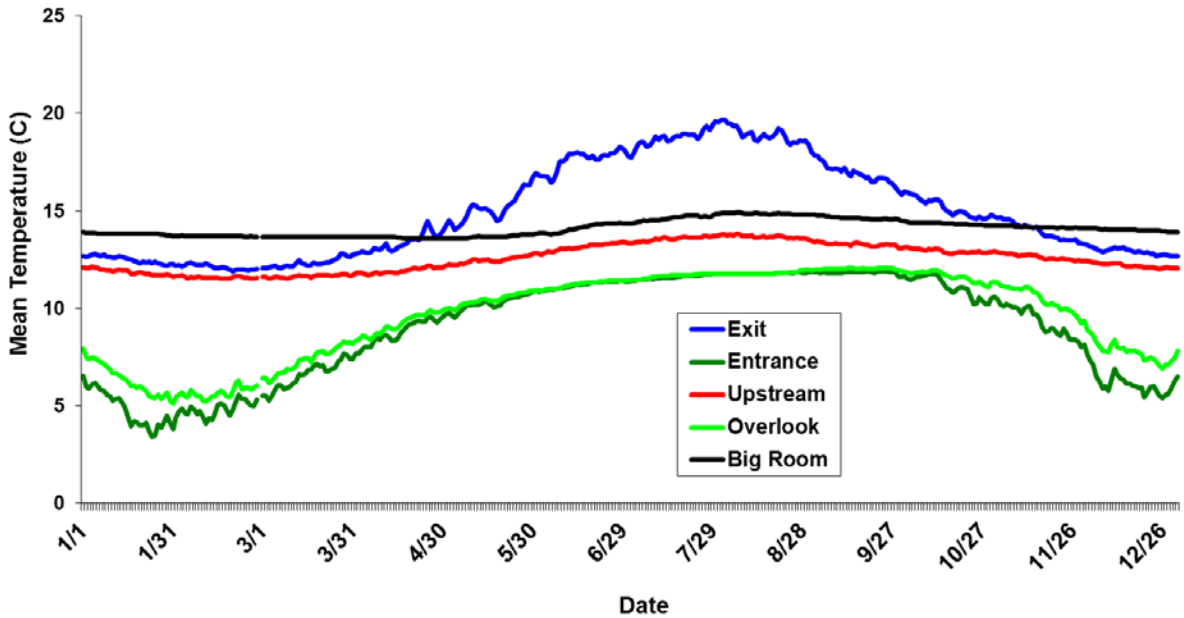


Figure 11. Mean temperature across years calculated using daily means from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park.

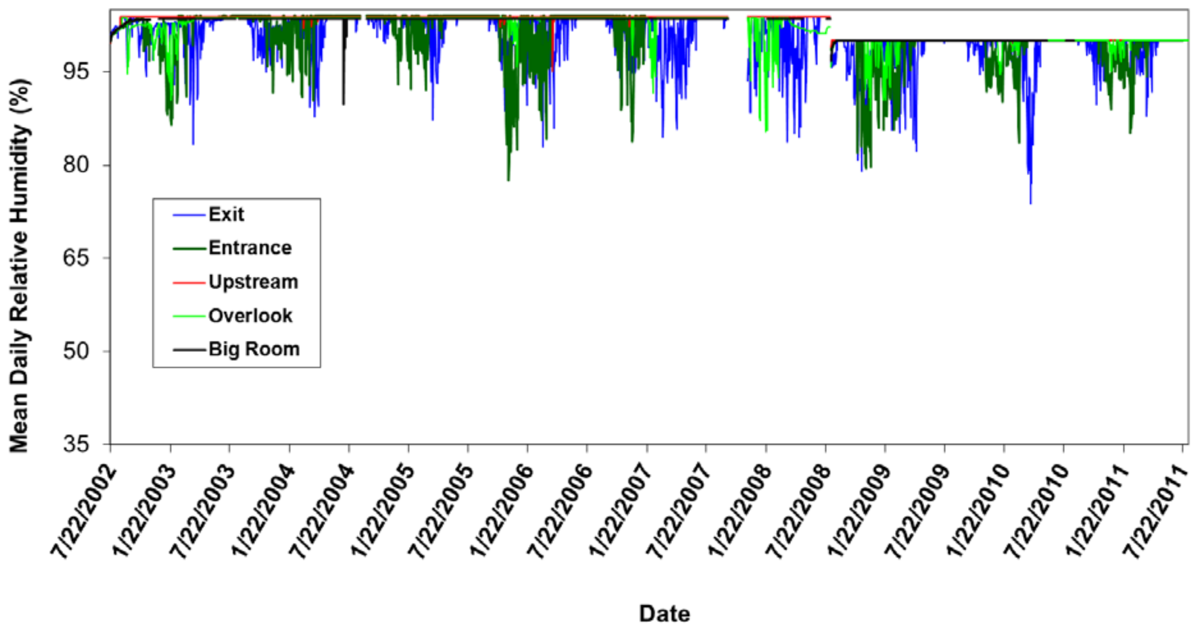


Figure 12. Mean daily relative humidity from 2002-2011 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park.

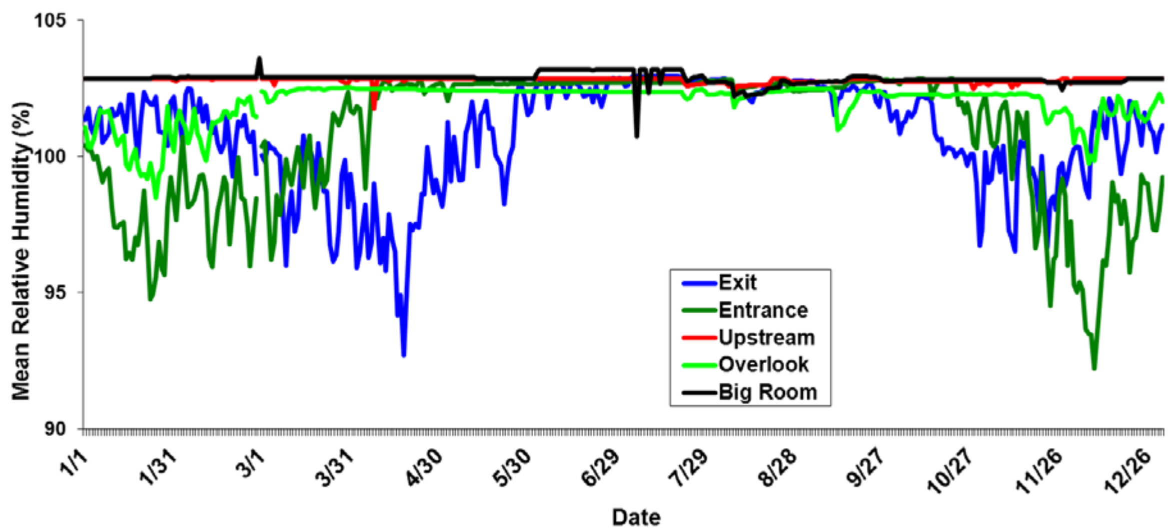


Figure 13. Mean relative humidity across years calculated using daily means from 2002-2009 from data loggers placed at five locations in Gap Cave, Cumberland Gap National Historical Park.

Cave A had a generally consistent yearly temperature profile over the monitored time period, and the temperature regime varied between the location of the NPS logger and the logger placed by VDGIF (Figure 14). At the NPS logger locations, mean daily temperatures remained between 3 and 17 ºC during all but a few days over the time period, and never dipped below freezing. The temperature at the bat hibernacula was less variable and generally stayed between 7 and 12 ºC throughout the year. Humidity data only were available from the NPS logger. Relative humidity in Cave A had a greater range of variability than relative humidity in Gap Cave (Figure 15).

Although the relative humidity remained above 75% in Cave A much of the time, it regularly fell below 30% when air temperatures were lowest.

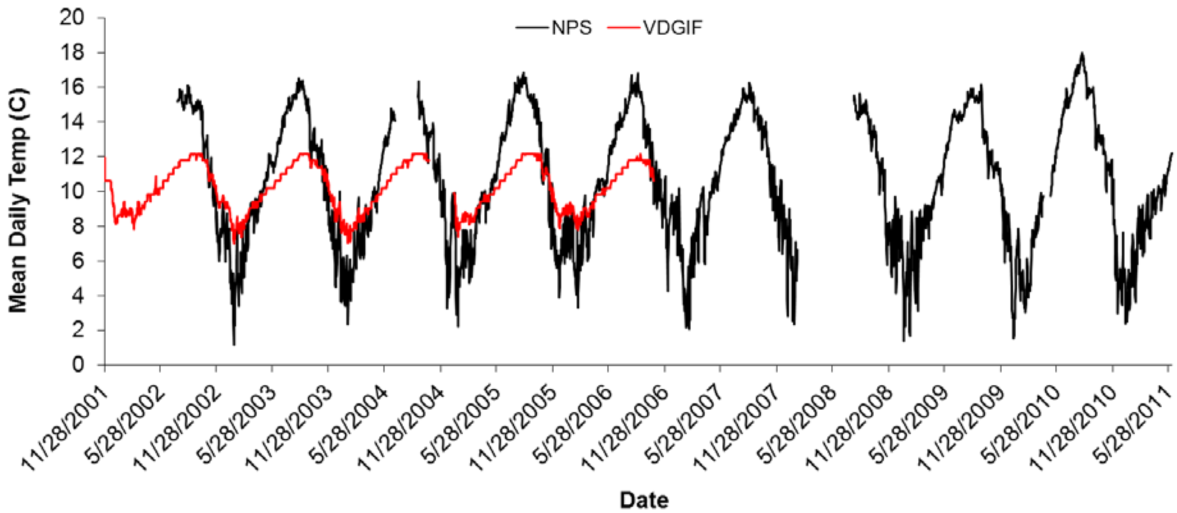


Figure 14. Mean daily temperature collected 2001-2011 from data loggers placed in Cave A by the National Park Service and the Virginia Department of Inland Game and Fisheries. The dataloggers were placed at different locations in the cave and the VDGIF logger was located close to an Indiana bat hibernacula.

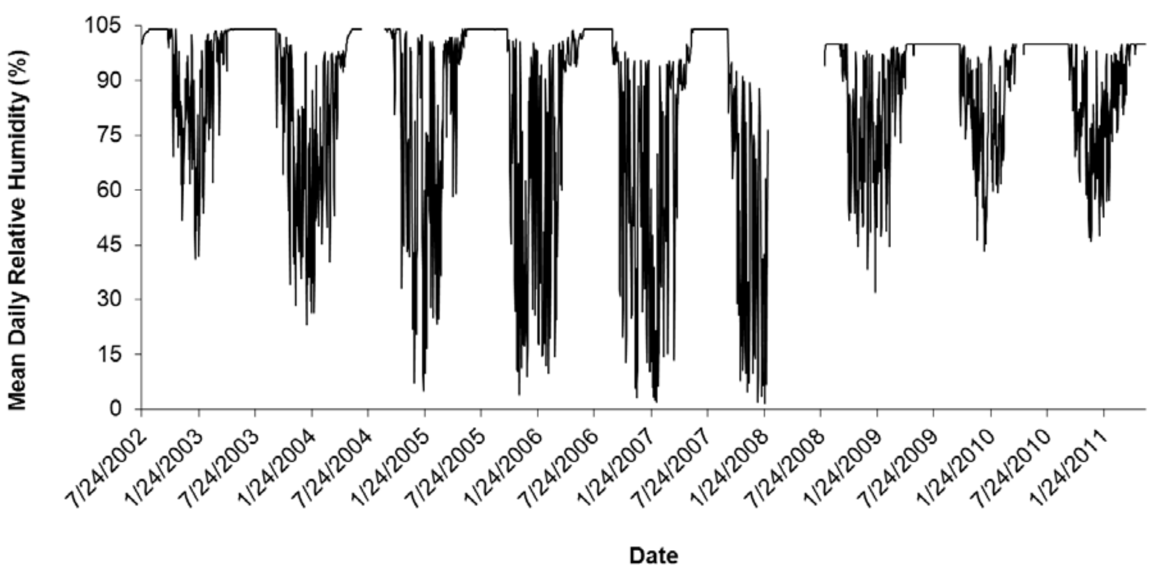


Figure 15. Mean daily relative humidity from 2002-2011 from a data logger placed in Cave A, an Indiana bat hibernacula in Cumberland Gap National Historical Park.

Because the VDGIF data logger was placed near an Indiana bat hibernacula, we examined temperature regimes from this logger relative to bat requirements. Relative humidity data were not available for this logger. For temperature, we took the mean across years of the daily means and plotted the values in relation to a theoretically optimal timing and temperature window

(Figure 16). Optimal temperature regimes for hibernating Indiana bats are imperfectly understood. Most known hibernacula remain below 10 ºC (50 °F) but rarely or never fall below freezing during the winter (USFWS 2007). Researchers have found that stable and increasing hibernating populations were found in caves where "midwinter" temperatures remained between 3 and 7.2 ºC (37.4 and 45.0 °F) (USFWS 2007) and that the mean ambient temperature in microhabitats of hibernating bats was 7.0 ºC (44.6 °F) (Raesly and Gates 1987). Determining optimal hibernacula temperatures is confounded by the fact that micro-climates within caves vary considerably (Raesly and Gates 1987) and that tight clustering alters the temperature experienced by individuals and therefore larger colonies may be more cold-tolerant (USFWS 2007). Based on findings in the literature, we used the period from November 15 to April 15 as the hibernation period, and temperatures between 3 and 10 ºC (37.4 °F and 50 °F) as the preferred temperature range. The mean ambient temperature during the hibernation period, calculated as the mean of all the daily mean temperatures from November 15 to April 15, was 9 ºC (48.2 °F). The daily mean temperature at this site fell largely within the preferred range during the hibernation period (Figure 16).

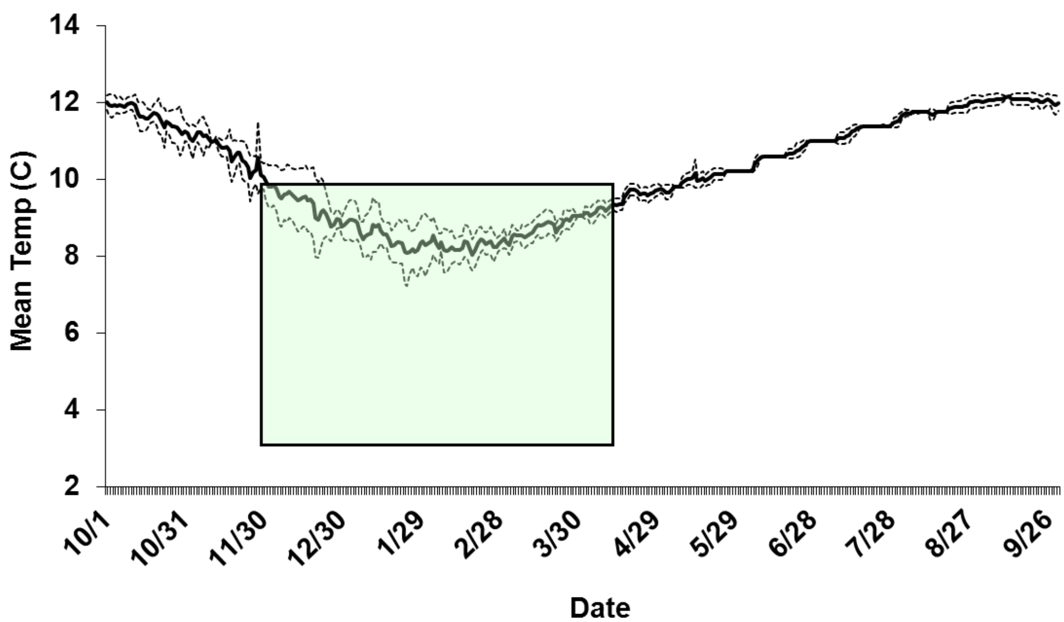


Figure 16. Mean temperature across years of the mean daily temperatures recorded from a VDGIF datalogger placed near an Indiana bat hibernacula in Cave A. Green box shows an approximate window of ideal time and temperature limits for Indiana bats (3 - 10 °C; November 15-April 15).

Relative humidity is important to hibernating bats. Hibernating bats experience greater evaporative water loss as air humidity decreases. Research suggests bats arouse from torpor more frequently in less humid environments, and that arousals account for over 70% of winter fat depletion (USFWS 2007). Cryan et al. (2010) suggested that the evaporative water loss from the wings of bats was greater for individuals infected with the fungus causing white-nosed syndrome. Raesly and Gates (1987) found that the mean relative humidity of microhabitats occupied by *M. sodalis* in caves in Maryland, Pennsylvania, and West Virginia was 78% (95% CI: 76.3-79.8) which was significantly higher than three of four other species studied. Relative humidity varied among the sites examined for this report. Because the data from the logger placed at the Indiana bat hibernacula did not include relative humidity, we did not examine relative humidity relative to specific bat requirements.

For natural resource management purposes, the quality of meteorological conditions within caves is defined relative to natural regimes and the requirements of various species. Temperature and relative humidity regimes vary naturally among caves and among microenvironments within caves. Different meteorological regimes support uses by different organisms or communities. Some areas may have less climate variability than nearby areas outside the cave, and this stability is an important environmental quality for some cave-dwelling species. In CUGA, the existence of caves that maintain winter temperatures that are cool yet above freezing is important for some species of hibernating bats. However, probably the best general indication of good meteorological regimes in caves is the existence of a regime that is free from anthropogenic alteration. For the caves monitored in CUGA, this historical baseline is not known. In Gap Cave, three openings and an interior connection have been altered by humans (Jenny Beeler personal communication), but the effects of this on cave climate are not known. Future cave management in the park may include restoration of these altered areas, and the data collected could provide a valuable baseline to monitor any effects.

We did not assign a rank to the condition of cave meteorology at CUGA (Table 10). No obvious new human-caused climate disruptions were observed during the monitoring period, although the effect of alterations persisting from before monitoring began are unknown. Within both monitored caves, temperature regimes existed that did not preclude Indiana bat hibernation. However, the understanding of other natural species assemblages and accompanying meteorological requirements is not well-developed. We ranked the quality of the data as poor. The data were recently collected using appropriate methods within park boundaries. However, data were only available from two of at least 30 known caves in the park and therefore the spatial coverage was not adequate to give a comprehensive assessment of park caves. Although the data were collected using broadly appropriate methods, there are concerns about the accuracy of the relative humidity data. We ranked the trend of cave meteorology condition as stable. The seasonality of temperature and RH fluctuations was consistent throughout the analyzed time period. The maximum and minimum yearly temperature did not show an obvious trend over the time period.

Table 10. No rank was assigned to cave meteorology condition at Cumberland Gap National Historical Park. The trend of cave meteorology was stable. The quality of the data used in the assessment was poor.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Cave Meteorology				✓
		1 of 3: Poor		

Water Quality

Overview and Parameters

Water quality monitoring began at each of the CUPN park units in 2004. Each park unit in the network was assigned a significance category pertaining to their water resources—CUGA is a category one park, meaning that the park's water resources are central to its establishment or mission, and that monthly sampling lasts for 24 months with five years off between sampling periods. At CUGA, the first round of monthly sampling lasted from October 2006 until September 2008. Of the ten monitoring stations within CUGA, eight are located in Kentucky within the Upper Cumberland accounting unit, which straddles the regional watershed divide with the Upper Tennessee unit along the Cumberland Mountains (Figure 17). The remaining two stations fall within Tennessee and Virginia, respectively. Monitoring station locations were chosen in 2001 to coincide with previous monitoring efforts. In addition, most of the locations are along the boundary of the park to serve as "an integrator of the basin," meaning they are intended to capture water quality characteristics of the whole watershed (Meiman 2009). Five stations are located close to the park boundary near Middlesboro, KY and just downstream from Fern Lake Reservoir. The other monitoring stations are on Gap Creek and Station Creek in Tennessee and Virginia, respectively, which are located just upstream from Shawanee, TN.

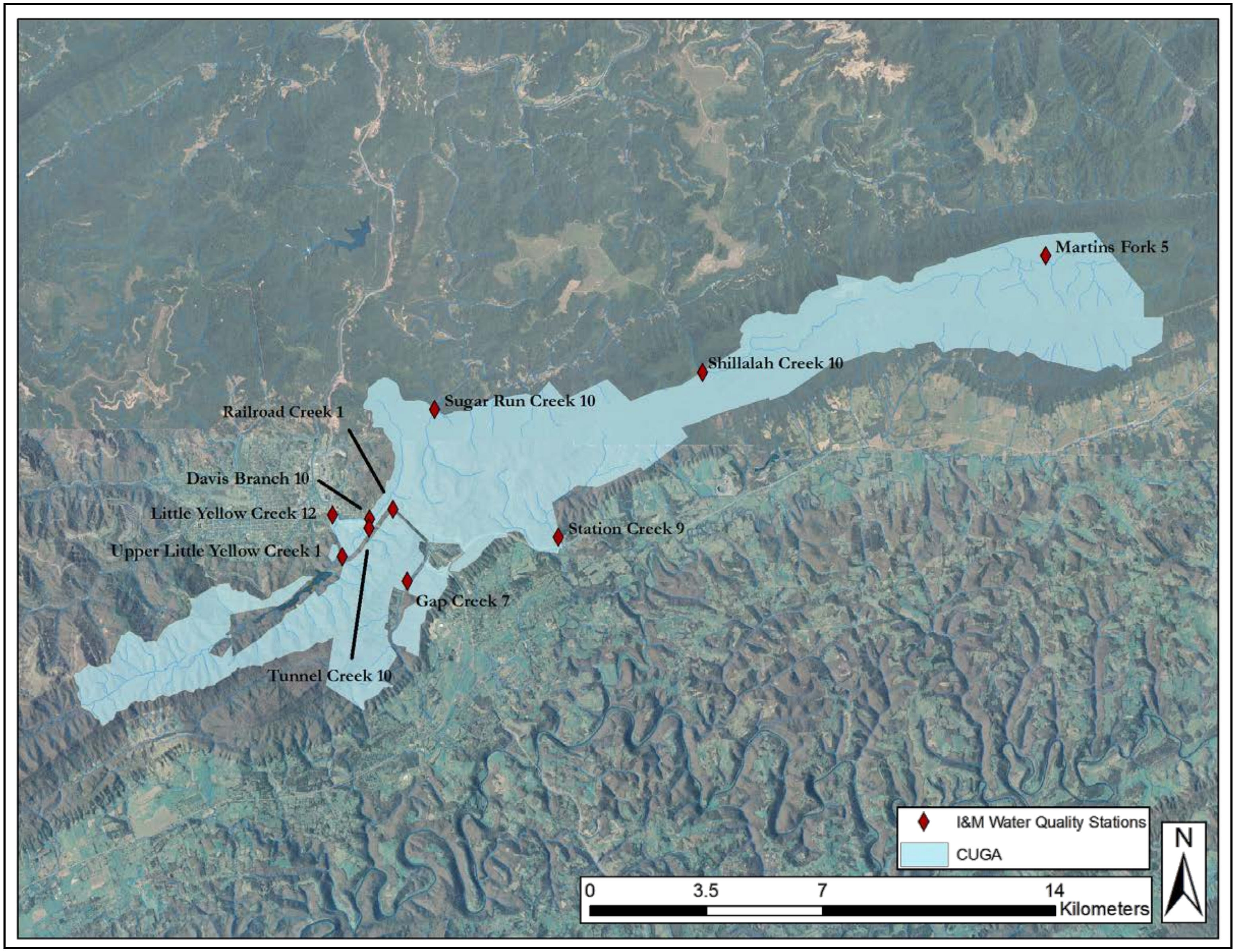


Figure 17. Ten I&M water quality stations within CUGA were sampled monthly between 2006 and 2008.

As part of the CUPN I&M plan, the NPS Water Resources Division requires monitoring of water temperature, pH, specific conductance, and DO, referred to as the core parameters, in addition to any other parameters deemed necessary by the Vital Signs process (Leibfreid et al. 2005). Parks in CUPN also collect field measurements of Acid Neutralizing Capacity (ANC) and bacterial contamination, usually in the form of *Escherichia coli* and fecal coliform concentrations. At CUGA, turbidity is additionally stipulated in the monitoring plan.

Meiman (2009) completed a comprehensive analysis of each of the parameters for the first period of water quality monitoring. In it, he points out that each of the creeks are assigned a use status according to individual state standards. These use classifications help inform which water quality parameters are most important for monitoring. All the I&M streams except two in KY at CUGA are classified for warmwater aquatic habitat, primary contact recreation, and secondary contact recreation. Both Martin Fork and Davis Branch are additionally included as outstanding state resource waters. The two exceptions are Tunnel Creek and Railroad Creek, which were specified by Meiman (2009) as coldwater aquatic habitat and warmwater aquatic habitat, respectively. Gap Creek, the only I&M sampled stream in TN, is classified for 1) fish and aquatic life, 2) irrigation, 3) livestock watering and wildlife, 4) trout, and 5) recreation. Station Creek in VA is classified as Class vi, or natural trout waters (Meiman 2009). Davis Branch is unique in that it is the only stretch of stream in the park unit with a documented population of blackside dace (*Chrosomus cumberlandensis*), a federally threatened fish species.

Temperature

State maximum temperatures are comparable for TN and KY, which are 30.5ºC and 31.7ºC, respectively. None of these stations exceeded the state limit. Station Creek (ST9) in VA is limited to 20.0ºC due to its status as a trout water stream. This station exceeded the maximum a total of 5 times in 2007 and 2008, though its mean was comparable to all other CUGA I&M stations (Figure 19).

Specific Conductance

Specific conductance is collected using a dip-cell electrode sensor, which gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Higher amounts of solids increase conductance levels, which are measured as the reciprocal of electrical resistance and expressed in micro-Siemens per cm (µS/cm). Generally, specific conductance measures are closely related to the parent material of the stream. Although no state standards exists for this parameter, the EPA (1997) sampling methods manual identifies an ideal range of 150 to 500 µS/cm for "inland fresh waters…supporting good mixed fisheries," and furthermore indicates that "conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates."

Values for specific conductance at CUGA averaged well into the EPA recommended range at most stations, except for YC1, MF5, SH10, and SR10, where they were invariably low (Figure 19). Meiman (2009) reports that these low conductance values indicate "limited contact with carbonate strata" and are therefore the result of natural conditions.

pH

Measurements of pH are important to water quality because it affects multiple biological processes within aquatic ecosystems. Low levels of pH can potentially increase the mobility of toxic elements, and in turn, their uptake by aquatic plants and animals (EPA 1997). Even at only slightly acidic levels (6.0-6.5), species richness of phytoplankton, zooplankton, and benthic invertebrates can be inhibited, while levels between 5.0 and 6.0 can result in mortality of several fish species. In addition, algal growth increases at these acidic levels, which translates into an increased risk of mortality for macroinvertebrate species. Levels of pH below 5.0 can result in the loss of most fish species, decreased rate of nutrient cycling and organic matter decomposition, and can result in reproductive failure of certain acid-sensitive amphibians (Driscoll et al. 2003).

All three state standards for pH specify the range 6.0 to 9.0 standard units (SU). Means at I&M stations were generally within the range 6.5 to 8.0 SU, with the exception of MF5 and SH10, which averaged 4.9 and 5.5, respectively (Figure 19). Again, Meiman (2009) suggests these values are due to minimal contact with carbonate strata and instead reflect the acidity of rainwater, the main source of flow for those mountain streams. He supports this claim in the latest water quality monitoring report (2009) with plots showing a correlation between depressed pH and flow from rainfall on Shillalah Creek and Martin’s Fork.

Dissolved Oxygen

The importance of dissolved oxygen (DO) as a water quality parameter derives from its sensitivity to natural or anthropogenic alterations to the stream, because sensitive aquatic plants are one of the main sources of oxygen, along with aeration and mixing of atmospheric O2. As a result, concentrations of DO are important to the survival of virtually all aquatic species (Meiman 2007). Taxa such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are particularly vulnerable to hypoxic waters, though these conditions may also be lethal to other benthic macroinvertebrates. Under hypoxic conditions, certain organisms may divert energy from growth and reproduction to oxygen uptake, which may in turn lower fecundity rates (Garvey et al. 2007). Several sources of runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (EPA 1997).

Standards for TN and KY stipulate concentrations of DO no less than 5.0 mg/L, while VA stipulates 6.0 mg/L. Tunnel Creek, Shillalah Creek, and Martin’s Fork have the special distinction of coldwater habitat classification, and as a result have a minimum DO threshold of 6.0 mg/L. Although all means were relatively similar and above these thresholds for I&M data at the park, Yellow Creek (Upper and Lower), Martin’s Fork, Shillalah Creek and Station Creek all dip below their respective standards for some samples (Figure 19).

Acid-Neutralizing Capacity

Acid-neutralizing capacity (ANC) values, measured in mg/L of calcium carbonate ($CaCO_3$), are collected to assess the relative ability of the water to buffer acidic loading resulting from precipitation or other sources. Higher values of ANC, or alkalinity, are influenced by concentrations of carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), phosphates (PO_4^{3-}), and hydroxides (OH^-). Although there are no state standards for this parameter, the EPA Goldbook recommends values greater than 20 mg/L $CaCO_3$ to benefit aquatic life. Like measurements for specific conductance and pH, measurements for ANC at Upper Little Yellow Creek, Martin's Fork, Shillalah Creek, and Sugar Run were depressed, representing the lack of carbonate parent material.

Microorganisms
In addition to the core water quality parameters outlined above, measurements of microorganism contamination were also collected through measurements of *Escherichia coli*, a type of fecal coliform bacteria. Coliform are a group of bacteria that live in the intestines of both warm and cold-blooded organisms and are typically used as indicators of health risks presented by associated pathogenic bacteria and viruses.

Criteria for microorganism concentration are variable and depend in large part on the use classification of a waterbody. Waters with high recreational use receive more stringent limits due to the potential danger towards human health. The EPA specifies an *E. coli* limit of 576 colony forming units (CFU) per 100ml for infrequent contact recreation, whereas the individual sample limit in TN is 941 CFU/100ml for recreation, and 1173 CFU/100ml for secondary contact recreation in VA. Data collected at CUGA showed overall low concentrations of *E. coli*, except for Gap Creek and Station Creek, which both showed elevated concentrations. Respectively, these stations exceeded the EPA standard 15% and 33% of the time.

Meiman further analyzed a time series of discharge, *E. coli*, and precipitation data for these sites, and determined that Station Creek is mainly the result of a point-source contamination, while Gap Creek demonstrates signs of both point and non point-source contamination. Station Creek is the only park sampling location in Virginia, and is located just downstream of one of the park campgrounds that utilizes a septic system, which may explain the high bacterial contamination. Recent sampling at two locations above and below the campground seem to reinforce this notion (Figure 21). As of this writing, a new septic system is scheduled for installation beginning in November 2011 (NPS 2010b).

At Gap Creek, a wastewater treatment plant was recently constructed upstream in the town of Cumberland Gap, TN. According to Meiman (2009), that facility was previously found to be discharging untreated effluent into Gap Creek, which likely contributed to these elevated bacterial concentrations. He also offers that high flow events may exceed the capacity of the treatment plant and result in bacterial contamination. Since these elevated measurements, however, the treatment facility has been updated, and more recent sampling has shown no evidence of continued contamination (J. Beeler personal communication).

Hydrology

Turbidity

Turbidity is a measure of the loss of light transmission in water due to scattering or absorption. During high flow events, solids can become suspended in the water column and raise turbidity levels, along with concentrations of plankton and organic detritus. Turbidity is usually measured using a nephelometer and expressed in nephelometric turbidity units (NTUs). Although no quantitative turbidity criteria are offered in the tri-states surrounding CUGA, aquatic species are sensitive to changes in the amount of suspended sediment and can be affected in numerous ways.

For fish, these effects may include reduced reproductive ability and feeding success, increased predation and parasitism risk, and direct gill damage (Hazelton 2008). Although suspended sediment may not always be the only source of turbidity, measurements of turbidity are commonly used due to their easy determination in the field (Waters 1995). Increases of only five NTUs above natural conditions may prove deleterious, resulting in losses of up to 13% in gross primary production (Lloyd et al. 1987, Waters 1995). Overall, turbidity levels in the park appear to present little concern. All stations average less than 10 NTUs, though Lower Little Yellow Creek, Railroad Creek, and Gap Creek show somewhat higher values, possibly reflecting higher amounts of runoff (Figure 19). Both Little Yellow Creek stations as well as Railroad Creek showed high outliers >40 NTUs, probably representing extreme flow events.

Flow

Flow is also monitored at sampling stations to scale the flux of other parameter concentrations. Flows at Martin's Fork, Little Yellow Creek, Gap Creek, and Shillalah Creek are slightly higher than other stations, averaging ~100 l/sec discharge, while the others are ≤20 l/sec. The highest outliers occurred on both stations of Little Yellow Creek.

Summary

Overall, Meiman (2009) assesses the condition of waters within CUGA as quite good, with a few instances of standards violations. Kentucky, Tennessee, and Virginia all have water quality standards stipulating pH no lower than 6.0, which sampling stations at Martin's Fork and Shillalah Creek regularly fell below during monitoring (Figure 19). Meiman (2009) interprets this as a natural condition of the sites, which includes a lack of carbonate rocks upstream of these locations to buffer natural acidity levels. Nevertheless, Meiman (2009) indicates that additional sampling is underway to make that determination.

CUGA Historical Water Monitoring

Methodology

In addition to the ten I&M water quality stations at CUGA, the park has conducted periodic sampling since 1980 on many of the major streams within the park. Unlike the I&M monitoring that started in 2006, however, many of the sampling locations are not located in the same place each year, and the data and parameters collected at these stations do not always include the four core parameters that inform the I&M sampling. Using the monitoring data available from the EPA Storet database, historical sampling locations were aggregated to streams and areas matching the ten official I&M stations. Samples collected on the same stream segment as I&M data were combined and labeled according to the I&M station name, whereas outlying sites were excluded. The I&M data collected from Oct. 2006 – Sept. 2008 were also included for analysis. Results from this aggregation are shown in Figure 20. Each parameter was averaged on an annual basis and included for analysis when there were at least ten observations for a particular attribute for at least two consecutive years at a given site. As a result, there are some attributes for which some stations and years are excluded from the analysis. Generally, standard errors for all attributes were fairly small and represent minimal variability and sufficient confidence. Data within the vicinity of I&M stations at (lower) Little Yellow Creek, Railroad Creek, and Shillalah Creek were not well-represented in past monitoring, and thus these locations are not included for any of the parameters.

Temperature

Temperature observations were within acceptable limits for each of the three states during all years of monitoring (1990-1997, 2003-2007), though means showed high standard errors during the latter years of observations (Figure 20). Mean annual temperatures were typically in the range of 10-15 ºC, which closely aligns with the means observed at each of the ten I&M stations from 2006-2008.

Dissolved Oxygen

Dissolved oxygen varied consistently across sites when data was available from 1990-1996, reaching a minimum in 1994 at all sites except Sugar Run due to a low flow year. Overall means, though, fell within the same range as they did for sites during the I&M period a decade later (Figure 20), which ranged from around 7 – 10 mg/L. None of the sites consistently demonstrated the highest or lowest concentrations, and only the low year at Sugar Run (5.4 mg/L) was based on a single sample. With this exception, none of the sampling stations fell below respective state standards.

pH

Past monitoring for pH has also shown similar values to the I&M period. Using data mostly available from 1990-1997 and 2003-2007, means and standard errors for all sites fell within the tri-state limits with the exception of Martins Fork, which consistently had pH values of 5 or less (Figure 20). This was the same pattern observed in the I&M data, which Meiman (2009) attributes to a lack of carbonate rocks in the upstream of the watershed which would otherwise

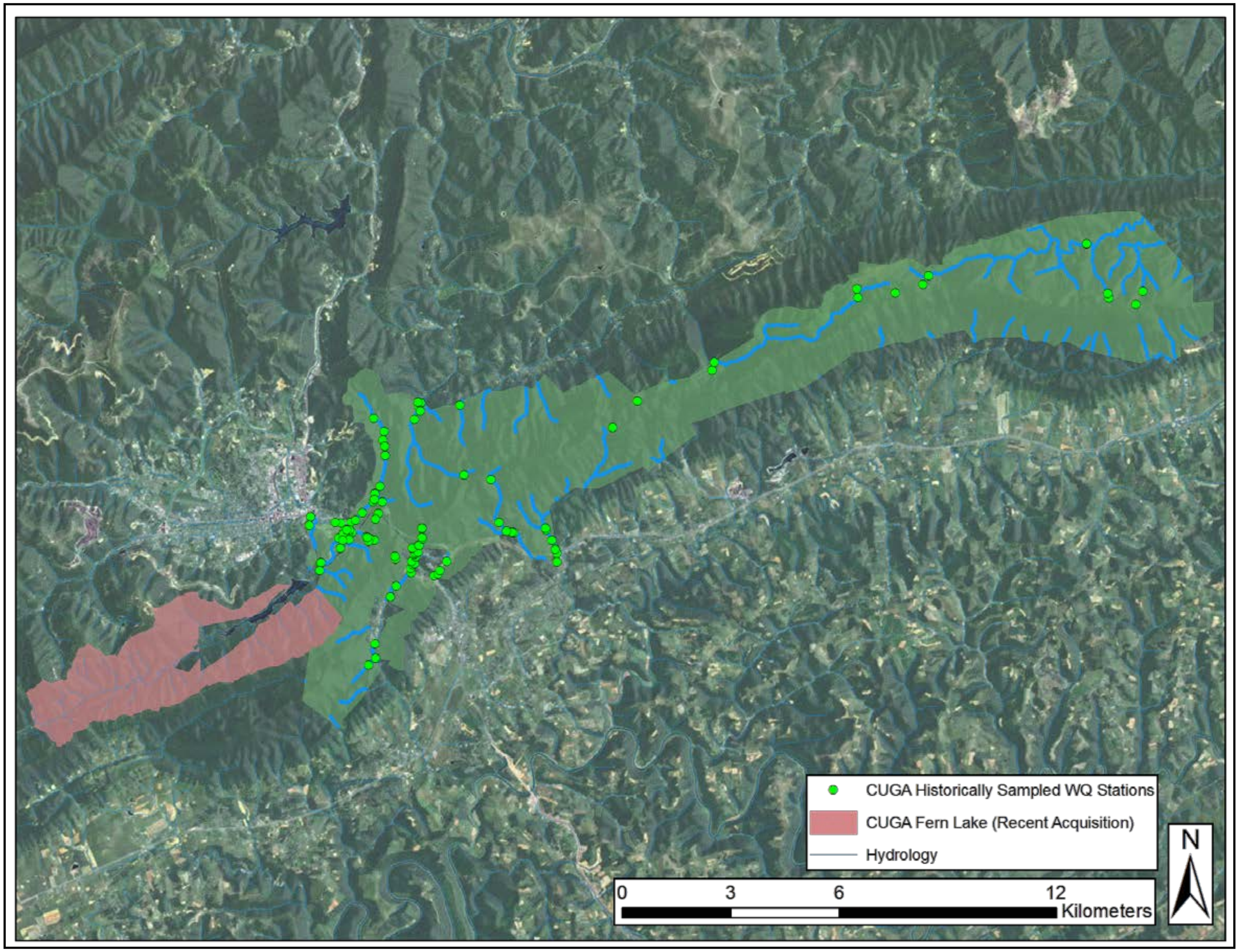


Figure 18. Data from stations available in EPAStoret were used to assess historical monitoring at CUGA. Stations were aggregated along the streams they occurred to match official I&M stations.

buffer acidity levels. He also notes that rainwater is the primary source of flow for this site, which as a result moderates the pH of the creek flow. Because of the sub-standard acidity levels at both Martin's Fork and Shillalah Creek (for which historical data was not available), Meiman (2009) reports the planning of additional efforts at these locations to determine how parent material affects acidity levels. The resemblance of the historical data at Martin's Fork to current I&M results for pH, however, further supports the basis of a natural source of low pH levels, and perhaps somewhat alleviates the need to explicate this effect with much additional sampling.

Specific Conductance
Values for specific conductance from historical monitoring were extremely variable (Figure 20) among sites and across the sampling record. Overall sample means ranged from 10 to ≥300 µS/cm, with a notable separation of Martin's Fork, Shillalah Creek, Upper Little Yellow Creek, and Sugar Run, all of which showed steady, low values, consistent with those observed during I&M sampling ('06-'08). None of these stations ever reached the EPA recommended range of 150 µS/cm, and thus further support the notion that these low specific conductance values are a result of natural conditions.

Acid Neutralizing Capacity
Sampling data for ANC showed variable values on Station Creek, but relatively consistent data among other sites, ranging from 5 to 150 mg/L $CaCO_3$. Overall historical data for this parameter was sparse. Very low values for ANC were observed at Martin's Fork, Shillalah Creek, and Sugar Run.

Microorganisms
Data for bacterial monitoring at CUGA was available for *E. coli* concentrations from 2003-2007 for three monitoring branches, and for fecal coliform from 2003-2006 at five monitoring branches. Station Creek, a common monitoring location for both parameters, showed the highest overall concentrations of both *E. coli* and fecal coliform. In 2003, average fecal coliform exceeded the VA limit of 200 colonies/100mL, though the state sampling protocol was not followed and thus does not constitute an official violation (Figure 21). This pattern matches that observed in the I&M data from Oct. 2006 – Sept. 2008, which showed highest *E. coli* levels among all ten monitoring sites at Station Creek. Meiman (2009) suggests that the high bacterial contamination levels present at Station Creek may be due in part to its proximity to the septic field of the nearby campground. Although historical monitoring did collect samples at Station Creek both below and above the septic field, there is unfortunately only sufficient and reliable data at five downstream locations located within 400m of each other. Since I&M collections began for Station Creek in Oct. 2006, three measurements have exceeded the VA secondary contact recreation limit for *E. coli* of 1173 colonies/100mL (Figure 19). Prior to this, only one sampling date in 2005 exceeded the limit. The trend appears to show increasing concentrations during the total six years of monitoring; linear regression shows an average increase of 60 colonies/100mL per year (p = 0.06), which may reflect increased usage of the campground over the years of monitoring. As suggested by Meiman (2009), these data support the addition of monitoring locations to examine the source of bacterial loading, especially on Station Creek upstream of the campground.

Hydrology

Historical monitoring for turbidity and flow both consist of data for 1990-1996 and 2003-2008 with relative consistency of local minima and maxima among stations. Each station experienced a local maximum for turbidity measurements in 1991, though Tunnel Creek showed particularly high values. This might be due in part to the fact that groundwater discharge is the only source of flow at the station. As for flow, the overall maximum for all monitoring stations occurred in 1997, though this phenomenon does not appear to correspond with any of the other monitored attributes.

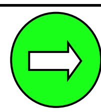
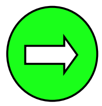
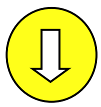
Summary

Overall, the recently collected I&M water quality data at CUGA generally reflects historical monitoring. Data for pH falls below the standard of 6 SU for past monitoring at Martin'sFork, and would probably show a similar pattern for Shillalah Creek if past data were available. However, these low values are most likely natural for these waters, as Meiman (2009) points out. *E. coli* also exceeded limits during and before the I&M period at Station Creek, though again, this might be due to a point-source contamination, such as the septic field of the nearby campground. Because of the lack of large-scale and consistent violations of water quality standards, as well as the consistency between historical monitoring and current I&M water data, water chemistry is assigned a stable and good condition status rating (Table 11).

In addition, because of the elevated bacterial concentrations observed at Gap Creek and Station Creek, microorganisms is assigned a fair condition status, though an expansion of sampling at those two sites has been recommended to isolate contamination sources. Trend analysis of *E. coli* concentrations revealed evidence, though not strong, that contamination is increasing, which may be tied with increased campground use since monitoring began. As a result, a degrading trend is assigned for microorganisms (Table 11).

Finally, virtually all flows at CUGA originate inside the park. One of two exceptions to this are Little Yellow Creek, which flows from the southern end of the Fern Lake acquisition into the reservoir, exiting the park briefly before reentering below Hwy 25. The other exception is Gap Creek, which begins in the park, but exits and reenters twice before ultimately flowing out of the boundary. As a result, the flow rate of streams generally reflect natural conditions that are free from impoundments or increased runoff due to impervious surfaces. Historical flow monitoring shows consistency among sites, and thus surface water is assigned a condition status of good with a stable trend (Table 11).

Table 11. The condition status for water quality is divided into three attributes: surface water, water chemistry, and microorganisms. Respectively, these attributes received condition statuses of good, good, and fair, with respective trends stable, stable, and declining. The data quality for each of the attributes was ranked good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Surface Water		✓	✓	✓
		3 of 3: Good		
Water Chemistry		✓	✓	✓
		3 of 3: Good		
Micro-organisms		✓	✓	✓
		3 of 3: Good		

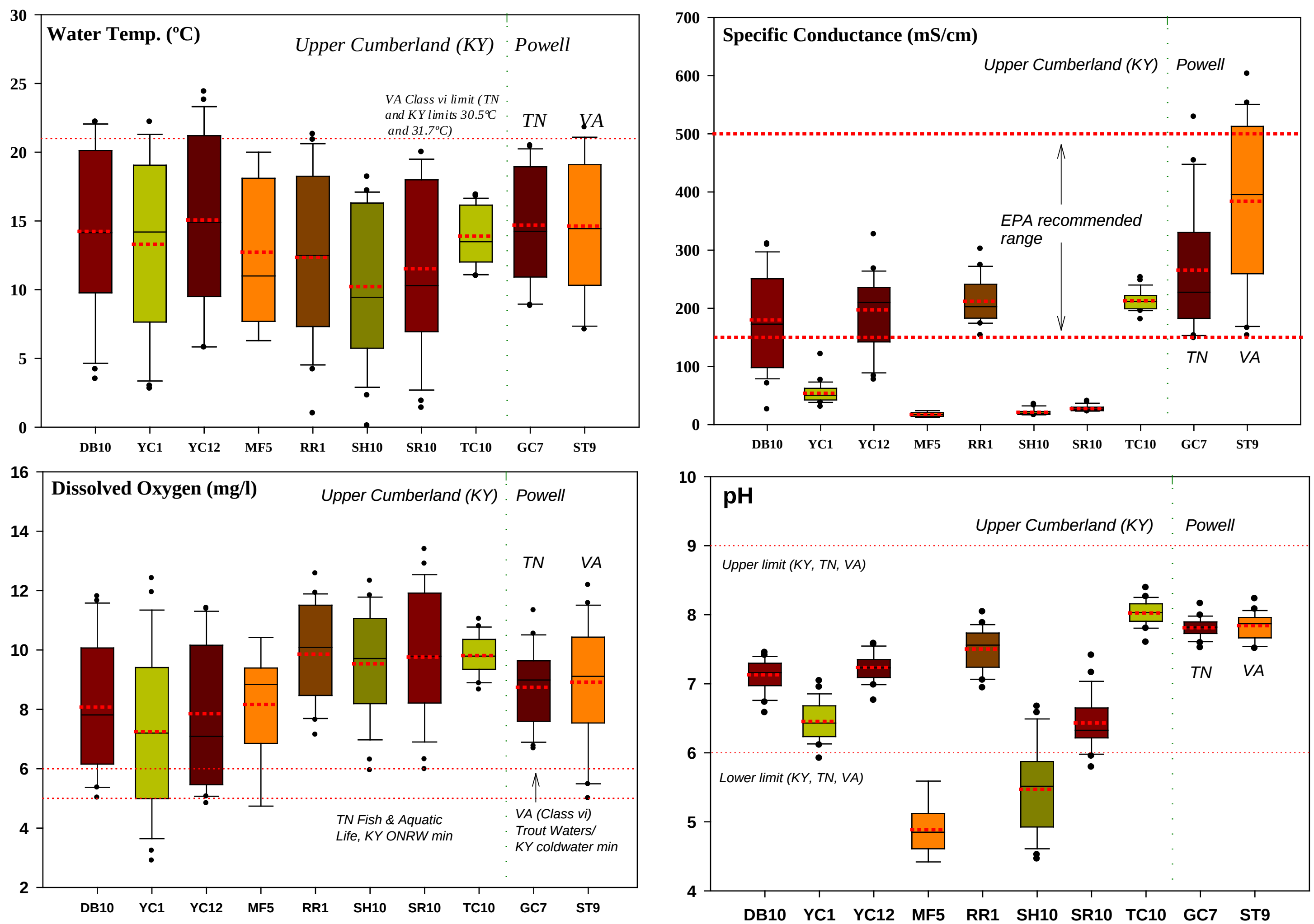


Figure 19. Box and whisker water quality data at CUGA during the first round of monthly I&M sampling ('06-'08): Davis Branch (DB10), Gap Creek (GC7), Martin's Fork (MF5), Railroad Creek (RR1), Shillalah Creek (SH10), Sugar Run (SRSR), Station Creek (ST9), Tunnel Creek (TC10), Upper Little Yellow Creek (YC1), and Little Yellow Creek (YC12). All stations are in Kentucky except where noted, and state standards are listed for each parameter where available. Boxes represent 25th to 75th percentiles, whiskers 5th to 95th percentiles, central solid line is the median, and detached dots are outliers. Horizontal dotted lines within boxes represent mean values over sampling period.

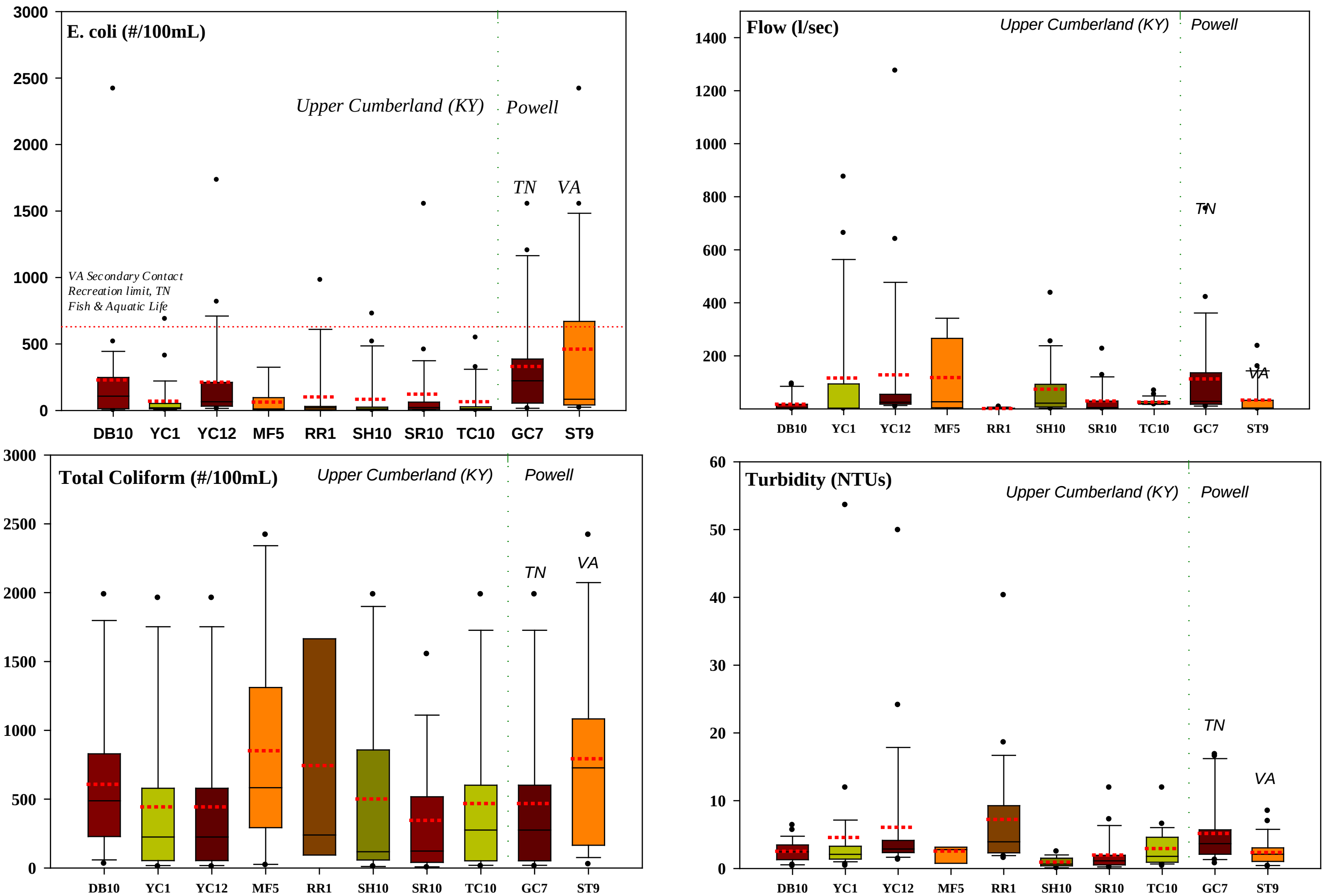


Figure 16 continued. Box and whisker water quality data at CUGA during the first round of monthly I&M sampling ('06-'08): Davis Branch (DB10), Gap Creek (GC7), Martin's Fork (MF5), Railroad Creek (RR1), Shillalah Creek (SH10), Sugar Run (SRSR), Station Creek (ST9), Tunnel Creek (TC10), Upper Little Yellow Creek (YC1), and Little Yellow Creek (YC12). All stations are in Kentucky except where noted, and state standards are listed for each parameter where available. Boxes represent 25th to 75th percentiles, whiskers 5th to 95th percentiles, central solid line is the median, and detached dots are outliers. Horizontal dotted lines within boxes represent mean values over sampling period.

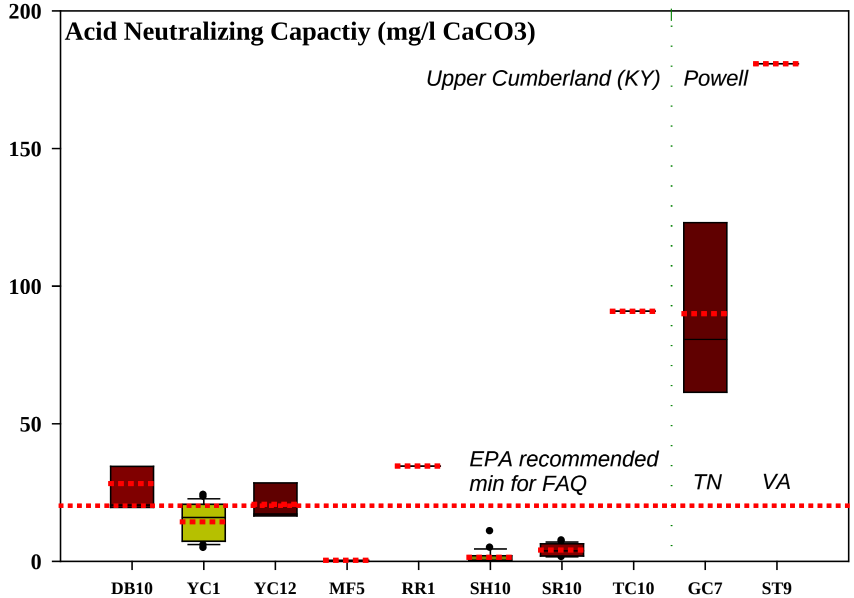


Figure 16 continued. Box and whisker water quality data at CUGA during the first round of monthly I&M sampling ('06-'08): Davis Branch (DB10), Gap Creek (GC7), Martin's Fork (MF5), Railroad Creek (RR1), Shillalah Creek (SH10), Sugar Run (SRSR), Station Creek (ST9), Tunnel Creek (TC10), Upper Little Yellow Creek (YC1), and Little Yellow Creek (YC12). All stations are in Kentucky except where noted, and state standards are listed for each parameter where available. Boxes represent 25th to 75th percentiles, whiskers 5th to 95th percentiles, central solid line is the median, and detached dots are outliers. Horizontal dotted lines within boxes represent mean values over sampling period.

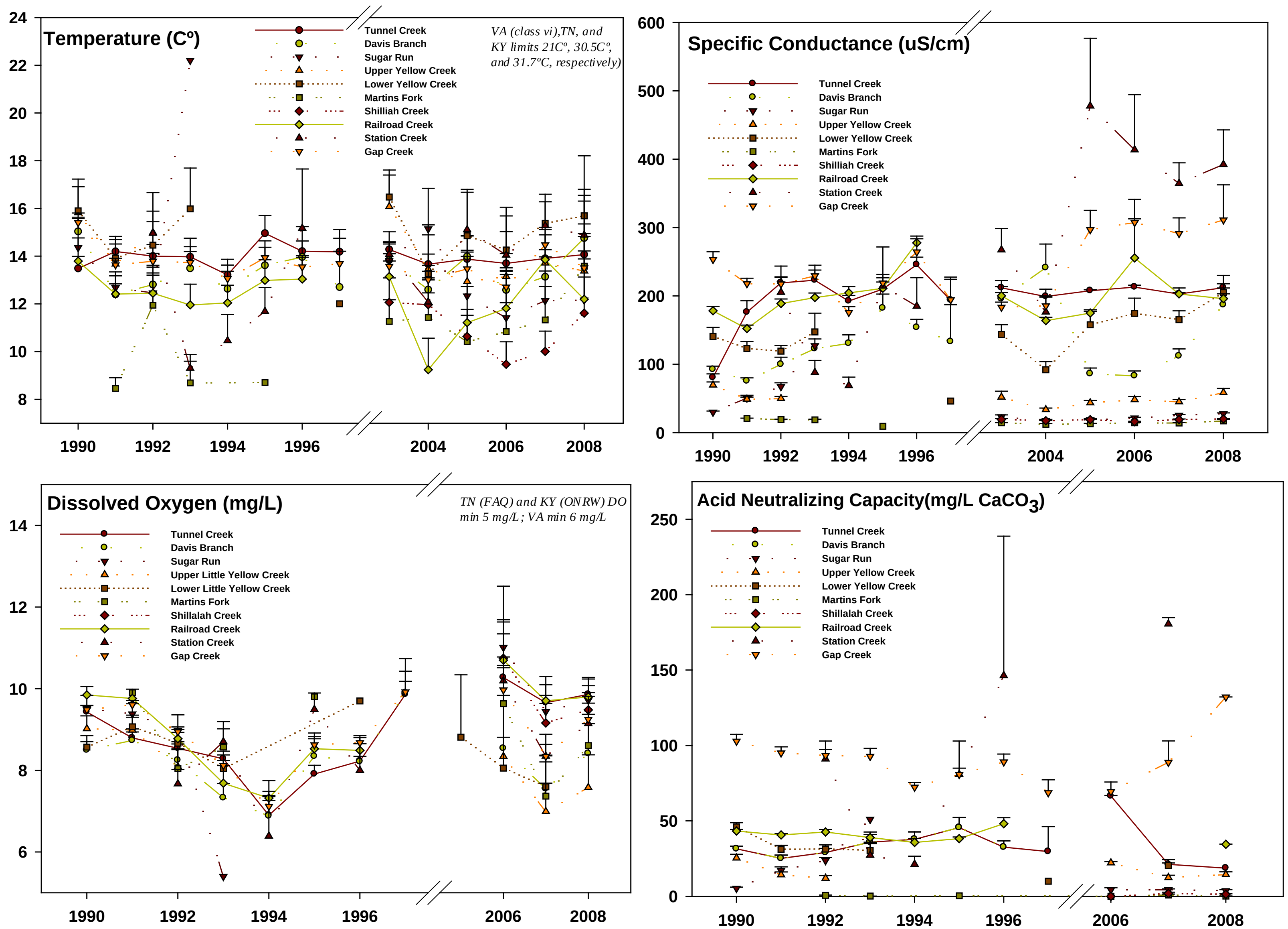


Figure 20. Annual series of historical monitoring data at CUGA from EPAStoret (1990-2007) plotting mean with standard error. Points are grouped by location to match official I&M stations where data is available.

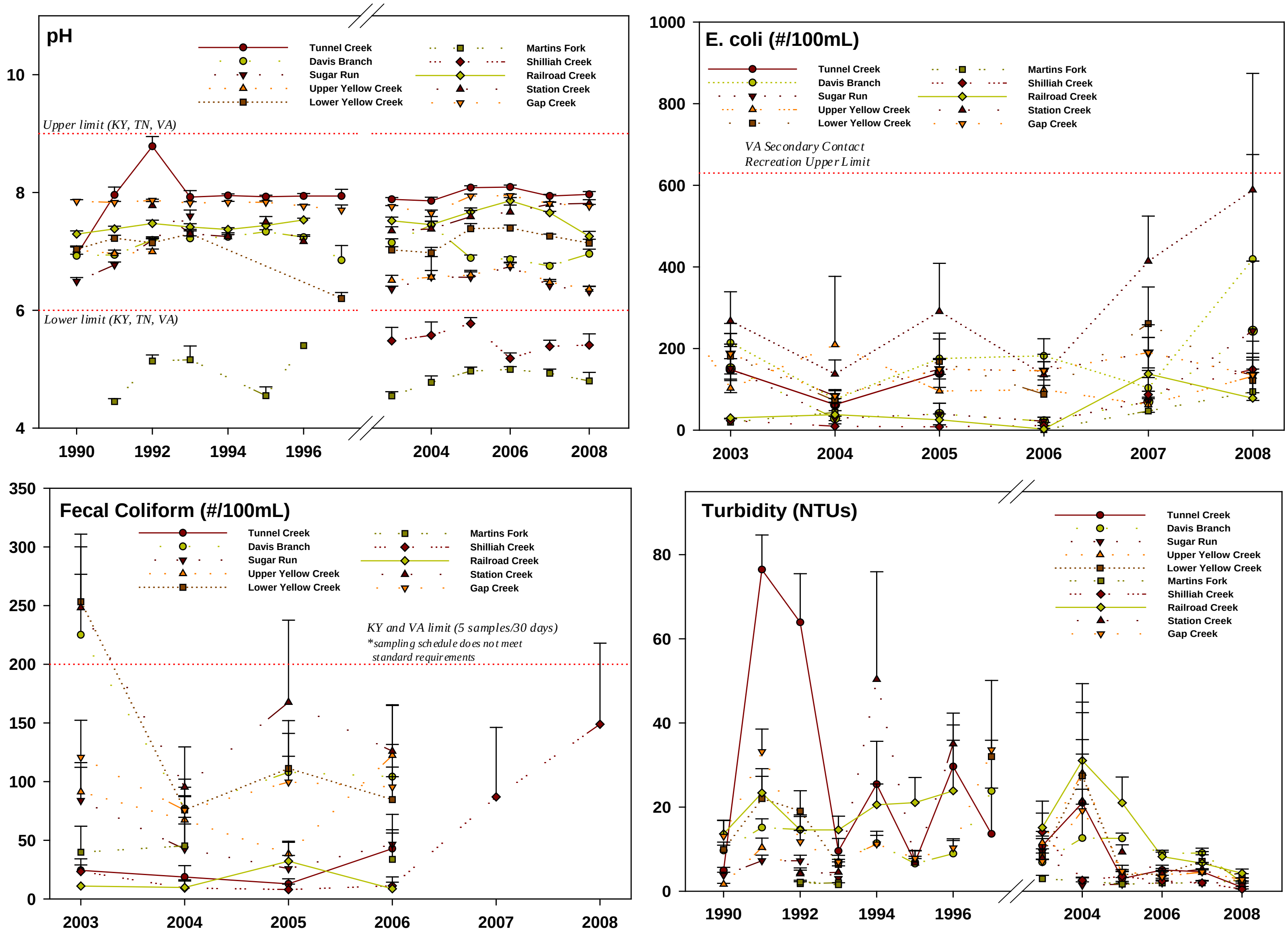


Figure 20 continued. Annual series of historical monitoring data at CUGA from EPAStoret (1990-2007) plotting mean with standard error. Points are grouped by location to match official I&M stations where data is available.

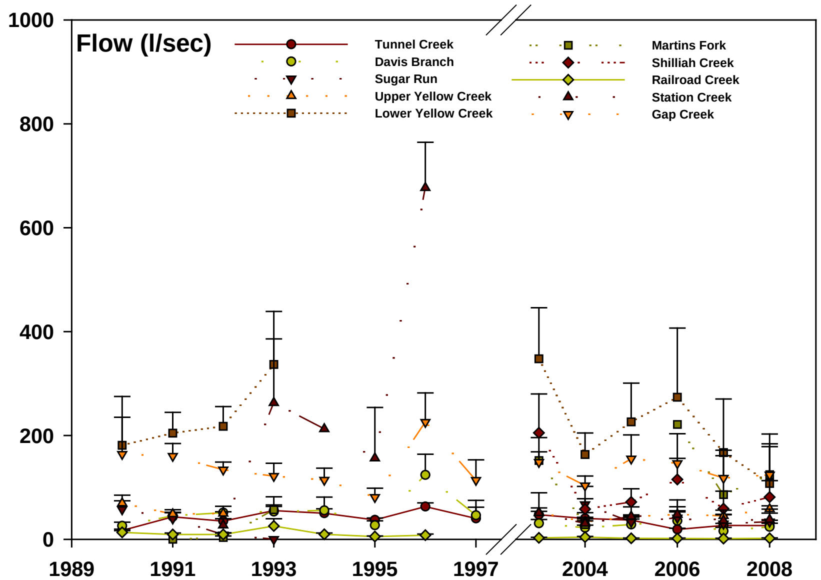


Figure 20 continued. Annual series of historical monitoring data at CUGA from EPAStoret (1990-2007) plotting mean with standard error. Points are grouped by location to match official I&M stations where data is available.

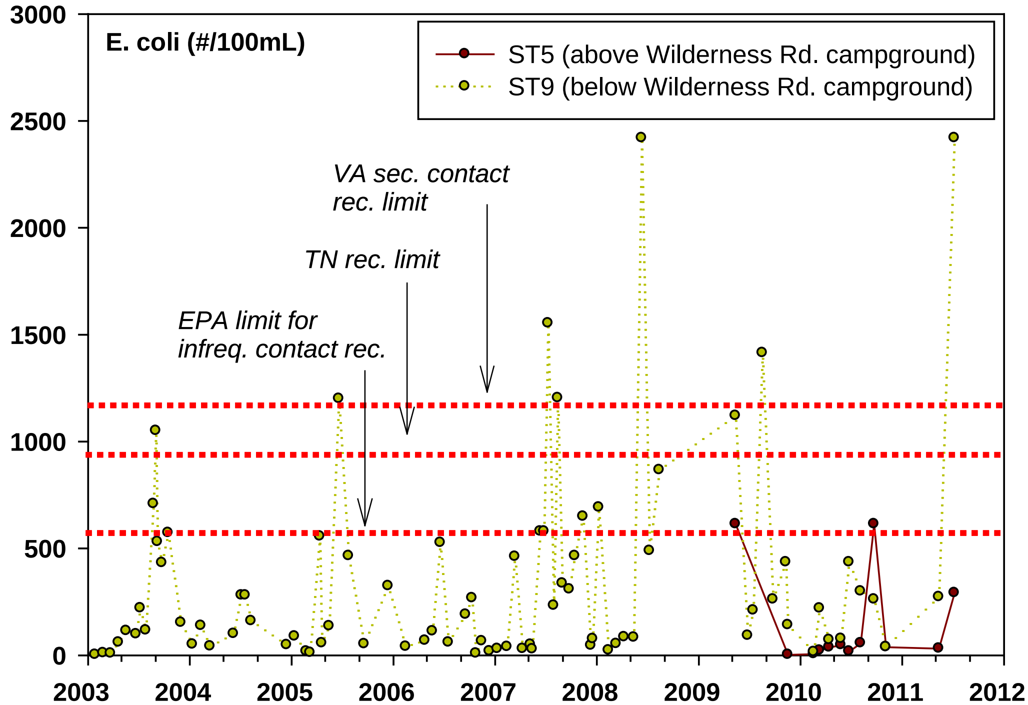


Figure 21. *E. coli* concentrations were collected on Station Creek from 2003-2011, including the official I&M collections beginning in Oct. 2006.

Invasive Plants

According to results from the NatureServe vegetation assessment conducted by White (2006), 108 total non-native species were documented during 2003-2004 field work at CUGA. The current total exotics shown in NPSpecies (2011) is 123, or 13% of species documented in the park. This includes 31 species considered highly aggressive/invasive based on assessments by the Tennessee and Kentucky Exotic Plants Pest Councils (EPPC 2001) and NatureServe I-ranks (Morse et al. 2009, Table 12). White (2006) further suggests that, collectively, these invasive species are currently the single greatest threat to the overall ecological health of the park.

As part of the vegetation assessment, White (2006) selected a top-six list of species whose removal would be the most beneficial to the ecological health of the park. These species include:

1) Japanese stiltgrass (*Microstegium vimineum*)
2) Autumn olive (*Elaeagnus umbellata*)
3) Johnsongrass (*Sorghum halepense*)
4) Princess tree (*Paulownia tomentosa*)
5) Tree-of-heaven (*Ailanthus altissima*)
6) Mimosa (*Albizia julibrissin*)

Another 1980 survey conducted by Butler et al. (1981) documented 20 exotics in the park, and listed the top five most abundant exotics, in order, as follows:

1) Japanese honeysuckle
2) Multiflora rose (*Rosa multiflora*)
3) Mimosa
4) Apples/Peaches (*Pyrus malus, Prunus persica*)
5) Kudzu (*Pueraria montana*)
6) Privet (*Ligustrum* spp.—presumably *L. sinensis*).

These species, as well as those that pose a particular ecological threat, are abundant, or result in frequent management efforts at the park are discussed further below.

Focal Species

<u>Autumn olive</u>

Throughout its range, autumn olive was frequently replanted over strip mine and disturbed areas, and seems to be a particular problem in areas where it was planted in stands or rows within the last 10-20 years. As a result, is has spread to various ecoregions, and currently occurs in all eastern US states. It unfortunately still continues to be planted for wildlife and soil stabilization projects in certain areas (NatureServe 2011). The Fern Lake acquisition at CUGA also contains an abundance of autumn olive and will necessarily require significant management attention (J. Beeler personal communication).

<u>Chinese privet</u>

One of the most troublesome characteristics of privet is that it easily invades multiple habitat types, including wetland forests, wet meadows, forest edges, prairies/old fields, and ravines. In these areas, it can create dense layers that shade out other native species (Munger 2003). It currently is distributed in the Southeast and most mid-Atlantic states, and usually requires a minimum of three to five years of repeated treatments for eradication (NatureServe 2011).

Johnsongrass

Johnsongrass, a frequently listed noxious weed throughout the US, also has the ability to invade a variety of habitats, most typically including disturbed areas, flooded bottomlands, forest edges, or roadsides. On roadsides in particular, it can establish quickly using rhizomatous movement to eventually outcompete native plants. Johnsongrass is easily spread via field cultivation and is difficult and expensive, though necessary, to control (NatureServe 2011). At CUGA, Johnsongrass is mostly found along roadsides and in old field habitat (R. White personal communication).

Figure 22. Princesstree is a prolific seed-producer that can colonize hard-to-reach places. [Source: James H. Miller, USDA Forest Service, Bugwood.org]

Princesstree

Princesstree is another species that is still planted throughout the US for its fast growth and can adapt to many different environments (Figure 22). The extremely rapid growth of this tree—up to 15 ft a year—necessitates quick treatment before it is able to produce seeds and outcompete surrounding native vegetation. Seed production per tree can reach up to 20 million every year (NatureServe 2011). Princesstree is also able to colonize steep rocky slopes where other species may be unable to adapt, thus making treatment in these locations particularly difficult. At CUGA, this is a salient issue due to the frequency of rare species that grow along rocky slopes, especially in the White Rocks cliff system in the northern portion of the park (SEEPPC 2011, R. White personal communication).

Tree-of-heaven

Tree-of-heaven is already a widespread species and primarily invades habitat of low quality or disturbed areas. These disturbed areas may be the result of human activity or natural disturbance, such as a tree fall (R. White personal communication). It is able to tolerate extreme conditions including acidic soils, stony and thin topsoils, and high levels of air pollution. This species is also allelopathic, meaning it secretes chemicals from its roots that can negatively impact the shrub layer or other competing species in its vicinity. At CUGA, it may occur most frequently around roadsides and in cultivated meadows. Although seed production is high, persistent root sprouts also make this species particularly difficult to eradicate (NatureServe 2011).

Mimosa

Mimosa is a predominant invasive in the southern US, where it is planted frequently as an ornamental (Figure 23). It usually invades human-disturbed areas, though it can also grow in riparian areas and forest edges, adapting to several types of soil conditions. Because of its lasting seed viability, quick growth, and propensity for resprouting, treatment of this species proves difficult and usually necessitates herbicidal control in addition to manual cutting. Besides the ability to outcompete native vegetation, it also can alter the native growing environment by fixing nitrogen into the soil (SEEPPC 2011, NatureServe 2011).

Garlic mustard

Although White (2006) did not find garlic mustard (*Alliaria petiolata*) during his inventory, he warns that it could potentially arrive at the park in the near future and would most likely adversely affect the bottomland and cove forests such as the Northern Mixed Mesophytic Forest Type. In recent years, garlic mustard was discovered and eradicated in a single location along a park road by the Southeast Exotic Pest Plant Management Team (SEEPMT 2011) and currently, no other infestations are known in the park (J. Beeler personal communication). Garlic mustard generates allelopathic compounds that are harmful to the germination of other species, and can eventually create too much shade for the success of native understory species.

Figure 23. Mimosa, a legume with a propensity for resprouting, is among the invasives treated at CUGA. [Source: James H. Miller, USDA Forest Service, Bugwood.org]

Kudzu

Another significant problem in the park is kudzu, which is a fast-growing vine that can quickly form an impenetrable blanket over existing vegetation and fundamentally alter the existing community by outcompeting native species (Figure 24). Vines can grow up to 15m each season,

Figure 24. Kudzu can quickly invade and cover native vegetation. [Source: Kerry Britton, USDA Forest Service, Bugwood.org]

while roots can penetrate to depths of 3m (SEEPPC 2011).
Treating kudzu infestations can require considerable investment, including repeated cutting, digging, and herbicide application to prevent spread via runners. Currently, this species is one of the main targets for management attention in the park (J. Beeler personal communication).

Sericea

Lespedeza, also known as sericea, is an herbaceous species that, like kudzu, can form dense monotypic mats that completely exclude other native species. Originally introduced as forage and a means of erosion control, this species also produces allelopathic chemicals and fixes nitrogen into the soil, further suppressing growth of competing species. Treatment options include herbicide, mowing, or burning, though each of these might also negatively affect native species. Management attention for this species may be required for upwards of five years due to its long seed viability, prolific resprouting, and ability to spread vegetatively (NatureServe 2011, SEEPPC 2011).

Crown vetch

Like mimosa, kudzu, and sericea, crown vetch is another leguminous species that requires substantial management attention from the park (J. Beeler personal communication). Crown vetch is a vine that spreads vegetatively through adventitious roots as well as via seeds, which can remain viable for multiple years. Treatment commitments are estimated to be at least 3-5 years, and manual removal through pulling and mowing may prove successful (NatureServe 2011, SEEPPC 2011).

Oriental Bittersweet

A woody deciduous vine, oriental bittersweet shares several traits with other invasive vines, including a high reproductive rate, rapid growth, and the ability to outcompete native vegetation either by direct mortality from girdling, or indirectly from shading. Unlike many of the other invasives commonly treated at CUGA, oriental bittersweet can adapt to a wide variety of light conditions, leading it to occupy roadsides, open wooded areas, or interior forests.

Figure 25. Crown vetch is another exotic legume that requires considerable management attention at CUGA.

In addition to these species already outlined, Chinese silvergrass (*Miscanthus sinensis*) and teasel (*Dipsacus fullonum*) represent emerging threats in the Wilderness Road area (J. Beeler personal communication). In other areas, species of concern include burningbush (*Euonymus alatus*), Japanese knotweed (*Polygonum cuspidatum*), pear (*Pyrus calleryana*), and coltsfoot (*Tussilago farfara*).

Threat Ranking

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics to native species and ecosystems, called the I-rank (Table 12). The overall I-rank consists of 20 questions which together cover four main subranks: ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty. We recalculated the I-ranks for each species, excluding consideration of current distribution and abundance, because that metric is relevant to the rangewide status and we desired a park unit-level status. These rankings are shown in Table 12 and are expressed on a scale of zero to three, with three representing the greatest threat to park resources. Following this approach, only one species, Japanese honeysuckle, resulted in an I-Rank in the highest category (>2.00).

Table 12. Thirty-one plant species at CUGA are considered significantly or severely invasive by the TN and KY Exotic Pest Plant Councils based on their ability to invade and displace native vegetation communities. VA Dept. of Conservation and Recreation (VADCR) invasiveness rankings are also provided. These classifications are shown with nationwide I-ranks adapted from Morse et al. (2004).

		EPPC Rank		DCR Rank	
Species		TN	KY	VA	I-Rank
Lonicera maackii	Amur honeysuckle	Severe	Severe	Moderate	2.5
Lonicera japonica	Japanese honeysuckle	Severe	Severe	High	2.3
Elaeagnus umbellata	Autumn olive	Severe	Severe	High	2.2
Lespedeza cuneata	Chinese bushclover	Severe	Severe	High	2
Microstegium vimineum	Japanese stiltgrass	Severe	Severe	High	2
Polygonum cuspidatum	Japanese knotweed	Severe	Severe	High	2
Rumex acestosella	Sheep sorrel	-	Significant	Moderate	2
Dioscorea oppositifolia	Chinese Yam	-	Severe	High	1.8
Pueraria montana	Kudzu	Severe	Severe	High	1.8
Sorghum halepense	Johnsongrass	Severe	Severe	High	1.8
Miscanthus sinensis	Chinese silvergrass	Significant	-	Occasional	1.7
Poa pratensis	Kentucky bluegrass	-	Significant	-	1.7
Albizia julibrissin	Mimosa	Severe	Significant	Moderate	1.7
Carduus nutans	Musk thistle	Significant	Severe	Moderate	1.7
Coronilla varia	Common crown-vetch	Significant	Severe	Occasional	1.7
Leucanthemum vulgare	Oxeye Daisy	Lesser	Significant	-	1.7
Ailanthus altissima	Tree-of-heaven	Severe	Severe	High	1.5
Verbascum thapsus	Common mullein	Significant	-	-	1.5
Berberis thunbergii	Japanese barberry	Significant	Significant	Moderate	1.3
Kummerowia stipulacea	Korean clover	Lesser	Significant	-	
Paulownia tomentosa	Princess tree	Severe	Significant	Moderate	1.3
Ipomoea purpurea	Purple morning-glory	-	Significant	Moderate	1.2
Rosa multiflora	Multiflora rose	Severe	Severe	High	1.2
Glechoma hederacea	Ground ivy	Lesser	Significant	Moderate	1
Stellaria media	Chickweed	-	Severe	Moderate	1
Vinca minor	Common periwinkle	Significant	Significant	Occasional	1
Daucus carota	Queen Anne's Lace	Severe	Significant	-	0.3
Torilis arvensis	Field hedge-parsley	Significant	-	-	Not Ranked
Bromus japonicus	Japanese brome	Significant	-	-	Not Ranked
Clematis terniflora	Leatherleaf clematis	Significant	-	-	Not Ranked
Eleusine indica	Indian goosegrass	-	Significant	-	Not Ranked
Setaria viridis	Green bristle grass	Significant	Significant	Moderate	Not Ranked

I-Rank is calculated as a mean of ecological impact, trend in distribution and abundance, and general management difficulty, each of which is assigned a value of 1 to 3 (Morse et al., 2003). Each category is assigned a number based on its categorical rating and mean to give the overall I-Rank: low (0.01-1.00), medium (1.01-2.00), or high (2.01-3.00). Ranks do not reflect overall abundance within the park unit.

The first category—ecological impact—generally relates to the effects of the species on community structure and composition, or to more general ecosystem processes. The second category—current distribution and abundance—considers the broad-scale range of the species and the diversity of communities it invades. The greater the area and amount of habitat a species invades, the more damage it can potentially cause. However, this abundance measure does not address localized presence, such as at the scale of CUGA. As a result, widespread species with a high ranking for this category may in fact be sparse at CUGA, or species with relatively constrained broad-scale distributions may be common and widespread in the park, resulting in conflicting influence on the overall I-Rank. Consequently, this category is not used to recalculate the quantitative I-Rank for species at CUGA. The third category—trend in distribution and abundance—is used to inform the I-Rank because it is scale-independent, and generally addresses its rate of spread and increase in abundance. Lastly, management difficulty addresses how hard the species is, once identified, to eradicate or control. This category also addresses the potential of common control methods to cause collateral damage to other native species (Morse et al. 2004).

Three species had an overall I-rank between moderate and severe: Amur honeysuckle (*Lonicera maackii*), Japanese honeysuckle, and autumn olive (*Elaeagnus umbellata*). Amur honeysuckle is predominant in most of the states in the eastern US, where in forested areas it can lead to decreased species richness and suppression of native tree species (Collier et al. 2002). In addition, Gould and Gorchov (2002) showed that the presence of Amur honeysuckle reduced the fecundity and survival of three native annuals—stickywilly (*Galium aparine*), pale jewelweed (*Impatiens pallida*), and Canadian clearweed (*Pilea pumila*)—depending on the level of disturbance present at the site. Each of these species was documented at CUGA by White (2006). In addition to affecting these three species, it is assumed that Amur honeysuckle likely affects other native species negatively as well. Repeated control measures are recommended to eliminate this invasive, including repeated clipping in forested areas at least once a year, and clipping in combination with herbicide application in open areas (Luken and Mattimiro 1991).

Japanese honeysuckle is also reported to change forest structure, which may include suppression of understory herbs, a simplified understory, and death for various trees and shrubs due to the amount of biomass it can accumulate (NatureServe 2011). This species is noted as particularly difficult to remove, especially after it is established, due to its extensive rhizome, root system, and ability to resprout after hand-pulling or mowing. Again, manual removal is recommended in combination with herbicide application (Bravo 2005).

The third highest ranked species, autumn olive, is a nitrogen-fixer that occurs commonly in wet or riparian areas where it also can suppress understory plants. Suggested treatment options include cutting, girdling, and hand removal either alone or in combination with herbicide application (SEEPPC 2009).

Despite their high I-Rank, these species may not necessarily represent the top management priorities for invasives in the park. Amur honeysuckle, especially, is limited to rich/basic soils, and thus will have a limited range in the acidic soils (R. White personal communication).

Susceptible Areas
Of the 33 ecological community types within the vicinity of the park, there are three that appear to have the highest level of invasion by invasive exotics: Virginia pine successional forest (CEGL2591), Red-Cedar successional forest (CEGL7124), and Sycamore-Sweetgum swamp forest (CEGL7340), the former two of which are considered to be early successional forests (2591 and 7124), and the third (7340) is often early successional in nature. Each of these types comprise <1% of the overall park area. The cultivated meadow vegetation community (CEGL4048), another early successional community, also contains European fescues and Kentucky bluegrass—a species that, surprisingly, is not native to Kentucky and is included on the KY EPPC list as a significant invasive threat (Table 12). These maintained communities are most frequent along the main park roads and at the Hensley Settlement, which is maintained as a cultural site. Several of the old homesites in the park have also served as sources of exotic species after they were allowed to return to natural woodland without removing non-natives (White 2006). In general, it appears that communities that are most disturbed (i.e., early successional), also generally have some of the largest problems with invasive exotics. In contrast, examples of stands that are less disturbed by humans and further away from "edges" generally have less invasive exotic presence (R. White personal communication).

Butler et al. (1981) reports that exotic species were most clustered around the Gap itself, in addition to the area between the visitor's center and the wilderness road campground—all of which are areas close to roads with higher rates of fragmentation. In general, most occurrences, especially for princess tree and tree-of-heaven, were along roadsides (mainly HWY-25) and developed areas with high levels of human impact. As such, there were virtually no occurrences of exotic species documented east of Gibson Gap. Butler et al. (1981) documented 16 forest types in the park, and 69% of exotics found in natural areas occurred in either the tulip-poplar—oak-hickory (~CEGL7220/7221) or tulip-poplar—sycamore (~CEGL7340) forest types. Most of the remainder occurred in the mixed Virginia/pitch pine forest type (~CEGL2591). Although several non-native fruit trees were observed as well, most were located at the Hensley Settlement where they likely add to the cultural interpretation of the area. Butler et al. (1981) also noted that the invasibility of these trees is minimal, and predicted their eventual decline as a result of low replacement rates. Today, exotic species are much more widespread at CUGA than just along Wilderness Rd., and have been found in Shillalah Creek Rd., Civic Park, Ewing Trail, and along the Ridge Trail (J. Beeler personal communication).

A main difference between White (2006) and Butler et al. (1982) was the lack of Chinese privet documented by White (2006) in the recent assessment, while Butler et al. (1981) had acknowledged privet by genus as the sixth most abundant exotic species at CUGA. Privet does occur at CUGA (J. Beeler personal communication)—likely Chinese privet (*Ligustrum sinense*)--which occurs frequently throughout the southeastern US where it has become naturalized. It seems unlikely that CUGA would not contain occurrences of this species, especially if it was identified during the initial Butler et al. (1981) survey.

Treatments for exotics since 2005 have occurred in many locations along the Wilderness Road Trail. GPS readings show a virtually continuous stretch of invasion where treatments have occurred along the Wilderness Road Trail. (Figure 26). This stretch of the Wilderness Road Trail. originates from its intersection with highway 58 near Cumberland Gap to its intersection with highway 25E in Middlesboro. Part of the reason for the predominance of exotics in this area is the large number of roads that were once present along this corridor. Despite revegetation with native species during restoration, exotics quickly invaded and now represent a significant management concern in this area.

Taken as a whole, CUGA represents a large contiguous tract of relatively undisturbed land, the result of which is high vegetation diversity in most areas with specific locations of concentrated invasives. Though quite a few exotic species have been documented at CUGA, including 31 species considered highly invasive, exotics represent only 13% of vascular plants documented at CUGA, which is low compared to other park units in the CUPN (Moore 2010).

White (2006) mentions that four high priority forest types may be threatened by the incursion of exotics, though collectively they are quite rare and comprise <1% of the park. The Dry Calcareous Forest/Woodland (CEGL8458) faces a threat from tree-of-heaven and princess tree, while the Hi Lewis Pitch Pine Barrens (CEGL3617) may be susceptible to exotic invasion after widespread pine mortality from the southern pine beetle (*Dendroctonus frontalis*). Generally, White (2006) recommends controlling all instances of highly invasive exotics and devoting particular effort to protecting the high quality and rare communities in the park.

Summary
Although invasive plants represent a relatively small proportion of vascular plant species identified at CUGA, they still represent one of the biggest expenditures of management effort by the park. Treatments are concentrated on hotspots, mainly along the Wilderness Road Trail, but invaded sites also exist in other locations such as Hensley Settlement and Civic Park. For these reasons, the condition status at CUGA is assigned a ranking of “fair” (Table 13). Although the number of exotic species documented in surveys by White (2006) compared to Butler et al. (1981) represents a fivefold increase much of this is likely due to a difference in survey methods, such as Butler’s concentration woody species. As a result, we find insufficient information to assign a trend to this ranking.

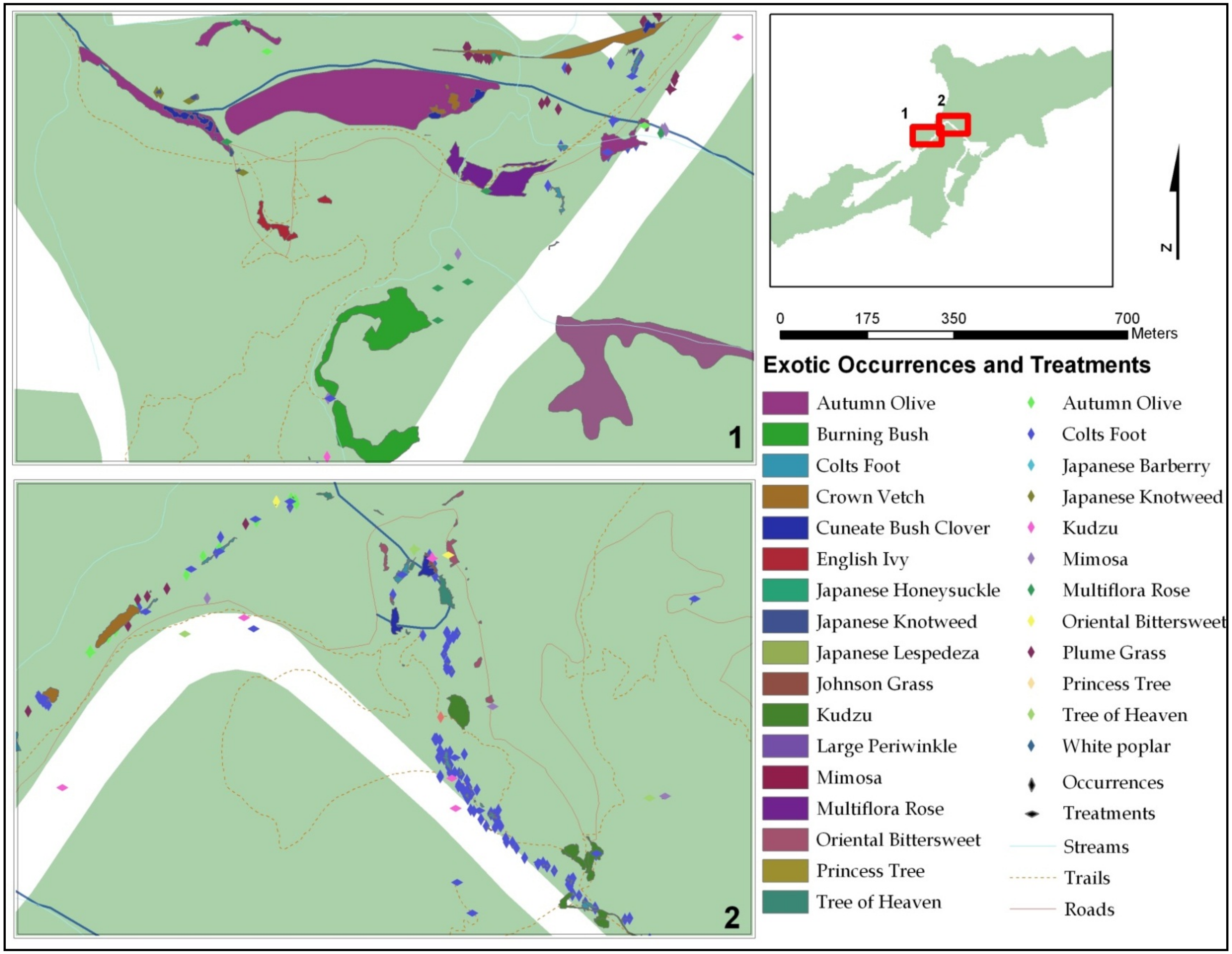


Figure 26. Exotic treatment sites along Wilderness Rd. since 2005.

Table 13. CUGA was assigned a status of fair for invasive plants with no trend. Data quality was assigned a status of good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Invasive Plants		✓	✓	✓
		3 of 3: Good		

Infestations and Disease

Hemlock Woolly Adelgid

Cumberland Gap NHP monitors for several non-native insect pest species. Currently, one of the most serious and threatening pests to hemlock communities in the region and the park itself is the hemlock woolly adelgid, which was first discovered at the park in 2006 along the Martin's Fork drainage (J. Beeler personal communication). Since that time, Bell, Harlan, and Lee counties in KY and VA have reported infestation, and most recently in Clairborne county in TN (NPS 2009b, NAS&PF 2008). Native to southern Japan, this species of adelgid preys upon species of eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*), usually resulting in fatal damage to the tree within 3 to 10 years of infestation (USDA 2005).

In his 2006 vegetation assessment, White reports that the Cumberland/Appalachian Hemlock-Hardwood Cove Forest at CUGA is particularly susceptible to woolly adelgid due to the high concentration of hemlocks in this forest type. This community is predominant along the floodplains of many of the streams throughout the northern side of the ridgeline, overall encompassing 212 ha. Hemlock functions as a keystone species in this community, meaning that its role in the community is essential to their function. Numerous studies predicted a multitude of effects on the structure and function of hemlock riparian and cove hardwood communities due to adelgid-induced decline, including transpiration rates, carbon cycling, vegetation dynamics, structural complexity, wildlife, and potential spread of exotic species (Ford and Vose 2007, Cleavitt et al. 2008, Nuckolls et al. 2009, Daley et al. 2007, Eschtruth et al. 2006). While the park continually monitors infestation rates and health of trees throughout the park, it is especially important that treatments reach hemlocks in the uncommon communities where they serve such a vital function. Large-scale application of pesticides would not be feasible for the park, and the efficacy of bio-control projects is still being tested throughout the Southern Appalachians. Although the hemlock-hardwood cove forest area at CUGA covers a small proportion of area, the loss of this species could be potentially devastating to this important and diverse ecosystem.CUGA resource managers are implementing ongoing efforts to control the spread of the adelgid throughout this small, but important, community.

Beginning in 2007, resource managers implemented two aggressive treatment measures in an attempt to control and eliminate the spread of the adelgid: imidacloprid pesticide treatments and predatory beetle releases. Pesticide control focused primarily on the Cumberland/Appalachian Hemlock-Hardwood Cove Forest (CEGL8407) in the southwest of the park (total 140 acres), as well as a few stands of Southern Appalachian Eastern Hemlock Forest (CEGL7136, total 37 acres, Figure 27). Overall, this encompasses almost the entire Sugar Run drainage within the park, in addition to several spot treatments around more conspicuous road and trail areas. Treatments have been conducted every year since 2007, with particular concentration this year (2011) on backcountry areas. Starting in 2010, an additional pesticide, dinotefuran, was incorporated into treatment as both a soil drench and basal bark spray.

Besides imidacloprid treatments, 16 predatory beetle releases have been conducted along riparian corridors such as Davis Branch, Laurel Branch, Sugar Run, and Shillalah Creek. These beetle releases involve two species—*Pseudoscymnus tsugae* and *Laricobius nigrinus*. As of this writing, the treated areas appear to be doing well, though no beetles have been released since the 2009 season (J. Beeler personal communication).

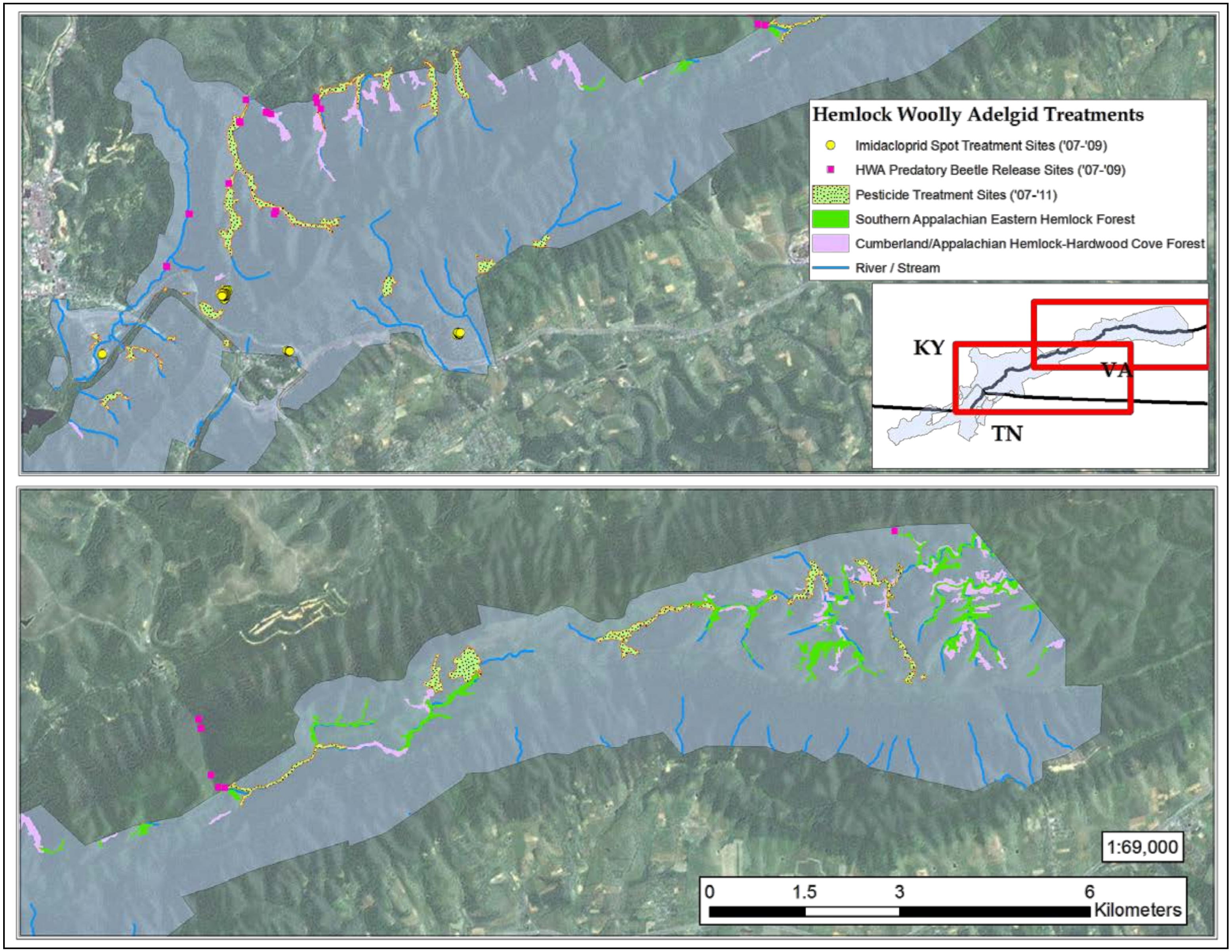


Figure 27. Treatments for hemlock woolly adelgid included pesticide drenches and predatory beetle releases from 2007 – 2011.

Emerald Ash-Borer

Emerald ash-borer (*Agrilus planipennis*), another invasive insect pest, is currently on the watch list at CUGA (NPS 2009a). Emerald ash-borer (EAB) is native to NE Asia, and was first discovered in the US in 2002. It attacks only ash trees (*Fraxinus* spp.), which are usually killed 3-4 years after infestation (McCullough and Usborne 2008). In 2007, the Kentucky Division of Forestry noted that the borer had been found in Hamilton County, OH just north of the KY border. A subsequent placement of 2,500 traps in northern Kentucky between 2007 and 2008 resulted in no catches. However, in May 2009, the borer was confirmed in KY in two counties and in three months, the list of infested counties had expanded to eight (Townsend 2009). As of this writing, 20 counties in northern Kentucky and five counties in Tennessee have been quarantined for Emerald ash-borer, including Clairborne County adjacent to the park. No infestations have been documented in the park unit (J. Beeler personal communication).

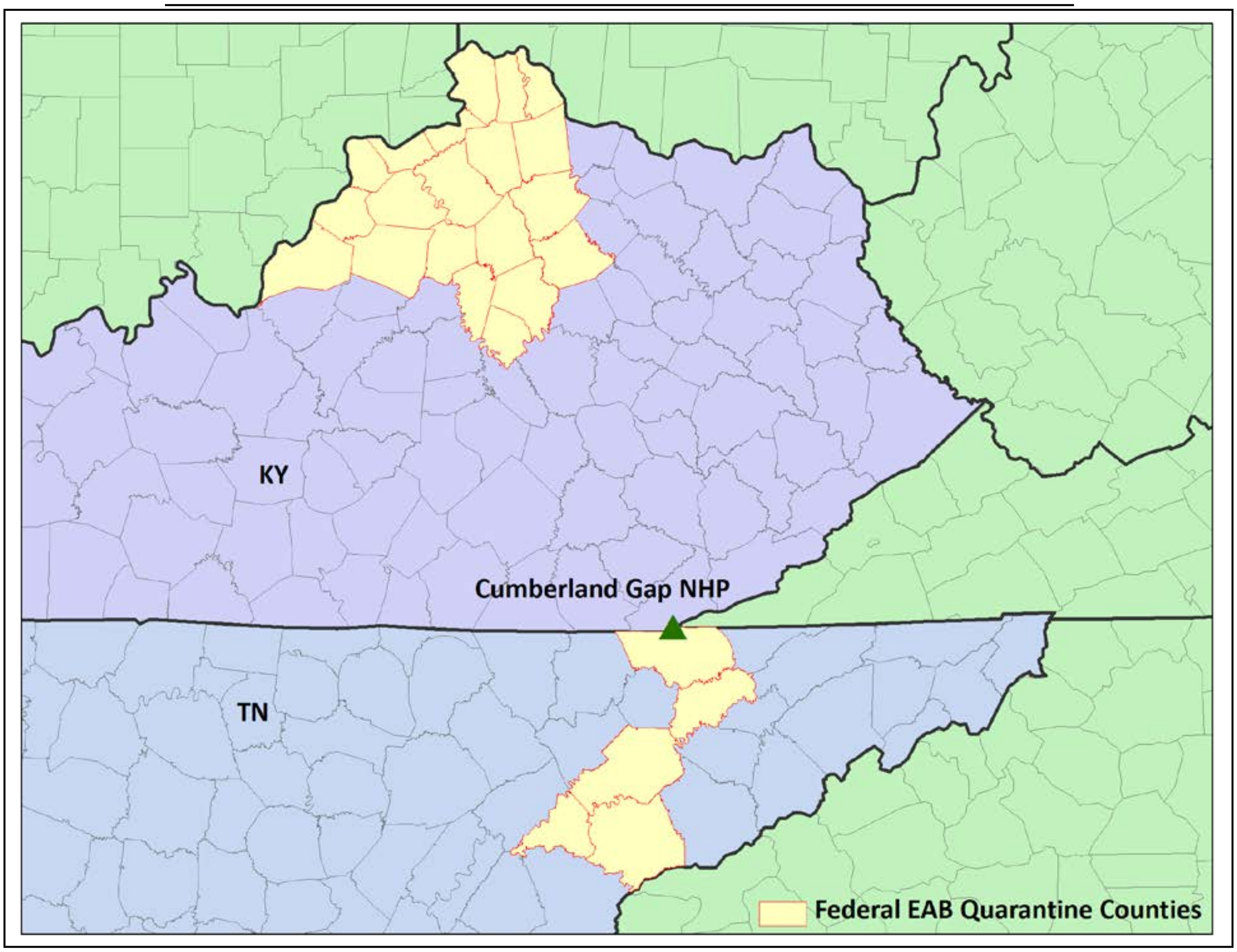


Figure 28. As of 2011, 20 counties in NW KY and five counties in TN have been quarantined due to the presence of emerald ash-borer.

European Gypsy Moth

The European gypsy moth (*Lymantria dispar*) is another invasive insect that stays on the watch list of invasive pests at CUGA. The larva of these moths can quickly defoliate trees and portions of forests, and feed on a variety of common tree species. Originating in the US from an introduction to Massachusetts, the invasion front of gypsy moths, according to the Cooperative Agricultural Pest Survey (CAPS), continues to spread southwest towards CUGA (Figure 29).

The US Forest Service has also monitored 11-15 traps in CUGA since 2004, from which it reported a single capture in Virginia in 2007 (J. Beeler personal communication). During 2002-2005, Claiborne County in TN, which encompasses the southern portion of CUGA, underwent eradication efforts, but has not reported gypsy moth presence since that time (NAPIS 2011). Although the pest has not been identified close to the park at this time, it seems likely that the invasion front will eventually reach southeastern Kentucky and the park.

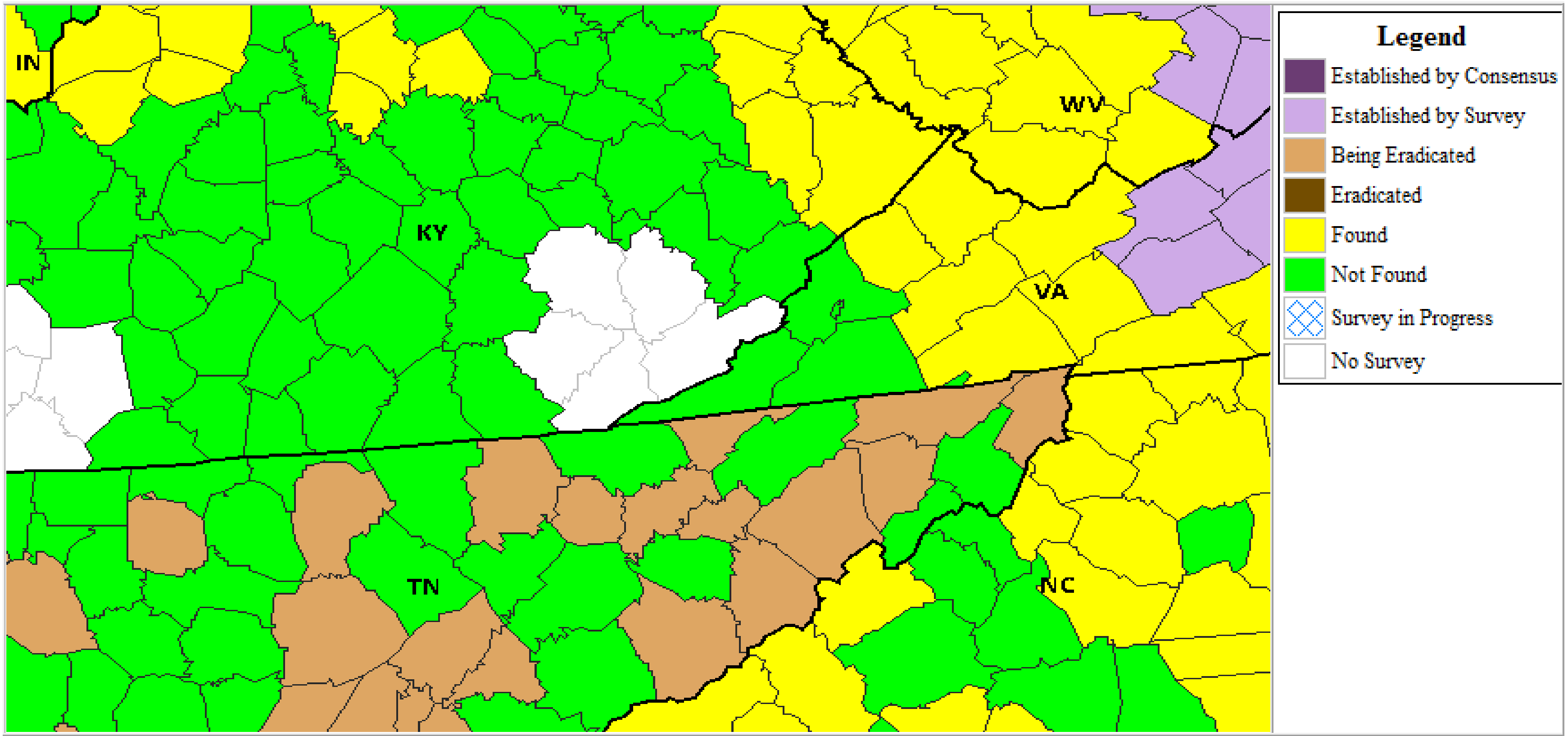


Figure 29. Since 2008, the invasion front of gypsy moth continues to spread southwest into Kentucky, though no counties surrounding CUGA have reported gypsy moth sightings to the Cooperative Agricultural Pest Survey (CAPS) (NAPIS 2011).

Asian Long-Horned Beetle

The Asian long-horned beetle (*Anoplophora glabripennis*) is another pest on the watch list of exotic insects posing a threat to the park. The beetles threaten a variety of deciduous hardwoods, which most notably includes several maple species. However, the beetles have yet to be discovered in KY, VA, or TN, and most likely pose the least threat to the park of the insects currently included on the watch-list (USFS 2009).

Southern Pine Beetle

Southern pine beetle (*Dendroctonus frontalis)*, a native forest insect to the southern US, has caused pine mortality over several hundred acres at CUGA in the past, largely affecting Virginia pine (*Pinus virginiana*, NPSa 2009). Krist et al. (2007), as part of the Forest Health Technology and Enterprise Team (FHTET), produced a prediction map for the US showing potential basal area loss for southern pine beetle for the next 15 years, which showed virtually no risk for the CUGA region.

A separate spatial model produced for a finer resolution, also by the FHTET, used a combination of pine species composition, slope, shadow effect, and basal area to predict the susceptibility and vulnerability for forested regions using a categorical ranking from no risk to very high risk. Again, the overall risk for the park was quite low, with small patches of forest ranked from moderate to high risk (Figure 30). These small patches of high risk most closely correspond to forest regions classified as Blue Ridge Table Mountain Pine-Pitch Pine Woodland (CEGL7097) by the Center for Remote Sensing and Mapping Science (CRMS) at the University of Georgia. This particular vegetation type typically occurs on the ridgelines at higher elevations. In his report on the vegetation communities at CUGA, White (2006) mentions that this community, which totals 194 hectares at CUGA, has already been heavily impacted by pine beetle, and whose regeneration may currently be limited by fire suppression. If this continues, White (2006) notes that this particular community is in danger of extirpation from the park.

The CUGA Fire Use Module does conduct prescribed burning that can help minimize fuel loads and facilitate natural regeneration, though it is not an objective to target areas specifically to combat pine beetle (NPS 2003). The park is divided into five main burn areas which are further subdivided into 16 individual units. Four of the main areas are along the exterior region of the park in the west, while the Lookout Tower area is centralized in the eastern part of the park adjacent to the White Rocks area (Figure 31). Burning within the units began mainly in 2005, with each unit targeted using periodic cycles.

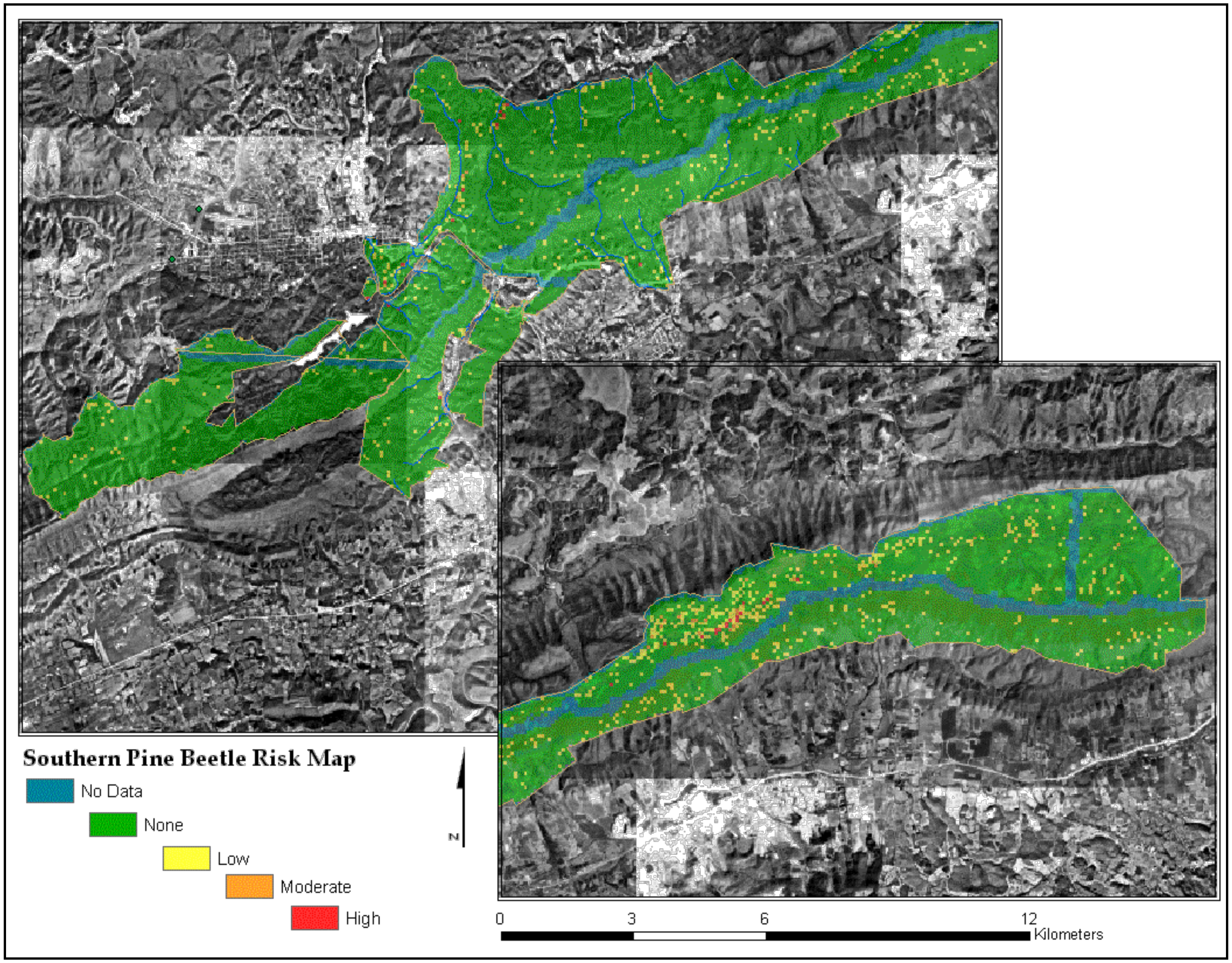


Figure 30. Southern pine beetle risk map produced by Forest Health Technology Enterprise Team (Ellenwood and Krist 2007) shown for the CUGA area shows forest stands of highest risk in the north-central section of the park, which closely coincides with the Blue Ridge Table Mountain Pine-Pitch Pine Woodland forest type.

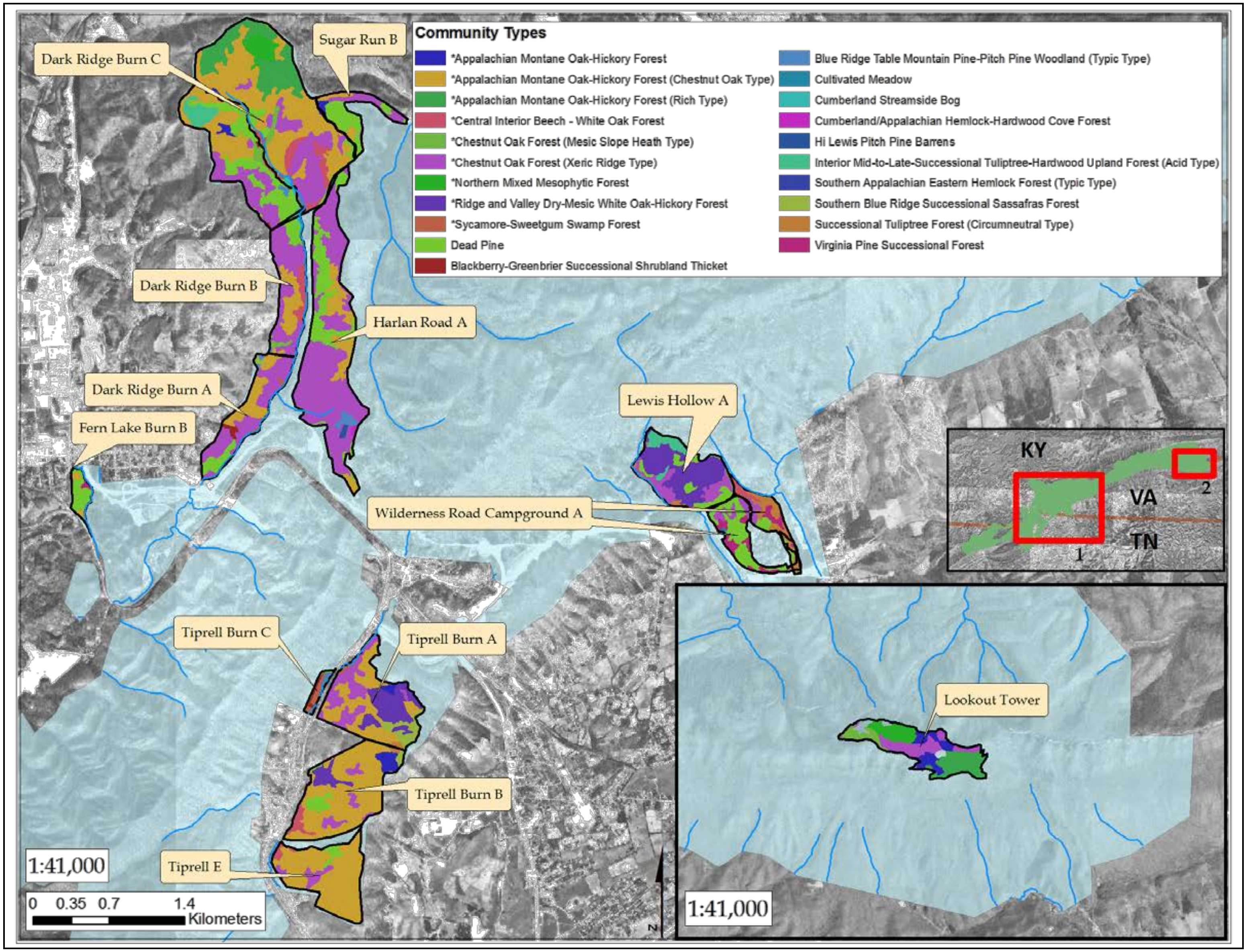


Figure 31. The CUGA Fire Use Module prescribes periodic burns in each of the different burn units in the park.

Thousand Cankers Disease

Another potential threat at CUGA is thousand cankers disease, which affects black walnut trees (*Juglans nigra*) and is spread by a combination of fungus (*Geosmithia* sp.) and the walnut twig beetle (*Pityophthorus juglandis*). As the beetle bores into the bark, it facilitates fungal infection and canker formation at each of the numerous tunnels it creates. Tree death typically occurs within 3 years of onset (USFS 2011).

TN is the only state in the southeast reporting an infestation, which is currently centered around Knoxville. The TN Dept. of Agriculture has invoked a quarantine that includes Campbell and Claiborne counties near CUGA, which prohibits the transfer of walnut tree products or hardwood firewood outside these areas (TN Dept. Agr. 2011). Though the disease has not been detected inside the park, its potential to spread represents a management concern.

Summary

Overall, CUGA faces threats from several insects and a single fungal infection. Though the emerald ash-borer has yet to be found at CUGA, the invasion front of this insect continues towards the park region, and infestation within the park is likely within coming years. The gypsy moth appears to represent even more of an immediate threat, having been trapped at CUGA in 2007, and whose invasion front is much closer than the ash-borer. Also threatening the park in the near term is the thousand cankers disease, which has been identified near the park, but not yet within it.

Southern pine beetle has already inflicted damage on hundreds of acres in the park, which includes the G3-ranked Blue Ridge Table Mountain Pine-Pitch Pine Woodland. White (2006) also noted evidence of southern pine beetle damage, among other disturbance types, at eight of 100 NatureServe plots. These eight sites were mainly clustered in the western and less remote sections of the park (Figure 32).

The most aggressive and detrimental forest pest at CUGA, however, is the hemlock woolly adelgid, which has the potential to permanently alter forest communities, particularly in the vulnerable mesic cove hardwood forests where eastern hemlock plays a keystone role. Compounding this issue is the difficulty of eradicating this pest, which most likely would include both chemical treatments (e.g. imidacloprid, horticultural oils) over smaller areas and individual trees in combination with bio-control (e.g. predator beetles) over larger regions and in forest stands. The stands of eastern hemlock that might be the most vulnerable and susceptible at CUGA are mostly found within the Cumberland/Appalachian Hemlock-Hardwood Cove Forest and the Southern Appalachian Eastern Hemlock Forest types. Together, these types comprise roughly 380 ha—mostly riparian areas. With the exception of the Davis Branch, these riparian hemlock communities comprise virtually all streamside areas north of the ridgeline.

Because of the major threat posed to these riparian ecosystems from hemlock loss, and to a much lesser degree the ongoing threat posed by the southern pine beetle, the condition status for forest pests at CUGA receives a “poor” ranking (Table 14). Furthermore, because of the recent discovery of HWA in the park, its history of quick spread and infestation, difficulty of treatment, and the imminent presence of gypsy moth and emerald ash-borer in counties near the park, the condition status is assigned a degrading trend.

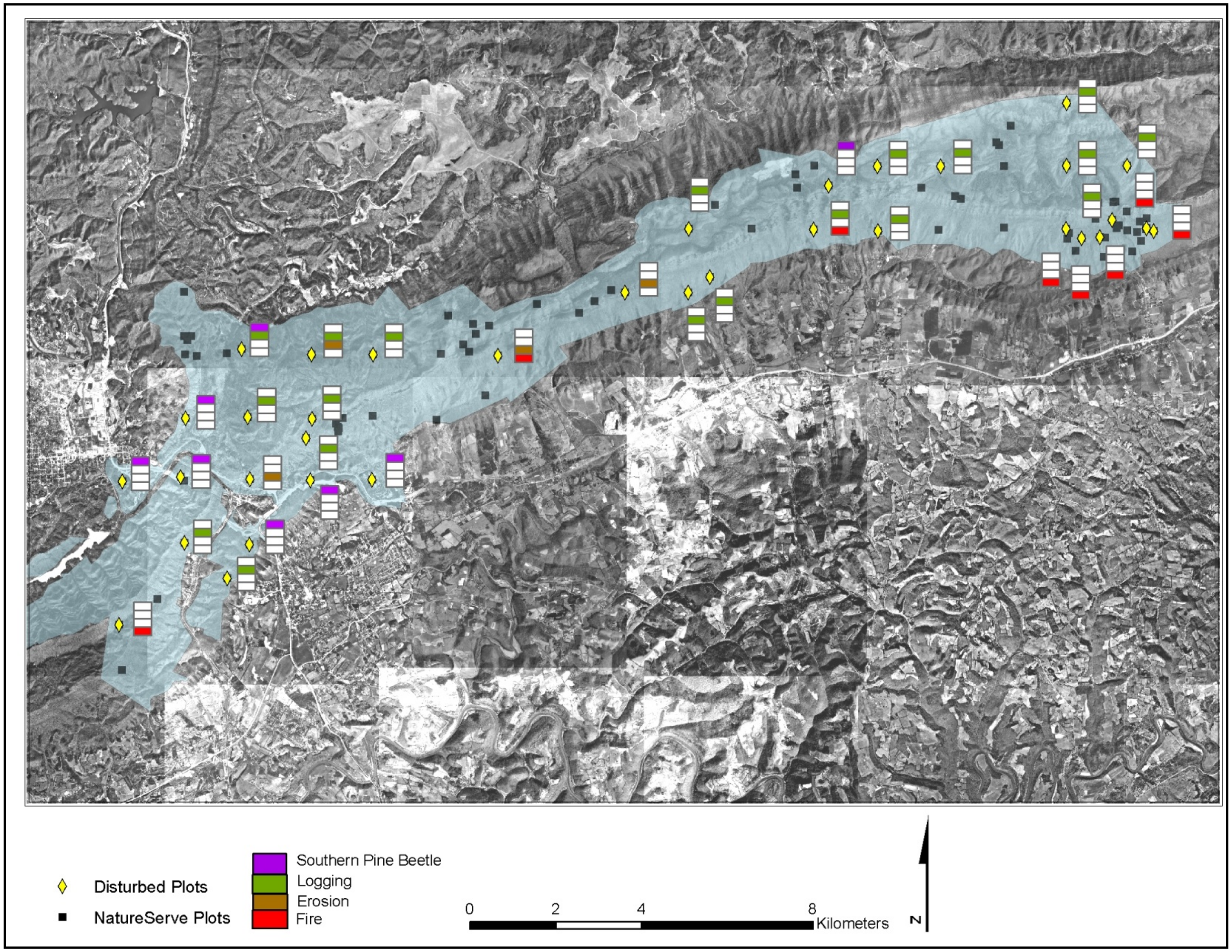


Figure 32. As part of the recent NatureServe assessment by White (2006), 35 of 100 plots recorded one of four main disturbances: southern pine beetle damage, evidence of logging, erosion, or evidence of fire. Stacked boxes in the map represent presence (colored) or absence (white) of a total of four specific disturbances according to the ordered legend.

Table 14. The condition status for insect pests at CUGA was assigned a ranking of poor with a decreasing trend. The data quality was good.

		Data Quality		
Attribute	Condition & Trend	Thematic	Spatial	Temporal
Forest Pests		✓	✓	✓
		3 of 3: Good		

Focal Species and Communities

Vegetation Communities

<u>Forest Communities</u>

NatureServe's Southeast office in Durham, NC collaborated with the Center for Remote Sensing and Mapping Science (CRMS) at the University of Georgia to classify photo imagery into a spatially explicit description of the vegetation communities at CUGA, in accordance with the national standards outlined by the Federal Geographic Data Committee (FGDC 2008). In fall 2002, aerial color infrared photos were collected during leaf-on by US Forest Service Air Photographics. These images were in turn orthorectified and interpreted using software and manual analysis to assign vegetation types to specific signatures, in addition to repeated ground-truthing to agree on and modify vegetation classifications.

Overall, there were 37 community map classes outlined at CUGA by CRMS out of almost 2100 patches, which includes 24 natural vegetation types and 9 successional or exotic-dominated communities (Figure 33). These community types are the same NatureServe associations as those described by White (2006). For comparison, Hinkle (1975) outlined 15 major plant communities and noted that they all were altered from their original composition due to changing fire regimes, logging, and chestnut blight. Hinkle (1975) observed that chestnut oak-dominated communities were the most common throughout the park, which he suggested, might be areas of former Oak-Chestnut (*Castanea dentata*) forest where chestnut oak (*Quercus prinus*) became the dominant replacement. Although CUGA contains multiple vegetation types, there exists a slightly higher diversity of communities on the north side of the main ridgeline that divides the park. The overall predominant community is the Appalachian Montane Oak-Hickory Forest (CEGL7692), which is divided into the chestnut oak type north of the ridgeline and a rich type with more mixed species to the south. Throughout the park, these two forest types comprise 2820 ha, or about 35% of the park.

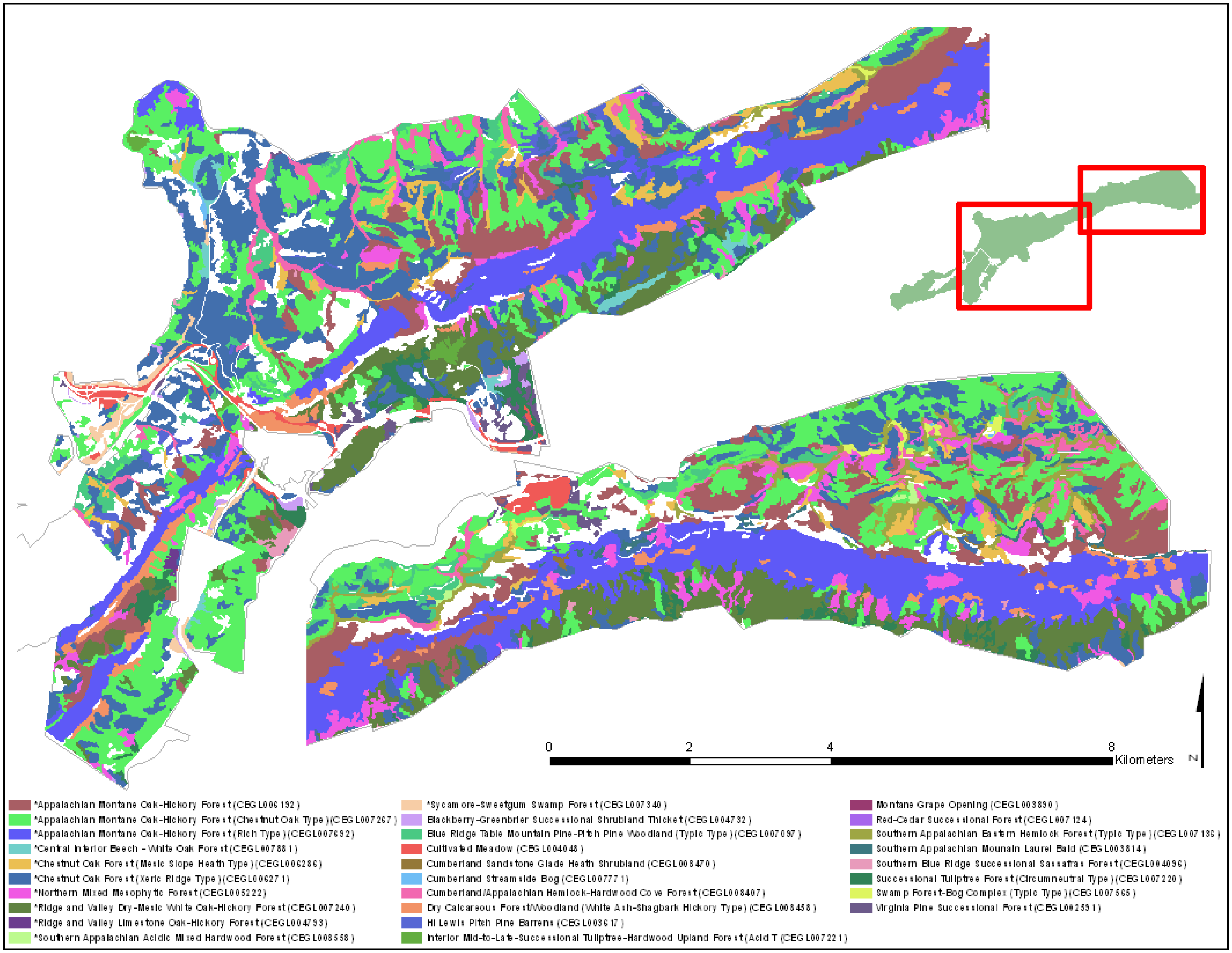


Figure 33. Using the NatureServe (2005) classification scheme, 33 vegetation community types were identified in CUGA [Source: CRMS].

Rare Communities

Of the 15 vegetation types outlined by Hinkle (1975), he mentions that the only community unique to CUGA is the Red Maple-Blackgum-Hemlock Community, which is most likely comparable to NatureServe's Southern Appalachian Eastern Hemlock Forest (CEGL7136) (White 2006). White (2006) notes that this community contains over 50% hemlock cover and usually occurs on lower slopes and terraces. Overall, this G3G4 (Table 15) community encompasses 166 ha—mainly north of the ridgeline in the northeastern portion of the park. Hinkle (1975) also describes the Northern Red Oak-Hickory community type as unique to the park, which most likely matches the Red Oak Type of the Appalachian Montane Oak-Hickory Forest (CEGL6192) described by White (2006).

Table 15. NatureServe conservation global status ranks are based on the rarity and risk of elimination for a vegetation community throughout its range (NatureServe 2011). Combination ranks (e.g. G3/G4) indicate uncertainty about the exact status of a community type. A "?" qualifier denotes inexact ranks.

Global Rank	Description
G1	Critically Imperiled—Very high risk of extinction due to extreme rarity (often ≤5 pop.), very steep declines, or other factors.
G2	Imperiled—At high risk of extinction or elimination due to very restricted range, very few pop., steep declines, or other factors.
G3	Vulnerable—At moderate risk of extinction or elimination due to a restricted range, relatively few pop., recent and widespread declines, or other factors.
G4	Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	Secure—Common; widespread and abundant.

In his 2006 report on the ecological communities at CUGA, White notes that the park contains the largest tract of roadless land (5700 ha) of any of the units in the CUPN. As a result, many of the natural communities in the park are considered high quality examples of certain forest types, several of which are globally-ranked as significant communities. The highest ranked community is the Dry Calcareous Forest/Woodland (G1?; Figure 34), which exists at a single location in VA other than CUGA. Overall, the UGA map shows that it occupies 169 ha in the park and generally extends linearly for its length along a band of limestone below the ridgeline (Figure 34). However, it is possible that this community is much rarer in the park than its mapping showed, because the accuracy assessment of the map showed that this community was only mapped correctly 11% of the time (Smart et al. 2010). This community is dominated by white ash (*Fraxinus americana*), shag-bark hickory (*Carya ovata*), and northern red oak (*Quercus rubra*), and also includes a diverse understory. As a result, this community is highly susceptible to damage from the emerald ash borer. In addition, invasives like princess tree and tree-of-heaven are adapted to the rocky slopes and medium/high light conditions typical of this community (White 2006), and therefore close monitoring is necessary to protect the current distribution of these sensitive areas.

Another rare community is the Cumberland Streamside Bog (CEGL7771, G2), which has been upgraded from a G1? ranking since the original report by White (2006). This community totals just over 1 ha in four different parcels, including one near the northern terminus of Davis Branch

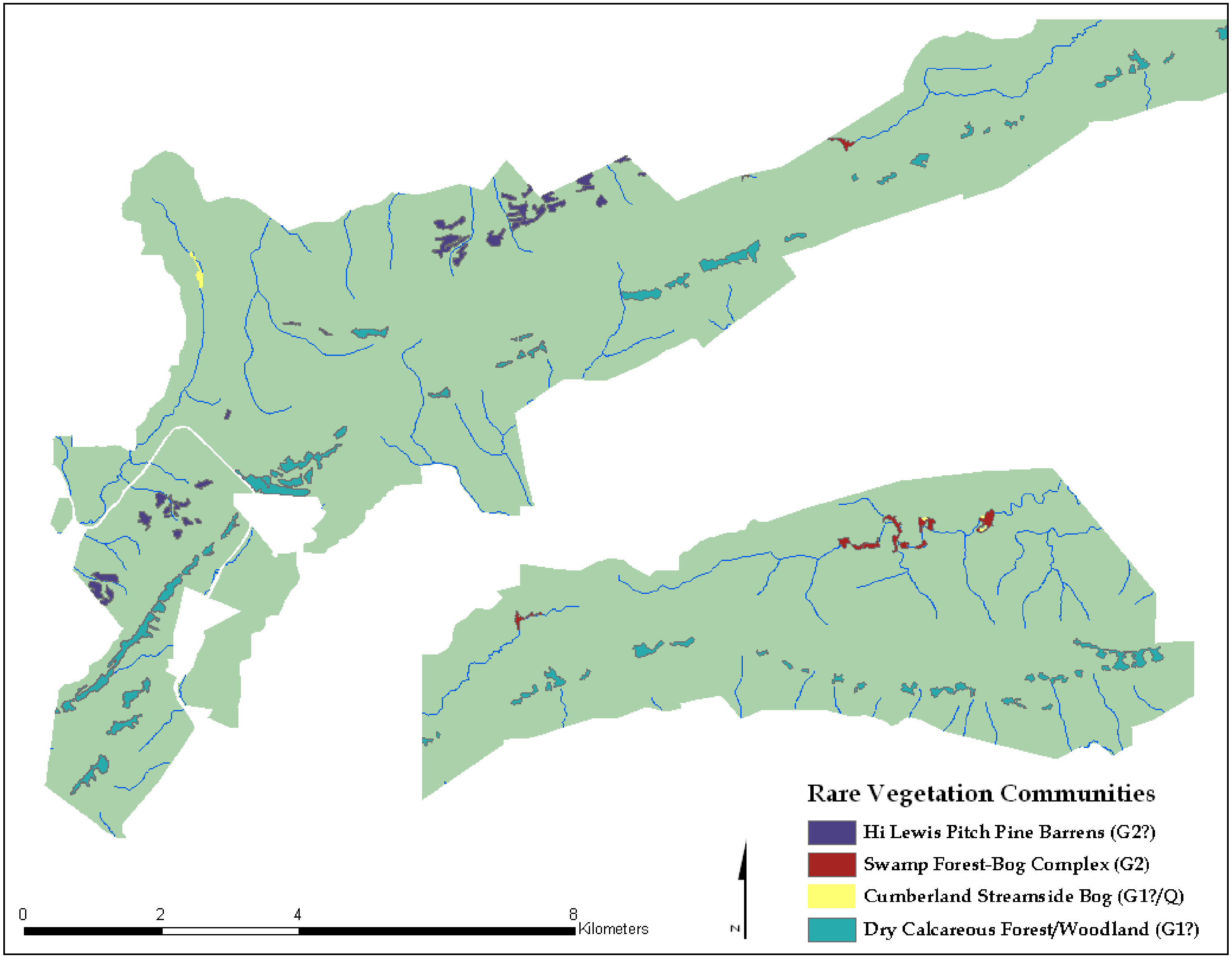


Figure 34. Four vegetation community types at CUGA are globally ranked as G2 or G1, representing globally imperiled and critically imperiled, respectively. Overall, these communities collectively represent 255 ha, or ~3% of the total park area.

and three in the extreme northeast corner along Martin's Fork, overall at elevations around 750 m. Understory of this community is typified by shrubs such as maleberry (*Lyonia ligustrina*), black chokeberry (*Photinia melanocarpa*), cinnamon fern (*Osmunda cinnamomea*), and royal fern (*Osmunda regalis*). NatureServe (2009) notes that instances of the Cumberland Streamside Bog face a particular threat from vegetative succession, and that in some places the exotic broadleaf cattail (*Typha latifolia*), which is present at CUGA, can become invasive and displace native vegetation. Most patches of this vegetation community were threatened in the past by forest clearing or flooding during farmland conversion. These communities are generally adapted to some kind of natural disturbance (most likely occasional fire), without which they tend to be of lower diversity (White 2006).

The Swamp-Forest Bog Complex (CEGL7565) is also ranked a G2 community, mainly due to the infrequency of its occurrence. This community occurs alongside the streamside bog in several places along the Davis Branch and Shillalah Creek. At CUGA it totals 21 ha in 10 patches mainly around the Martin's Fork region in poorly drained bottomlands. Vegetation in this type includes a varying canopy of hemlock with an understory of rosebay rhododendron (*Rhododendron maximum*). As a result, this community is particularly susceptible to infestation by hemlock woolly adelgid. Most occurrences of this community have been altered or destroyed via hydrologic alterations, so the patches remaining at CUGA represent particularly valuable examples of this vegetation type (NatureServe 2011).

The final community at CUGA to achieve a rating of imperiled or critically imperiled from NatureServe is the Hi Lewis Pitch Pine Barrens (G2?), which White (2006) refers to as the most threatened community in the park due to its vulnerability after a recent pine beetle outbreak. The uncertainty in the ranking, according to NatureServe, refers to the limited number of areas assessed for the occurrence of this community. Like the Blue Ridge Table Mountain Pine-Pitch Pine Woodland forest type, this community type contains pitch pine and Virginia pine, which are both preferred pine beetle hosts. White (2006) suggests additional study of this particular community to determine what management actions, if any, would be most effective in its recovery. This community is fire-adapted (NatureServe 2011) and occurs on approximately 25 ha on south-facing slopes in the park, mainly in the southern portion on the Kentucky side of the ridgeline. It is dominated by pitch pine (*Pinus rigida*), and includes a diverse and unique understory which typically includes horseflyweed (*Baptisia tinctoria*), little bluestem (*Schizachyrium scoparium*), poverty oatgrass (*Danthonia spicata*), and Virginia tephrosia (*Tephrosia virginiana*) (NatureServe 2011). White (2006) outlines the danger that the community may be altered by colonization of red maple and/or exotics, and that prescribed fire may help facilitate the regeneration of pines.

<u>Cliffline Community Assemblages</u>

At CUGA, the White Rocks cliff system, though not specifically recognized with a unique community type classification, contains a distinct and fragile ecosystem that includes several rare lichens and bryophytes, in addition to vascular plants (Walker 2007). The cliffs are located on the east side of the park and reach 150 m in height. Surrounding the base of the cliff is typically the Appalachian Oak Forest type, while adjacent to the cliff edge is the Southern Appalachian Mountain Laurel Bald—a rare (G2G3) community characterized by a diverse and thick shrubland, but also with areas of exposed rock, lichens, and herbs (NatureServe 2011). White

(2006) indicates that the stability of this community is largely dependent on solum thickness, whereby deeper soils are more likely to support recruitment of trees like sourwood (*Oxydendrum arboreum*) or blackgum (*Nyssa sylvatica*) that may eventually form a canopy over the shrub layer. A comprehensive 2005-2006 survey conducted by the Walker and Ballinger (2007) documented 14 vascular plants, 9 bryophyte species, and 48 lichen species throughout the White Rocks cliff system (Figure 35). Twelve vertical transects were located along the cliff system, with each transect containing various $1m^2$ survey plots separated by 3m. Similar surveys conducted at the Obed Wild and Scenic River cliff systems yielded slightly lower lichen diversity for all six systems compared to the single system at CUGA (Walker and Ballinger 2007).

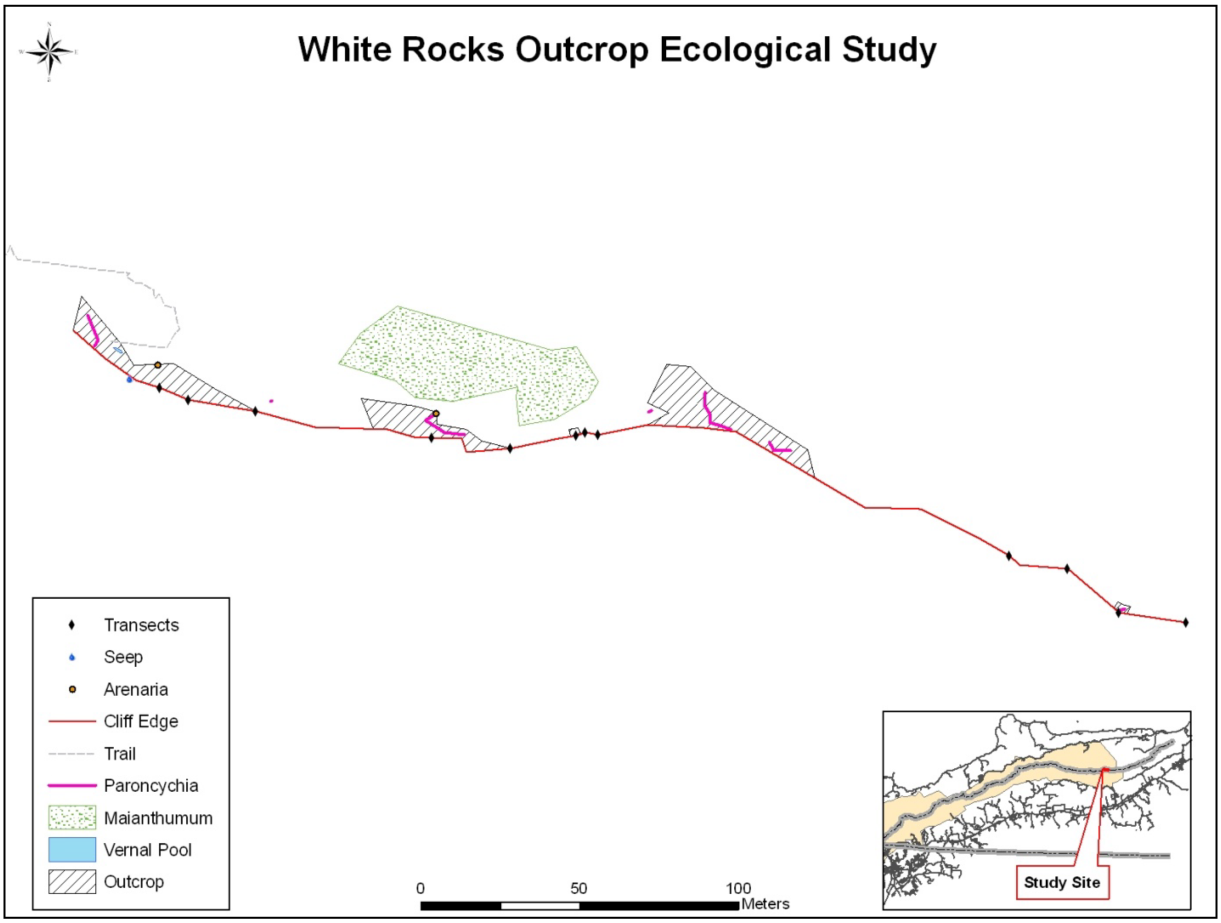


Figure 35. Walker and Ballinger (2007) conducted plant and lichen community surveys along the White Rocks cliff system at 12 transects. [Figure taken from White et al. (2007)]

Overall, Walker et al.'s (2007) analysis found that vascular plant, bryophyte, and lichen communities were collectively affected mostly by slope, soil volume, and local heterogeneity, whereby areas with lower slopes and greater surface heterogeneity were more apt to accumulate and retain moisture and nutrients. These areas supported vascular plants, whereas areas without these characteristics were more often occupied by non-vascular species. As a result, areas in the cliff system with southerly aspects were more likely to have higher temperatures and lower moisture availability, and therefore were particularly conducive to abundant lichen assemblages.

Of the 14 vascular plants documented in the cliff system, silvery nailwort *(Paronychia argyrocoma*) is one of the rarest species, listed as S1 and endangered in Kentucky. Throughout its range, this species is particularly vulnerable to trampling in vista areas, such as at White Rocks (NatureServe 2011). Wavy hairgrass (*Deschampsia flexuosa*), also documented at the sites, is listed as an S2 species in Kentucky. And although it was not specifically included in any of the surveys, Michaux's saxifrage (*Saxifraga michauxii*) was documented along the cliff base along perennial streams, a species listed as S2 in Kentucky. Finally, wild lily-of-the-valley (*Maianthemum canadense*), an S2 species in Kentucky, was documented in one location near a cliff ledge (Walker and Ballinger 2007).

The White Rocks cliff system provides unique habitat for species that would otherwise face environmental stress and competition in other areas. Other shade-tolerant species, for instance, could likely outcompete species of lichen and bryophyte, were they not limited to other sites. Walker and Ballinger (2007) note that the collection of lichen species found at White Rocks is particularly unique, and that many species represent disjunct or previously undocumented specimens for that particular region. One of the most significant examples of this is the navel lichen (*Umbilicaria torrefacta*) which was documented at White Rocks, but known previously to only occur outside the southeastern US region in the Rocky Mountains and through Canada and Alaska (Walker and Ballinger 2007). Table 16 shows the complete list of disjunct species found at White Rocks and their origins. In addition to these disjunct species, three species of lichen found in the southeast US (*Hypotrachyna croceopustulata*, *Dirinaria aegialita*, and *Canoparmelia texana*) were found on the rock cliff face habitats, whereas before they were only known to exist on the bark of trees (Walker and Ballinger 2007).

Walker and Ballinger (2007) also point out that these cliff areas are generally protected from anthropogenic and natural disturbances, though areas along the cliff tops have already been impacted by trampling, possibly eliminating previously existing populations of silvery nailwort and Appalachian sandwort (*Minuartia glabra*), which is also listed as a Kentucky S1 species. In contrast to the cliff edges, Walker and Ballinger (2007) reports that the face and talus areas of the cliff are relatively pristine and unimpacted. As part of its management implications, Walker and Ballinger (2007) recommends continuing to restrict access to the cliff face at CUGA. The report notes evidence of previous illegal climbing activity on the cliffs. In addition, they recommend discontinuing unrestricted hiking at the cliff edge not only at White Rocks, but at all cliff systems in the park until vegetation surveys are performed for those areas. At Obed Wild and Scenic River, the report cites the construction of boardwalks and wooden platforms as a successful method of preventing access to the fragile cliff edges. These protective structures ultimately resulted in a recovery of previously impacted plant and lichen communities at that park unit.

Table 16. Geographically disjunct lichen species identified by Walker and Ballinger (2007) at White Rocks in CUGA.

Species		Original Distribution
Navel lichen	*Umbilicaria torrefacta*	Rocky Mountains, Canada, Alaska
Wyoming xanthoparmelia lichen	*Xanthoparmelia wyomingica*	Rocky Mountains
No common name	*Arctoparmelia centrifuga*	Arctic/boreal regions in NE US
No common name	*Arctoparmelia incurva*	Arctic/boreal regions in NE US
Rim lichen	*Lecanora rupicola*	Rocky Mountains
Cup lichen	*Cladonia pocillum*	NE US, Rocky Mountains

Artificial Wetland Community

Although several streamside bog wetland areas are present at CUGA, the only NPS-monitored wetland area located within CUGA is an artificial 1.0 acre mitigation site created near Little Yellow Creek in collaboration with the Federal Highway Administration (FHWA). This mitigation site was created in part to adhere to the FHWA's 2001 Strategic Plan and Performance Agreement that the agency will compensate for area of impacted wetlands by constructing wetland mitigation sites at a rate of 1.5 acres for every 1.0 acre impacted (FHWA 2001). The wetland at CUGA encompasses 0.5 acres and was constructed in response to wetland loss and degradation from the construction of the Cumberland Gap Tunnel (Petranka 2002). The constructed habitat is ideally intended to function as a forested hardwood floodplain that provides habitat for the four-toed salamander (*Hemidactylium scutatum*), wood frog (*Rana sylvatica*), spotted salamander (*Ambystoma maculatum*), in addition to other amphibians. Petranka (2005) notes that the mitigation wetland is particularly important for survival and reproduction of amphibian species, because small seasonal wetlands are generally rare throughout CUGA. After the construction of the mitigation site in 1998, annual assessments of several variables were used to gauge the success of wetland function starting in 2000. These variables included hydroperiod, focal species breeding success, and proportion of facultative or obligate wetland species.

Overall, the requirements for hydroperiod were met, and breeding amphibians successfully colonized and reproduced in the three holding ponds composing the mitigation site during all years of documented monitoring by Petranka (2000-2005). During these years, eleven species were observed breeding in the artificial wetland area, though that did not include the targeted four-toed salamander. Petranka (2005) predicts that the four-toed salamander may potentially colonize the site after canopy closure, since this species prefers habitat under mature, shaded forest canopies, though it is also possible this species was simply not detected. Petranka (2005) also notes that one regionally rare species—the eastern spadefoot toad (*Scaphiopus holbrooki*)—was noted in a single pond in 2004. The community did not meet the requirements for proportion of wetland obligate and facultative species (14% coverage), but instead mainly consisted of upland and facultative upland species (Petranka 2002). In fact, greater than 75% of the herbaceous coverage in the mitigation area was comprised by perennial ryegrass (*Lolium perenne*) and tall fescue (*Lolium arundinaceum*), both of which are remnant species from prior use as pastureland (Petranka 2005). In 10-15 years, Petranka (2005) predicts that the mitigation site will most likely undergo canopy closure, which would improve likelihood of colonization by the four-toed salamander.

Summary

Because there is no recommended protocol or ranking system in place for vegetation communities, we did not assign a ranking to this vital sign as it pertains to forest and wetland areas at CUGA (Table 17). Data collected by NatureServe and Walker and Ballinger (2007), as well as vegetation classifications performed by the CRMS provide a thorough baseline knowledge of vegetation resources at CUGA. As of this writing, the CUPN continues to work with NatureServe to develop a vegetation monitoring protocol for the network. This protocol will likely provide methods to evaluate condition objectives for vegetation communities within the park unit (T. Leibfreid personal communication).

Table 17. The condition status for vegetation communities at CUGA was not ranked and no trend was assigned. The data quality was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Vegetation Communities		✓	✓	✓
		3 of 3: Good		

Fish Communities

The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000), and contains multiple drainages with faunal assemblages noted for high endemism (Sheldon 1988). Cumberland Gap National Historical Park contains headwater streams from two of the Southeast's richest drainages in terms of fish species (Sheldon 1988). The park straddles the roughly east-west oriented ridge of Cumberland Mountain. North-slope streams flow into the Cumberland River drainage, and south-slope streams flow into the Powell River drainage of the Upper Tennessee River basin (Figure 36). Most park streams are located on the north slope, and all south slope streams are small first order flows. The park contains over 50 kilometers of surface flowing, high gradient streams with habitat suitable for a variety of species. Martin's Fork, a north-slope stream flowing eastward out of CUGA, is one of three primary headwater flows of the Cumberland River. Recent land acquisitions in the western portion of CUGA include the watershed surrounding the109-acre impoundment Fern Lake.

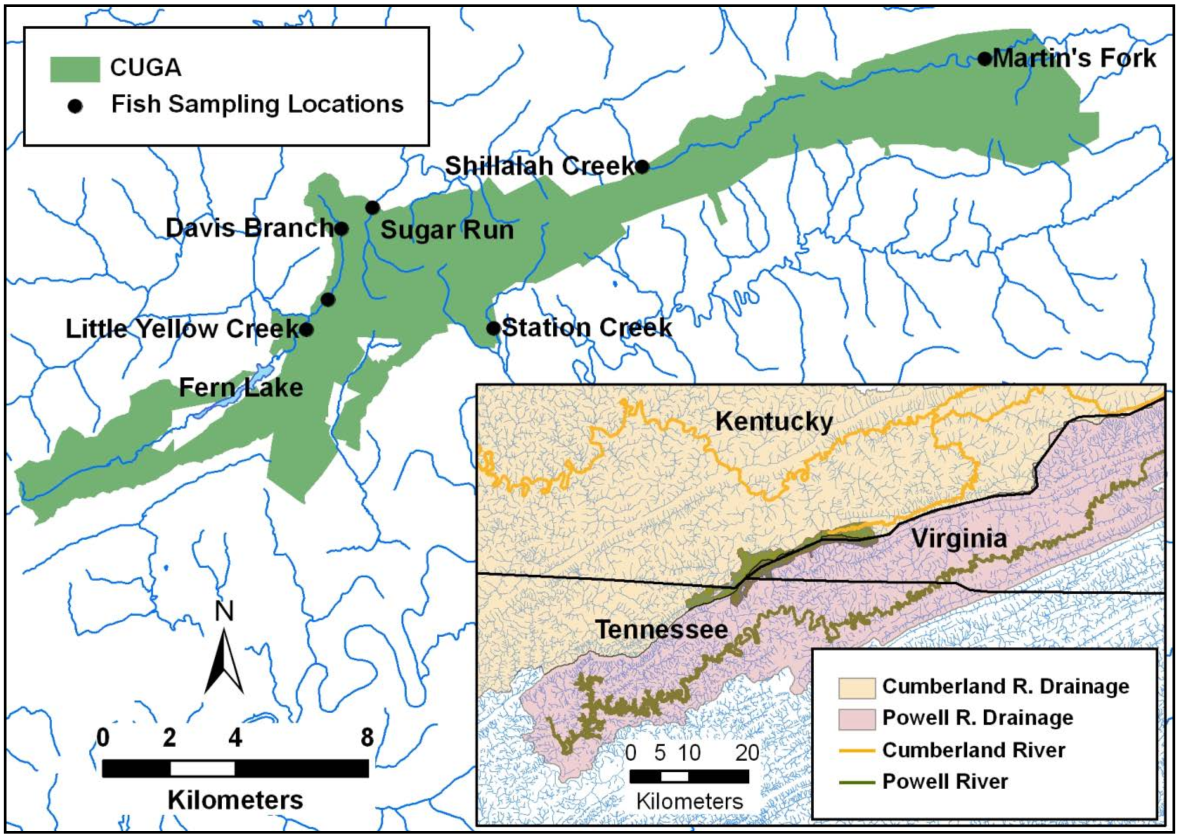


Figure 36. Streams in and around Cumberland Gap National Historical Park, showing locations of fish samples collected in 2004 by Remley (2005). Gap Creek is not shown because it was sampled in its subterranean section. Inset shows broader area, including portions of the Cumberland River watershed and the Powell River watershed (which is part of the Upper Tennessee River watershed).

Several survey efforts have reported 35 species of fishes from eight families in CUGA (Table 18). Barbour et al. (1979) sampled fish as part of a general vertebrate survey of the park. They sampled 12 locations, from eight park flows, using seine-netting, and reported 27 species from eight families (Barbour et al. 1979). In 1995, the Tennessee Department of Environment and Conservation (TDEC) conducted fish surveys of Little Lellow Creek in an area which was not then part of the park. This team used backpack electroshocking equipment and seining at four locations and reported eight species, including the federally threatened blackside dace (*Chrosomus cumberlandensis*, TDEC 1995). Beginning in 1990, Stephens (2002a, 2007) conducted frequent fish surveys in Davis Branch to monitor the status of the blackside dace. In 2002, he sampled seven locations on the creek using backpack electroshocking equipment, and reported 15 species (Stephens 2002a). In 2006 he sampled the same seven locations and reported 18 species (Stephens 2007). In spring of 2007, Stephens sampled Davis Branch upstream from previous sample locations and reported six species, of which blackside dace were the fourth most abundant species (Stephens 2007). From 1996 to 2002 Stephens (2002b) used backpack electroshocking to sample fish from Gap Creek near the southern border of the park and reported 15 species from four years of sampling (Stephens 2002b). Remley (2005) conducted a park-wide survey of CUGA streams in 2004. This effort sampled eight park flows and reported 22 species from five families (Remley 2005). Remley (2005) only sampled Gap Creek in a subterranean section of the flow. Fourteen species were common among surveys by all research teams listed above, and seven were reported only by Barbour et al. (1979). The NPSpecies online database for CUGA lists 25 fish species certified as present in CUGA (NPSpecies 2010), all of which were reported by Stephens (2002 a,b) and Remley (2005).

Differences in species assemblages are expected and have been observed between north-slope streams and south-slope streams in CUGA. The silverjaw minnow (*Ericymba buccata*), rosyface shiner (*Notropis rubellus*), blackside dace, and arrow darter (*Etheostoma sagitta*) have been reported only from north-slope, Cumberland River drainage flows in the park, and are not native to the south-slope Upper Tennessee River drainage flows (Warren et al. 2000). Stargazing minnow (*Phenacobius uranops*), and bigeye chubs (*Hybopsis amblops*) have only been reported from single sampling occasions on Gap Creek (Stephens 2002b) although they are reported to be native to both the Cumberland and Upper Tennessee drainages (Warren et al. 2002). The banded sculpin (*Cottus carolinae*) is also native to both drainages but has only been reported from Gap and Station Creeks, where it has been consistently reported in relatively high densities from survey efforts (Barbour et al. 1979, Warren et al. 2000, Stephens 2002b, Remley 2005). The Tennessee snubnose darter (*Etheostoma simoterum simoterum)*, reported only from Gap Creek (Stephens 2002b), is unique to the Tennessee River drainage; the related Cumberland snubnose darter (*Etheostoma s. atripinne*) has not been reported from the park.

Table 18. Family and species of fishes reported from fish sampling efforts by Barbour et al. (1979), Stephens (2002a,b; 2007), and Remley (2005) in Cumberland Gap National Historical Park.

Scientific Name	Common name	Barbour et al. 1979	Stephens 2002a,b; 2007	Remley 2005
Atherinopsidae				
Labidesthes sicculus	Brook silverside	X		
Catostomidae				
Catostomus commersoni	White sucker	X	X	X
Hypentelium nigricans	Northern hogsucker	X	X	X
Centrarchidae				
Ambloplites rupestris	Rock bass	X	X	X
*Lepomis auritus**	Redbreast sunfish		X	X
Lepomis cyanellus	Green sunfish		X	
Lepomis gulosus	Warmouth	X		X
Lepomis macrochirus	Bluegill	X	X	X
Lepomis megalotis	Longear sunfish	X		
Micropterus punctulatus	Spotted bass	X		X
Micropterus salmoides	Largemouth bass	X		X
Cottidae				
Cottus carolinae	Banded sculpin	X	X	X
Cyprinidae				
Campostoma anomalum	Central stoneroller	X	X	X
Chrosomus cumberlandensis	Blackside dace	X	X	X
Cyprinella galactura	Whitetail shiner	X		
*Cyprinus carpio**	Common carp	X		
Ericymba buccata	Silverjaw minnow	X		X
Hybopsis amblops	Bigeye chub		X	
Notropis chrysocephalus	Striped shiner	X	X	X
Notropis rubellus	Rosyface shiner			X
Phenacobius uranops†	Stargazing minnow		X	
Phoxinus erythrogaster	Southern redbelly dace	X	X	X
Pimephales notatus	Bluntnose minnow	X	X	X
Rhinichthys atratulus	Blacknose dace	X	X	X
Semotilus atromaculatus	Creek chub	X	X	X
Percidae				
Etheostoma blennioides	Greenside darter			X
Etheostoma caeruleum	Rainbow darter	X	X	X
Etheostoma flabellare	Fantail darter	X		X
Etheostoma kennicotti	Stripetail darter	X	X	X
Etheostoma sagitta	Arrow darter	X	X	
Etheostoma simoterum	TN snubnose darter		X	
*Perca flavescens**	Yellow perch	X		
Petromyzontidae				
Lampetra sp.	Lamprey	X		
Salmonidae				
*Oncorhynchus mykiss**†	Rainbow trout		X	
*Salvelinus fontinalis***	Brook trout	X		

* Non-native

** Native to Tennessee River drainages, but not the Cumberland River drainage

† Reported in Stephens 2002b from his previous collections, but not collected in 2002

The blackside dace, a federally threatened minnow (Federal Register 1987), was reported within current park boundaries from Davis Branch (Barbour et al. 1979, Stephens 2002a, Remley 2005), from Little Yellow Creek by TDEC (1995), and from Sugar Run downstream of park boundaries (Jenny Beeler personal communication). The collection from Little Yellow Creek occurred prior to park's recent acquisition of this property. Blackside dace are only native to the Cumberland River basin (Warren et al. 2000). They occupy pool habitats in small, canopied, relatively cool streams with relatively low riffle-area:pool-area ratios (Starnes and Starnes 1981). General threats to blackside dace populations include coal mining, timber harvesting, and land development (Starnes and Starnes 1981, Etnier and Starnes 1993, McAbee 2008). Since 1993, beavers have expanded into Davis Branch, reducing optimal blackside dace habitat by creating more pools with greater levels of silt deposition and potentially higher maximum water temperature (Stephens 2002a, 2007). Beaver activity has coincided with a reduction in observed numbers of dace (Stephens 2002a; 2007). Both Stephens (2002a, 2007) and Remley (2005) commented on the presence of beavers in the creek and stated that beaver activity was having a negative impact on blackside dace habitat. Surveys of Davis Branch in 2008 and 2009 failed to report blackside dace, and a single individual was found in June of 2010 (Jenny Beeler personal communication).

Salmonids have been introduced in the park, but were not reported during the 2004 survey (Remley 2005). The US Fish and Wildlife Service introduced brook trout (*Salvelinus fontinalis*) into Martin's Fork and Shillalah Creek in the 1960s, and the state of Kentucky expanded brook trout introductions in these flows in 1980-81 (KDFWR 2009c). Brook trout are not believed to be native to these headwaters of the Cumberland River, although they are native to the adjacent Upper Tennessee River drainage (Warren et al. 2000). The KDFWR verified brook trout in the county in the late 1980s and in 2001 (KDFWR 2009a). Both Martins Fork and Shillalah Creek were listed as wild brook trout water in 2008 fishing regulations (KDFWR 2009c). Remley (2005) did not report brook trout from these creeks and reported they were nearly devoid of fish. The apparent decline or extirpation of brook trout from these flows may result from high water acidity. Martins Fork and Shillalah Creek had the lowest pH among 10 streams monitored by the NPS (Figure 19), and Remley (2005) recorded pH values of 4.9 and 4.1, respectively for these streams. Brook trout are relatively acid tolerant, although sustained pH values less than 4.5 may cause lethal and sublethal effects (Dunson and Martin 1973; Dively et al. 1977). Another potential contributing factor to the decline of brook trout in Martins Fork and Shillalah Creek could be higher average stream temperatures in recent years. Mean annual temperatures for Martins Fork were higher, on average, for the 2003-2008 period than for the 1991-1995 period (Figure 19). Rainbow trout (*Onchoryhchus mykiss*), a non-native species, have not been introduced in the park, but have been placed in Gap Creek near park boundaries (Stephens 2002b). They were reported by Stephens (2002b) from sampling in 1996 and 2001 and were not sampled in 2002, though Stephens observed them in Gap Creek near park boundaries in 2002.

Several exotic fish species have been reported from CUGA. Rainbow trout have been discussed above, and their occurrence in the park is sporadic and results from introductions occurring on private land outside park boundaries (Stephens 2002b). Barbour et al. (1979) reported single observations of common carp (*Cyprinus carpio*) and yellow perch (*Perca flavescens*) from lower Little Yellow Creek. They noted that the yellow perch probably escaped from Fern Lake where the species had been introduced to support recreational fishing (Barbour et al. 1979). The common carp was also reported from a sampling station that included habitat outside the park, and was probably a rare upstream migrant (Barbour et al. 1979). Neither of these species has been reported in recent decades. Redbreast sunfish (*Lepomis auritus*) were not reported by Barbour et al. (1979), but were commonly reported from Davis Branch and Little Yellow Creek in more recent surveys (Stephens 2002a, Remley 2005, Stephens 2007). This species may have replaced the longear sunfish (*Lepomis megalotis*) and has probably been aided in its expansion by habitat alterations caused by beavers (Remley 2005). Redbrest sunfish occurred in all Davis Branch samples collected from 2002 onward, and were the only exotic species occurring in the samples collected by Stehpens (2002a, 2007) and Remley (2005).

Fish are good indicators of freshwater habitat quality. They are nearly ubiquitous in freshwater streams, occur in diverse communities including multiple trophic levels, are relatively easy to sample and identify, and are widely studied (Karr 1981). We used the Kentucky Index of Biotic Integrity (KIBI; Compton et al. 2003) to explore the quality of CUGA fish communities. The IBI approach to evaluating aquatic resources assesses fish assemblages based upon relative density and diversity of sampled populations, as well as the life history attributes and the ecological roles of community species (Karr 1981). Generally, good conditions are indicated when communities contain a diversity of trophic specialists, and relatively high proportions of specialists and sensitive species. The KIBI was developed for use in Kentucky wadeable and headwater streams, including the streams of the Cumberland River drainage (Compton et al. 2003). The Upper Tennessee River system flows found in the Virginia and Tennessee portions of the park are not part of the published application region of the KIBI. However, because the habitat is similar, and because all species found in the Upper Tennessee flows were included on the list of KIBI species, we felt that the index was robust to use on Station Creek and Gap Creek. We applied the KIBI to the individual site samples collected by Remley (2005), and to the individual site samples collected in Davis Branch and Gap Creek by Stephens (2002a, 2002b, 2007). We applied the KIBI to samples with catchments within the recommended size range of 5 - 777 km^2 (Compton et al. 2003). This precluded from analysis many of the samples collected in the park.

We found that KIBI scores varied from 43-62 for the samples evaluated, corresponding with quality interpretations from “fair” to “excellent” (Table 19). The sites on Davis Branch scored in the good or excellent categories for samples evaluated from 2002, 2005, and 2006. Despite the negative impact of beavers are having on blackside dace habitat, the general quality of Davis Branch fish communities, as indicated by KIBI scores, was good. A single site on Gap Creek was large enough to evaluate with the KIBI, and scored as good using the KIBI. Portions of Gap Creek flow through small communities on private land, and therefore do not enjoy the level of watershed protection of other CUGA streams. There are anecdotal reports of historical sewage pollution in the creek (Barbour et al. 1979) and some water is withdrawn from Gap Creek for bottling by a private company (Stephens 2002b). However, Stephens (2002b) suggested that the quality of the fish community in Gap Creek had improved since the Barbour et al. (1979) survey. Remley (2005) only sampled subterranean portions of Gap Creek, and did not report any fish from those sections. Little Yellow Creek scored in the good or excellent KIBI category. This stream’s watershed area places it within a “gray area” for KIBI interpretation, allowing it to be classified as either a headwater or a “wadeable” flow (Compton 2003). It has the largest watershed among CUGA streams and had the greatest species richness in the most recent survey

(Remley 2005). This creek is the source and outflow of Fern Lake. The watershed above the lake has been recently acquired by CUGA and current status of fishes there is not known. However, a population of blackside dace existed there in 1995 (TDEC 1995), and this reach has great potential value as a refuge for this threatened species. Excepting two creek chubs sampled from Shillalah Creek, Martin's Fork and Shillalah Creek did not contain fish populations in the recent survey (Remley 2005) and were not assessable using the KIBI. The high acidity of these flows may preclude viable fish communities. Station Creek and Sugar Run scored as fair on the KIBI and had lower richness than Little Yellow Creek, Davis Branch, or the surface flowing portions of Gap Creek.

Remley (2005) also evaluated seven of his fish sampling locations using an adapted physical habitat assessment protocol for wadeable streams (Barbour et al. 1999). He found that six of the seven sites met the ecoregional criteria to be categorized as "fully supporting" of biotic integrity (Table 19, KDOW 2002, Remley 2005). The only site not ranked in this category was on upper Davis Branch, which scored in the "not supporting" range, primarily because of habitat alterations caused by beavers (Remley 2005).

Table 19. Individuals sampled (N), species richness (S) with number native species in parentheses, Kentucky Index of Biotic Integrity (KIBI) score, and KIBI interpretation, for sampling efforts reported in three fish survey reports at Cumberland Gap National Historical Park (Stephens 2002a/b, Remley 2005, Stephens 2007). For Davis Branch 2002 samples, Station 1a was the most downstream site and Station 4 was the most upstream site (Stephens 2002a). For Gap Creek 2002 samples, Station 1 was the most upstream site and Station 4 was the most downstream site (Stephens 2002b). See text for description of survey efforts.

Study	Location	N	S	KIBI	Interpretation
Stephens 2007	Davis Branch headwaters	474	6(5)	N/A	
Stephens 2006	Davis Branch 2006 (Sta. 1a)	250	16(15)	53	Good
	Davis Branch 2006 (Sta. 1b)	193	14(13)	58	Excellent
	Davis Branch 2006 (Sta. 2)	348	14(13)	N/A	
	Davis Branch 2006 (Sta. 3)	258	11(10)	N/A	
	Davis Branch 2006 (Sta. 3a)	116	8(7)	N/A	
	Davis Branch 2006 (Sta. 4)	116	7(6)	N/A	
	Davis Branch 2006 (Sta. 4a)	138	6(5)	N/A	
Remley 2005	Davis Branch (upper)	351	9(8)	N/A	
	Davis Branch (lower)	452	13(12)	61	Excellent
	Little Yellow Creek	471	17(16)	48/61*	Good/Excellent
	Station Creek	460	4	43	Fair
	Sugar Run	210	5	46	Fair
	Martin's Fork	0	0	N/A	
	Shillalah Creek	2	1	N/A	
	Gap Creek	0	0	N/A	
Stephens 2002a	Davis Branch 2002 (Sta. 1a)	261	11(12)	55	Good
	Davis Branch 2002 (Sta. 1b)	246	9(10)	62	Excellent
	Davis Branch 2002 (Sta. 2)	166	11(10)	N/A	
	Davis Branch 2002 (Sta. 3)	375	7(6)	N/A	
	Davis Branch 2002 (Sta. 3a)	324	8(7)	N/A	
	Davis Branch 2002 (Sta. 4)	151	6(5)	N/A	
Stephens 2002b	Gap Creek 1996 (all sites)	590	11	N/A	
	Gap Creek 2000 (all sites)	1463	10	N/A	
	Gap Creek 2001 (all sites)	931	12	N/A	
	Gap Creek 2002 (Sta. 1)	0	0	N/A	
	Gap Creek 2002 (Sta. 2)	299	10	N/A	
	Gap Creek 2002 (Sta. 3)	213	9	N/A	
	Gap Creek 2002 (Sta. 4)	202	11	52	Good

* Sample catchment area places it within the “gray area” identified by the KIBI. Therefore sample was scored for both headwater stream and wadeable streams.

Table 20. Physical habitat scores calculated by Remley (2005) based upon Environmental Protection Agency bioassessment techniques (Barbour et al. 1999). Scores of 165 or greater indicate full support of biotic integrity for the region.

Location	Habitat Score
Davis Branch (upper)	122
Davis Branch (lower)	182
Little Yellow Creek	168
Station Creek	166
Sugar Run	165
Martin's Fork	175
Shillalah Creek	172
Gap Creek	N/A

We ranked the condition of fish communities at Cumberland Gap National Historical Site as good (Table 21). The park provides protection for headwater streams feeding into two major drainages. Endemic species with small native ranges have been reported from both drainages within the park (Table 18). An index of biotic integrity applied to fish samples taken from CUGA showed that park flows had fish assemblages indicative of fair, good, and excellent habitat (Table 19). Little Yellow Creek and Davis Branch, the largest park streams with the richest fish assemblages, had IBI scores indicative of high quality habitat (Table 19). Habitat assessments taken from fish sampling points indicated that the park contains physical macrohabitat suitable for a diversity of fish species (Table 20). There were several issues potentially affecting the quality of CUGA fish habitat. Beavers in Davis Branch were altering the habitat of the stream and negatively impacting the habitat of the federally threatened blackside dace. Blackside dace had declined in abundance because of these alterations. Two high-elevation coldwater streams in the park, Martin's Fork and Shillalah Creek, exhibit high acidity. We assigned a trend of stable to the CUGA fish community. The assemblages reported from a general fish survey in 2004, were similar to those reported from a survey conducted in 1978-79 (Barbour et al. 1979, Remley 2005). The data used to make the assessment were good.

Table 21. The quality of fish communities at Cumberland Gap National Historical Park was good. The trend of fish condition was stable. The data used to make the ranking was good.

		Data Quality		
Attribute	Condition & Trend	Thematic	Spatial	Temporal
Fish Community		✓	✓	✓
		3 of 3: Good		

Bird Communities

Birds specialize in a variety of habitats and are relatively easy to monitor, making them valuable indicators of terrestrial ecosystem quality and function (Maurer 1993). Cumberland Gap National Historical Park provides breeding and nesting habitat for interior forest species, and is an important flyway for migrating birds. The publically available park bird checklist included 159 species reported to occur, at least occasionally, in the park (NPS 2007). Although we discuss results of multiple bird-surveying efforts in CUGA, and considered alternate sources for determining a trend, we primarily used data from the 2003-2004 survey to determine our condition ranking (Monroe 2005).

There have been several bird sampling efforts at CUGA. Barbour et al. (1979) conducted bird counts as part of a wider vertebrate survey of CUGA. This team sampled during the breeding season by walking park trails and noting all birds heard or seen, reporting 87 species from CUGA (Barbour et al. 1979). Monroe (2005) conducted a comprehensive bird survey in the park during 2003-2004. Sampling included breeding season point counts at 49 locations throughout the park, driving and walking surveys during winter spring and fall, and fall raptor observations from a high elevation overlook (Monroe 2005). Monroe (2005) reported 145 bird species on or in close proximity to the park, including 63 breeding season species, at CUGA (Appendix B). A small portion of a Breeding Bird Survey route also intersects the park (Sauer 2008). The BBS is a long-term bird monitoring program, overseen by the USGS, in which volunteer surveyors drive set routes during the breeding season and conduct point counts at 0.5-mile intervals. The first 10 stops of the Cumberland Gap route, sampled sporadically since 1966, were located in or very near the borders of CUGA. Since the inception of this route, 85 bird species have been reported from it.

Cumberland Gap contains a number of birds of potential management concern (Table 22). Of the 145 species reported by Monroe (2005), 20 were listed by at least one of the three CUGA states as threatened, endangered, or of special concern (TNHP 2009, VDGIF 2009, KSNPC 2011). In the last 10 years, to be eligible for certain wildlife management funds, states were required to develop Comprehensive Wildlife Conservation Strategies (CWCS) indicating species of greatest conservation concern (CWCS 2005). Thirty-nine bird species were included on at least one of the three CUGA state's CWCS as species of priority conservation concern (KDFWR 2010, TWRA 2005, VDGIF 2005). Partners in Flight (PIF), an organization of cooperating federal, state, academic, and NGO partners, uses available data to create conservation scores for North American birds (Panjabi et al. 2005). These scores indicate the level of perceived threats to persistence of individual species at regional and national levels (Panjabi et al. 2005). Nuttle et al. (2003) used regional PIF scores to create a ranking of conservation importance with four being the highest-priority rank. Nine birds from the CUGA 2003-2004 survey had PIF-based ranks of four (Nuttle et al. 2003, Panjabi et al. 2005). The park harbors several high-elevation specialist bird species and several species near the edge of their geographic range (Monroe 2005).

Table 22. Birds of conservation concern reported from CUGA during a 2003-2004 survey (Monroe 2005). Shown are listings by individual states as threatened (T), endangered (E), special concern (S), or deemed in need of management (D; TN equivalent of special concern), indication of species with PIF-based conservation ranks of four, and inclusion on each state's Comprehensive Wildlife Conservation Strategy (CWCS) as birds of conservation concern.

Scientific Name	Common Name	KY List	VA List	TN List	PIF 4	CWCS
Accipiter striatus	Sharp-shinned Hawk			D		KY,TH
Ardea herodias	Great Blue Heron	S				
Bonasa umbellus	Ruffed Grouse				X	
Caprimulgus carolinensis	Chuck-will's-widow					TN
Caprimulgus vociferus	Whip-poor-will					TN
Carpodacus purpureus	Purple Finch		S			
Catharus guttatus	Hermit Thrush		S			
Certhia americana	Brown Creeper	E	S			KY,TN
Circus cyaneus	Northern Harrier	T	S	D		KY,TN,VA
Coccyzus americanus	Yellow-billed Cuckoo					TN
Contopus cooperi	Olive-sided Flycatcher			D	X	TN
Contopus virens	Eastern Wood-Pewee					TN
Corvus corax	Common Raven	T		T		KY,TN
Dendroica caerulescens	Black-throated Blue Warbler					TN
Dendroica cerulea	Cerulean Warbler		S	D	X	KY,TN,VA
Dendroica discolor	Prairie Warbler					KY,TN
Dendroica dominica	Yellow-throated Warbler					TN
Dendroica fusca	Blackburnian Warbler	T				KY
Dendroica magnolia	Magnolia Warbler		S			
Empidonax minimus	Least Flycatcher	E				TN
Empidonax virescens	Acadian Flycatcher					KY,TN
Falco peregrinus	Peregrine Falcon	E	S	E	X	KY,TN,VA
Haliaeetus leucocephalus	Bald Eagle	T	T	D		KY,TN,VA
Helmitheros vermivorus	Worm-eating Warbler					KY,TN
Hylocichla mustelina	Wood Thrush					KY,TN
Icterus spurius	Orchard Oriole					TN
Junco hyemalis	Dark-eyed Junco	S				
Limnothlypis swainsonii	Swainson's Warbler		S	D	X	KY,TN,VA
Melanerpes erythrocephalus	Red-headed Woodpecker				X	KY,TN
Oporornis formosus	Kentucky Warbler					KY,TN
Pandion haliaetus	Osprey	S				KY
Parula americana	Northern Parula					TN
Pheucticus ludovicianus	Rose-breasted Grosbeak	S				KY,TN
Poecile atricapillus	Black-capped Chickadee			D		
Regulus satrapa	Golden-crowned Kinglet		S			TN
Scolopax minor	American Woodcock					KY,TN
Seiurus motacilla	Louisiana Waterthrush				X	KY,TN
Sitta canadensis	Red-breasted Nuthatch	E	S			KY,TN
Sphyrapicus varius	Yellow-bellied Sapsucker			D		TN,VA
Troglodytes troglodytes	Winter Wren					TN,VA
Vermivora chrysoptera	Golden-winged Warbler	T	S	D	X	KY,TN,VA
Vermivora pinus	Blue-winged Warbler				X	KY,TN
Vireo flavifrons	Yellow-throated Vireo					TN
Vireo griseus	White-eyed Vireo					TN
Wilsonia canadensis	Canada Warbler	S				KY
Wilsonia citrina	Hooded Warbler					KY,TN

Several general plans have been prepared to address bird management in the region containing CUGA. Watson (2005) prepared an Avian Conservation Implementation Plan (ACIP) for CUGA, and a larger-scale regional bird conservation plan has been prepared by PIF (Rosenberg

2003). Birds of management concern for the park include the Cerulean Warbler, the Worm-Eating Warbler, and the Wood Thrush for forest interior species, the Golden-Winged Warbler and the Prairie Warbler for early successional scrub species, and the Louisiana Waterthrush for forest riparian species (Rosenberg 2003). All of these species occurred in the most recent bird survey (Monroe 2005).

Based on recent inventory efforts (Monroe 2005), forest interior species such as Ovenbirds, Red-eyed Vireos, tanagers, etc. were the most commonly observed species both during the breeding season and migration. Conversely, waterfowl, with the exception of flyovers, and grassland species were virtually absent due to a lack of habitat (Monroe 2005). Five Cerulean Warblers (*Dendroica cerulea*) were reported, three during breeding season point counts (Monroe 2005). Cerulean Warblers are declining throughout much of their range and are especially sensitive to landscape level habitat changes (Rosenberg 2003 Hamel 2000). They are canopy foragers that specialize in large tracts of tall, mature, mixed hardwoods with scattered openings, especially preferring stream valleys (Hamel 2000). They may seek out the most mature forest available in the region for breeding purposes (Rosenberg 2003). In the Mid-Atlantic region of the U.S., Cerulean Warblers may require at least 700 hectares of habitat to maintain a breeding population (Hamel 2000). Forty-two Wood Thrushes (*Hylocichla mustelina*) were reported during breeding season point counts in the 2003-2004 survey (Monroe 2005). This interior forest species has been well-studied and has declined in abundance over much of its range since the 1970s (Roth et al. 1996). Although it also nests near edges and in small forest patches, it shows a marked preference for the interior of mature, mixed hardwood forests (Roth et al. 1996). The Wood Thrush is vulnerable to nest predation and nest parasitism, and experiences lower nest success in smaller fragments (Roth et al. 1996). Fourteen Worm-eating Warblers (*Helmitheros vermivorum*) were sampled during breeding season point counts (Monroe 2005). Though populations may be stabilizing now, this species declined in abundance over three decades (Rosenberg 2000). The Cumberland Plateau is a significant breeding area for this warbler. This species is a ground nester preferring mature, deciduous, forested slopes with a dense shrub layer and requires large tracts for successful breeding (Hanners and Patton 1998).

Riparian and early successional specialist species were reported less commonly than forest species in the 2003-2004 survey (Monroe 2005). Three Louisiana Waterthrushes (*Seiurus motacilla*) were sampled in the park, two during breeding season point counts. This species nests in hardwood canopied riparian zones (Mattsson et al. 2009). It prefers low order, high gradient flows with robust macroinvertebrate communities (Mattsson et al. 2009). A single Golden-winged Warbler (*Vermifora chrysoptera*) and a single Prairie Warbler (*Dendroica discolor*) were sampled during migratory periods, and not noted in breeding season efforts (Monroe 2005). Evidence suggests that both species have been rare in the park for decades. Barbour et al. (1979) did not report Golden-winged warblers during his survey, but offered second-hand reports of breeding season individuals from 1968 and 1969. He stated that the habitat where the species were noted in 1969 had matured out of preferred condition by the time of his survey (Barbour et al. 1979). Barbour et al. (1979) reported a single nesting pair of Prairie Warblers. Northern Bobwhites (*Colinus virginianus*), another early successional habitat specialist species, were not seen in the recent survey and were rare in the Barbour et al. (1979) survey. These findings are not surprising because early successional habitat is rare in Cumberland Gap National Historical Park.

We used an index of biotic integrity to explore the condition of the CUGA bird community and park bird habitat. Bird community assemblage data can be used to assess ecological integrity and level of anthropogenic habitat disturbance (Bradford et al. 1998, Canterberry et al. 2000, O'Connell et al. 2000). O'Connell et al. (1998) developed a breeding bird community index (BCI) for the region of the eastern U.S. containing Cumberland Gap National Historical Park. To apply this BCI, bird species are grouped into guilds based upon breeding season life history traits, and the relative proportions of species in each guild are used to create overall scores ranging from 20 (low integrity) to 77 (highest integrity, O'Connell 1998). The index was developed in reference to undisturbed habitats. Higher scores result when disturbance-sensitive species and species with forest-specialist life history traits are more commonly present in a bird list relative to nest parasite, nest predator, urban-tolerant, and exotic species (O'Connell 1998).

We applied the regional bird community index to the 2003-2004 CUGA baseline point count data. During this CUGA survey, each plot was sampled a single time (Monroe 2005). We applied the BCI to individual point counts to explore the relationship among individual plots and to assess relative quality of bird habitat across the park (Figure 37a). The mean score of all individual point counts from the survey was 59.7 (SD±8.0), corresponding to an interpretation of "high integrity" (O'Connell et al. 1998). The BCI was developed using species lists compiled from sets of five 10-minute, unlimited radius point counts spaced along 1-km transects (O'Connell et al. 1998). To more closely match these methods, and to provide more independently interpretable scores, we applied the BCI to 5-count bird lists compiled from each plot and its four nearest neighbors (Figure 37b). Some adjacent plots had identical 5-plot lists and there were 36 unique lists among the 49 plots. The mean of all the 5-plot BCI scores across the 49 plots was 61.6 (SD±5.5), corresponding to an interpretation of "highest integrity" for the park. Generally, the BCI scores indicated that CUGA had high quality forest bird communities and habitat, relative to reference sites across the Mid-Atlantic region. This resulted because the CUGA sample contained a greater proportion of interior forest specialists and disturbance-sensitive species relative to exotic, urban-tolerant, and nest-disrupting species.

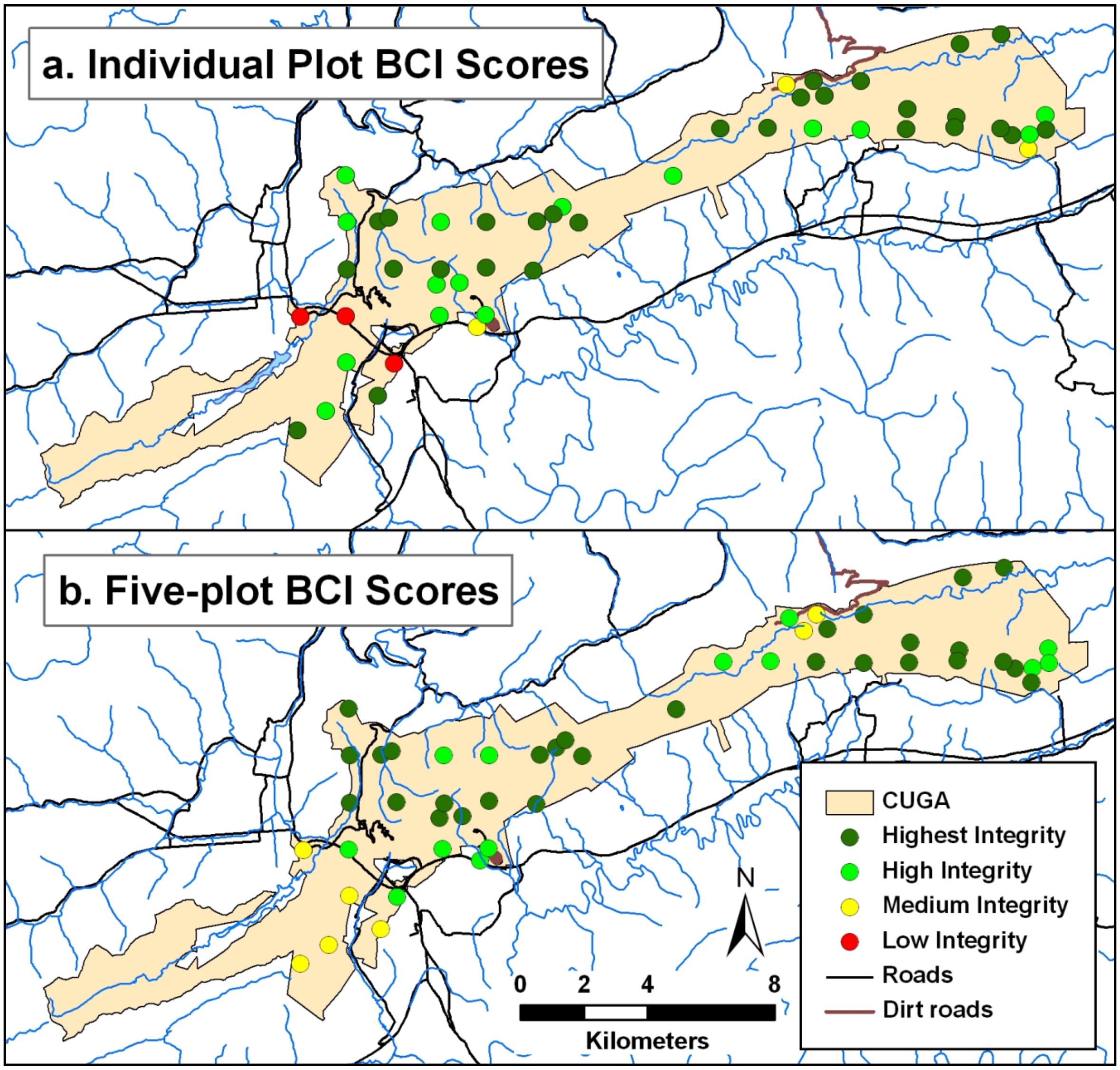


Figure 37. Bird Community Index (BCI) scores for 49 individual point count bird lists (top figure) and for five-count bird lists (bottom figure), for bird counts taken during a 2003-2004 survey at Cumberland Gap National Historical Park (Monroe 2005).

To explore the CUGA breeding bird community in a broader regional context, we used the BCI to compare BBS data collected in the park to data collected in the surrounding region. Breeding Bird Survey routes were sampled once a year, in June, using 3-minute point-count observations at 0.80-km intervals along the length of each 40-km route, for a total of 50 counts per route (Sauer et al. 2008). O'Connell et al. (2007) found that 10-stop sub-samples of BBS data were useful in applying the BCI to indicate relative differences in habitat disturbance across broad landscape scales. Consecutive 10-stop BBS data summaries were available for download from the BBS website (Sauer et al. 2008). Eight of the first 10 stops on the Cumberland Gap BBS route were located in CUGA; the first and tenth stops were located adjacent to park boundaries (Sauer et al. 2008). Therefore, the BBS Cumberland Gap 0-10 stop sub-sample represented a park bird sample that was suitable for comparison with identically-collected data from the broader region. We selected active BBS routes within 100 km of CUGA and calculated the BCI score for 0-10 stop data collected in the last 10 years. We found nine routes within the 100 km radius suitable for comparison to the Cumberland Gap BBS route. Cumberland Gap data resulted in the highest BCI score among the 10 routes in eight of the 10 years analyzed (Figure 38). The mean BCI score for the CUGA route over the 10-year period was 55.1 (SD±2.4) which was higher than any of the mean scores for the comparison routes. This indicated that bird samples collected in CUGA generally contained a greater proportion of forest specialists than similarly-collected samples from the region within 100 km of the park.

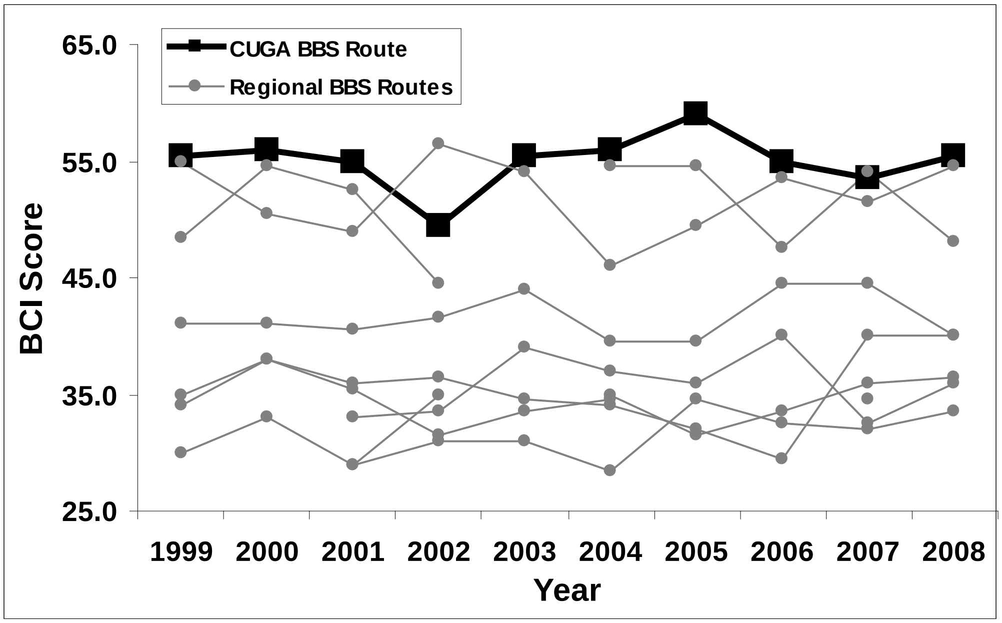


Figure 38. Bird Community Index scores (O'Connell et al. 1998) for 0-10 stop BBS data collected from Cumberland Gap (bold series) and for nine other BBS routes within 100 km of Cumberland Gap National Historical Park over a 10-year period (Sauer et al. 2008).

We further explored the BBS 10-stop data described above using a "conservation value index". This index is designed to give a greater relative score to samples whose composition is more heavily weighted toward species that face greater threats (Nuttle et al. 2003). We used a ranking system designed by Nuttle et al. (2003) and based upon regional PIF scores (Panjabi et al. 2005). For each sample, we calculated the rank for each species, with "0" representing exotic species and "4" representing species facing the greatest threats to persistence (Nuttle et al. 2003). We multiplied each species rank by the sample relative abundance of the species, and the index was the sample composite of this value (Nuttle et al. 2003). The Cumberland Gap sample scored highest among the 10 samples for five of the 10 years, and scored second or third highest for each of the other five years (Figure 39). This suggested that CUGA contained a relatively high proportion of birds that managers and natural resource professionals have identified as targets of conservation concern.

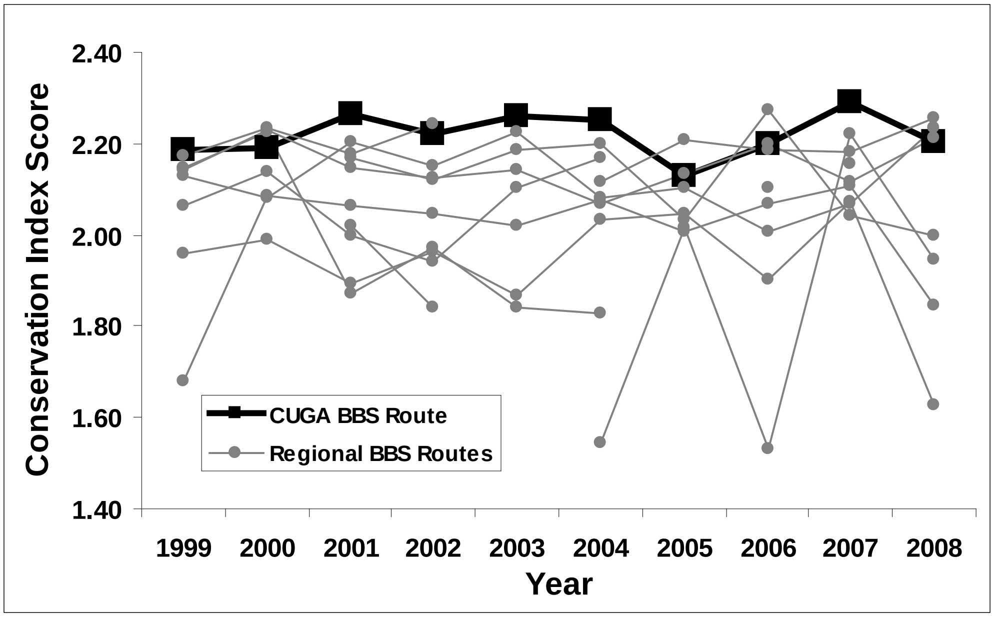


Figure 39. Conservation value index scores (Nuttle et al. 2003) for 0-10 stop BBS data collected from Cumberland Gap (bold series) and for nine other BBS routes within 100 km of Cumberland Gap National Historical Park over a 10-year period (Sauer et al. 2008).

We used park-wide survey data from two bird survey efforts to explore changes in the CUGA bird community over time. Because of disparities in type and amount of effort between the Barbour et al. (1979) survey and the Monroe (2005) survey, quantitative comparisons of the studies were not possible. Qualitatively, the samples were similar. Barbour et al. (1979) reported five species not reported by Monroe (2005). Four of these—the Grasshopper Sparrow (*Ammodramus savannarum*), Northern Bobwhite, Common Nighthawk (*Chordeiles minor*), and Green Heron (*Butorides virescens*)—prefer habitat not common in CUGA and their absence from the Monroe (2005) survey is unremarkable. Conversely, Monroe (2005) reported 61 species not reported by Barbour et al. (1979), but used greater sampling effort over all seasons. Barbour et al. (1979) stated that Bachman's Sparrows (*Aimophila aestivalis*), and Red-cockaded Woodpeckers (*Picoides borealis*) had been reported from the park since 1969, but did not find these species in 1978-1979. Both of these species have experienced significant range contractions in recent decades and neither is expected to occur in the region (Jackson 1994, Dunning 2006).

We found the condition of the bird community at Cumberland Gap National Historical Park to be excellent (Table 23). About one third of the bird species reported from the park in the most recent bird survey were identified by states or NGOs as species with some level of conservation priority (Table 22). Park point count data used in a Bird Community Index (O'Connell et al. 1998) indicated that the CUGA bird habitat was, on average, of the "highest integrity" relative to reference sites used to develop the index (Figure 37). A comparison of BBS data collected in the park with identically-collected BBS data from the surrounding region suggested that forest bird habitat in CUGA was generally less disturbed and hosted a greater proportion of mature forest specialist species than did sites within 100 km of the park (Figure 38). Similarly, comparisons of a conservation value index among CUGA and regional BBS data indicated that the park breeding bird population consisted of a greater proportion of threatened birds than did the surrounding habitat (Figure 39). Threats to birds include the loss of some of the hemlock habitat in the park. Hemlock wooly adelgid occurs in the park, and will result in the death of some hemlocks despite ongoing efforts to mitigate the pest (Jenny Beeler personal communication). Species specifically adapted to this habitat may decline in abundance in the future.

We found the trend of bird populations at CUGA to be stable (Table 23). Monroe (2005) observed a similar population to that observed by Barbour et al. (1979) over two decades previously. We found that the BCI for 0-10 stop BBS data from the park was stable over a 10-year period (Figure 38).

Table 23. The condition of the bird community at Cumberland Gap National Historical Park was excellent. The trend of bird community condition was stable. The quality of the data used to make the condition assessment was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Bird Community		✓	✓	✓
		3 of 3: Good		

The apparent high quality of the bird community reported from Cumberland Gap National Historical Park is consistent with expectations for a large, protected hardwood forest. The increase in richness and density of BBS sample data is interesting and worthy of further study to determine if this trend is observable in the park generally. We recommend that future bird surveys be conducted using standardized point count methods at set plots, similar to the methods used by Monroe (2005). Ideally, the same points utilized by Monroe (2005) should be re-sampled where feasible, allowing the results from Monroe to serve as baseline for future efforts.

Mammal Communities

Two comprehensive mammal surveys have been conducted at Cumberland Gap National Historical Site. Barbour et al. (1979) conducted mammal surveys between the autumns of 1977 and 1979 documenting 36 species. This effort included around 6140 trap nights using standard mouse and rat traps, an unreported number of trap nights using around 70 “beer can” pit traps, intermittent use of several mole traps and small live traps, and mist-netting at the mouths of selected caves (Barbour et al. 1979). Other mammal records resulted from incidental sightings, from tracks and scat observations, from skeletal remains, and from road-killed specimens (Barbour et al. 1979). Barbour et al. (1979) further reported that the park was “plagued with numerous free ranging dogs and abandoned pets”. Gumbert et al. (2006) conducted a comprehensive mammal survey during 2005 and 2006 documenting 40 species. This effort included sampling at 24 sites (Figure 40) with 11,348 combined trap nights using Museum Special snap traps, Sherman live traps, Tomahawk box traps, pitfall cup traps, drift fence bucket pitfall traps, and mole traps (Gumbert et al. 2006). Bats were sampled during 27 nights using mist nets or harp nets and also with Anabat II bat detectors (Gumbert et al. 2006). Further mammal records resulted from 213 nights with automatic trail cameras, and from visual observations of animals or sign (Gumbert et al. 2006). Combined, these surveys have verified 43 species of mammals within CUGA, including 9 bats and 34 non-volant species.

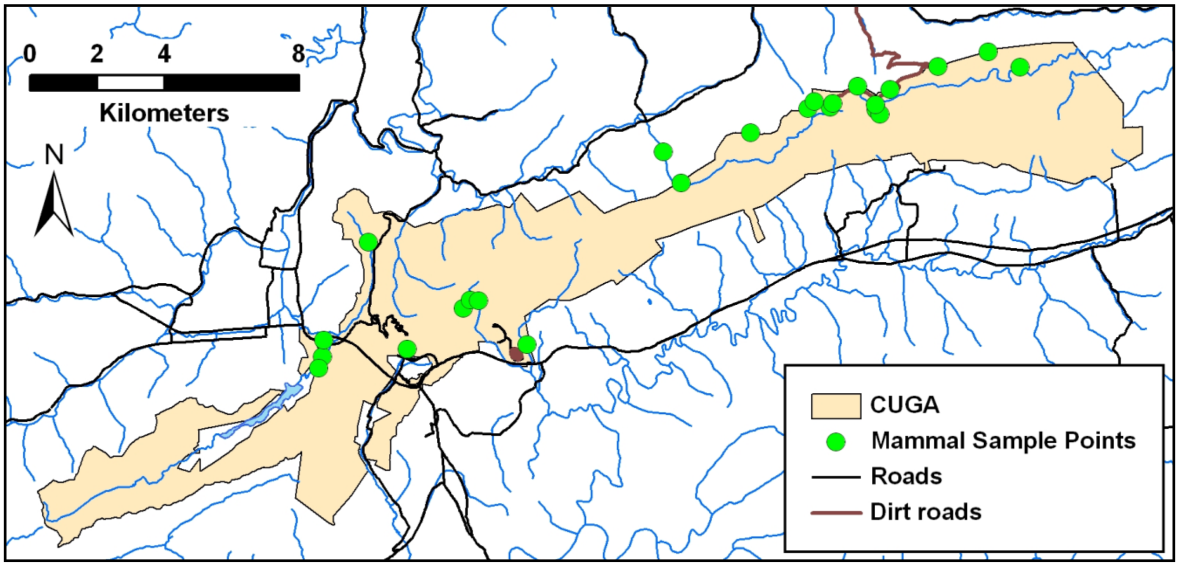


Figure 40. Points sampled for mammals in the most recent CUGA mammal survey conducted by Gumbert et al. (2006).

The findings from these two mammal surveys indicate an ecologically diverse native mammal community including habitat specialists and generalists from all trophic levels. Eight carnivore species have been documented at CUGA. Of these, three species are obligate or near-obligate carnivores, and five species are significantly omnivorous (Trani et al. 2007). Since the extirpation of large apex mammalian predators, smaller carnivores fill the role of apex predators in many communities (Roemer 2009). Although the evolving ecological role of these "mesocarnivores" is poorly understood, there is evidence of classic top-down trophic effects when members of this guild are excluded or removed (Roemer 2009). Barbour et al. (1979) reported that bears were rare transients in the park, but Gumbert et al. (2006) found that bears were common in high-elevation areas.

Nine species of bats, including the federally endangered Indiana bat (*Myotis sodalis*), have been documented at CUGA. Of these, at least six species are probably full-year residents. Most of these species may use caves as roosts or hibernacula. The documented bat species exhibit a range of insectivore foraging behaviors including foraging above the forest canopy, below the canopy, along edges, riparian zones, and in open spaces (Trani et al. 2007). Twenty-two species of shrews and rodents, of which one is exotic, have been documented at CUGA. This group of "small mammals" consists of a diversity of habitat specialists and generalists including at least nine species that are near the southern extent of their range or are Appalachian specialists (Trani et al. 2007). Preferred habitats range from early successional to mature, high-elevation, hardwood forests (Trani et al. 2007). Diets include obligate insectivores, seed and mast eaters, herbivores, fungivores, and extreme generalists (Trani et al. 2009).

Exotic and range expanding mammal species were rare in the park. Feral hogs (*Sus scrofa*), house mouse (*Mus musculus*), and Norway rats (*rattus norvegicus*) were not seen during the most recent survey. Feral hogs have been expanding their range in North America, and a population has existed approximately 70-100 km west of the park for over 20 years (Gipson et al. 1998, SCWDS 2004). The house mouse is a peridomestic exotic species that was sampled in the1979 survey near human structures in the park (Barbour et al. 1979). Although it may still occur in the park, its rarity is not surprising given the lack of human development. The Norway rat is also a peridomestic exotic pest and has never been documented in the park. Barbour et al. (1979) mentions dogs and abandoned pets in the park, but gives no further explanation. Although feral or free-ranging domestic pets were not noted in the most recent survey, they occur in the park and sometimes cause wildlife damage issues. Feral cats have depredated summer roosting bats in Gap Cave on more than one occasion (Jenny Beeler personal communication). Coyotes (*Canis latrans*) were not seen during the 1979 survey, but were noted in the 2006 survey. This may result from recent expansion into the park, or the species may have been missed in the 1979 survey. Coyotes were introduced in Tazewell, Virginia as early as 1952, and there have probably been unrecorded introductions in the region as well (Hill et al. 1987). Coyotes are native to North America and their continuing range expansion may be partially into ecological niches left un-filled following the extirpation of native apex predators.

Table 24. Mammals reported in Cumberland Gap National Historical Site by Barbour et al. (1979) and Gumbert et al. (2006). Shown are official listings as threatened (T), endangered (E), special concern (S), candidate species (C), or deemed in need of management (D) by the federal government (F), Kentucky (K), Tennessee (T), or Virginia (V), and inclusion as a priority concern species on each state's comprehensive wildlife conservation strategy (CWCS).

Scientific Name	**Common Name**	**Barbour et al. 1979**	**Gumbert et al. 2006**	**Listing**	**CWCS**
Blarina brevicauda	short-tailed shrew	X	X		
Canis latrans	coyote		X		
Castor canadensis	beaver		X		
Clethrionomys gapperi (maurus)	red-backed vole	X	X	S(K)	K
Cryptotis parva	least shrew		X		
Didelphis virginiana	Virginia opossum	X	X		
Eptesicus fuscus	big brown bat	X	X		
Glaucomys volans	southern flying squirrel	X	X		
Lasionycteris noctivagans	silver-haired bat	X	X		
Lasiurus borealis	eastern red bat	X	X		
Lasiurus cinereus	hoary bat		X		
Lynx rufus	bobcat	X	X		
Marmota monax	woodchuck	X	X		
Mephistes mephistes	striped skunk	X	X		
Microtus pinetorum	pine vole	X	X		
Mus musculus	house mouse	X			
Mustela vison	mink	X			
Myotis leibii	eastern small-footed bat	X	X	T(K)	K,T,V
Myotis lucifugus	little brown bat	X	X		
Myotis septentrionalis	northern bat	X	X		
Myotis sodalis	Indiana bat	X	X	E(F,K,T,V)	K,T,V
Napaeozapus insignis	woodland jumping mouse	X	X		T
Netotoma magister	Allegheny woodrat	X	X	D(T)	K,T
Ochrotomys nuttalli	golden mouse	X	X		T
Odocoileus virginianus	white-tailed deer	X	X		
Ondatra zibethicus	muskrat		X		
Parascalops breweri	hairy-tailed mole	X	X		T
Peromyscus leucopus	white-footed mouse	X	X		
P. maniculatus nubiterrae	cloudland deer mouse	X	X		
Pipistrellus subflavus	eastern pipistrelle	X	X		
Procyon lotor	raccoon	X	X		
Scalopus aquaticus	eastern mole	X			
Sciurus carolinensis	gray squirrel	X	X		
Sigmodon hispidus	hispid cotton rat	X	X		
Sorex cinereus	masked shrew		X	S(K)	K,T
Sorex fumeus	smoky shrew	X	X		T
Sorex hoyi	pygmy shrew		X		T
Spilogale putorius	eastern spotted skunk	X	X	S(K)	K,T
Sylvilagus floridanus	eastern cottontail	X	X		
Synaptomys cooperi	southern bog lemming	X	X		T
Tamias striatus	eastern chipmunk	X	X		
Urocyon cinereoargenteus	gray fox	X	X		
Ursus americanus	black bear	X	X	S(K)	K

We compared the species list of shrews and native mice and rats from the most recent survey (Gumbert et al. 2006) with species lists from other southeastern Appalachian and Kentucky mammal studies conducted across a variety of habitats using similar methods. The CUGA survey resulted in a greater number of species overall, and an equal or greater number of shrews and native rats, mice, and voles (Table 25). Among CUPN parks, CUGA had the greatest number of confirmed and probably present mammals (Moore 2010). These findings are not suitable for rigorous statistical comparisons because of disparities in sampling effort and differences in location. Nevertheless, they suggest that the CUGA mammal community is diverse relative to communities found in other forest habitats in the broad region.

Table 25. Summary of trapping result for shrews, and native rats, mice, and voles for four studies in Kentucky and in the south and central Appalachian Mountains showing total species by category and number of species unique among the studies.

	Gumbert et al. 2006	Mitchell et al. 1997	Menzel et al. 1999	Thomas 2012
Location	Cumberland Gap National Historical Park, eastern Kentucky	George Washington National Forest, northern Virginia	Nantahala National Forest, western North Carolina	Mammoth Cave National Park, western-central Kentucky
Habitat	All types including fields, wetlands, forests	Gradient from recent clearcut to climax hardwood forest	Gradient from wildlife openings to deep forest	All types including fields, wetlands, forests
Effort	11,348 trap nights including snap, Sherman, box, and pitfalls	12,600 trap days using drift fence pitfall arrays	12,000 trap nights using live traps and pitfall traps	117,121 trap nights using live traps, pitfalls, and drift fence pitfall arrays
Total Species	14	11	7	12
Shrew Species	5	5	2	5
Native Rats/mice/voles	9	6	5	7
Unique Species	3	2	0	4

We compared native species observed in the most recent mammal inventory (Gumbert et al. 2006) to native species expected for various components of the reported mammal assemblages (Table 26). Gumbert el al. (2006) used previous work and a variety of literature sources to prepare a list of 60 mammal species that could be expected to occur in the park. Because the purpose of our comparisons was to explore quality, we removed exotic and range expanding species from all lists to avoid artificially inflating the "good" observed richness or the "ideal" expected richness. Around 70% of the overall expected native mammal assemblage was reported from CUGA (Table 26). Many of the expected species not found, such as the fox squirrel, red fox, meadow vole, and river otter, were considered rare, had limited ranges, were cryptic, or had limited preferred habitat available (Gumbert et al. 2006, Trani et al. 2007). The least represented group examined was the carnivores with six of 11 (55%) expected species reported. Of the five species missing, long-tailed weasel (*Mustela frenata*), the least weasel (*Mustela nivalis*), and the mink (*Mustela vison*) were considered rare or highly cryptic (Gumbert et al. 2006, Linehan et al. 2008). River otters (*Lontra canadensis*) have been re-introduced into the region, but the primarily small headwater streams found in the park may not be attractive habitat to this mammal. Of the four missing insectivores, the southeastern shrew (*Sorex longirostris*), and eastern mole (*Scalopus aquaticus*), have localized ranges (Gumbert et al. 2006). Elk (*Cervus elapus*) have been re-introduced in the region and this animal has been noted by park staff near the borders of the park, indicating that elk may be at least transient residents (Jenny Beeler personal communication).

Table 26. Number of native species reported from a recent mammal inventory at CUGA, compared to number of native species expected (Gumbert et al. 2006). Exotic and range expanding species (ie. coyote) are not included in expected or reported lists.

Comparison	Reported	Expected	% Expected Observed
All Native Species	39	56	70
Bats	9	11	82
Carnivores	6	11	55
Insectivores (Shrews and Moles)	6	10	60
Rodents	15	19	79

We found the condition of the mammal community at Cumberland Gap National Historical Site to be good (Table 27). This was indicated by the occurrence of at least 13 species of regional conservation concern, the high native richness of the CUGA mammal sample relative to similarly-collected regional samples (Table 25), and by the similarity of the observed CUGA community to an idealized regional community (Table 26). We did not assign a trend for CUGA mammal community condition. A previous comprehensive survey was three decades old and was not conducted with similar effort to the recent inventory. The existence of a single well-conducted recent survey is not sufficient to determine even a qualitative trend. The data used to make this assessment were good. Because of their importance in CUGA, cave bats were assessed in a separate section of this report.

Cumberland Gap National Historical Site has benefited from two well-conducted comprehensive mammal surveys. The recent survey by Copperhead Environmental Consulting, Inc. provided good coverage of park habitat although fewer points were located on the southern slopes of Cumberland Mountain and future researchers may wish to include this area. The survey included sufficiently intense and diverse effort to collect a representative mammal sample. We recommend that future efforts conform closely to the design used in this survey. At the least, future comprehensive mammal surveys should include sampling in all significant park habitats with several varieties and sizes of traps, sampling with pitfall arrays, sampling with automated cameras, and sampling with baited sign stations. Future researchers may desire to conduct special efforts directed towards mustelids, shrews, and native mice and rats. There are approximately 10 expected members of these groups that have not been found in CUGA. Mammal communities are inherently more difficult to sample than bird or fish communities and several surveys may be necessary to adequately document 90% of the species occurring in CUGA, which contains a large area of diverse and remote habitat.

Table 27. The condition of the mammal community at Cumberland Gap NHP was good, with good data quality. No trend was assigned to mammal community condition. Cave bats were assessed separately.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Mammal Community	●	✓	✓	✓
		3 of 3: Good		

Herpetofauna Communities

Amphibians and reptiles are important components of southeastern US ecosystems. The southeastern US contains the highest diversity of herpetofauna in North America (Gibbons and Buhlmann 2001), and the southern and central Appalachian region is characterized by high amphibian diversity (Dodd 2003). Global declines in amphibians (Stuart et al. 2004) and reptiles (Gibbons et al. 2000) have been noted for decades, and herpetofauna have become the focus of increasing management concern and effort. Known threats to herpetofauna include habitat loss and fragmentation, habitat degradation, pollution, disease, and invasive species (Gibbons et al. 2000, Semlitsch 2000). Wetland habitats are of particular importance to amphibians (Semlitsch 2000) and are important to many species of reptiles as well (Gibbons et al. 2000).

Several efforts have examined herpetofaunal communities in CUGA. Barbour et al. (1979) sampled reptiles and amphibians as part of a comprehensive vertebrate fauna survey of the park. This effort consisted of active searches, incidental sightings, and several second-hand reports from park personnel made during the two-year period of the study (Barbour et al. 1979). This survey reported 45 species of reptiles and amphibians in the park (Barbour et al. 1979). Meade (2003) conducted a 12-month herpetofaunal survey of CUGA including sampling in pre-existing vegetation sampling plots and sampling in specifically chosen habitats. Meade (2003) used area-constrained searches, coverboards, road cruising, and incidental observations and reported 35 species from CUGA. In 1993, Petranka et al. (2004) began monitoring wood frog (*Rana sylvatica*) and spotted salamander (*Ambystoma maculatum*) breeding use of small ponds in CUGA and in three other southeastern national parks. In 1999, monitoring was expanded to include three small ponds created as mitigation for wetlands lost to highway construction (Petranka 2005). These efforts reported 11 species using the wetlands, including the regionally rare eastern spadefoot toad (*Scaphiopus holbrooki*), that had not been previously reported from CUGA (Petranka 2005). Combined, these efforts have reported 47 species in the Cumberland Gap National Historical Park (Table 28). The NPSpecies online database of NPS biodiversity lists 35 species of herpetofauna (those reported by Meade 2003) as verified present in the park (NPSpecies 2010).

Table 28. Herpetofaunal species expected to occur in Cumberland Gap National Historical Park, and those actually reported from sampling in the park. B=reported by Barbour et al. (1979); M=reported by Meade (2003); P=reported by Petranka (2005).

Scientific Name	Common Name	Obs.	Scientific Name	Common Name	Obs.
Anurans			**Salamanders**		
Bufo americanus	American toad	B,M,P	*Ambystoma maculatum*	spotted salamander	B,M,P
Bufo fowleri	Fowler's toad	B	*Ambystoma opacum*	marbled salamander	B,M,P
Hyla chrysoscelis	Cope's gray treefrog	B,M,P	*Aneides aeneus*	green salamander	B,M
Pseudacris brachyphona	mountain chorus frog	B,M,P	*Desmognathus fuscus*	northern dusky salamander	B,M
Pseudacris c. crucifer	northern spring peeper	B,M,P	*Desmognathus monticola*	seal salamander	B,M
Pseudacris feriarum	upland chorus frog	B,M,P	*Desmognathus welteri*	black mountain salamander	B,M
Rana catesbeiana	bullfrog	B,M	*Eurycea cirrigera*	southern two-lined salamander	B,M
Rana clamitans melanota	green frog	B,M	*Eurycea l. longicauda*	long-tailed salamander	B
Rana palustris	pickerel frog	B,M,P	*Eurycea lucifuga*	cave salamander	B,M
Rana sylvatica	wood frog	B,M,P	*Gyrinophilus porphyriticus duryi*	Kentucky spring salamander	B,M
Scaphiopus holbrooki	eastern spadefoot toad	P	*Hemidactylium scutatum*	four-toed salamander	B,M
Snakes			*Notophthalmus v. viridescens*	red-spotted newt	B,M,P
Agkistrodon contortix mokasen	northern copperhead	B,M	*Plethodon glutinosus*	northern slimy salamander	B,M
Carphophis a. amoenus	eastern worm snake	B,M	*Plethodon kentucki*	Cumberland Plateau salamander	M
Coluber c. constrictor	northern black racer	B,M	*Plethodon richmondi*	southern ravine salamander	B,M
Crotalus horridus	timber rattlesnake	B,M	*Pseudotriton diastictus*	midland mud salamander	B
Diadophis punctatus edwardsii	northern ringneck snake	B,M	*Pseudotriton ruber ruber*	northern red salamander	B
Lampropeltis getula nigra	black kingsnake	B	**Turtles**		
Lampropeltis t.triangulum	eastern milk snake	B	*Chelydra serpentina*	common snapping turtle	B
Nerodia s. sipedon	northern water snake	B,M	*Sternotherus odoratus*	common musk turtle	B
Opheodrys aestivus	rough green snake	B	*Terrapene carolina*	eastern box turtle	B,M
Scotophis spiloides	midland rat snake	B,M	**Lizards**		
Storeria o. occipitomaculata	northern redbelly snake	B,M	*Eumeces fasciatus*	five-lined skink	B,M
Thamnophis s. sirtalis	eastern garter snake	B,M	*Sceloporus undulatus*	eastern fence lizard	B,M
Virginia v. valeriae	eastern earth snake	B	*Scincella lateralis*	ground skink	B

We compared lists of reptiles and amphibians reported from recent sampling efforts by Meade (2003) and Petranka (2005) to lists of herpetofauna expected to occur in the park. Meade (2003) prepared an expected list using several sources relying primarily upon the inventory of Barbour et al. (1979). This expected list included 47 species, all of which were reported by Barbour et al. (1979) or Meade (2003, Table 28). Around 77% of expected herpetofaunal species were reported from the park (Table 29). Amphibians were better-represented than reptiles, with 86% of expected amphibians and 63% of expected reptile species actually reported from the park. Frogs and toads were the best represented amphibian group, with only one expected species not reported from the park.

Table 29. Number of expected herpetofaunal species and number and percentage of species actually reported during recent sampling efforts at CUGA.

Comparison	**Expected**	**Reported**	**% Expected Reported**
All species	47	36	77
Reptiles	19	12	63
Amphibians	28	24	86
Snakes	13	9	69
Lizards	3	2	67
Turtles	3	1	33
Salamanders	17	14	82
Anurans	11	10	91

Long-term efforts have monitored amphibian breeding activity at ponds in Cumberland Gap National Historical Park. In 1993 researchers began a project to monitor the number of egg masses of spotted salamanders (*Ambystoma maculatum*) and wood frogs (*Rana sylvatica*) at small ponds in CUGA and in three other southeastern national parks (Petranka 2005, Petranka et al. 2004). In 1998 the NPS and Federal Highways Administration constructed a wetland in CUGA as mitigation for a wetland lost during construction of a highway through the park (Petranka 2005). Three ponds were constructed and an existing ditch was altered on a 0.40-ha site in the Little Yellow Creek watershed below Fern Lake (Petranka 2005). Existing monitoring efforts were expanded in 1999 to include the new sites (Petranks et al. 2004). In 2006, NPS personnel took over monitoring duties at all sites. Sixteen monitored ponds occurred in three distinct clusters, termed here “north ponds,” “middle ponds,” and “south ponds” (Figure 41). The constructed wetlands were in the south cluster, with included seven ponds in the floodplain of Little Yellow Creek below Fern Lake. The middle cluster of ponds included seven ponds in the Little Yellow Creek floodplain downstream of the south ponds. The north cluster included two sites on upper Davis Branch.

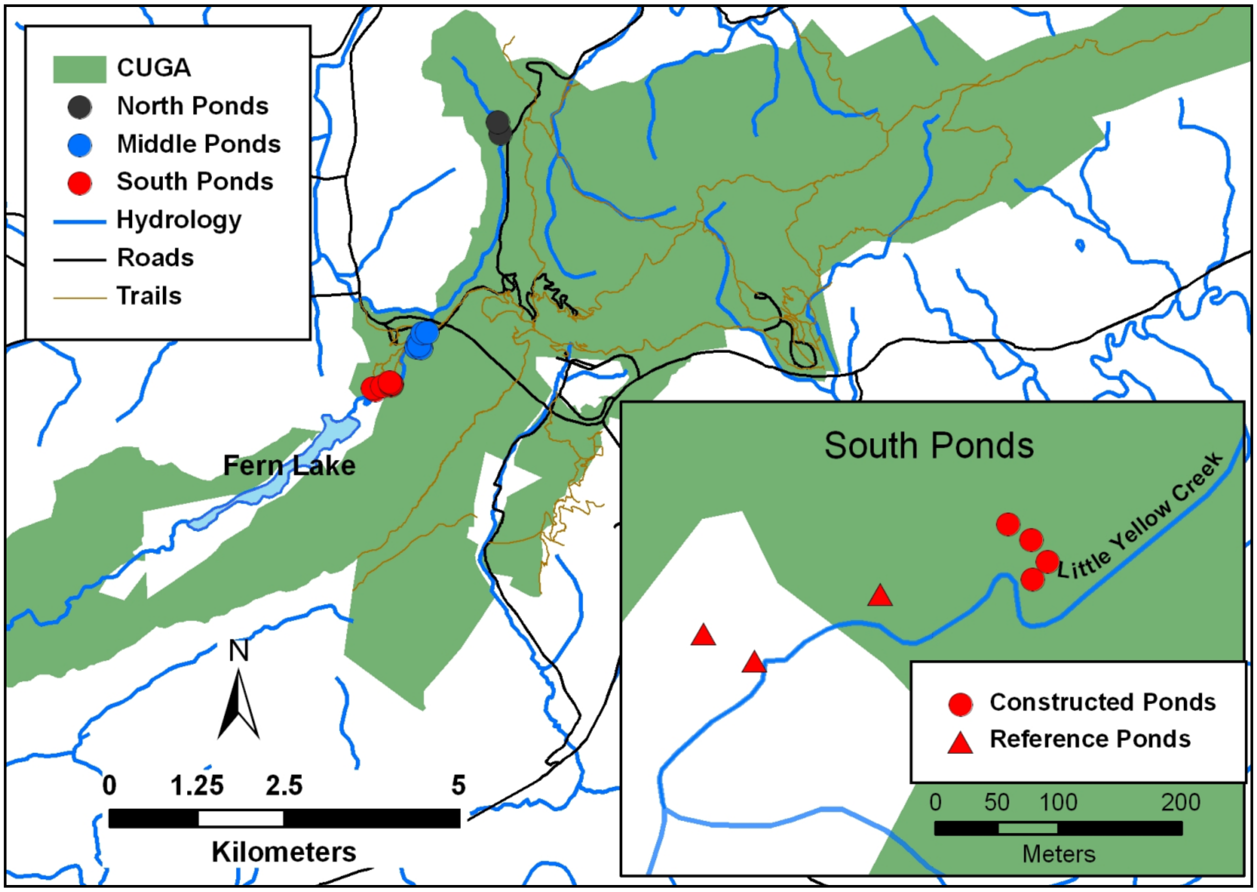


Figure 41. Three pond clusters containing 16 ponds were monitored for breeding effort of wood frogs (Rana sylvatica) and spotted salamander (Ambystoma maculatum) since 1993. In 1999, four ponds were constructed in the south cluster and were included in long-term monitoring (inset).

We plotted the total number of egg masses of wood frogs and spotted salamanders counted annually at each pond cluster from 1993-2010, and included counts from the mitigation sites established in 1999 (Figure 42). The breeding activity of both species was greatest in the southern cluster of ponds, and breeding activity was highly variable among years. Wood frog egg mass counts decreased during 2006-2009, but showed signs of increasing in 2010. Drought and extreme cold in 2007 lowered egg success, and the timing of counts in 2009 caused early breeding efforts to be missed and thus counts this year were artificially low (unpublished CUGA data). Spotted salamander egg mass counts were relatively stable during the period. Weather patterns, flooding from streams, fish predation, alterations by beavers, successional changes, and other variables, affect amphibian breeding in small ponds (Petranka et al. 2004, Petranka 2005). *A. maculatum* and *R. sylvatica* exhibit different specific breeding strategies and respond to different environmental cues during the breeding season (Petranka et al. 2004). Petranka (2005) reported that the region experienced mild drought conditions from 1998-2001. The region also experienced a drought from 2006-2008. We compared 2002-2010 precipitation data from the collection site located at the CUGA Visitor Center to egg mass counts of wood frogs and spotted salamanders in the park. For each year, we plotted the total centimeters of precipitation from November 1 of the previous year, through April 30 of the current year, alongside park-wide total egg mass counts (Figure 43). Precipitation data were missing for the 2005 breeding season.

Breeding effort of the two species was asynchronous over the time period, though low counts were observed for both species in 2007-2008 (Figure 43).

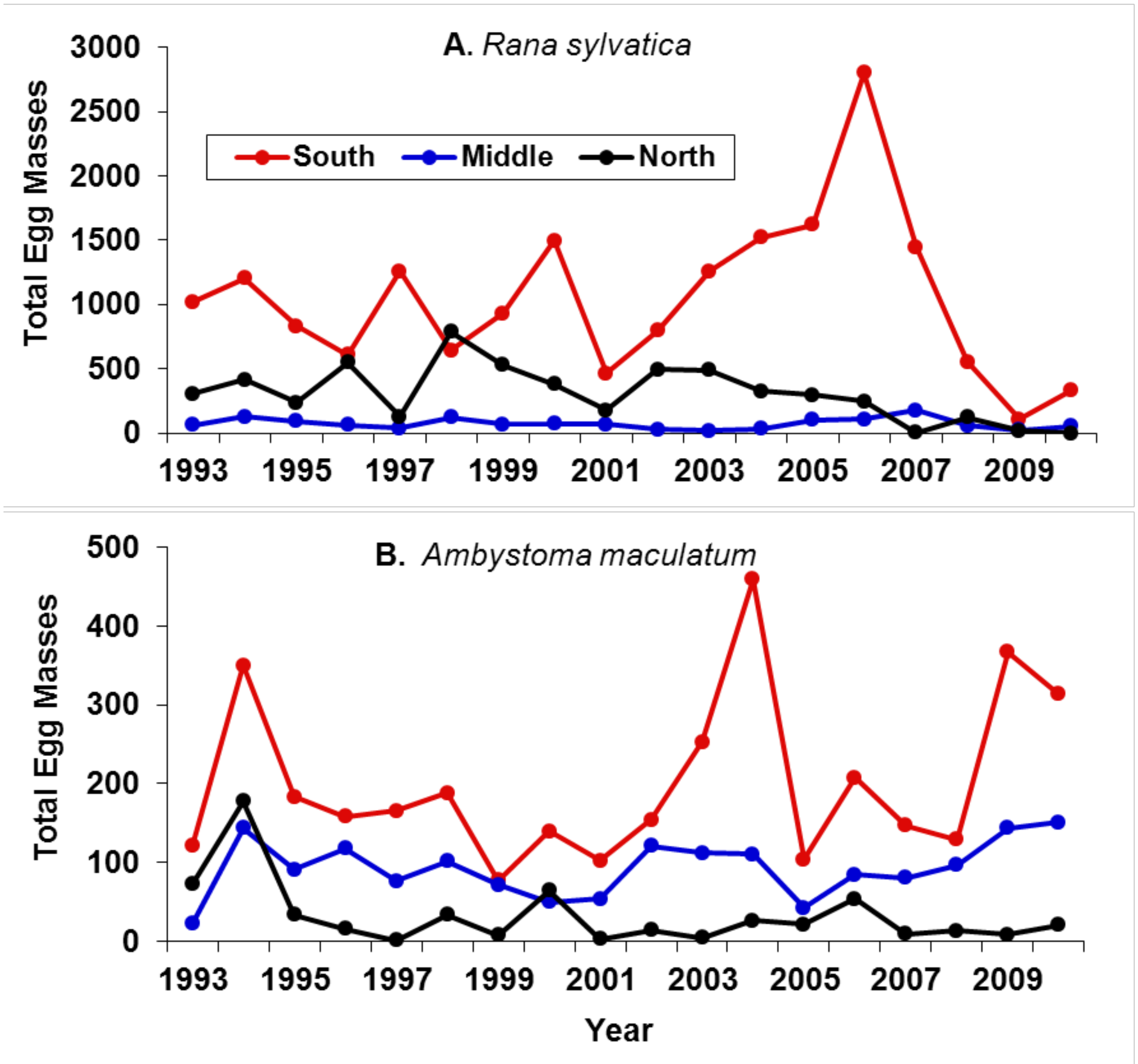


Figure 42. Total egg masses of Rana sylvatica and Ambystoma maculatum counted annually at three clusters of ponds (south, middle, and north) in Cumberland Gap National Historical Site. Data shown include all counts at all ponds, including constructed mitigation ponds filled in 1999.

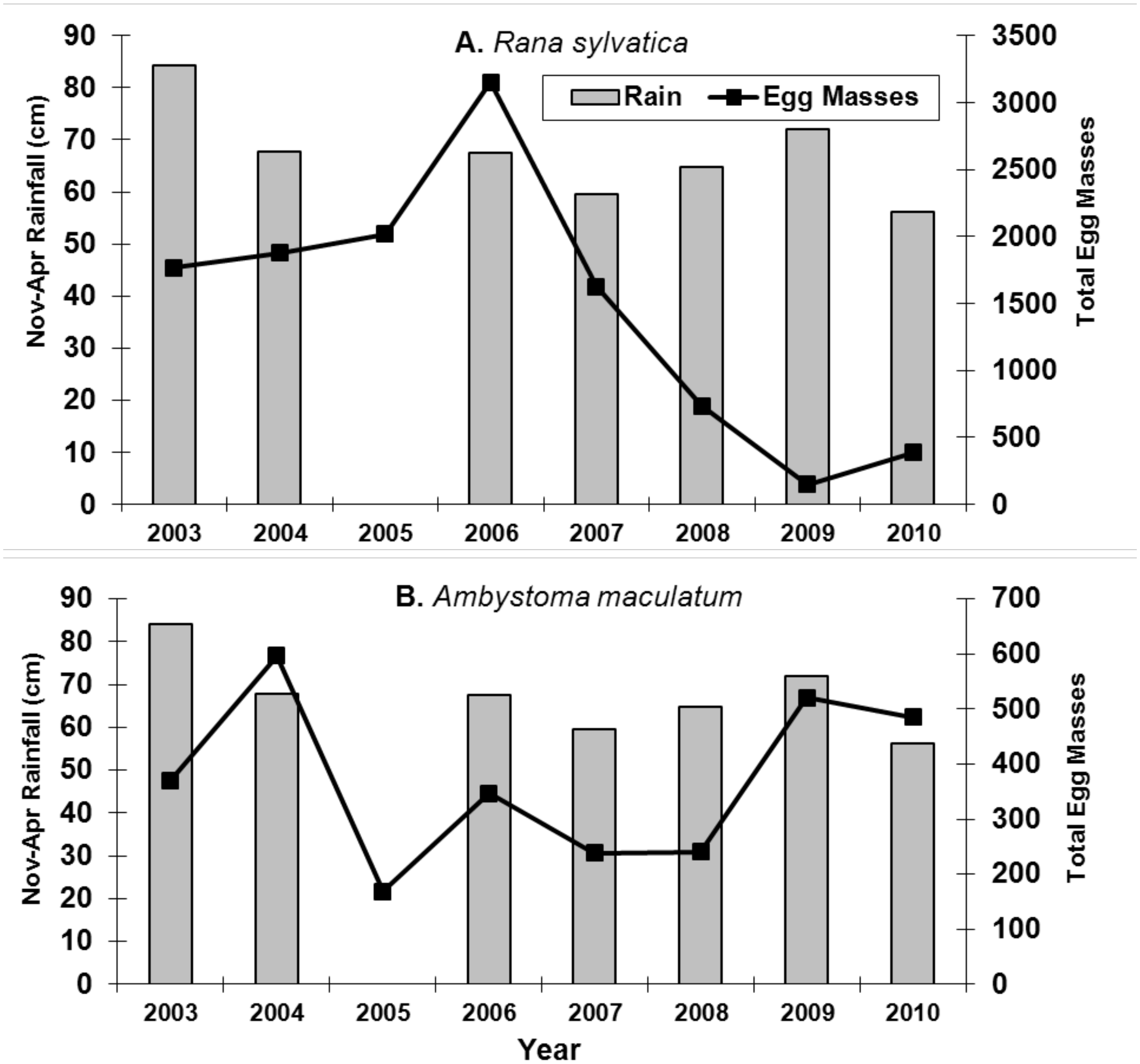


Figure 43. Total precipitation (cm) from November 1 of the previous year through April 30 of the current year and total egg masses of *Rana sylvatica* and *Ambystoma maculatum* counted at all sites from 2003-2010 at Cumberland Gap National Historical Park.

We examined the amphibian activity and success of mitigation ponds. Criteria for the successful mitigation of the constructed wetlands included specific goals for hydroperiod, amphibian use, and plant community structure (Petranka 2005). For amphibian use, the criterion was that wood frogs and spotted salamanders use the pond for five of 10 years. This goal was met and these species were found in all years of monitoring. From 1999-2009, 12 amphibian species were reported from the ponds during breeding season counts. Richness ranged from 5 to 9 species with a mean richness of 6.8 species (SD±1.2). A long term objective for the constructed wetlands was to provide breeding habitat for the four-toed salamander (*Hemidactylium scutatum*). Petranka (2005) suggested this goal would most likely be met following canopy closure of the new wetlands. Four-toed salamanders had not been reported from the ponds by

2009. Following their construction, the mitigation wetlands were compared to three nearby reference ponds that were part of the long-term amphibian monitoring project (Petranka 2005). Wood frogs showed evidence of habitat shifting in the cluster because significant portions of the population moved to the newly constructed ponds (Petranka et al. 2004, Figure 44). Across the mitigation ponds, spotted salamander breeding activity increased steadily over the time period (Figure 44), though activity varied among sites.

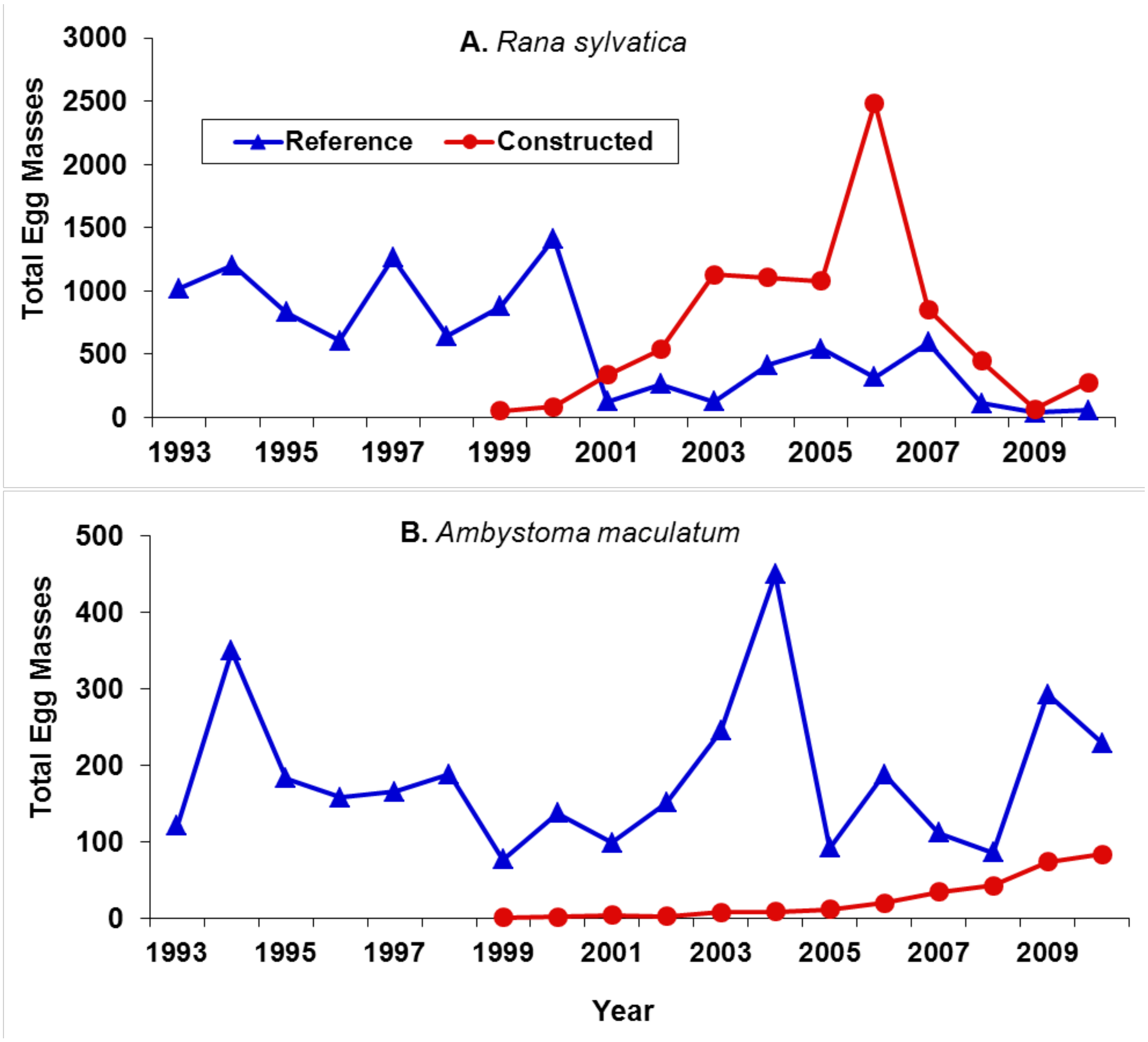


Figure 44. Total egg masses of *Rana sylvatica* and *Ambystoma maculatum* counted at constructed wetlands and at nearby reference ponds from 1993-2010 at Cumberland Gap National Historical Park.

Potential threats to the persistence of amphibians in CUGA include infestations of pathogens including *Ranavirus* and the chytrid fungus (*Batrachochytrium dendrobatidis*). Both pathogens are implicated in the decline or failure of amphibian populations in the U.S. The chytrid fungus is an emerging disease that is the cause of local declines and extinctions of anuran populations in the western U.S. (Briggs et al. 2005). The fungus has been found to be widely occurring in anuran populations in the northeastern (Longcore et al. 2007) and southeastern (Rothermel et al.

2008) U.S. where it has not been specifically implicated in large-scale amphibian die-offs and is believed to result in sub-clinical infestations in many cases. The chytrid fungus was reported from 33% of wood frog samples collected in CUGA in 2009 (unpublished CUGA data). *Ranavirus* is known to kill larval amphibians, including wood frogs and spotted salamanders, and caused high mortality from 1997-2006 in populations of these amphibians in the Tulula Wetland Mitigation Site in western North Carolina (Petranka et la. 2007). Further exploration into the presence and effects of these pathogens may be warranted in CUGA.

Recent efforts at documenting herpetofaunal diversity in CUGA have relied significantly upon active searching, and have not included drift fence-pitfall arrays (Meade 2003). Because behavior and habitat associations vary widely among herpetofaunal species, multiple methods should be used when sampling an assemblage (Gibbons et al. 1997, Tuberville et al. 2005). Total effort expended, sample method, sample timing, and the microhabitat sampled all affect the results of herpetofaunal surveys (Greenberg et al. 1994, Gibbons et al. 1997, Metts et al. 2001, Floyd et al. 2002, Ryan et al. 2002). Drift fencing with pitfall traps is among the most effective and commonly used methods of sampling herpetofauna assemblages, particularly salamanders (Greenberg et al. 1994; Ryan et al. 2002; Wilson and Gibbons 2009). Funnel trapping on drift fences is also effective at sampling some herpetofauna, and may be particularly effective for sampling species such as large snakes that are relatively poorly sampled by pitfalls (Greenberg et al. 1994, Todd et al. 2007). Additional metal coverboards in the low-lying areas of the park may also be useful at sampling some of the missing snakes.

We ranked the condition of reptile and amphibian communities in CUGA as good (Table 30). Around 77% of expected herpetofaunal species were reported from the park in recent years (Table 29). Amphibians, a group of special importance in the southeastern Appalachian region, were well-represented in the CUGA with 86% of expected species reported in recent inventories (Table 29). The most recent herpetofauna inventory of the park (Meade 2003) had fewer species than did an earlier survey (Barbour et al. 1979), but the new survey was conducted over a single 12-month period and the older survey was conducted over multiple years. Habitat in the park had likely become more forested over the time period between the studies, altering animal assemblages. Furthermore, Barbour et al. (1979) reported some species only from second-hand reports, so more uncertainty exists in the results of this survey. Monitoring of the breeding effort of wood frogs and spotted salamanders at small ponds in the park suggested that the populations of these species, though variable, remained relatively stable over the long term (Figure 42). The marked decrease in wood frog breeding effort from 2006-2009 may have resulted from drought conditions or from variances in sampling timing. The species has shown a possible reversal of this trend and should continue to be monitored carefully. Mitigation ponds filled in 1999 have been used annually by breeding amphibians. These ponds have met short-term objectives for breeding amphibians.

We did not assign a trend to CUGA reptile and amphibian community condition. Long-term monitoring data was only available for two species of amphibians. The two comprehensive inventories of reptiles and amphibians were widely separated in time and used different techniques and sampling effort. Of the amphibian species monitored, spotted salamanders have been relatively stable with recent reported declines, and possible signs of rebound.

Table 30. The condition of the herpetofauna community at Cumberland Gap National Historical Park was good. No trend was assigned to herpetofauna community condition. The data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality: Thematic	Spatial	Temporal
Herpetofauna Community		✓	✓	✓
		3 of 3: Good		

If further herpetofaunal sampling is conducted at CUGA with the goal of documenting most of the species present, we recommend the use of significant effort with several sampling methods. We recommend that future comprehensive inventories include active searches as well as sampling with drift fences combined with pitfalls and funnel traps. Drift fence pitfall arrays are labor intensive to install and are easily visible if placed in areas with high human visitation. However, once in place they can be used over long time periods with minimal maintenance and can be periodically deactivated during non-sampling periods. Furthermore, this method is also effective at sampling small mammals, a community that may be of interest to park managers.

Cave Bats

Caves provide habitat for many unique organisms and biological communities. Over 1,300 cave-adapted species are known from the United States and many more probably remain undescribed (Elliot 1998). Cave species are highly endemic, and many are known only from individual caves or cave systems (Elliot 1998). In CUGA, ongoing monitoring efforts for cave biota included biennial monitoring of two hibernacula for the federally endangered Indiana bat (*Myotis sodalis*). Recent inventory efforts of vertebrate groups had included limited sampling directed at discovering cave herpetofauna (Meade 2003), fish (Remley 2005), and bats (Gumbert et al. 2006). Because data were not available for multiple cave species, we focused our assessment on cave bats.

Of nine species of bats reported by Gumbert et al. (2006) in a general park mammal inventory, seven species were cave-hibernating bats (Table 31). All seven of these species had been previously reported by Barbour et al. (1979). Gumbert et al. (2006) prepared a list of expected bats for the park including 11 species. The two species on this expected list not reported from the park, gray bat (*Myotis grisescens*) and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), are cave hibernating species. Both species are rare and the gray bat is federally endangered. Therefore, seven of nine (77.8%) potential cave bats have been reported from CUGA. Six of these seven species accounted for 95% of the total individual bats captured using mist nets and harp traps during the survey (Gumbert et al. 2006). Gumbert et al. (2006) used live capture methods at 10 sites, of which three were cave openings. Sampling at cave openings resulted in 73% of the total bats captured at all sites. The eastern red bat (*Lasiurus borealis*), reported from the survey, may occasionally use caves as roosts (Shump and Shump 1982), but was not considered a cave-using species in this assessment. The silver-haired bat, though not normally considered a cave bat, occasionally roosts in cave entrance zones in winter, and was considered with the cave bats in this report (Kunz 1982). The Indiana bat (*Myotis sodalis*), a federally endangered species, was not captured alive in the park during the recent mammal inventory, but was recorded using Anabat II electronic bat detectors swarming at the entrance of Gap Cave (Gumbert et al. 2006). From other efforts, Indiana bats are known to hibernate in the park. A female Indiana bat from Gap Cave was banded as part of a banding project with Rick Reynolds of VADGIF on (10/21/09). (Jenny Beeler personal communication).

The endangered Indiana bat is known to hibernate in two CUGA caves. Based on the numbers reported from CUGA, the hibernacula in the park are classified as "Priority 3" by the USFWS and considered to be of minor importance in the overall survival of the species (USFWS 2007). Indiana bats hibernate from approximately mid-November to mid-April in the southern part of their range (USFWS 2007). Resource managers from the VDGIF have conducted counts of hibernating Indiana bats at these caves on a biennial schedule since 1993 (NPS unpublished data). From 1993-2011 numbers of hibernating Indiana bats in CUGA initially declined, then remained constant or increased slightly (Figure 45). Indiana bats declined generally throughout their range between 1965 and 2000, but populations may be stabilizing in recent years (USFWS 2007, King 2009). Much of the apparent population stabilization results from increasing numbers in a few of the largest known hibernacula (USFWS 2007). Indiana bats hibernate in large, dense colonies, making populations uniquely vulnerable to disturbances during hibernation. Anthropogenic alterations of hibernacula are a primary cause of decline for the species (USFWS 2007).

Table 31. Cave-hibernating bats captured in mist nets or harp traps in Cumberland Gap National Historical Park during a general mammal survey by Gumbert et al. (2006), the relative abundance (RA) of each species in the total sample of captured bats, and the number of cave entrances of three sampled, in which each species was reported.

Common Name	**Scientific Name**	**RA**	**CUGA Cave Presence**
Northern bat	*Myotis septentrionalis*	43.8	3
Eastern pipistrelle	*Pipistrellus subflavus*	19.2	3
Little brown bat	*Myotis lucifugus*	19.2	2
Big brown bat	*Eptesicus fuscus*	10.8	3
Small-footed myotis	*Myotis leibii*	1.5	1
Silver-haired bat	*Lasionycteris noctivagans*	0.8	0
Indiana bat	*Myotis sodalis*	*	0

***** Species was only reported from electronic Anabat II detection.

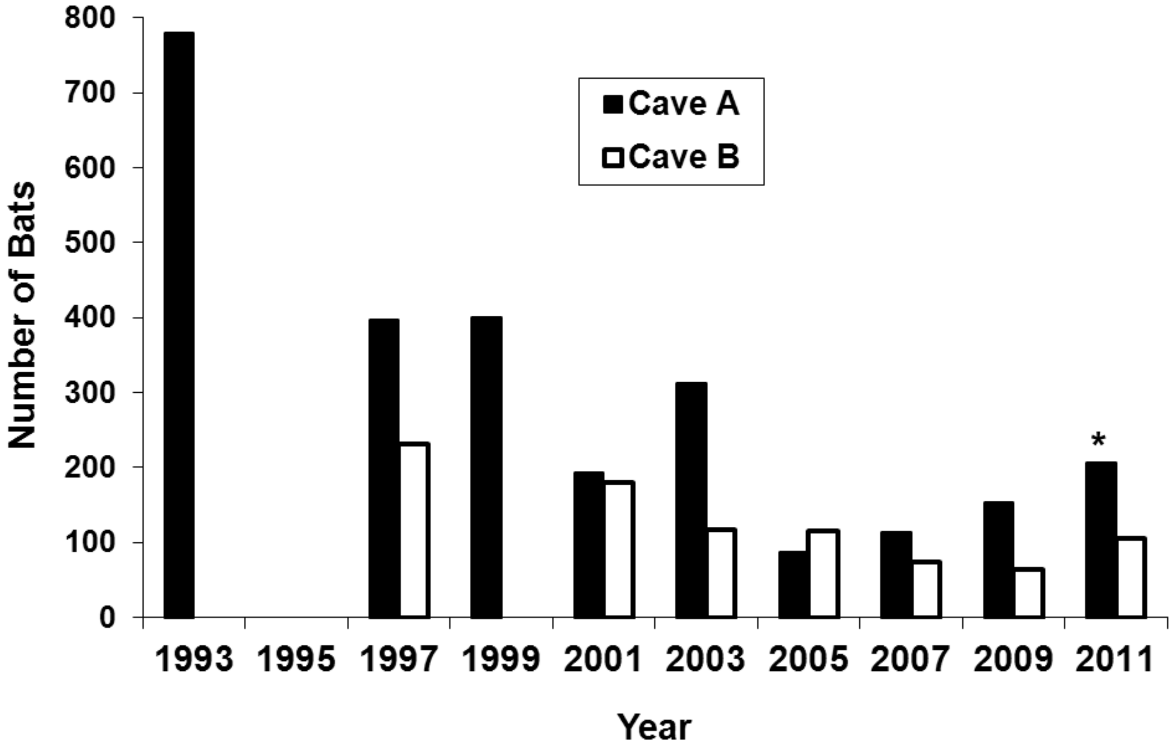


Figure 45. Numbers of Indiana bats (*Myotis sodalis*) counted biennially, 1993-2011, in two winter hibernacula in Cumberland Gap National Historical Park. The asterisk indicates that a greater area was searched in Cave A in 2011, and this value may be artificially elevated relative to other years.

In addition to Indiana bats, six other species of cave-hibernating bats have been reported from CUGA, although their use of park caves has not been described or quantified. The small-footed myotis (*Myotis leibii*) is a rare bat documented at CUGA. Rarely sampled in CUGA (Table 31), it was captured at the mouth of a park cave in late October (Gumbert et al. 2006), suggesting that it may hibernate within the park. *M. leibii* is listed as threatened in Kentucky (KSNPC 2011) and generally recognized as a species of concern (Erdle and Hobson 2001) with a NatureServe global rank of G3 (vulnerable). It is easily overlooked in cave surveys because it often hibernates under rocks or talus on the cave floor or in small crevices (Erdle and Hobson 2001). Research suggests it is more cold tolerant than many other bats and can occupy spaces in hibernacula that fall below freezing (Erdle and Hobson 2001). It typically begins hibernation around mid-November and leaves hibernacula by March (Erdle and Hobson 2001).

The silver-haired bat (*Lasionycteris noctivagans*) was captured a single time at a non-cave location during the recent survey (Gumbert et al. 2006), and was the least-commonly captured bat from mist netting and harp trapping efforts (Table 31). It occasionally uses caves as hibernacula, though it is not an obligate cave hibernator and has been reported hibernating in a variety of other structures (Kunz 1982). This species is migratory, but the timing and nature of its migrations are poorly understood. Gumbert et al. (2006) suggest it is likely that *L. noctivagans* hibernates in CUGA.

The eastern pipistrelle (*Pipistrellus subflavus* becoming known as *Perimyotis subflavus*) was found in the park during the recent survey, (Gumbert et al. 2006), was captured at all three cave sites sampled, and accounted for 19.2% of captured bats (Table 31). This bat typically hibernates singly in caves, mines, and man-made structures, often near mixed-species groups of hibernating bats (Fujita and Kunz 1984). Although it hibernates in the same caves with other species, it selects the deeper, more temperately stable passages (Fujita and Kunz 1984). In caves in Maryland, Pennsylvania, and West Virginia, it selected microhabitats with significantly higher mean relative humidity (84.8%) and mean ambient temperatures (10.9 ºC) than four other temperate cave species (Raesly and Gates 1987). Among five species surveyed across multiple hibernacula, it was the only bat for which the mean minimum temperature of occupied sites was significantly greater than for unoccupied sites (Raesly and Gates 1987). It emerges from hibernations later than most other species and shows fidelity to specific hibernacula (Fujita and Kunz 1984).

Little brown bats (*Myotis lucifugus*) were found in the park during the recent survey (Gumbert et al. 2006), were captured at two of the three cave sites sampled, and accounted for 19.2% of captured bats (Table 31). This species typically hibernates from mid-November to mid-March in the southern part of its range, and remains in torpor for long periods during winter hibernation without arousing (Fenton and Barclay 1980). Although all bats may suffer decreased survival with increasing number of arousals, this species may be uniquely susceptible to mortality from disturbance during hibernation (Fenton and Barclay 1980). It has been found hibernating in microhabitats within caves with mean ambient temperatures of 7.5 °C (45.5 °F) and mean relative humidity of 73.2% (Raesly and Gates 1987). Other research suggests that *M. lucifugus* hibernacula were characterized by high humidity and temperatures above freezing (Fenton and Barclay 1980).

Big brown bats (*Eptesicus fuscus*) were found in the park during the recent survey (Gumbert et al. 2006), were captured at each of the three cave sites sampled, and accounted for 10.8% of captured bats (Table 31). A very widely distributed generalist, *E. fuscus s*eems to prefer larger volume caves with noticeable airflow (Agosta 2002). This species hibernates singly or in small clusters and prefers hibernacula with ambient temperatures above freezing (Agosta 2002). It has been found hibernating in microhabitats within caves with mean ambient temperatures of 7.1 °C (44.8 °F) and mean relative humidity of 67.3% (Raesly and Gates 1987).

The northern bat (*Myotis septentrionalis*) was the most commonly captured bat in CUGA during the recent survey (Gumbert et al. 2006). It was captured at each of the three sampled cave habitats and accounted for 43.8% of the total bats captured (Gumbert et al. 2006, Table 31). It hibernates in caves and abandoned mines in mixed-species groups where it usually makes up a relatively small proportion (<10%) of the overall hibernating bat population (Caceres and Barclay 2000). It prefers to hibernate singly or in clusters in tight crevices and can easily be overlooked in surveys of hibernacula (Caceres and Barclay 2000). The timing of hibernation varies with latitude, but starts during September-November and ends from March-May (Caceres and Barclay 2000). This species has been found hibernating in microhabitats within caves with mean ambient temperatures of 6.9 ºC (44.4 °F) and mean relative humidity of 65.2% (Raesly and Gates 1987).

White-nose syndrome (WNS) is a severe and emerging threat to hibernating bats throughout the eastern U.S. (Cyran 2011). This disease, caused by infection with the *Geomyces destructans* fungus (Lorch et al. 2011), was discovered in New York in 2006, and has spread rapidly westward including occurrences in Virginia (2009), Tennessee (2010), and Kentucky (2011) (Cryan 2011). The disease affects hibernating bats and may result in catastrophic declines of >75% in local hibernating populations (Blehert et al. 2009). Of nine species of bats reported from CUGA, six are hibernating species at risk from WNS and the disease has been found in all of these species (Cryan 2011). Given the steady advance of this pathogen across the eastern U.S., its eventual arrival in CUGA is very likely and may be inevitable. A VDGIF team searching Gap Cave in 2011 found no evidence of the disease at that time (unpublished data). More cave hibernating species could become federally listed throughout their range as a result of the disease. The park has placed information about WNS on its website and practices decontamination measures to decrease the risk of the spread of the disease, and park managers have created a WNS response plan (WNS Response Plan 2011). All visitors inquiring about cave tours receive information from park staff regarding decontamination, and individuals with items that have been in other caves or mines since 2005 must remove or decontaminate those items prior to the cave tour (Jenny Beeler personal communication).

We ranked the condition of CUGA cave bats as good (Table 32). Seven of nine potential cave species were reported from the park in widely separated surveys (Table 31, Barbour et al. 1979,Gumbert et al. 2006). These species comprised the majority of bats captured in a recent survey and sampling at cave entrances resulted in the highest capture rates among all sites where live-capture sampling techniques were used (Gumbert et al. 2006). The park harbors at least two species identified as species of conservation concern, including the federally endangered Indiana bat. The Indiana bat had declined since it was first monitored, but numbers may be leveling off in recent years (Figure 45). The rangewide decline of this species is driven by factors outside of park control. The trend of cave bat condition was declining. This trend is assigned because of the severe and inevitable threat of WNS. Although not found in the park by 2011, the future condition of cave-hibernating species in the park will almost certainly be affected. The quality of the data was fair. Although the data were collected recently within the park, only two of at least 30 known caves were monitored for temperature, and only three caves were sampled for bats in the recent mammal survey. Furthermore, the use of caves by bats had not been quantified, except for the case of Indiana bats at two sites.

Table 32. The condition of cave bats was good at Cumberland Gap National Historical Park. The trend of cave bat condition was declining. The quality of the data used to make this assessment was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Cave Bats			✓	✓
		2 of 3: Fair		

At-Risk Plants

Rare Plants

The vegetation assessment conducted by White (2006) is the most recent comprehensive contribution to the inventory of flora at CUGA. In the survey, White (2006) identified 882 plant species in the park, including 127 new species not collected in previous surveys. Although none of the species are federally-listed, several are listed as significant in one or a combination of the three states comprising the park. In his evaluation of biological inventory data at CUGA, Moore (2010) updated this rare species list to include a total of 90 plant species that were, as of 2008, federally or state-listed or state-ranked (S1 or S2), and Present or Probably Present in the park (Table 33).

In 1984, Pounds et al. (1989) conducted a general flora survey at CUGA and documented 59 rare plant species, defined as state-listed species or species not known previously to occur in a specific state. Pounds et al. (1989) recommended continued monitoring of six species: 1) fly poison (*Amianthium muscaetoxicum*), 2) Appalachian stitchwort (*Arenaria glabra*), 3) Purple disk sunflower (*Helianthus atrorubens*), 4) Rough blazingstar (*Liatris aspera*), and 5) Prairie Dock (*Silphium terebinthinaceum*). These recommendations were based on accessibility, which reflects both the ease of monitoring and threat of decline. In 2008, White and Littlefield (2008) conducted a survey to verify locations of rare plants previously documented by Pounds et al. (1989) and other sources. Ten of the species previously found at CUGA were not located by White and Littlefield (2008, Table 34). They also note that fire historically played a role in the persistence of certain species, such as fly poison and veiny peavine (*Lathyrus venosus*). These species occur along the Ridge Trail and have declined in this area, possibly due to the lack of fire and change in cover (White and Littlefield 2008).

Fortunately, White and Littlefield (2008) noted that exotic plants in general did not pose a threat to rare plants in the park, though the closest exception might be the threat posed by periwinkle (*Vinca minor*), which could potentially outcompete American lily-of-the-valley (*Convallaria montana*) and Porter's reedgrass (*Calamagrostis porteri*) along the Cumberland and Ridge trails.

Overall, White and Littlefield (2008) noted that the potential loss of eastern hemlock from HWA might be one of the most significant impacts on the persistence of rare plants at CUGA, particularly in riparian and mesic communities. To a lesser degree and only in certain areas, they warn that recreational use could also negatively affect plants like American lily-of-the-valleyand veiny peavine. Specific areas susceptible to overuse include White Rocks, Sand Cave, and the Ewing Trail. Overall, White and Littlefield provide management guidelines for 26 rare plant species at CUGA according to their anticipated response/susceptibility to fire, recreation, and hemlock decline.

Table 33. State or federally-listed and state-ranked plant species identified as Present in Park or Probably Present at CUGA. [table and definitions from Moore (2010); statuses current as of June 2008].

Species		State[1]/Federal Status[3]/Rank[2]	Global Rank[4]	Park Presence Status
Adlumia fungosa	Climbing fumitory	KY=E, S1; TN=T, S2	G4	Present in Park
Agrimonia gryposepala	Tall hairy groovebur	KY=T, S1	G5	Present in Park
Allium tricoccum	Wild leek	TN=S-CE, S1	G5	Present in Park
Amianthium muscitoxicum	Fly-poison	KY=T, S1	G4	Present in Park
Aralia nudicaulis	Wild sarsaparilla	KY=E	G5	Present in Park
Boykinia aconitifolia	Brook saxifrage	KY=T, S2	G4	Present in Park
Calamagrostis porteri	Porter's reedgrass	KY=N, S2; TN=E, S1	G4	Present in Park
Calamagrostis porteri ssp. *porteri*	Porter's reedgrass	KY=T, S2	T4	Present in Park
Cardamine rotundifolia	Round-leaf water cress	TN=S, S2	G4	Present in Park
Carex appalachica	Appalachian sedge	KY=T, S2; TN=S1	G4	Present in Park
Carex austrocaroliniana	Tarheel sedge	KY=S; TN=S2	G4	Present in Park
Carex interior	Inland sedge	VA=S1	G5	Present in Park
Carex purpurifera	Purple sedge	VA=S2	G4	Present in Park
Carex radiata	Stellate sedge	KY=N, S2	G4	Present in Park
Castanea dentata	American chestnut	KY=E, S1; TN=S, S2	G4	Present in Park
Castanea pumila	Allegheny chinkapin	KY=T, S2	G5	Present in Park
Castanea pumila var. *pumila*	Allegheny chinkapin	KY=S1	T5	Present in Park
Cheilanthes alabamensis	Alabama lipfern	KY=H, SHS1	G4	Present in Park
Clematis catesbyana	Satincurls	KY=H, SHS1	G4	Present in Park
Cocculus carolinus	Carolina coralbead	VA=S1	G5	Present in Park
Convallaria majuscula	Convallaria	KY=E, S1	G4	Present in Park
Corydalis sempervirens	Pale corydalis	KY=S; TN=E, S1	G4	Present in Park
Crataegus calpodendron	Pear hawthorn	VA=S1	G5	Present in Park
Cypripedium acaule	Pink lady's-slipper	TN=S-CE, S4	G5	Present in Park
Cypripedium parviflorum	Small yellow lady's-slipper	KY=T, S2	G5	Present in Park
Deschampsia flexuosa	Wavy hairgrass	KY=T, S2	G5	Present in Park
Desmodium cuspidatum	Largebract ticktrefoil	VA=S2	G5	Present in Park
Desmodium strictum	Pinebarren ticktrefoil	VA=S2	G4	Present in Park
Elymus canadensis	Nodding wild-rye	VA=S2	G5	Present in Park
Eriophorum virginicum	Tawny cottongrass	KY=E, S1; TN=E, S1	G5	Present in Park
Eryngium yuccifolium	Rattlesnake-master	VA=S2	G5	Present in Park
Eupatorium incarnatum	Pink thoroughwort	VA=S2	G5	Present in Park
Eupatorium steelei	Steele's eupatorium	KY=T, S2	G4	Present in Park
Euphorbia mercurialina	Mercury spurge	KY=T, S1	G4	Present in Park
Eurybia surculosa	Creeping aster	VA=S1	G4	Present in Park
Gentiana decora	Showy gentian	KY=S	G4	Present in Park
Hexastylis contracta	Mountain heartleaf	KY=E, S1	G3	Present in Park
Hieracium scabrum	Rough hawkweed	TN=T, S2	G5	Present in Park
Houstonia canadensis	Canadian summer bluet	VA=S2	G4	Present in Park
Huperzia porophila	Rock clubmoss	VA=S1	G4	Present in Park
Hydrastis canadensis	Golden-seal	TN=S-CE	G4	Present in Park

Species		State[1]/Federal Status[3]/Rank[2]	Global Rank[4]	Park Presence Status
Hydrophyllum virginianum	Shawnee salad	KY=T, S2; TN=T	G5	Present in Park
Juglans cinerea	Butternut	KY=S, S3; TN=T	G4	Present in Park
Juncus subcaudatus	Woods-rush	KY=N, S1	G5	Present in Park
Lathyrus venosus	Smooth veiny peavine	KY=S, S2	G5	Present in Park
Lilium canadense	Canada lily	TN=T, S3	G5	Present in Park
Listera smallii	Kidney-leaf twayblade	KY=T, S2	G4	Probably Present
Lonicera dioica	Limber honeysuckle	TN=S, S2	G5	Present in Park
Lycopodium clavatum	Running clubmoss	KY=E, S1	G5	Present in Park
Lysimachia tonsa	Southern loosestrife	TN=S2	G4	Present in Park
Magnolia macrophylla	Bigleaf magnolia	VA=S1	G5	Present in Park
Maianthemum canadense	False lily-of-the-valley	KY=T, S2	G5	Present in Park
Melampyrum lineare	American cow-wheat	KY=N, S2	G5	Present in Park
Melampyrum lineare var. *latifolium*	American cowwheat	KY=T, S2	T5	Present in Park
Melanthium parviflorum	Small-flowered false helleborne	KY=E, S1	G4	Present in Park
Minuartia glabra	Appalachian sandwort	KY=T, S1	G4	Present in Park
Minuartia groenlandica	Appalachian sandwort	TN=E, S1S1	G5	Present in Park
Oclemena acuminata	Whorled wood aster	KY=T, S2	G5	Present in Park
Oligoneuron rigidum var. *rigidum*	Stiff goldenrod	VA=S2	T5	Present in Park
Panax quinquefolius	American ginseng	TN=S-CE; VA=T	G3	Present in Park
Paronychia argyrocoma	Silvery nailwort	KY=E, S1; TN=T, S1	G4	Present in Park
Penstemon calycosus	Longsepal beardtongue	VA=S1	G5	Present in Park
Phlox amplifolia	Large-leaved phlox	VA=S2	G4	Present in Park
Polygonatum biflorum var. *commutatum*	Smooth Solomon’s seal	TN=S2	T5	Present in Park
Polygonum arifolium	Halberd-leaf tearthumb	TN=T, S1	G5	Present in Park
Prosartes maculata	Nodding Mandarin	KY=S	G3	Present in Park
Ranunculus allegheniensis	Allegheny mountain buttercup	TN=S1	G4	Present in Park
Rhododendron catawbiense	Catawba rhododendron	KY=N, S2	G5	Present in Park
Rhododendron minus	Carolina rhododendron	TN=S2	G4	Present in Park
Robinia hispida var. *rosea*	Bristly locust	KY=N, S2	T3	Present in Park
Rosa setigera	Prairie rose	VA=S1	G5	Present in Park
Rosa virginiana	Virginia rose	TN=S, SH	G5	Present in Park
Rubus canadensis	Smooth blackberry	KY=E, S1	G5	Present in Park
Ruellia purshiana	Pursh's wild-petunia	TN=S, S1	G3	Present in Park
Salvia urticifolia	Nettle-leaf sage	KY=E, S1	G5	Present in Park
Saxifraga michauxii	Michaux's saxifrage	KY=T, S2	G4	Present in Park
Scutellaria incana	Hoary skullcap	VA=S2	G5	Present in Park
Silene ovata	Ovate catchfly	KY=E, S1; TN=E, S2S1	G3	Present in Park
Silene rotundifolia	Roundleaf catchfly	VA=S2	G4	Present in Park
Silphium terebinthinaceum	Prairie rosinweed	TN=S2S1	G4	Present in Park
Sisyrinchium albidum	White blue-eyed grass	VA=S2	G5	Present in Park
Smilax ecirrata	Upright carrionflower	VA=S1	G5	Present in Park
Solidago curtisii	Curtis’ goldenrod	KY=T, S2	G4	Present in Park
Solidago roanensis	Roan mountain goldenrod	KY=T, S1	G4	Present in Park

Species		State[1]/Federal Status[3]/Rank[2]	Global Rank[4]	Park Presence Status
Streptopus lanceolatus var. *roseus*	Twistedstalk	TN=S1	T4	Present in Park
Symphyotrichum laeve	Smooth blue aster	KY=N, S2	G5	Present in Park
Trillium undulatum	Painted trillium	KY=T, S2	G5	Present in Park
Vaccinium erythrocarpum	Southern mountain cranberry	KY=E, S1	G5	Present in Park
Vitis labrusca	Fox grape	KY=S, S2	G5	Present in Park
Woodsia appalachiana	Appalachian cliff fern	KY=H, SH; TN=S, S1	G4	Present in Park

[1]State Rank (KY, TN, VA): E=Endangered, T=Threatened, S=Special Concern, CE=Commercially Exploited, N=None.

[2] Rounded NatureServe conservation status of a species from a state/province perspective, characterizing the relative imperilment of the species. S1=Critically Imperiled, S2=Imperiled, S3=Vulnerable, S4=Apparently Secure, S5=Secure, SH = Possibly Extirpated, H = Historic; Refer to <http://www.natureserve.org/explorer/nsranks.htm> for additional information on ranks.

[3] U.S. Endangered Species Act: Current status of the taxon as designated or proposed by the U.S. Fish and Wildlife Service (USFWS) or the U.S. National Marine Fisheries Service, and as reported in the U.S. Federal Register in accordance with the U.S. Endangered Species Act of 1973, as amended.

[4] Rounded NatureServe conservation status from a global (i.e., rangewide) perspective, characterizing the relative imperilment of the species. G1=Critically Imperiled, G2=Imperiled, G3=Vulnerable, G4=Apparently Secure, G5=Secure. Refer to <http://www.natureserve.org/explorer/ranking.htm> for additional information on ranks.

Table 34. Rare plant species previously found at CUGA by Pounds et al. (1989) and other sources that were not located by White and Littlefield (2008) in 2008.

Species		Additional Comments (from White and Littlefield 2008)
Solidago roanensis	Roan Mountain goldenrod	--
Silene ovata	Ovate catchfly	Originally along Cumberland Mtn. ridge, potentially still located along VA side of Ewing trail
Salvia urticifolia	Nettle-leaf sage	--
Listera smallii	Kidney-leaf twayblade	Likely still occurs in park
Castanea pumila	Allegheny chikapin	Originally on ridge near Cumberland Gap
Boykinia aconitifiolia	Brook Saxifrage	Originally along Martin's Fork; insufficient location information to resurvey, but likely still occurs
Carex austrocaroliniana	Tarheel sedge	Originally a single ridgetop specimen SW of White Rocks
Aralia nudicaulis	Wild Sarsaparilla	--
Rubus canadensis	Smooth blackberry	Originally reported in a single location in CUGA and other nearby areas
Adlumia fungosa	Allegheny-vine	Previous individuals very low (< 5), no other KY reports in last 50 years

Table 35. Management Guideline for Rare Plants. (from White and Littlefield 2008)

Species Name	Common name	Fire	Recreation (Near recreation areas i.e. trails and campsites)	Loss of Hemlock
Adlumia fungosa	Allegheny vine	Beneficial	No	Not likely/ indirectly
Amianthium muscitoxicum	Flypoison	Beneficial	Yes	Not likely/ indirectly
Aralia nudicaulis	Wild sarsaparilla	Likely Detrimental	No	Detrimental
Boykinia aconitifolia	Brook saxifrage	Detrimental	No	Detrimental
Calamagrostis porteri ssp. *porteri*	Porter's reedgrass	Beneficial	Yes	Not likely/ indirectly
Carex austrocaroliniana	Tarheel sedge	Unknown	No	Not likely/ indirectly
Castanea pumila	Allegheny chinkapin	Beneficial	No	Not likely/ indirectly
Convallaria montana	American lily-of-the-valley	Not likely	Yes	Not likely/ indirectly
Corydalis sempervirens	Rock harlequin	Beneficial	Yes	Not likely/ indirectly
Deschampsia flexuosa	Wavy hairgrass	Likely Beneficial	Yes	Not likely/ indirectly
Eriophorum virginicum	Tawny cottongrass	Detrimental	No	Detrimental
Lathyrus venosus	Veiny pea	Beneficial	Yes	Not likely/ indirectly
Listera smallii	Kidneyleaf twayblade	Detrimental	No	Detrimental
Maianthemum canadense	Canada mayflower	Likely Detrimental	Yes	Detrimental
Melampyrum lineare var. *latifolium*	Narrowleaf cowwheat	Beneficial	Yes	Not likely/ indirectly
Minuartia glabra	Appalachian stitchwort	Likely Beneficial	Yes	Not likely/ indirectly
Oclemena acuminata	Whorled wood aster	Detrimental	Yes	Detrimental
Paronychia argyrocoma	Silvery nailwort	Likely Beneficial	Yes	Not likely/ indirectly
Rubus canadensis	Smooth blackberry	Beneficial	No	Not likely/ indirectly
Saxifraga michauxii	Michaux's saxifrage	Detrimental	Possibly	Detrimental
Silene ovata	Ovate catchfly	Likely Beneficial	No	Unknown/ not likely/indirectly
Solidago curtisii	Curtis' goldenrod	Likely Beneficial	Yes	Not likely/ indirectly
Solidago roanensis	Roan Mountain goldenrod	Likely Beneficial	Possibly (location not found)	Not likely/ indirectly
Trillium undulatum	Painted trillium	Detrimental	Possibily	Detrimental
Vaccinium erythrocarpum	Southern mountain cranberry	Unknown	No	Detrimental
Veratrum parviflorum	Appalachian bunchflower	Likely Detrimental	Yes	Detrimental

Commercially Valuable Plants

Some state-listed plant species at CUGA are also of economic value and therefore face a potential risk of overexploitation. In particular, goldenseal (*Hydrastis canadensis*), pink lady's slipper (*Cypripedium acaule*), black cohosh (*Actaea racemosa*) and American ginseng (*Panax quinquefolius*) are present at CUGA and represent potential targets of interest in the commercial trade.

The root of goldenseal is popular as a natural herbal medicine and has commonly been reported as a target of poaching. The roots contain medicinal alkaloids and are used as an antibiotic, immune system booster, and even an HIV/AIDS treatment (Sinclair and Catling 2001). Goldenseal is sold by the root and the herb, though the former is more valuable. Steadily increasing prices over the last few decades most recently reached ~$25 per pound in 2005 (Burkhart and Jacobson 2006). It typically occurs on rich, mesic, and alkaline soils in deciduous forests and is particularly susceptible to encroachment of invasives like garlic mustard (NatureServe 2011).

Pink lady's slipper is another species affected by commercial exploitation. Like goldenseal, this species is harvested for medicinal purposes, but also is targeted because of horticultural demand. Pink lady's slipper typically grows in wetland areas, dry oak or conifer woodland areas, and is adversely affected by fire suppression (NatureServe 2011).

Ginseng, like goldenseal, occurs in rich, mesic forests under moderately closed canopy where average populations can include dozens to hundreds of individual plants. Wild-harvested ginseng roots are the most commonly exported native medicinal plant in the US (Gabel 2009). Ginseng is also under threat by invasive plants such as multiflora rose, garlic mustard, and Japanese barberry, and has been impacted largely in the past by periods of timber harvest and overall loss of forest habitat. Wixted and McGraw (2009a) observed an increased susceptibility of ginseng to invasive encroachment in harvested populations, as well as increased mortality of ginseng seedlings in the presence of garlic mustard. In addition, ginseng is susceptible to invasion by tree-of-heaven, which, like garlic mustard, produces allelochemicals that can decrease chances of survival for ginseng seedlings (Wixted and McGraw 2009b). In a Virginia study plot close to CUGA, Wixted and McGraw (2009b) documented Japanese stiltgrass (*Microstegium vimineum*) and multiflora rose among a ginseng population during field assessments in 2006 and 2007. Wixted and McGraw (2009b) described the ability of multiflora rose to form dense thickets that eventually may exclude native species including ginseng. Efforts to determine minimum viable population (MVP) sizes have resulted in estimates ranging from 172 plants in Canada, 510 in the Great Smoky Mountains National Park (GRSM), and up to 800 in West Virginia where populations are influenced by white-tailed deer predation (Gabel 2009, NatureServe 2011). Although a general assessment of population size has not been conducted at CUGA, the survey at GRSM observed that none of the populations there reached the 510 MVP level (NatureServe 2011). Ginseng poaching is an ongoing issue at CUGA, and as of this writing, law enforcement rangers have already confiscated over 300 roots from poachers this year, with an estimated value of $100 per wet pound (J. Beeler personal communication).

Besides ginseng, the only current poaching issue at CUGA is black cohosh. Valuable as a medicinal herb, cohosh is commonly regarded as an anti-inflammatory, sedative, and diuretic, among other functions. It is also the subject of several clinical trials as a potential alternative to hormone replacement therapy (Predny et al. 2006). In 2004, dry cohosh root was valued at $3 per pound. Although it is not state-listed in any of the tri-states, it is in danger of decline, especially in public land areas where larger tracts of forest are available for collecting (NatureServe 2011).

Summary

The recent survey by White and Littlefield (2008) of rare plants in KY is perhaps the most up-to-date information on the persistence of these species and their potential threats, which mainly include visitor use and hemlock decline from HWA. As a result of this survey, several species previously documented in the KY Natural Heritage Database were not located in the park. White Rocks is specifically mentioned as an area in the park with plant populations susceptible to trampling-related declines in the near future. Exotic plants currently pose little threat to rare plants, though monitoring for encroachment would ensure this status is maintained. Certain rare plant species may also benefit more than others from targeted management attention (Table 35). Plant poaching is also an issue at CUGA, mainly for American ginseng and increasingly black cohosh, though other potentially exploitable species are present in the park. The park would greatly benefit from survey(s) in the manner of White and Littlefield (2008) for the status of rare plants in VA and TN, especially given the new acquisition of land in the Fern Lake watershed.

Overall, CUGA harbors a large amount of protected habitat for several species of rare plants, and as a result receives a condition status of good for at-risk plants. However, due to the imminent threat of HWA and the impact this will likely have on certain plant populations, the emerging threat of plant poaching and exploitation, as well as the perceived loss by White and Littlefield (2008) of species previously documented in the park, the condition receives a declining trend.

Table 36. The condition status of rare plants at CUGA was ranked as good with a declining trend. The data quality was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Rare Plants		✓	✓	✓
		3 of 3: Good		

Landscape Dynamics

Land Use

Landscape dynamics is a broad category that can potentially utilize a variety of metrics or measures to describe land characteristics and how they change over time. One of the major metrics associated with landscape dynamics is habitat fragmentation, which usually takes place in close association with habitat loss. Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself.

Because CUGA is located beside the moderately developed region of Middlesboro, KY, it is prone to the influence and alteration of continued expansion around its periphery. Infringements on the boundary of the park can serve as threats in several ways, including: 1) vectors for invasive species, 2) producers of air and depositional pollution, or 3) sources of water quality degradation, in addition to a variety of other effects.

National Landcover Dataset (NLCD)

To understand how landscape changes could affect the park unit, it is useful to compare changes in the surrounding area over time. To that end, the Multi-Resolution Land Characteristics Consortium (MRLC) constructed a retrofitted landcover change map to compare the 1992 to 2001 National Landcover Dataset (NLCD) data layers, while correcting for differences in mapping methodologies and classification types between the two time periods (MRLC 2009). After this correction, the retrofitted layer shows which areas have transitioned to new landcovers, and which have not changed at a 30m resolution. Within the park boundary, including the area of the 2008-2009 Fern Lake acquisitions, the NLCD change layer shows 24 hectares of reclassification as forest loss either from development (e.g. roads) or conversion to grassland/shrub. These changes appear mainly to be the result of construction and alterations of the Old Wilderness Rd./Highway 58 along the southern border of the park unit around the Lewis Hollow area.

Table 37 shows landcover classes for the most recent NLCD layer at the park scale in addition to 400m and 1km perimeter buffers. As expected, as the area around the park boundary increases, the amount of forest decreases and the amount of developed land increases (Figure 46). The NLCD change layer shows a loss of 212 ha of forest in the 1km buffer to other classes—a rate of loss about ten times that shown inside the park over the same time period. Approximately one-third of the forest loss is due to development.

Table 37. Comparison of park unit 2001 NLCD classifications, including Fern Lake watershed, with 400m and 1 km buffers (areas in ha).

Landcover	**Park 2001 NLCD**	**400m 2001 NLCD**	**1 km 2001 NLCD**
		---ha---	
Grassland/Shrub	59 (1%)	214 (5%)	631 (7%)
Forest	9490 (97%)	3640 (86%)	7601 (78%)
Barren	4 (<1%)	2 (<1%)	16 (<1%)
Developed	233 (2%)	250 (6%)	735 (8%)
Wetlands	<1 (<1%)	<1 (<1%)	<1 (<1%)
Water	<1 (<1%)	42 (1%)	43 (<1%)
Total	**9760**	**4222**	**9694**

Gap Analysis Project (GAP)

Another source of classified landcover information is the Gap Analysis Project (GAP) dataset, which was created to identify areas of potential wildlife habitat for protection (USGS 2009). In addition to the NLCD, the GAP dataset can provide a means to compare landcover changes over different time periods or at different park unit buffer widths. GAP data is collected from multi-season satellite imagery collected by the Landsat ETM+ satellite. At CUGA, landcover is divided into 13 classes, the majority of which are the Allegheny – Cumberland Dry Oak Forest/Woodland (79%) and the Southern and Central Appalachian Cove Forest (13%, Table

38). GAP Classes like the Appalachian Hemlock-Hardwood Forest and Southern and Central Appalachian Cove Forest corresponded well with the Cumberland/Appalachian Hemlock-Hardwood Cover Forest (CEGL8407) and Appalachian Montane Oak-Hickory Forests (CEGL6192), respectively, though GAP classes corresponded to multiple CRMS classes and often the relationships are not consistent. Like the NLCD forest classes, these landcover types decrease proportionally at each buffer width, with complementary gains of agriculture, grassland/shrub, and developed area (Figure 46).

Table 39 shows the total area, mean patch size, number of patches, and mean patch fractal dimension for each community type included in the CRMS classification, in addition to mean biodiversity based on the NatureServe surveys at each plot location. Mean patch fractal dimension is a metric that expresses shape complexity on a scale of one to two, with higher numbers representing more complex shapes (Elkie et al. 1999). Community types were sampled at different rates based on predominance, with frequency ranging from 19 plots in the Appalachian Oak-Hickory Forest type to several communities that were sampled with only a single plot. Nine communities appearing in the CRMS classification were not included in any of the plots and are therefore not assigned a mean diversity. Figure 47 depicts mean species richness for each community type sampled, which shows the highest richness at the Ridge and Valley Limestone Oak-Hickory Forest.

Table 38. Comparison of park unit 2001 GAP classifications, including Fern Lake, with 400m and 1 km buffers (areas in ha).

Landcover	**Park 2001 GAP**	**400m 2001 GAP**	**1 km 2001 GAP**
		---ha---	
Agriculture	2 (<1)	70 (2%)	645 (7%)
Allegheny - Cumberland Dry Oak Forest and Woodland - Hardwood	7703 (79%)	3012 (71%)	6097 (63%)
Appalachian Hemlock – Hardwood Forest	234 (2%)	112 (3%)	288 (3%)
Developed	191 (2%)	211 (5%)	631 (6%)
Grassland/Shrub	74 (1%)	208 (5%)	616 (6%)
South Central Interior Mesophytic Forest	1 (<1%)	7 (<1%)	29 (<1%)
South-Central Interior Small Stream and Riparian	28 (<1%)	16 (<1%)	31 (<1%)
Southern and Central Appalachian Cove Forest	1286 (13%)	465 (11%)	1041 (11%)
Southern Appalachian Low Mountain Pine Forest	64 (1%)	43 (1%)	133 (1%)
Southern Appalachian Montane Pine Forest and Woodland	160 (2%)	23 (1%)	57 (1%)
Southern Interior Acid Cliff	47 (1%)	5 (<1%)	8 (<1%)
Southern Ridge and Valley Dry Calcareous Forest	<1 (<1%)	6 (<1%)	46 (1%)
Water	<1 (<1%)	40 (1%)	42 (<1%)
Total	**5679**	**4220**	**9688**

Summary
Overall, because of the lack of standards and assessment ability, the status of landscape dynamics is not assigned a ranking, though a stable trend is assessed based on minimal observed changes over time (Table 40). Because no landscape information is available within the past five years, this condition does not receive a temporal check for data quality.

As of this writing, NPS is developing additional landscape analysis tools as part of a project called NPScape, which is intended to standardize the way landscape change is monitored for all park units with significant natural resources. This new landscape dynamics monitoring protocol will undoubtedly provide a basis by which to assess landscape conditions for all NPS units.

Table 39. Of the 33 vegetation communities identified by White (2006), 27 were represented by one of the 101 survey plots established during 2002-2004. Landscape metrics are expressed for each of these communities, along with mean species richness (S).

Vegetation Type	Ecological Group	Total Area	Mean Patch Size	Number Patches	Mean Patch Fractal Dim.	Mean *S* (# plots)
		----ha-----				
Southern Appalachian Eastern Hemlock Forest	Appalachian (Hemlock) – Northern Hardwood Forest	166	5	35	1.43	42 (1)
Cumberland/Appalachian Hemlock – Hardwood Forest	Appalachian (Hemlock) – Northern Hardwood Forest	212	3	81	1.40	116 (2)
Ridge and Valley Limestone Oak-Hickory Forest	Central Appalachian Alkaline Glade and Woodland	6	2	3	1.77	134 (1)
Dry Calcareous Forest/Woodland	Central Appalachian Alkaline Glade and Woodland	169	3	56	1.36	77 (6)
Virginia Pine Successional Forest	Human Modified / Successional	57	1	43	1.39	93 (4)
Cultivated Meadow	Human Modified / Successional	78	2	40	1.41	--
Blackberry – Greenbrier Successional Shrubland Thicket	Human Modified / Successional	20	1	23	1.44	--
Red-Cedar Successional Forest	Human Modified / Successional	<1	<1	2	1.59	--
Successional Tuliptree Forest	Human Modified / Successional	143	3	41	1.43	56 (2)
Interior Mid- to Late- Successional Tuliptree-Hardwood Upland Forest Type	Human Modified / Successional	28	3	11	1.36	85 (3)
Swamp Forest-Bog Complex	South and Central Appalachian Bog and Fen	21	2	10	1.39	--
Cumberland Streamside Bog	South and Central Appalachian Bog and Fen	3	1	4	1.42	73 (2)
Northern Mixed Mesophytic Forest	South Central Interior Mesophytic Forest	293	3	95	1.40	103 (8)
Central Interior Beech – White Oak Forest	South Central Interior Mesophytic Forest	39	3	13	1.40	14 (2)
Sycamore-Sweetgum Swamp Forest	South-Central Interior Small Stream and Riparian	43	2	20	1.43	32 (1)
Southern Appalachian Mountain Laurel Bald	Southern Appalachian Grass and Shrub Bald	32	1	35	1.42	15 (1)
Cumberland Sandstone Glade Heath Shrubland	Southern Appalachian Grass and Shrub Bald	18	1	13	1.41	--
Hi-Lewis Pitch Pine Barrens	Southern Appalachian Montane Pine Forest and Woodland	61	2	31	1.36	54 (1)

Table 36 continued. Of the 33 vegetation communities identified by White (2006), 27 were represented by one of the 101 survey plots established during 2002-2004. Landscape metrics are expressed for each of these communities, along with mean species richness (S).

Vegetation Type	**Ecological Group**	**Total Area**	**Mean Patch Size**	**Number Patches**	**Mean Patch Fractal Dim.**	**Mean *S* (# plots)**
		----ha-----				12 (3)
Montane Grape Opening	Southern Appalachian Oak Forest	<1	<1	1	1.34	13 (1)
Southern Blue Ridge Successional Sassafras Forest	Southern Appalachian Oak Forest	26	1	22	1.39	22 (2)
Appalachian Montane Oak – Hickory Forest (Red Oak Type)	Southern Appalachian Oak Forest	1271	16	82	1.35	43 (11)
Chestnut Oak Forest (Xeric Ridge Type)	Southern Appalachian Oak Forest	1312	3	421	1.37	66 (8)
Chestnut Oak Forest (Mesic Slope Heath Type)	Southern Appalachian Oak Forest	198	3	72	1.38	43 (5)
Ridge and Valley Dry-Mesic White Oak-Hickory Forest	Southern Appalachian Oak Forest	671	6	105	1.40	134 (1)
Appalachian Oak-Hickory Forest (Chestnut Oak Type)	Southern Appalachian Oak Forest	1548	5	306	1.38	42 (19)
Appalachian Montane Oak-Hickory Forest (Rich Type)	Southern Appalachian Oak Forest	721	6	124	1.37	98 (15)
Southern Appalachian Acidic Mixed Hardwood Forest	Southern Appalachian Oak Forest	7	2	3	1.35	20 (3)
Total	--	**7338**	**3**	**1793**	**--**	**60 (5)**

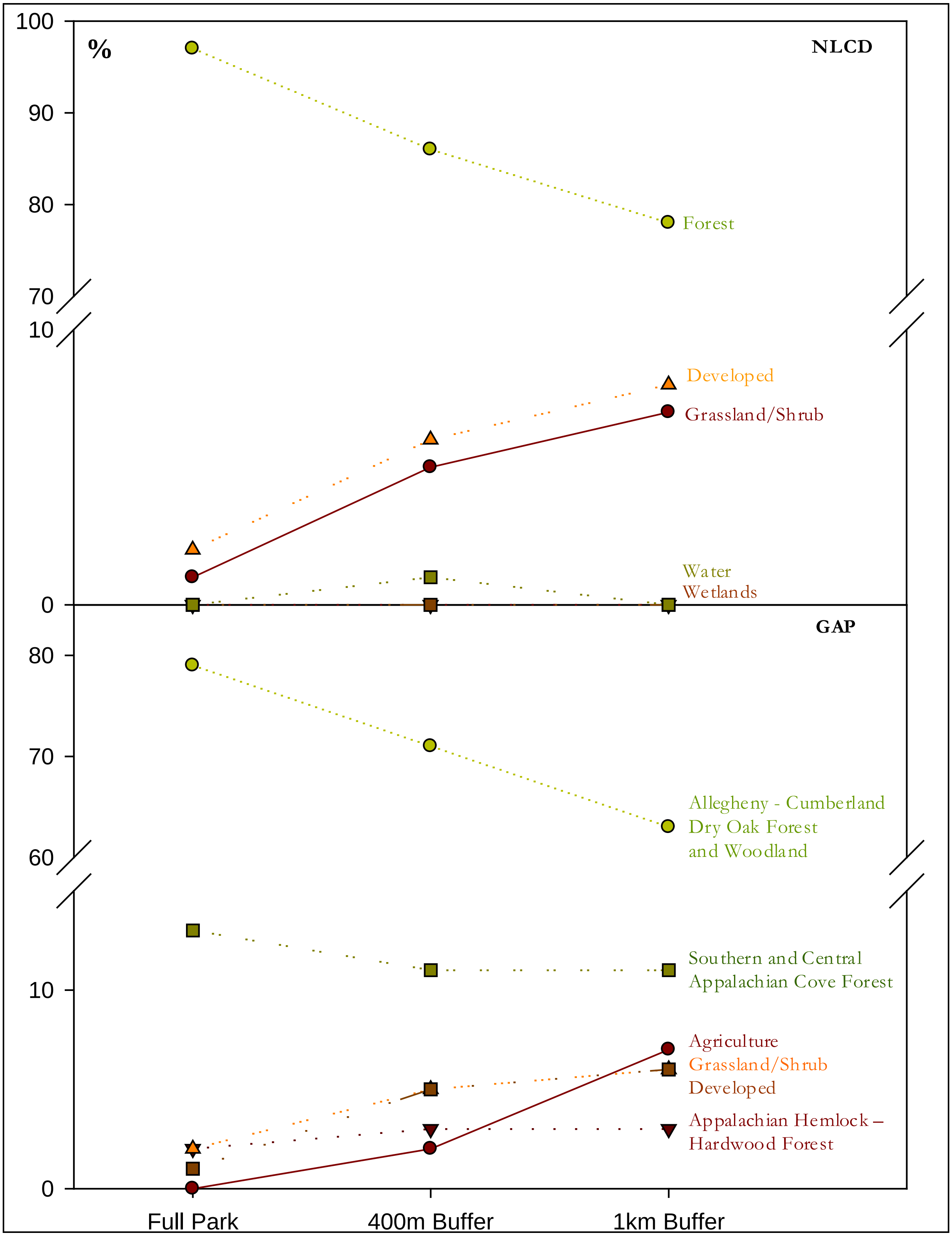


Figure 46. With each successive buffer perspective, developed and grassland/shrub landcover increase at the expense of forest under both NLCD and GAP landcover datasets.

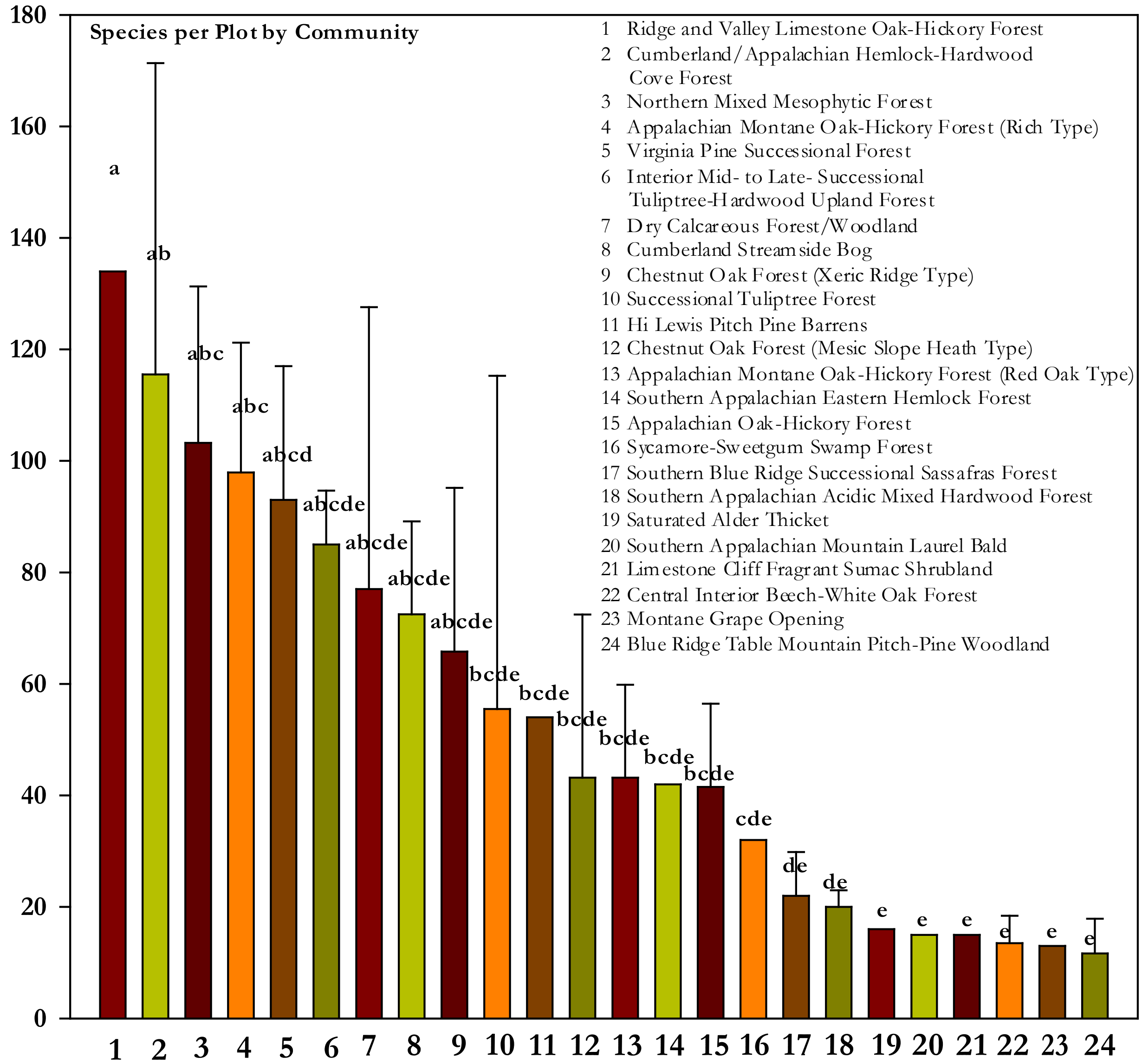
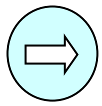


Figure 47. Mean species richness for each community type sampled by White (2006). Appalachian Oak-Hickory Forest was the most commonly sampled vegetation type (19 plots), while the Ridge and Valley Limestone Oak-Hickory Forest showed the highest average plant biodiversity (1 plot). Plots are expressed with 95% confidence intervals.

Table 40. The condition status for landscape dynamics at CUGA was not ranked, but was assigned a stable trend. The data quality was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Landscape Dynamics		✓	✓	
		2 of 3: Fair		

Conclusions

Summary

Based on a review of available ecological information at CUGA, we have addressed the current condition of 16 natural resources attributes in the park. We provided qualitative condition ranks for 13 of the 16 attributes, while the other three attributes were discussed and not ranked. Overall, one attribute (6%) was ranked as excellent, seven attributes (44%) were ranked as good, four (25%) were ranked as fair, and one (6%) was ranked as poor. The remaining three attributes (19%) were not ranked.

Summarized into broad Level-1 categories (Table 1) the ranking were:

Air and Climate (two attributes)—100% Fair
Geology and Soils (one attribute)—100% Not Ranked
Water (three attributes)—66% Good, 33% Fair
Biological Integrity (nine attributes)—11% Excellent, 56% Good, 11% Fair, 11% Poor, 11% Not Ranked
Landscapes (one attribute)—100% Not Ranked

We also characterized the quality of information used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Data were classified as fair for two attributes (landscape dynamics and cave bats), and poor for one attribute (cave meteorology), while the remainder was classified as good.

Natural Resource Conditions

Natural resources at CUGA were chosen based on data availability, park-level importance, and vital sign status. The level of data completeness varied greatly among natural resource categories, though this aspect was considered independently when assigning condition rankings. Where appropriate, suggestions are offered to improve natural resource datasets.

Ozone

Beginning in 2005, CUGA began ozone monitoring at 3 sites in the park, 2 of which showed abnormally high concentrations compared to other CUPN park units. These measurements, however, did not exceed the EPA NAAQS. Monitoring with a POMS began the following year and showed decreasing concentrations as observed from 3-yr 4th highest annual 8-hr concentrations. None of the metrics exceeded the EPA NAAQS during 2007-2010. Monitoring at the nearby Speedwell CASTNET station showed a discernible reduction since monitoring began in 1999, though measurements exceeded the NAAQS most years, including the most recent 3-yr average (2007-2009). Because it appears that ozone concentrations at CUGA have recently fallen into the region of compliance, it received a condition status of fair with an improving trend. Continued observations will hopefully verify this decreasing trend.

<u>Data quality</u>

The ongoing monitoring using the POMS at CUGA provides a good basis for ozone data. Data for this assessment was supplemented using monitoring from the EPA Speedwell CASTNET station located 10 km south of the park. Although useful given its long record of monitoring, measurements may not correspond to those at the park due to differences in elevation. As the dataset from the POMS grows, use of the CASTNET data will likely become less useful.

Foliar injury

Risk of ozone damage to vegetation is closely tied to ozone concentrations, though it is also affected by exposure duration, species sensitivity, and soil moisture conditions. The severity of the three foliar injury metrics interpreted from national interpolation maps was inconsistent at CUGA, though they overall averaged a moderate risk. Two field studies at CUGA in 2006 and 2008 confirmed some foliar injury, though the first one much more so than the second. As a result, foliar injury received a condition status of fair with a stable trend. Available data for soil moisture showed moisture levels did not appear to exacerbate foliar injury, and if anything the predominance of drought years served to mitigate the risk.

<u>Data quality</u>

Foliar injury metrics are useful for assessing risk to vegetation, though at CUGA they were only available in 2006 and 2008 from actual measurements. More useful are the on-the-ground foliar injury surveys conducted by the CUPN on a six-year rotation among parks. An obvious data gap is the calculation of foliar injury metrics using data collected from the POMS already in place at CUGA. The combination of this annual monitoring, metric calculation, and periodic field surveys would be ideal in determining the impact of ozone at CUGA.

Cave Meteorology

Caves are one of the park's outstanding resources and CUGA contains at least 30 known caves. Caves provide habitat for unique animal assemblages. In CUGA these include cave roosting and hibernating bats, including the federally endangered Indiana bat. Meteorological datasets were available for several locations within two caves, one of which is an Indiana bat hibernacula. Data, including temperature and relative humidity, were recorded by automatic dataloggers. Measurements were taken at regular intervals from 1998 - 2011. Only data from 2002 - 2011 were used in this report. Temperature and relative humidity fluctuated seasonally and the data did not show any obvious trends or effects of anthropogenic disturbance over the analyzed period. However, human alterations in the cave systems predate monitoring, so a comparison of the existing regimes with a natural baseline was not possible. The temperature regime recorded at the known Indiana bat hibernacula and at other locations did not preclude successful hibernation for this species. We did not assign a rank to cave meteorology. We assigned a trend of stable to reflect the stability of temperature and humidity regimes observed over the time period.

<u>Data Quality</u>

We ranked the quality of the data for cave meteorology as poor. The available data provides accurate and appropriately-recorded temperature data over a relatively long time frame. However, data are only available for two of at least 30 known caves in the park. Therefore the coverage was insufficient to assess CUGA cave climate generally. Furthermore, the dataloggers used have relatively poor accuracy in high humidity and condensing environments such as are found in many caves.

Water Quality

The condition of water quality at CUGA is divided into three main attributes: surface water, water chemistry, and microorganisms. Monitoring includes ten I&M stations where monitoring began in 2006, as well as historical monitoring dating back to 1980. Of note were the consistently low pH values observed on Martin's Fork and Shillalah Creek, which are likely due to natural conditions, especially given their particularly pristine setting. Overall, however, water chemistry parameters fell within range of expected values, resulting in a condition status of good.

Sampling revealed issues with microorganisms at the Gap Creek and Station Creek monitors, the former of which were likely due to effluent discharge from the wastewater treatment plant in the town of Cumberland Gap, TN. The treatment facility was recently updated, and latest data suggests this issue is resolved. Bacterial contamination on Station Creek was likely due to its proximity to the septic field of the Wilderness Road campground. Prior sampling above and below the campground supports a distinctive pattern of this point-source contamination, which also appeared to worsen over time. As a result, a new septic system is scheduled for installation at this location in November 2011. As of this writing however, contamination issues at Station Creek still appear ongoing, and as a result microorganisms receives a ranking of fair with a declining trend.

Finally, because of the positioning of CUGA along a regional watershed divide, virtually all streams passing through the park unit also originate inside it. The exceptions are Gap Creek, which exits and reenters at the town of Cumberland Gap, and Little Yellow Creek, whose headwaters are in the recent Fern Lake acquisition, but which is impounded to create Fern Lake before flowing again through the park. Despite this alteration, the headwaters status of the other streams lends itself to a condition ranking of good for surface water, with a stable trend.

<u>Data quality</u>

Prior to the beginning of I&M collections in 2006, CUGA regularly sampled at locations throughout the park unit, providing a solid foundation for investigating general and specific water quality issues. Clearly, the greatest data need at the moment is the expansion of sampling throughout the Fern Lake unit to include at minimum the headwaters region of Little Yellow Creek. Continued sampling on Station Creek should also confirm the resolution of microorganism contamination following the installation of the new septic system this year.

Invasive Plants

Although as a whole, CUGA contains large areas of relatively unimpacted vegetation, human-impacted portions of the park, particularly the Wilderness Road Trail, contain several invasive species that impact the ecological health of these areas. As a result, combating these invasive plants represents one of the largest investments of time and effort by the park staff. Previous vegetation assessments in the park provide lists of suggested target species, while the current most managed species likely include autumn olive, kudzu, and crown vetch. Although a vegetation assessment has yet to be conducted in the Fern Lake acquisition, autumn olive represents the largest management concern in this area. For these reasons as a whole, the condition status for invasive plants was assigned a rank of fair.

Data quality
Overall, the data quality for this condition is good, mainly as a result of the recent vegetation assessment by White (2006). As previously mentioned, a general vegetation assessment, or one focusing specifically on exotics, would be the most helpful for the Fern Lake watershed. Updates in the main targeted areas of the park would also confirm the efficacy of management efforts.

Infestations and Disease
There are currently several pest species of concern at CUGA, the most significant of which is hemlock woolly adelgid. This pest was originally observed in the park in 2006 and continues to spread around the region, where it threatens to fundamentally alter hemlock forests. Because of the keystone role of hemlocks in these forest ecosystems, their loss could negatively impact myriad other functions important to these communities. Along with the treatment of invasive plants, combating the adelgid infestation currently represents the main management priority for the park. Treatments at CUGA are ongoing and include bio-control and pesticide application.

Besides the hemlock woolly adelgid, other pest insect species currently threaten the park. Emerald ash-borer is spreading south from the Great Lakes region, and was recently discovered in five counties in TN adjacent to the park, though it has not yet been discovered in the park itself. The European Gypsy Moth is also spreading south from its introduction in the New England area. US Forest Service traps throughout CUGA confirmed a single capture of the moth in 2007, though the invasion front has not yet reached the park and as a result it does not currently represent a management concern. The Asian Long-Horned Beetle, a pest to deciduous hardwoods, represents perhaps the least threat to the park at this time, though it remains on the watchlist of potential pest species. Finally, thousand cankers disease represents a potential threat to the park. Affecting black walnut trees, this disease includes a canker-producing fungus transmitted by the walnut twig beetle. It was originally reported in Knoxville, TN and has resulted in a quarantine of Campbell and Claiborne counties, the latter of which includes the TN portion of CUGA. As of this writing however, this disease has not been reported inside the park.

Southern pine beetle represents a unique pest at the park due to its native status, whose infestation comes in cycles. A recent infestation at CUGA caused several hundred acres of pine mortality throughout the park. One of the more heavily impacted communities was the Hi Lewis Pitch Pine Barrens, which is now at risk of invasion from exotics. A risk assessment model indicated that the Blue Ridge Table Mountain Pine-Pitch Pine Woodland community is at an elevated risk for pine beetle infestation, and though already impacted by pine beetle, its regeneration may currently be limited by fire suppression.

Although CUGA faces an imminent threat from several pest species, the current infestation of hemlock woolly adelgid poses perhaps the greatest ecological threat to the park, and as a result this is the only park condition to be assigned a status of poor with a declining trend. With continued aggressive treatment, it is hopeful that the impact to these communities can be minimized.

Data Quality
Data regarding woolly adelgid includes specific treatment locations, including pesticide treatment areas and predatory beetle release sites, though specific data on the extent of its

infestation throughout the park is unknown and might help focus treatment efforts. Data for southern pine beetle mainly stems from White's (2006) assessment, while the remaining discussion involving imminent pest threats stems from park staff observations and general extent maps. Overall, data quality is good, and continued observations will be important to catch the new threats that are likely to reach the park in the future.

Vegetation Communities

It is apparent that CUGA offers refuge for several vegetation types important to the southern Appalachians, as well as numerous rare plant species associated with these communities. The Dry Calcareous Forest/Woodland type occurs at CUGA and is considered to be one of two remaining examples, while four parcels of Cumberland Streamside Bog, considered imperiled, are dependent on periodic fire to maintain species diversity. This latter community is often associated with the Swamp-Forest Bog Complex, which is also considered imperiled. Due to the canopy presence of hemlock, this community is especially vulnerable to decline. The Hi Lewis Pitch Pine Barrens, also imperiled, is now vulnerable due to a recent outbreak of southern pine beetle. In addition to these community types, a recent assessment of the White Rocks cliff system revealed an overall unique assemblage of vascular and non-vascular plants, which may have been impacted in the past by trampling. Although much information is available regarding vegetation communities at CUGA, it did not receive a condition status ranking due to the lack of evaluation criteria, though plans for a monitoring protocol are underway by the CUPN.

Data Quality

The recent vegetation assessments and landcover classification map provide detailed baseline knowledge of the current distribution of forest types at CUGA. Extension of this knowledge to the Fern Lake acquisition currently appears to be the most pressing data need for this attribute.

Fish Communities

The park contains warm water, cool water, and cold water stream habitat in the headwaters of two major drainages. Around 25 species of fish currently occur in the park. Generally, fish assemblages are healthy and diverse, containing several endemic species and species of concern, including the federally threatened blackside dace. Recently acquired land in the Little Yellow Creek watershed has added significantly to the available high quality fish habitat in the park. Important threats exist to CUGA fishes. Most importantly, beaver activity in the upper reaches of Davis Branch has resulted in decreased numbers of blackside dace in this system. Non-native redbreast sunfish have invaded park streams, apparently since the early 1980s. Although probably non-native in these extreme headwaters of the Cumberland River, brook trout were once present in the park and provide an indication of habitat quality in change. They have apparently been extirpated from Martins Fork and Shillalah Creek within recent decades. These threats aside, the park supports relatively rich fish assemblages. An index of biotic integrity indicated good or excellent condition for seven of nine samples assessed in the park. We ranked the condition of the fish community as good. We assigned a trend of stable based on similarities between historical and recent surveys, and on the long-term sampling conducted at Gap Creek and Davis Branch within the park.

Data Quality

We ranked the quality of the data as good. Available data included historical and recent comprehensive park surveys and two relatively long-term sampling reports for specific creeks in the park. Data were collected with appropriate methods.

Bird Communities

The park supports a rich bird fauna dominated by species specializing in mature forest habitats. A recent inventory of the park reported 145 species including 87 species seen during the breeding season. No federal threatened or endangered species are known to occur, but 19 species from the recent inventory were listed as threatened, endangered, or of special concern at the state level. An index of biotic integrity applied to point count data showed that most locations had communities indicative of good or excellent bird habitat. A 10-count portion of a USGS BBS route is included in CUGA. Data from this 10-count section resulted in higher IBI scores and conservation value indices than did similar data from other regional BBS routes. We ranked the quality of CUGA bird communities as excellent. We assigned a trend of stable to this condition based on similarity between historical and recent observations and on the long-term data available from the BBS routes.

Data Quality

The quality of the data used to assess birds was good. It was recently collected in the park using appropriate methods, and multiple data sources were available.

Mammal Communities

The park has a rich and regionally-typical mammal fauna. Forty species were reported from a recent park survey. Comparisons with results from other studies in the broad region indicate that CUGA had comparable or greater mammal richness of small mammals than other protected forest sites. Around 70% of expected mammals were actually reported from the park, and some of the missing species probably occur but are difficult to sample. We ranked the condition of CUGA mammal communities as good. We did not assign a trend to mammal condition. Although there is a historical inventory report, methods were different between it and recent work. Furthermore, there were no accompanying longer-term monitoring datasets available.

Data Quality

The quality of the data used to assess mammals was good. It was appropriately collected within the park recently using a variety of methods. The effort was similar to that observed in other mammal assemblage sampling in the southeast.

Herpetofauna Communities

Cumberland Gap NHP contains a diverse herpetofauna that includes around 77% of expected species. Amphibians, and especially anurans, are very well represented with 82% and 91% of expected species actually reported. This results, in part, because of a long-term amphibian monitoring project that has been ongoing in the park since 1993 to measure breeding effort of spotted salamanders and wood frogs. Declines in reported breeding effort of wood frogs were observed from 2006-2009, although this apparent trend might be partly accountable to variance in sampling. In 2010, breeding effort appeared to be increasing. Mitigation wetlands constructed in the park around 1999 are meeting stated goals and are receiving breeding effort from a variety of species. Threats to amphibian populations include *Ranavirus*, which has apparently been responsible for die-offs in nearby areas of western North Carolina. Another potential threat includes chytrid fungus, which has been widely reported from the southeastern U.S. and was confirmed in CUGA in 2009. However, largescale mortality resulting from this fungus, have not been reported from the eastern U.S. We ranked the condition of CUGA herpetofaunal assemblages as good. We did not assign a trend to this condition. Although a relatively long-term dataset exists for amphibians, it only quantitatively monitors two species.

Data Quality

We ranked the quality of the data as good. The inventory was conducted recently using appropriate techniques and provided good coverage of the park. A supplemental dataset or amphibian monitoring was also available.

Cave Bats

Caves and cave bats are among CUGA's most important resources. At least six species of cave-hibernating bats, including the federally endangered Indiana bat, occur in CUGA. One or more other species, though not obligate cave users, probably use caves as important roosting habitat. In a recent mammal inventory, three cave openings were sampled for bats. These sample sites accounted for 95% of individual bat captures, despite the fact that seven other non-cave habitats were sampled. This suggests that cave-using bats make up a major percentage of CUGA bat assemblages. The Indiana bat has been monitored within two minor hibernacula in the park. Hibernating numbers declined from 1993 to the early 2000s, but appear to be stabilizing in recent years. These trends are qualitatively similar to the range-wide observations for the species. White-nose syndrome, a fungal infection causing catastrophic declines in some bat populations, poses a severe threat to CUGA cave bats. The disease had not been observed in the park in 2011, although it has been steadily expanding its range into the southeast since its discovery in New York in 2006. Recently reported in Kentucky, the occurrence of this disease may be nearly inevitable in CUGA. We ranked the quality of the CUGA cave bat population as good. We assigned a decreasing trend to this condition to reflect the impending threat from White-nose syndrome.

Data Quality

We ranked the quality of the data on cave bats as fair. The available data were appropriately collected, but scant. Only two of at least 30 known caves in the park have been surveyed for bat hibernation use, and only a few samples have been taken showing summer cave use. The lack of data on cave biota generally represents one of CUGA's most significant data gaps.

At-Risk Plants

The most recent biological inventory at CUGA listed a total of 90 plant species that were federally listed, state-listed, or state-ranked. These include several species in the White Rocks cliff system that represent geographically disjunct populations. A recent assessment noted the absence of rare plants previously documented in the park, and suggested that hemlock decline from woolly adelgid might pose the greatest risk to rare plants in the park. In addition to these rare species, several species might be at risk of illegal poaching due to their commercial value. Ginseng and black cohosh are currently the only poaching issues in the park, but other exploitable species such as goldenseal and pink lady's slipper are present and may represent future targets. Currently, CUGA serves as a refuge for numerous state and regionally-rare plant species. As a result, it receives a condition status ranking of good. However, due to the potential impact on rare plants associated with hemlock decline, the potential loss of rare plants previously identified in the park (White and Littlefield 2008), and the growing issue of plant poaching, this category received a trend of declining.

Data Quality

Multiple floral surveys discuss rare plants at CUGA, and recent fieldwork by White and Littlefield (2008) in particular provides a valuable update to their distribution at CUGA, as well as management guidelines. However, this survey was only for the KY portion of the park. A similar assessment for TN and VA would prove valuable, especially given the recent acquisition of the Fern Lake watershed in TN.

Landscape Dynamics

Numerous factors are involved in an explanation of landscape dynamics and its effects on the park unit. Several sources of landcover data allow a comparison of changes in the park and its periphery. The NLCD reveals virtually negligible (<1%) changes in the park landcover over the period 1992 to 2001, while outside the park boundary much forested land has been lost to development. In addition, both GAP and NLCD show gaining proportions of agriculture, grassland, and developed area at the cost of forest cover at successive buffer widths outside the park. This changing periphery can present several concerns to park natural resources, including facilitated species invasion, increased pollution, and water quality degradation. Although no condition rank was assigned to this attribute, the ongoing development of the NPScape suite of landscape analysis tools will facilitate the assessment of this attribute. Their availability, however, did not coincide with the writing of this report.

Data Quality

The data sources used in this assessment were sufficient to garner a basic impression of the relationship of park landcover with the surrounding region. The addition of the NPScape suite of data products, which investigates a larger buffer region than do our NLCD and GAP datasets, will undoubtedly provide a better understanding of the influences in the park landscape.

Natural Resource Synthesis

The natural resource attributes selected for this condition ranking are intended as a comprehensive summary of the ecological status of CUGA. Although each condition is assigned a rank separately, it is important to note their potential to interact and influence other attributes. A significant challenge to preserving natural resources is considering these interactions and prioritizing management efforts to affect the most beneficial outcomes. With this in mind, it is important to emphasize potential corollaries from the threat of hemlock woolly adelgid and resulting hemlock decline at CUGA, which led to the only "poor" condition status of any of the ranked attributes. Besides obvious changes in forest structure, loss of hemlock could result in changes to water quality via altered transpiration rates and decreased cover. Fish and benthic assemblages could be affected and terrestrial ecosystems could result in reduced diversity due to impacts on sensitive species and from exotic species. Other wildlife that depend on this specific habitat type may be excluded as well.

Landscape dynamics is another attribute that follows a complex relationship with other ecosystem processes. Potential landscape patterns, such as development or fragmentation, can serve as vectors for invasion of exotic species, while connected forest landscapes could act as corridors for insect or disease entry. Landscape changes can also result in additional sources of air pollution, which contributes to generation of ozone. This, in turn, has the potential to alter vegetation communities through foliar injury. Encroachment may have effects on water quality of streams at CUGA via atmospheric deposition, which are already susceptible to acidic loading due to naturally acidic waters along with low buffering capacities.

This project represents the first iteration in the development of a comprehensive natural resource monitoring program at CUGA. Beyond this report, continued monitoring of resources and attention to data gaps, as well as the development of additional condition assessment protocols will aid in the undertaking of future natural resource assessments.

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Appendix A. NPS Ecological Monitoring Framework table, with highlighted categories representing relevant vital signs and features specifically selected for CUGA—'*' denotes an official vital sign as identified by the CUPN for CUGA by the network monitoring plan. Highlighted entries with a '†' are significant natural resources mentioned elsewhere, or low priority vital signs mentioned in the original list of considerations in Appendix Q of the CUPN Monitoring Plan (Leibfreid et al. 2005). Measures listed under "Vital Sign / Measures" are suggested metrics or ones already available from existing data.

Ecological Monitoring Framework—CUGA			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Vital Sign / Measures**
Air and Climate	Air Quality	Ozone*	Official Vital Sign: "Ozone and ozone impact"; Measures: Ozone levels and impact on native plants
		Wet and Dry Deposition	
		Visibility and Particulate Matter	
		Air Contaminants	
	Weather and Climate	Weather and Climate	
Geology and Soils	Geomorphology	Windblown Features and Processes	
		Glacial Features and Processes	
		Hillslope Features and Processes†	Not an official Vital Sign: Geologic Formations significant to enabling legislation; Limestone Cliffs and climbing impacts
		Coastal/Oceanographic Features and Processes	
		Marine Features and Processes	
		Stream/River Channel Characteristics	
		Lake Features and Processes	
	Subsurface Geologic Processes	Geothermal Features and Processes	
		Cave/Karst Features and Processes*	Official Vital Sign: "Cave meteorology" (for MACA) Measures: Air temperature, relative humidity, airflow
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	
		Surface Water Dynamics*	Official Vital Sign: "Water Quality and Quantity"; Measures: Discharge, Turbidity measured against respective TN, VA, and KY standards
		Marine Hydrology	
	Water Quality	Water Chemistry*	Official Vital Sign: "Water Quality and Quantity" Measures: Temp, pH, specific conductivity, DO, ANC

Appendix A (continued).

Ecological Monitoring Framework—CUGA			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Vital Sign / Measures**
		Nutrient Dynamics	
		Toxics	
		Microorganisms*	Official Vital Sign: “Water Quality and Quantity” Measures: *E. coli* and fecal coliform
		Aquatic Macroinvertebrates and Algae	
Biological Integrity	Invasive Species	Invasive/Exotic Plants*	Official Vital Sign: “Invasive Plants” (108 invasive; 29 aggressive) e.g. Autumn olive, Johnsongrass, Princesstree Measures: Abundance, Competition with native communities, I-ranks, TN and KY EPPC ranks
		Invasive/Exotic Animals	
	Infestations and Disease	Insect Pests*	Official Vital Sign: “Forest Pests” Measures: Current/Historical Abundance and Damage, Risk of Infestation
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities*	Official Vital Sign: “Vegetation communities”; Measures: Vegetation structure, composition, extent
		Riparian Communities*	"
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	
		Desert Communities	
		Grassland/Herbaceous Communities	
		Shrubland Communities	
		Forest/Woodland Communities*	"
		Marine Invertebrates	
		Freshwater Invertebrates	
		Terrestrial Invertebrates	
		Fishes†	Not an official vital sign
		Amphibians and Reptiles	
		Birds†	Not an official vital sign

Appendix A (continued).

Ecological Monitoring Framework—CUGA			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Vital Sign / Measures**
		Mammals*†	Official Vital Sign: "Allegheny Woodrats" (at MACA); Also elk(?), bats (18 species)
		Vegetation Complex (use sparingly)	Cliffline plant communities (14 plant species; 49 lichen species)
		Terrestrial Complex (use sparingly)	
	At-risk Biota	T&E Species and Communities	Park-specific issue: At-risk plants Measures: Species abundance/change 90 spp. rare/sensitive plants; Commercially exploitable plants: goldenseal, ginseng, pink lady's slipper, black cohosh
Human Use	Point Source Human Effects	Point Source Human Effects	
	Non-point Source Human Effects	Non-point Source Human Effects	
	Consumptive Use	Consumptive Use	
	Visitor and Recreation Use	Visitor Use	
	Cultural Landscapes	Cultural Landscapes	
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	
	Landscape Dynamics	Land Cover and Use	Official Vital Sign: "Landscape Dynamics" Measures: Changes in landcover over time, correlation of landcover with species of concern, adjacent land use patterns, areas managed as biodiversity hotspots or wildlife corridors Need: Ranking protocol undefined
	Extreme Disturbance Events	Extreme Disturbance Events	
	Soundscape	Soundscape	
	Viewscape	Viewscape/Dark Night Sky	
	Nutrient Dynamics	Nutrient Dynamics	
	Energy Flow	Primary Production	

Appendix B. Bird species reported from Cumberland Gap National Historical Park during a 2003-2004 survey (Monroe 2005).

Common Name	Scientific Name	Common Name	Scientific Name
Acadian Flycatcher	*Empidonax virescens*	Chuck-will's-widow	*Caprimulgus carolinensis*
American Crow	*Corvus brachyrhynchos*	Common Grackle	*Quiscalus quiscula*
American Goldfinch	*Carduelis tristis*	Common Raven	*Corvus corax*
American Kestrel	*Falco sparverius*	Common Yellowthroat	*Geothlypis trichas*
American Pipit	*Anthus rubescens*	Cooper's Hawk	*Accipiter cooperii*
American Redstart	*Setophaga ruticilla*	Dark-eyed Junco	*Junco hyemalis*
American Robin	*Turdus migratorius*	Downy Woodpecker	*Picoides pubescens*
American Woodcock	*Scolopax minor*	Eastern Bluebird	*Sialia sialis*
Bald Eagle	*Haliaeetus leucocephalus*	Eastern Kingbird	*Tyrannus tyrannus*
Baltimore Oriole	*Icterus galbula*	Eastern Meadowlark	*Sturnella magna*
Barn Swallow	*Hirundo rustica*	Eastern Phoebe	*Sayornis phoebe*
Barred Owl	*Strix varia*	Eastern Screech-Owl	*Otus asio*
Bay-breasted Warbler	*Dendroica castanea*	Eastern Towhee	*Pipilo erythrophthalmus*
Belted Kingfisher	*Ceryle alcyon*	Eastern Wood-Pewee	*Contopus virens*
Black Vulture	*Coragyps atratus*	European Starling	*Sturnus vulgaris*
Black-and-White Warbler	*Mniotilta varia*	Field Sparrow	*Spizella pusilla*
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Fox Sparrow	*Passerella iliaca*
Blackburnian Warbler	*Dendroica fusca*	Golden-crowned Kinglet	*Regulus satrapa*
Blackpoll Warbler	*Dendroica striata*	Golden-winged Warbler	*Vermivora chrysoptera*
Black-throated Blue Warbler	*Dendroica caerulescens*	Gray Catbird	*Dumetella carolinensis*
Black-throated Green Warbler	*Dendroica virens*	Gray-cheeked Thrush	*Catharus minimus*
Blue Grosbeak	*Passerina caerulea*	Great Blue Heron	*Ardea herodias*
Blue Jay	*Cyanocitta cristata*	Great Crested Flycatcher	*Myiarchus crinitus*
Blue-gray Gnatcatcher	*Polioptila caerulea*	Great Horned Owl	*Bubo virginianus*
Blue-headed Vireo	*Vireo solitarius*	Greater White-fronted Goose	*Anser albifrons*
Blue-winged Warbler	*Vermivora pinus*	Hairy Woodpecker	*Picoides villosus*
Broad-winged Hawk	*Buteo platypterus*	Hermit Thrush	*Catharus guttatus*
Brown Creeper	*Certhia americana*	Hooded Warbler	*Wilsonia citrina*
Brown Thrasher	*Toxostoma rufum*	Horned Lark	*Eremophila alpestris*
Brown-Headed Cowbird	*Molothrus ater*	House Finch	*Carpodacus mexicanus*
Canada Goose	*Branta canadensis*	House Sparrow	*Passer domesticus*
Canada Warbler	*Wilsonia canadensis*	House Wren	*Troglodytes aedon*
Cape May Warbler	*Dendroica tigrina*	Indigo Bunting	*Passerina cyanea*
Carolina Chickadee	*Poecile carolinensis*	Kentucky Warbler	*Oporornis formosus*
Carolina Wren	*Thryothorus ludovicianus*	Killdeer	*Charadrius vociferus*
Cedar Waxwing	*Bombycilla cedrorum*	Least Flycatcher	*Empidonax minimus*
Cerulean Warbler	*Dendroica cerulea*	Lesser Snow Goose	*Chen caerulescens*
Chestnut-sided Warbler	*Dendroica pensylvanica*	Louisiana Waterthrush	*Seiurus motacilla*
Chimney Swift	*Chaetura pelagica*	Magnolia Warbler	*Dendroica magnolia*
Chipping Sparrow	*Spizella passerina*	Mallard	*Anas platyrhynchos*

Appendix B (continued).

Common Name	Scientific Name	Common Name	Scientific Name
Merlin	*Falco columbarius*	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Mourning Dove	*Zenaida macroura*	Ruby-crowned Kinglet	*Regulus calendula*
Nashville Warbler	*Vermivora ruficapilla*	Ruby-throated Hummingbird	*Archilochus colubris*
Northern Cardinal	*Cardinalis cardinalis*	Ruffed Grouse	*Bonasa umbellus*
Northern Flicker	*Colaptes auratus*	Scarlet Tanager	*Piranga olivacea*
Northern Harrier	*Circus cyaneus*	Sharp-shinned Hawk	*Accipiter striatus*
Northern Mockingbird	*Mimus polyglottos*	Song Sparrow	*Melospiza melodia*
Northern Parula	*Parula americana*	Summer Tanager	*Piranga rubra*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Swainson's Thrush	*Catharus ustulatus*
Northern Waterthrush	*Seiurus noveboracensis*	Swainson's Warbler	*Limnothlypis swainsonii*
Olive-sided Flycatcher	*Contopus cooperi*	Swamp Sparrow	*Melospiza georgiana*
Orange-crowned Warbler	*Vermivora celata*	Tennessee Warbler	*Vermivora peregrina*
Orchard Oriole	*Icterus spurius*	Tree Swallow	*Tachycineta bicolor*
Osprey	*Pandion haliaetus*	Tufted Titmouse	*Baeolophus bicolor*
Ovenbird	*Seiurus aurocapillus*	Turkey Vulture	*Cathartes aura*
Palm Warbler	*Dendroica palmarum*	Veery	*Catharus fuscescens*
Peregrine Falcon	*Falco peregrinus*	Warbling Vireo	*Vireo gilvus*
Philadelphia Vireo	*Vireo philadelphicus*	Whip-poor-will	*Caprimulgus vociferus*
Pileated Woodpecker	*Dryocopus pileatus*	White-breasted Nuthatch	*Sitta carolinensis*
Pine Siskin	*Carduelis pinus*	White-eyed Vireo	*Vireo griseus*
Pine Warbler	*Dendroica pinus*	White-throated Sparrow	*Zonotrichia albicollis*
Prairie Warbler	*Dendroica discolor*	Wild Turkey	*Meleagris gallopavo*
Purple Finch	*Carpodacus purpureus*	Winter Wren	*Troglodytes troglodytes*
Purple Martin	*Progne subis*	Wood Thrush	*Hylocichla mustelina*
Red-bellied Woodpecker	*Melanerpes carolinus*	Worm-eating Warbler	*Helmitheros vermivorus*
Red-breasted Nuthatch	*Sitta canadensis*	Yellow Warbler	*Dendroica petechia*
Red-eyed Vireo	*Vireo olivaceus*	Yellow-bellied Sapsucker	*Sphyrapicus varius*
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Yellow-billed Cuckoo	*Coccyzus americanus*
Red-shouldered Hawk	*Buteo lineatus*	Yellow-rumped Warbler	*Dendroica coronata*
Red-tailed Hawk	*Buteo jamaicensis*	Yellow-breasted Chat	*Icteria virens*
Red-winged Blackbird	*Agelaius phoeniceus*	Yellow-throated Vireo	*Vireo flavifrons*
Ring-billed Gull	*Larus delawarensis*	Yellow-throated Warbler	*Dendroica dominica*
Rock Dove	*Columba livia*		

Appendix C. Certified species list of vascular plants listed as “Present” or “Probably Present” at CUGA.

Family	Scientific Name	Common name	Occurrence	Nativity
Alismataceae	*Alisma subcordatum*	Broad-leaved water-plantain	Present in Park	Native
Alismataceae	*Sagittaria latifolia*	Broadleaf arrowhead	Present in Park	Native
Apiaceae	*Angelica venenosa*	Hairy angelica	Present in Park	Native
Apiaceae	*Chaerophyllum procumbens*	Spreading chervil	Present in Park	Native
Apiaceae	*Chaerophyllum tainturieri* var. *tainturieri*	Hairyfruit chervil	Present in Park	Native
Apiaceae	*Cryptotaenia canadensis*	Canadian honewort	Present in Park	Native
Apiaceae	*Daucus carota*	Queen Anne's lace	Present in Park	Non-Native
Apiaceae	*Eryngium yuccifolium*	Rattlesnake-master	Present in Park	Native
Apiaceae	*Ligusticum canadense*	Lovage	Present in Park	Native
Apiaceae	*Osmorhiza claytonii*	Hairy sweet-cicely	Present in Park	Native
Apiaceae	*Osmorhiza longistylis*	Smoother sweet-cicely	Present in Park	Native
Apiaceae	*Oxypolis rigidior*	Stiff cowbane	Present in Park	Native
Apiaceae	*Sanicula canadensis*	Canadian black-snakeroot	Present in Park	Native
Apiaceae	*Sanicula odorata*	Clustered blacksnakeroot	Present in Park	Native
Apiaceae	*Sanicula smallii*	Small's black-snakeroot	Present in Park	Native
Apiaceae	*Taenidia integerrima*	Yellow pimpernell	Present in Park	Native
Apiaceae	*Thaspium barbinode*	Hairy-jointed meadow-parsnip	Present in Park	Native
Apiaceae	*Thaspium trifoliatum*	Purple meadow-parsnip	Present in Park	Native
Apiaceae	*Torilis arvensis*	Field hedge-parsley	Present in Park	Non-Native
Apiaceae	*Zizia aptera*	Golden alexander	Present in Park	Native
Araliaceae	*Aralia nudicaulis*	Wild sarsaparilla	Present in Park	Native
Araliaceae	*Aralia racemosa* ssp. *racemosa*	American spikenard	Present in Park	Native
Araliaceae	*Aralia spinosa*	Hercules club	Present in Park	Native
Araliaceae	*Panax quinquefolius*	American ginseng	Present in Park	Native
Acoraceae	*Acorus calamus*	Sweetflag	Present in Park	Native
Araceae	*Arisaema dracontium*	Green dragon	Present in Park	Native
Araceae	*Arisaema triphyllum*	Swamp jack-in-the-pulpit	Present in Park	Native
Lemnaceae	*Lemna minor*	Lesser duckweed	Present in Park	Native
Aristolochiaceae	*Aristolochia macrophylla*	Pipevine	Present in Park	Native
Aristolochiaceae	*Aristolochia serpentaria*	Virginia snakeroot	Present in Park	Native
Aristolochiaceae	*Asarum canadense*	Canada wild-ginger	Present in Park	Native
Aristolochiaceae	*Hexastylis arifolia*	Little brown jug	Present in Park	Native
Aristolochiaceae	*Hexastylis contracta*	Mountain heartleaf	Present in Park	Native
Aristolochiaceae	*Hexastylis heterophylla*	Variable-leaved heartleaf	Present in Park	Native
Asteraceae	*Achillea millefolium*	Common yarrow	Present in Park	Non-Native
Asteraceae	*Ageratina altissima*	White snakeroot	Present in Park	Native
steraceae	*Ageratina altissima* var. *altissima*	White snakeroot	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Asteraceae	*Ageratina aromatica*	Lesser snakeroot	Present in Park	Native
Asteraceae	*Ambrosia artemisiifolia*	Annual ragweed	Present in Park	Native
Asteraceae	*Ambrosia trifida* var. *trifida*	Great ragweed	Present in Park	Native
Asteraceae	*Antennaria plantaginifolia*	Plantain-leaf pussytoes	Present in Park	Native
Asteraceae	*Antennaria solitaria*	Single-head pussytoes	Present in Park	Native
Asteraceae	*Arnoglossum atriplicifolium*	Pale Indian-plantain	Present in Park	Native
Asteraceae	*Bidens aristosa*	Bearded beggarticks	Present in Park	Native
Asteraceae	*Bidens bipinnata*	Spanish-needles	Present in Park	Native
Asteraceae	*Bidens frondosa*	Devil's beggar-ticks	Present in Park	Native
Asteraceae	*Bidens tripartita*	Three-lobe beggar-ticks	Present in Park	Native
Asteraceae	*Brickellia eupatorioides*	False boneset	Present in Park	Native
Asteraceae	*Carduus nutans*	Musk thistle	Present in Park	Non-Native
Asteraceae	*Chrysopsis mariana*	Maryland golden aster	Present in Park	Native
Asteraceae	*Cichorium intybus*	Chicory	Present in Park	Non-Native
Asteraceae	*Cirsium discolor*	Field thistle	Present in Park	Native
Asteraceae	*Cirsium muticum*	Swamp thistle	Present in Park	Native
Asteraceae	*Cirsium vulgare*	Bull thistle	Present in Park	Non-Native
Asteraceae	*Conoclinium coelestinum*	Blue mistflower	Present in Park	Native
Asteraceae	*Conyza canadensis*	Canada horseweed	Present in Park	Native
Asteraceae	*Coreopsis lanceolata*	Lanceleaf tickseed	Present in Park	Native
Asteraceae	*Coreopsis major*	Wood tickseed	Present in Park	Native
Asteraceae	*Coreopsis tripteris*	Tall tickseed	Present in Park	Native
Asteraceae	*Doellingeria infirma*	Cornel-leaf whitetop	Present in Park	Native
Asteraceae	*Doellingeria umbellata* var. *umbellata*	Parasol whitetop	Present in Park	Native
Asteraceae	*Elephantopus carolinianus*	Carolina elephant-foot	Present in Park	Native
Asteraceae	*Elephantopus tomentosus*	Tobaccoweed	Present in Park	Native
Asteraceae	*Erechtites hieraciifolia* var. *hieraciifolia*	American burnweed	Present in Park	Native
Asteraceae	*Erigeron annuus*	White-top fleabane	Present in Park	Native
Asteraceae	*Erigeron philadelphicus*	Philadelphia fleabane	Present in Park	Native
Asteraceae	*Erigeron pulchellus*	Robin plantain fleabane	Present in Park	Native
Asteraceae	*Erigeron strigosus*	Daisy fleabane	Present in Park	Native
Asteraceae	*Eupatorium album* var. *album*	White thoroughwort	Present in Park	Native
Asteraceae	*Eupatorium fistulosum*	Hollow joe-pye weed	Present in Park	Native
Asteraceae	*Eupatorium purpureum* var. *purpureum*	Sweetscented joepyeweed	Present in Park	Native
Asteraceae	*Eupatorium rotundifolium* var. *ovatum*	Hairy boneset	Present in Park	Native
Asteraceae	*Eupatorium serotinum*	Late-flowering thorough-wort	Present in Park	Native
Asteraceae	*Eupatorium sessilifolium*	Upland boneset	Present in Park	Native
Asteraceae	*Eupatorium steelei*	Steele's eupatorium	Present in Park	Native
Asteraceae	*Eurybia divaricata*	White wood aster	Present in Park	Native
Asteraceae	*Eurybia surculosa*	Creeping aster	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Asteraceae	*Fleischmannia incarnata*	Pink thoroughwort	Present in Park	Native
Asteraceae	*Galinsoga quadriradiata*	Fringed quickweed	Present in Park	Non-Native
Asteraceae	*Gamochaeta purpurea*	Spoon-leaf purple everlasting	Present in Park	Native
Asteraceae	*Helenium autumnale* var. *autumnale*	Common sneezeweed	Present in Park	Native
Asteraceae	*Helenium flexuosum*	Purple-head sneezeweed	Present in Park	Native
Asteraceae	*Helianthus atrorubens*	Purple-disk sunflower	Present in Park	Native
Asteraceae	*Helianthus decapetalus*	Thin-leaved sunflower	Present in Park	Native
Asteraceae	*Helianthus divaricatus*	Woodland sunflower	Present in Park	Native
Asteraceae	*Helianthus hirsutus*	Stiff-hair sunflower	Present in Park	Native
Asteraceae	*Helianthus laevigatus*	Smooth sunflower	Present in Park	Native
Asteraceae	*Helianthus microcephalus*	Small wood sunflower	Present in Park	Native
Asteraceae	*Helianthus tuberosus*	Jerusalem artichoke	Present in Park	Native
Asteraceae	*Heliopsis helianthoides*	Ox-eye	Present in Park	Native
Asteraceae	*Hieracium caespitosum*	Meadow hawkweed	Present in Park	Non-Native
Asteraceae	*Hieracium gronovii*	Hairy hawkweed	Present in Park	Native
Asteraceae	*Hieracium paniculatum*	Panicled hawkweed	Present in Park	Native
Asteraceae	*Hieracium scabrum*	Rough hawkweed	Present in Park	Native
Asteraceae	*Hieracium venosum*	Rattlesnake hawkweed	Present in Park	Native
Asteraceae	*Ionactis linariifolius*	Flaxleaf aster	Present in Park	Native
Asteraceae	*Krigia biflora*	Two-flowered dwarf dandelion	Present in Park	Native
Asteraceae	*Krigia virginica*	Dwarf dandelion	Present in Park	Native
Asteraceae	*Lactuca canadensis*	Canada lettuce	Present in Park	Native
Asteraceae	*Lactuca floridana*	Woodland lettuce	Present in Park	Native
Asteraceae	*Lactuca saligna*	Willowleaf lettuce	Present in Park	Non-Native
Asteraceae	*Leucanthemum vulgare*	Oxeye daisy	Present in Park	Non-Native
Asteraceae	*Liatris aspera*	Tall gay-feather	Present in Park	Native
Asteraceae	*Oclemena acuminata*	Whorled wood aster	Present in Park	Native
Asteraceae	*Oligoneuron rigidum* var. *rigidum*	Stiff goldenrod	Present in Park	Native
Asteraceae	*Packera anonyma*	Small's ragwort	Present in Park	Native
Asteraceae	*Packera aurea*	Golden ragwort	Present in Park	Native
Asteraceae	*Packera obovata*	Roundleaf ragwort	Present in Park	Native
Asteraceae	*Pityopsis graminifolia* var. *graminifolia*	Silkgrass	Present in Park	Native
Asteraceae	*Pityopsis graminifolia* var. *latifolia*	Narrowleaf silkgrass	Present in Park	Native
Asteraceae	*Polymnia canadensis*	White-flower leafcup	Present in Park	Native
Asteraceae	*Prenanthes altissima*	Tall rattlesnake-root	Present in Park	Native
Asteraceae	*Prenanthes serpentaria*	Cankerweed	Present in Park	Native
Asteraceae	*Prenanthes trifoliolata*	Gall of the earth	Present in Park	Native
Asteraceae	*Pseudognaphalium obtusifolium*	Rabbit tobacco	Present in Park	Native
Asteraceae	*Pseudognaphalium obtusifolium* ssp. *obtusifolium*	Rabbittobacco	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Asteraceae	*Pyrrhopappus carolinianus*	Carolina false-dandelion	Present in Park	Native
Asteraceae	*Rudbeckia fulgida*	Orange coneflower	Present in Park	Native
Asteraceae	*Rudbeckia fulgida* var. *umbrosa*	Orange coneflower	Present in Park	Native
Asteraceae	*Rudbeckia hirta*	Black-eyed susan	Present in Park	Native
Asteraceae	*Rudbeckia laciniata*	Cut-leaved coneflower	Present in Park	Native
Asteraceae	*Rudbeckia triloba*	Brown-eyed Susan	Present in Park	Native
Asteraceae	*Sericocarpus linifolius*	Narrowleaf whitetop aster	Present in Park	Native
Asteraceae	*Silphium asteriscus* var. *asteriscus*	Roughleaf rosinweed, starry rosinweed	Present in Park	Native
Asteraceae	*Silphium terebinthinaceum*	Prairie rosinweed	Present in Park	Native
Asteraceae	*Silphium trifoliatum*	Three-leaved rosinweed	Present in Park	Native
Asteraceae	*Silphium trifoliatum* var. *latifolium*	Whorled rosinweed	Present in Park	Native
Asteraceae	*Silphium trifoliatum* var. *trifoliatum*	Three-leaved rosinweed	Present in Park	Native
Asteraceae	*Smallanthus uvedalius*	Yellow-flowered leafcup	Present in Park	Native
Asteraceae	*Solidago arguta*	Atlantic goldenrod	Present in Park	Native
Asteraceae	*Solidago arguta* var. *arguta*	Cut-leaved golden-rod	Present in Park	Native
Asteraceae	*Solidago arguta* var. *caroliniana*	Atlantic goldenrod	Present in Park	Native
Asteraceae	*Solidago bicolor*	White goldenrod	Present in Park	Native
Asteraceae	*Solidago caesia*	Bluestem goldenrod	Present in Park	Native
Asteraceae	*Solidago caesia* var. *curtisii*	Mountain decumbent goldenrod	Present in Park	Native
Asteraceae	*Solidago canadensis*	Canada goldenrod	Present in Park	Native
Asteraceae	*Solidago canadensis* var. *scabra*	Canada goldenrod	Present in Park	Native
Asteraceae	*Solidago flaccidifolia*	Appalachian golden-rod	Present in Park	Native
Asteraceae	*Solidago flexicaulis*	Broad-leaved goldenrod	Present in Park	Native
Asteraceae	*Solidago gigantea*	Late goldenrod	Present in Park	Native
Asteraceae	*Solidago nemoralis* var. *nemoralis*	Gray goldenrod	Present in Park	Native
Asteraceae	*Solidago odora* var. *odora*	Anisescented goldenrod	Present in Park	Native
Asteraceae	*Solidago patula*	Roundleaf goldenrod	Present in Park	Native
Asteraceae	*Solidago roanensis*	Roan mountain goldenrod	Present in Park	Native
Asteraceae	*Solidago rugosa*	Wrinkleleaf goldenrod	Present in Park	Native
Asteraceae	*Solidago rugosa* ssp. *rugosa* var. *rugosa*	Rough-leaf goldenrod	Present in Park	Native
Asteraceae	*Solidago speciosa* var. *erecta*	Showy goldenrod	Present in Park	Native
Asteraceae	*Solidago sphacelata*	Autumn goldenrod	Present in Park	Native
Asteraceae	*Solidago ulmifolia* var. *ulmifolia*	Elmleaf goldenrod	Present in Park	Native
Asteraceae	*Sonchus asper*	Spiny-leaf sowthistle	Present in Park	Non-Native
Asteraceae	*Symphyotrichum cordifolium*	Common blue wood aster	Present in Park	Native
Asteraceae	*Symphyotrichum dumosum* var. *dumosum*	Rice button aster	Present in Park	Native
Asteraceae	*Symphyotrichum laeve*	Smooth blue aster	Present in Park	Native
Asteraceae	*Symphyotrichum laeve* var. *concinnum*	Smooth blue aster	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Asteraceae	*Symphyotrichum lanceolatum* ssp. *lanceolatum* var. *lanceolatum*	White panicle aster	Present in Park	Native
Asteraceae	*Symphyotrichum lateriflorum*	Calico aster	Present in Park	Native
Asteraceae	*Symphyotrichum lateriflorum* var. *lateriflorum*	Calico aster	Present in Park	Native
Asteraceae	*Symphyotrichum lowrieanum*	Lowrie's blue wood aster	Present in Park	Native
Asteraceae	*Symphyotrichum oblongifolium*	Aromatic aster	Present in Park	Native
Asteraceae	*Symphyotrichum patens*	Late purple aster	Present in Park	Native
Asteraceae	*Symphyotrichum patens* var. *patens*	Late purple aster	Present in Park	Native
Asteraceae	*Symphyotrichum phlogifolium*	Phlox-leaf aster	Present in Park	Native
Asteraceae	*Symphyotrichum pilosum* var. *pilosum*	Hairy white oldfield aster	Present in Park	Native
Asteraceae	*Symphyotrichum prenanthoides*	Crookedstem aster	Present in Park	Native
Asteraceae	*Symphyotrichum undulatum*	Waxyleaf aster	Present in Park	Native
Asteraceae	*Taraxacum officinale* ssp. *officinale*	Wandering dandelion	Present in Park	Non-Native
Asteraceae	*Tussilago farfara*	Coltsfoot	Present in Park	Non-Native
Asteraceae	*Verbesina alternifolia*	Wingstem	Present in Park	Native
Asteraceae	*Verbesina occidentalis*	Yellow crownbeard	Present in Park	Native
Asteraceae	*Verbesina virginica* var. *virginica*	White crownbeard	Present in Park	Native
Asteraceae	*Vernonia gigantea* ssp. *gigantea*	Ironweed	Present in Park	Native
Asteraceae	*Xanthium strumarium*	Rough cocklebur	Present in Park	Native
Callitrichaceae	*Callitriche heterophylla*	Large water-starwort	Present in Park	Native
Campanulaceae	*Campanula divaricata*	Southern harebell	Present in Park	Native
Campanulaceae	*Campanulastrum americanum*	Tall bellflower	Present in Park	Native
Campanulaceae	*Lobelia cardinalis*	Cardinal flower	Present in Park	Native
Campanulaceae	*Lobelia inflata*	Indian-tobacco	Present in Park	Native
Campanulaceae	*Lobelia puberula*	Downy lobelia	Present in Park	Native
Campanulaceae	*Lobelia siphilitica* var. *siphilitica*	Great blue lobelia	Present in Park	Native
Campanulaceae	*Lobelia spicata*	Pale-spiked lobelia	Present in Park	Native
Campanulaceae	*Triodanis perfoliata* var. *perfoliata*	Clasping venus' looking-glass	Present in Park	Native
Brassicaceae	*Arabis canadensis*	Sicklepod	Present in Park	Native
Brassicaceae	*Arabis laevigata*	Smooth rockcress	Present in Park	Native
Brassicaceae	*Arabis lyrata*	Lyre-leaf rockcress	Present in Park	Native
Brassicaceae	*Barbarea verna*	Early yellowrocket	Present in Park	Non-Native
Brassicaceae	*Barbarea vulgaris*	Yellow rocket	Present in Park	Non-Native
Brassicaceae	*Brassica napus*	Turnip	Present in Park	Non-Native
Brassicaceae	*Brassica rapa*	Field mustard	Present in Park	Non-Native
Brassicaceae	*Capsella bursa-pastoris*	Common shepherd's purse	Present in Park	Non-Native
Brassicaceae	*Cardamine angustata*	Slender toothwort	Present in Park	Native
Brassicaceae	*Cardamine concatenata*	Cutleaf toothwort	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Brassicaceae	*Cardamine diphylla*	Two-leaf toothwort	Present in Park	Native
Brassicaceae	*Cardamine hirsuta*	Hairy bitter-cress	Present in Park	Non-Native
Brassicaceae	*Cardamine pensylvanica*	Pennsylvania bitter-cress	Present in Park	Native
Brassicaceae	*Cardamine rotundifolia*	Round-leaf water cress	Present in Park	Native
Brassicaceae	*Hesperis matronalis*	Dames rocket	Present in Park	Non-Native
Brassicaceae	*Lepidium campestre*	Field pepperweed	Present in Park	Non-Native
Brassicaceae	*Lepidium virginicum* var. *virginicum*	Virginia pepperweed	Present in Park	Native
Brassicaceae	*Rorippa nasturtium-aquaticum*	Watercress	Present in Park	Non-Native
Brassicaceae	*Sinapis arvensis*	Corn-mustard	Present in Park	Non-Native
Amaranthaceae	*Amaranthus spinosus*	Spiny amaranth	Present in Park	Native
Caryophyllaceae	*Cerastium brachypodum*	Shortstalk chickweed	Present in Park	Native
Caryophyllaceae	*Cerastium fontanum* ssp. *vulgare*	Big chickweed	Present in Park	Non-Native
Caryophyllaceae	*Dianthus armeria*	Deptford-pink	Present in Park	Non-Native
Caryophyllaceae	*Minuartia glabra*	Appalachian sandwort	Present in Park	Native
Caryophyllaceae	*Paronychia argyrocoma*	Silvery nailwort	Present in Park	Native
Caryophyllaceae	*Paronychia canadensis*	Forked nailwort	Present in Park	Native
Caryophyllaceae	*Saponaria officinalis*	Bouncing-bet	Present in Park	Non-Native
Caryophyllaceae	*Silene ovata*	Ovate catchfly	Present in Park	Native
Caryophyllaceae	*Silene rotundifolia*	Roundleaf catchfly	Present in Park	Native
Caryophyllaceae	*Silene stellata*	Widowsfrill	Present in Park	Native
Caryophyllaceae	*Silene virginica*	Fire pink	Present in Park	Native
Caryophyllaceae	*Stellaria media*	Common starwort	Present in Park	Non-Native
Caryophyllaceae	*Stellaria pubera*	Giant chickweed	Present in Park	Native
Chenopodiaceae	*Chenopodium album*	White goosefoot	Present in Park	Non-Native
Chenopodiaceae	*Chenopodium ambrosioides* var. *ambrosioides*	Mexican tea	Present in Park	Non-Native
Molluginaceae	*Mollugo verticillata*	Green carpet-weed	Present in Park	Native
Phytolaccaceae	*Phytolacca americana*	Common pokeweed	Present in Park	Native
Portulacaceae	*Claytonia caroliniana*	Carolina spring-beauty	Present in Park	Native
Portulacaceae	*Claytonia virginica*	Narrow-leaved spring beauty	Present in Park	Native
Aquifoliaceae	*Ilex ambigua*	Carolina holly	Present in Park	Native
Aquifoliaceae	*Ilex decidua*	Possumhaw	Present in Park	Native
Aquifoliaceae	*Ilex montana*	Mountain holly	Present in Park	Native
Aquifoliaceae	*Ilex opaca* var. *opaca*	American holly	Present in Park	Native
Celastraceae	*Celastrus orbiculatus*	Oriental bittersweet	Present in Park	Non-Native
Celastraceae	*Celastrus scandens*	Climbing bittersweet	Present in Park	Native
Celastraceae	*Euonymus americana*	American strawberrybush	Present in Park	Native
Celastraceae	*Euonymus atropurpurea*	Eastern wahoo	Present in Park	Native
Commelinaceae	*Commelina communis*	Asiatic dayflower	Present in Park	Non-Native
Commelinaceae	*Tradescantia ohiensis*	Ohio spiderwort	Present in Park	Native
Commelinaceae	*Tradescantia subaspera*	Zigzag spiderwort	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Commelinaceae	*Tradescantia virginiana*	Virginia spiderwort	Present in Park	Native
Cornaceae	*Cornus alternifolia*	Alternate-leaf dogwood	Present in Park	Native
Cornaceae	*Cornus amomum*	Silky dogwood	Present in Park	Native
Cornaceae	*Cornus florida*	Flowering dogwood	Present in Park	Native
Nyssaceae	*Nyssa biflora*	Swamp tupelo	Present in Park	Native
Nyssaceae	*Nyssa sylvatica*	Black gum	Present in Park	Native
Cyperaceae	*Carex abscondita*	Thicket sedge	Present in Park	Native
Cyperaceae	*Carex albicans*	Whitetinge sedge	Present in Park	Native
Cyperaceae	*Carex albicans* var. *albicans*	Whitetinge sedge	Present in Park	Native
Cyperaceae	*Carex amphibola*	Eastern narrowleaf sedge	Present in Park	Native
Cyperaceae	*Carex appalachica*	Appalachian sedge	Present in Park	Native
Cyperaceae	*Carex atlantica* ssp. *atlantica*	Prickly bog sedge	Present in Park	Native
Cyperaceae	*Carex austrocaroliniana*	Tarheel sedge	Present in Park	Native
Cyperaceae	*Carex baileyi*	Bailey's sedge	Present in Park	Native
Cyperaceae	*Carex blanda*	Woodland sedge	Present in Park	Native
Cyperaceae	*Carex bromoides*	Bromelike sedge	Present in Park	Native
Cyperaceae	*Carex careyana*	Carey's sedge	Present in Park	Native
Cyperaceae	*Carex cephalophora*	Oval-leaved sedge	Present in Park	Native
Cyperaceae	*Carex crinita*	Fringed sedge	Present in Park	Native
Cyperaceae	*Carex cumberlandensis*	Cumberland sedge	Present in Park	Native
Cyperaceae	*Carex debilis*	White edge sedge	Present in Park	Native
Cyperaceae	*Carex debilis* var. *pubera*	White edge sedge	Present in Park	Native
Cyperaceae	*Carex debilis* var. *rudgei*	White-edge sedge	Present in Park	Native
Cyperaceae	*Carex digitalis*	Slender wood sedge	Present in Park	Native
Cyperaceae	*Carex frankii*	Frank's sedge	Present in Park	Native
Cyperaceae	*Carex gracillima*	Graceful sedge	Present in Park	Native
Cyperaceae	*Carex gynandra*	Nodding sedge	Present in Park	Native
Cyperaceae	*Carex hirsutella*	Fuzzy wuzzy sedge	Present in Park	Native
Cyperaceae	*Carex interior*	Inland sedge	Present in Park	Native
Cyperaceae	*Carex intumescens*	Bladder sedge	Present in Park	Native
Cyperaceae	*Carex jamesii*	James' sedge	Present in Park	Native
Cyperaceae	*Carex laevivaginata*	Smooth-sheath sedge	Present in Park	Native
Cyperaceae	*Carex laxiculmis*	Spreading sedge	Present in Park	Native
Cyperaceae	*Carex laxiflora*	Loose-flowered sedge	Present in Park	Native
Cyperaceae	*Carex leavenworthii*	Leavenworth's sedge	Present in Park	Native
Cyperaceae	*Carex leptalea*	Bristly-stalk sedge	Present in Park	Native
Cyperaceae	*Carex lucorum*	Blue ridge sedge	Present in Park	Native
Cyperaceae	*Carex lucorum* var. *lucorum*	Blue ridge sedge	Present in Park	Native
Cyperaceae	*Carex lurida*	Shallow sedge	Present in Park	Native
Cyperaceae	*Carex mesochorea*	Midland sedge	Present in Park	Native
Cyperaceae	*Carex muehlenbergii* var. *enervis*	Muhlenberg's sedge	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Cyperaceae	*Carex nigromarginata*	Black edge sedge	Present in Park	Native
Cyperaceae	*Carex normalis*	Greater straw sedge	Present in Park	Native
Cyperaceae	*Carex pensylvanica*	Pennsylvania sedge	Present in Park	Native
Cyperaceae	*Carex plantaginea*	Plantainleaf sedge	Present in Park	Native
Cyperaceae	*Carex platyphylla*	Broad-leaved sedge	Present in Park	Native
Cyperaceae	*Carex prasina*	Drooping sedge	Present in Park	Native
Cyperaceae	*Carex projecta*	Necklace sedge	Present in Park	Native
Cyperaceae	*Carex purpurifera*	Purple sedge	Present in Park	Native
Cyperaceae	*Carex radiata*	Stellate sedge	Present in Park	Native
Cyperaceae	*Carex retroflexa*	Reflexed sedge	Present in Park	Native
Cyperaceae	*Carex rosea*	Rosy sedge	Present in Park	Native
Cyperaceae	*Carex scabrata*	Rough sedge	Present in Park	Native
Cyperaceae	*Carex striatula*	Lined sedge	Present in Park	Native
Cyperaceae	*Carex styloflexa*	Bent sedge	Present in Park	Native
Cyperaceae	*Carex swanii*	Swan sedge	Present in Park	Native
Cyperaceae	*Carex torta*	Twisted sedge	Present in Park	Native
Cyperaceae	*Carex tribuloides*	Blunt broom sedge	Present in Park	Native
Cyperaceae	*Carex virescens*	Ribbed sedge	Present in Park	Native
Cyperaceae	*Carex vulpinoidea*	Fox sedge	Present in Park	Native
Cyperaceae	*Cyperus retrofractus*	Rough flatsedge	Present in Park	Native
Cyperaceae	*Cyperus strigosus*	Straw-colored flatsedge	Present in Park	Native
Cyperaceae	*Eleocharis tenuis*	Slender spike-rush	Present in Park	Native
Cyperaceae	*Eriophorum virginicum*	Tawny cottongrass	Present in Park	Native
Cyperaceae	*Kyllinga gracillima*	Spikesedge	Present in Park	Native
Cyperaceae	*Rhynchospora capitellata*	Brownish beakrush	Present in Park	Native
Cyperaceae	*Scirpus cyperinus*	Cottongrass bulrush	Present in Park	Native
Cyperaceae	*Scirpus polyphyllus*	Leafy bulrush	Present in Park	Native
Poaceae	*Agrostis hyemalis*	Winter bentgrass	Present in Park	Native
Poaceae	*Agrostis perennans*	Perenial bentgrass	Present in Park	Native
Poaceae	*Agrostis stolonifera*	Spreading bentgrass	Present in Park	Native
Poaceae	*Andropogon gerardii*	Big bluestem	Present in Park	Native
Poaceae	*Andropogon virginicus*	Broom-sedge	Present in Park	Native
Poaceae	*Anthoxanthum odoratum*	Sweet vernalgrass	Present in Park	Non-Native
Poaceae	*Arundinaria gigantea*	Giant cane	Present in Park	Native
Poaceae	*Avena sativa*	Common oat	Present in Park	Non-Native
Poaceae	*Brachyelytrum erectum*	Bearded short-husk	Present in Park	Native
Poaceae	*Bromus japonicus*	Japanese brome	Present in Park	Non-Native
Poaceae	*Bromus pubescens*	Hairy wood brome grass	Present in Park	Native
Poaceae	*Calamagrostis porteri*	Porter's reedgrass	Present in Park	Native
Poaceae	*Calamagrostis porteri* ssp. *porteri*	Porter's reedgrass	Present in Park	Native
Poaceae	*Chasmanthium latifolium*	Indian woodoats	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Poaceae	*Cinna arundinacea*	Stout wood reed-grass	Present in Park	Native
Poaceae	*Cinna latifolia*	Slender wood reedgrass	Present in Park	Native
Poaceae	*Dactylis glomerata* ssp. *glomerata*	Orchardgrass	Present in Park	Non-Native
Poaceae	*Danthonia compressa*	Flattened oatgrass	Present in Park	Native
Poaceae	*Danthonia sericea*	Silky oatgrass	Present in Park	Native
Poaceae	*Danthonia spicata*	Poverty oatgrass	Present in Park	Native
Poaceae	*Deschampsia flexuosa*	Wavy hairgrass	Present in Park	Native
Poaceae	*Diarrhena americana*	American beakgrain	Present in Park	Native
Poaceae	*Dichanthelium acuminatum*	Tapered rosette grass	Present in Park	Native
Poaceae	*Dichanthelium acuminatum* var. *acuminatum*	Tapered rosette grass	Present in Park	Native
Poaceae	*Dichanthelium acuminatum* var. *fasciculatum*	Western panicgrass	Present in Park	Native
Poaceae	*Dichanthelium boscii*	Bosc's witchgrass	Present in Park	Native
Poaceae	*Dichanthelium clandestinum*	Deertongue	Present in Park	Native
Poaceae	*Dichanthelium commutatum*	Variable witchgrass	Present in Park	Native
Poaceae	*Dichanthelium dichotomum*	Cypress witchgrass	Present in Park	Native
Poaceae	*Dichanthelium dichotomum* var. *dichotomum*	Cypress witchgrass	Present in Park	Native
Poaceae	*Dichanthelium latifolium*	Broad-leaf witchgrass	Present in Park	Native
Poaceae	*Dichanthelium laxiflorum*	Openflower rosette grass	Present in Park	Native
Poaceae	*Dichanthelium sphaerocarpon*	Roundseed panicum	Present in Park	Native
Poaceae	*Dichanthelium sphaerocarpon* var. *isophyllum*	Roundfruit panicgrass	Present in Park	Native
Poaceae	*Dichanthelium sphaerocarpon* var. *sphaerocarpon*	Roundfruit panic grass	Present in Park	Native
Poaceae	*Digitaria ciliaris*	Southern crabgrass	Present in Park	Native
Poaceae	*Echinochloa crus-galli*	Barnyard grass	Present in Park	Non-Native
Poaceae	*Eleusine indica*	Indian goosegrass	Present in Park	Non-Native
Poaceae	*Elymus canadensis*	Nodding wild-rye	Present in Park	Native
Poaceae	*Elymus hystrix*	Bottle-brush grass	Present in Park	Native
Poaceae	*Elymus villosus*	Slender wild-rye	Present in Park	Native
Poaceae	*Elymus virginicus*	Virginia wild-rye	Present in Park	Native
Poaceae	*Eragrostis spectabilis*	Purple love-grass	Present in Park	Native
Poaceae	*Festuca rubra*	Red fescue	Present in Park	Native
Poaceae	*Festuca subverticillata*	Nodding fescue	Present in Park	Native
Poaceae	*Glyceria melicaria*	Slender manna grass	Present in Park	Native
Poaceae	*Glyceria striata*	Fowl manna-grass	Present in Park	Native
Poaceae	*Leersia virginica*	Virginia cutgrass	Present in Park	Native
Poaceae	*Lolium arundinaceum*	Tall fescue	Present in Park	Non-Native
Poaceae	*Lolium perenne*	Perennial ryegrass	Present in Park	Non-Native
Poaceae	*Lolium perenne* ssp. *multiflorum*	Perennial ryegrass	Present in Park	Non-Native
Poaceae	*Microstegium vimineum*	Nepalese browntop	Present in Park	Non-Native
Poaceae	*Miscanthus sinensis*	Chinese silvergrass	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Poaceae	*Muhlenbergia frondosa*	Wirestem muhly	Present in Park	Native
Poaceae	*Muhlenbergia schreberi*	Schreber muhly	Present in Park	Native
Poaceae	*Muhlenbergia sobolifera*	Cliff muhly	Present in Park	Native
Poaceae	*Muhlenbergia tenuiflora*	Slender muhly	Present in Park	Native
Poaceae	*Panicum anceps*	Beaked panic grass	Present in Park	Native
Poaceae	*Panicum capillare*	Common panic grass	Present in Park	Native
Poaceae	*Panicum dichotomiflorum*	Fall panic grass	Present in Park	Native
Poaceae	*Panicum gattingeri*	Gattinger's panic grass	Present in Park	Native
Poaceae	*Paspalum dilatatum*	Dallisgrass	Present in Park	Non-Native
Poaceae	*Paspalum pubiflorum*	Hairy-seed paspalum	Present in Park	Native
Poaceae	*Paspalum setaceum*	Thin paspalum	Present in Park	Native
Poaceae	*Pennisetum glaucum*	Pearl millet, pearl-millet, yellow bristlegrass	Present in Park	Non-Native
Poaceae	*Phleum pratense*	Meadow timothy	Present in Park	Non-Native
Poaceae	*Poa alsodes*	Grove bluegrass	Present in Park	Native
Poaceae	*Poa annua*	Annual bluegrass	Present in Park	Non-Native
Poaceae	*Poa autumnalis*	Autumn bluegrass	Present in Park	Native
Poaceae	*Poa compressa*	Canada bluegrass	Present in Park	Non-Native
Poaceae	*Poa cuspidata*	Early bluegrass	Present in Park	Native
Poaceae	*Poa pratensis*	Kentucky bluegrass	Present in Park	Non-Native
Poaceae	*Poa sylvestris*	Woodland bluegrass	Present in Park	Native
Poaceae	*Poa trivialis*	Rough bluegrass	Present in Park	Non-Native
Poaceae	*Saccharum alopecuroidum*	Silver plume grass	Present in Park	Native
Poaceae	*Schizachyrium scoparium*	Little bluestem	Present in Park	Native
Poaceae	*Setaria parviflora*	Bristly foxtail	Present in Park	Native
Poaceae	*Setaria viridis*	Green bristle grass	Present in Park	Non-Native
Poaceae	*Sorghastrum nutans*	Yellow Indian-grass	Present in Park	Native
Poaceae	*Sorghum halepense*	Johnsongrass	Present in Park	Non-Native
Poaceae	*Sphenopholis nitida*	Shiny wedge grass	Present in Park	Native
Poaceae	*Sphenopholis obtusata*	Prairie wedgescale	Present in Park	Native
Poaceae	*Tridens flavus*	Tall purple-top fluffgrass	Present in Park	Native
Poaceae	*Tripsacum dactyloides*	Eastern gamagrass	Present in Park	Native
Diapensiaceae	*Galax urceolata*	Beetleweed	Present in Park	Native
Caprifoliaceae	*Lonicera dioica*	Limber honeysuckle	Present in Park	Native
Caprifoliaceae	*Lonicera japonica*	Japanese honeysuckle	Present in Park	Non-Native
Caprifoliaceae	*Lonicera maackii*	Amur honeysuckle	Present in Park	Non-Native
Caprifoliaceae	*Sambucus nigra* ssp. *canadensis*	Blue elder, common elderberry, elder	Present in Park	Native
Caprifoliaceae	*Symphoricarpos orbiculatus*	Coral-berry	Present in Park	Native
Caprifoliaceae	*Triosteum aurantiacum*	Horse-gentian	Present in Park	Native
Caprifoliaceae	*Triosteum aurantiacum* var. *aurantiacum*	Orangefruit horsegentian	Present in Park	Native
Caprifoliaceae	*Triosteum perfoliatum*	Feverwort	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Caprifoliaceae	*Viburnum acerifolium*	Maple-leaf arrowood	Present in Park	Native
Caprifoliaceae	*Viburnum nudum* var. *cassinoides*	Possumhaw	Present in Park	Native
Caprifoliaceae	*Viburnum opulus*	Eureopean cranberrybush	Present in Park	Non-Native
Caprifoliaceae	*Viburnum prunifolium*	Smooth black-haw	Present in Park	Native
Caprifoliaceae	*Viburnum rufidulum*	Rusty blackhaw	Present in Park	Native
Dipsacaceae	*Dipsacus fullonum* ssp. *sylvestris*	Common teasel, Fuller's teasel, teasel	Present in Park	Non-Native
Valerianaceae	*Valerianella locusta*	Lewiston cornsalad	Present in Park	Non-Native
Ebenaceae	*Diospyros virginiana*	Persimmon	Present in Park	Native
Equisetaceae	*Equisetum arvense*	Field horsetail	Present in Park	Native
Equisetaceae	*Equisetum hyemale* var. *affine*	Scouringrush horsetail, stout scouringrush, tall scouring-rush	Present in Park	Native
Clethraceae	*Clethra acuminata*	Mountain pepper-bush	Present in Park	Native
Ericaceae	*Epigaea repens*	Trailing arbutus	Present in Park	Native
Ericaceae	*Gaultheria procumbens*	Teaberry	Present in Park	Native
Ericaceae	*Gaylussacia baccata*	Black huckleberry	Present in Park	Native
Ericaceae	*Kalmia latifolia*	Mountain laurel	Present in Park	Native
Ericaceae	*Lyonia ligustrina*	Maleberry	Present in Park	Native
Ericaceae	*Oxydendrum arboreum*	Sourwood	Present in Park	Native
Ericaceae	*Rhododendron calendulaceum*	Flame azalea	Present in Park	Native
Ericaceae	*Rhododendron catawbiense*	Catawba rhododendron	Present in Park	Native
Ericaceae	*Rhododendron cumberlandense*	Cumberland rhododendron	Present in Park	Native
Ericaceae	*Rhododendron maximum*	Great rhododendron	Present in Park	Native
Ericaceae	*Rhododendron minus*	Carolina rhododendron	Present in Park	Native
Ericaceae	*Rhododendron prinophyllum*	Early azalea	Present in Park	Native
Ericaceae	*Vaccinium corymbosum*	Highbush blueberry	Present in Park	Native
Ericaceae	*Vaccinium erythrocarpum*	Southern mountain cranberry	Present in Park	Native
Ericaceae	*Vaccinium pallidum*	Early lowbush blueberry	Present in Park	Native
Ericaceae	*Vaccinium simulatum*	Upland highbush blueberry	Present in Park	Native
Ericaceae	*Vaccinium stamineum*	Squaw huckleberry	Present in Park	Native
Monotropaceae	*Monotropa hypopithys*	American pinesap	Present in Park	Native
Monotropaceae	*Monotropa uniflora*	Indian-pipe	Present in Park	Native
Pyrolaceae	*Chimaphila maculata*	Spotted wintergreen	Present in Park	Native
Euphorbiaceae	*Acalypha rhomboidea*	Virginia threeseed mercury	Present in Park	Native
Euphorbiaceae	*Acalypha virginica*	Virginia threeseed mercury	Present in Park	Native
Euphorbiaceae	*Chamaesyce maculata*	Devil's-bit	Present in Park	Native
Euphorbiaceae	*Chamaesyce nutans*	Eyebane	Present in Park	Native
Euphorbiaceae	*Croton monanthogynus*	Prairie tea	Present in Park	Native
Euphorbiaceae	*Euphorbia corollata*	Flowering spurge	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Euphorbiaceae	*Euphorbia dentata* var. *dentata*	Toothed spurge, toothedleaf poinsettia	Present in Park	Native
Euphorbiaceae	*Euphorbia mercurialina*	Mercury spurge	Present in Park	Native
Fabaceae	*Albizia julibrissin*	Silk tree	Present in Park	Non-Native
Fabaceae	*Amphicarpaea bracteata*	American hog-peanut	Present in Park	Native
Fabaceae	*Apios americana*	American groundnut	Present in Park	Native
Fabaceae	*Cercis canadensis* var. *canadensis*	Redbud	Present in Park	Native
Fabaceae	*Chamaecrista fasciculata* var. *fasciculata*	Sleepingplant	Present in Park	Native
Fabaceae	*Chamaecrista nictitans* ssp. *nictitans* var. *nictitans*	Partridge pea	Present in Park	Native
Fabaceae	*Clitoria mariana*	Maryland butterfly-pea	Present in Park	Native
Fabaceae	*Coronilla varia*	Common crown-vetch	Present in Park	Non-Native
Fabaceae	*Desmodium canescens*	Hoary tick-treefoil	Present in Park	Native
Fabaceae	*Desmodium cuspidatum*	Largebract ticktrefoil	Present in Park	Native
Fabaceae	*Desmodium glabellum*	Dillenius' tick-trefoil	Present in Park	Native
Fabaceae	*Desmodium glutinosum*	Large tick-trefoil	Present in Park	Native
Fabaceae	*Desmodium laevigatum*	Smooth tick-trefoil	Present in Park	Native
Fabaceae	*Desmodium nudiflorum*	Bare-stemmed tick-treefoil	Present in Park	Native
Fabaceae	*Desmodium obtusum*	Stiff tick-trefoil	Present in Park	Native
Fabaceae	*Desmodium paniculatum*	Narrow-leaf tick-trefoil	Present in Park	Native
Fabaceae	*Desmodium pauciflorum*	Fewflower ticktrefoil	Present in Park	Native
Fabaceae	*Desmodium rotundifolium*	Prostrate tick-treefoil	Present in Park	Native
Fabaceae	*Desmodium strictum*	Pinebarren ticktrefoil	Present in Park	Native
Fabaceae	*Desmodium viridiflorum*	Velvety tick-treefoil	Present in Park	Native
Fabaceae	*Galactia volubilis*	Downy milkpea	Present in Park	Native
Fabaceae	*Gleditsia triacanthos*	Honey-locust	Present in Park	Native
Fabaceae	*Kummerowia stipulacea*	Korean clover	Present in Park	Non-Native
Fabaceae	*Kummerowia striata*	Common korean-clover	Present in Park	Non-Native
Fabaceae	*Lathyrus latifolius*	Broad-leaf peavine	Present in Park	Non-Native
Fabaceae	*Lathyrus venosus*	Smooth veiny peavine	Present in Park	Native
Fabaceae	*Lespedeza cuneata*	Chinese lespedeza	Present in Park	Non-Native
Fabaceae	*Lespedeza frutescens*	Wand bush-clover	Present in Park	Native
Fabaceae	*Lespedeza hirta*	Hairy bush-clover	Present in Park	Native
Fabaceae	*Lespedeza procumbens*	Trailing bush-clover	Present in Park	Native
Fabaceae	*Lespedeza repens*	Creeping bush-clover	Present in Park	Native
Fabaceae	*Lespedeza violacea*	Violet lespedeza	Present in Park	Native
Fabaceae	*Lespedeza virginica*	Slender lespedeza	Present in Park	Native
Fabaceae	*Lotus corniculatus*	Birdfood deervetch	Present in Park	Non-Native
Fabaceae	*Medicago lupulina*	Black medick	Present in Park	Non-Native
Fabaceae	*Melilotus officinalis*	Yellow sweetclover	Present in Park	Non-Native
Fabaceae	*Phaseolus polystachios*	Wild kidney bean	Present in Park	Native
Fabaceae	*Pueraria montana* var. *lobata*	Kudzu	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Fabaceae	*Robinia hispida*	Bristly locust	Present in Park	Native
Fabaceae	*Robinia hispida* var. *rosea*	Bristly locust	Present in Park	Native
Fabaceae	*Robinia pseudoacacia*	Black locust	Present in Park	Native
Fabaceae	*Senna marilandica*	Maryland senna	Present in Park	Native
Fabaceae	*Tephrosia virginiana*	Goat's-rue	Present in Park	Native
Fabaceae	*Trifolium campestre*	Low hop clover	Present in Park	Non-Native
Fabaceae	*Trifolium hybridum*	Alsike clover	Present in Park	Non-Native
Fabaceae	*Trifolium pratense*	Red clover	Present in Park	Non-Native
Fabaceae	*Trifolium repens*	White clover	Present in Park	Non-Native
Fabaceae	*Vicia caroliniana*	Carolina wood vetch	Present in Park	Native
Fabaceae	*Vicia sativa* ssp. *nigra*	Garden vetch	Present in Park	Non-Native
Betulaceae	*Alnus serrulata*	Brook-side alder	Present in Park	Native
Betulaceae	*Betula alleghaniensis*	Yellow birch	Present in Park	Native
Betulaceae	*Betula lenta*	Sweet birch	Present in Park	Native
Betulaceae	*Betula nigra*	River birch	Present in Park	Native
Betulaceae	*Carpinus caroliniana*	American hornbeam	Present in Park	Native
Betulaceae	*Corylus americana*	American hazelnut	Present in Park	Native
Betulaceae	*Ostrya virginiana*	Eastern hop-hornbeam	Present in Park	Native
Fagaceae	*Castanea dentata*	American chestnut	Present in Park	Native
Fagaceae	*Castanea pumila* var. *pumila*	Allegheny chinkapin	Present in Park	Native
Fagaceae	*Fagus grandifolia*	American beech	Present in Park	Native
Fagaceae	*Quercus alba*	White oak	Present in Park	Native
Fagaceae	*Quercus coccinea*	Scarlet oak	Present in Park	Native
Fagaceae	*Quercus falcata*	Southern red oak	Present in Park	Native
Fagaceae	*Quercus marilandica*	Blackjack oak	Present in Park	Native
Fagaceae	*Quercus muehlenbergii*	Chinkapin oak	Present in Park	Native
Fagaceae	*Quercus phellos*	Willow oak	Present in Park	Native
Fagaceae	*Quercus prinus*	Chestnut oak	Present in Park	Native
Fagaceae	*Quercus rubra*	Northern red oak	Present in Park	Native
Fagaceae	*Quercus stellata*	Post oak	Present in Park	Native
Fagaceae	*Quercus velutina*	Black oak	Present in Park	Native
Apocynaceae	*Apocynum cannabinum*	Indian-hemp	Present in Park	Native
Apocynaceae	*Vinca minor*	Common periwinkle	Present in Park	Non-Native
Asclepiadaceae	*Asclepias exaltata*	Poke milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias incarnata*	Swamp milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias quadrifolia*	Whorled milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias syriaca*	Common milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias tuberosa*	Butterfly milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias variegata*	White milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias verticillata*	Whorled milkweed	Present in Park	Native
Asclepiadaceae	*Asclepias viridiflora*	Green milkweed	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Gentianaceae	*Gentiana decora*	Showy gentian	Present in Park	Native
Gentianaceae	*Gentiana saponaria* var. *saponaria*	Harvestbells	Present in Park	Native
Gentianaceae	*Gentiana villosa*	Striped gentian	Present in Park	Native
Gentianaceae	*Obolaria virginica*	Virginia pennywort	Present in Park	Native
Gentianaceae	*Sabatia angularis*	Square-stemmed rose pink	Present in Park	Native
Balsaminaceae	*Impatiens capensis*	Spotted jewel-weed	Present in Park	Native
Balsaminaceae	*Impatiens pallida*	Pale jewel-weed	Present in Park	Native
Geraniaceae	*Geranium carolinianum* var. *carolinianum*	Carolina geranium	Present in Park	Native
Geraniaceae	*Geranium maculatum*	Wild crane's-bill	Present in Park	Native
Oxalidaceae	*Oxalis grandis*	Great yellow wood-sorrel	Present in Park	Native
Oxalidaceae	*Oxalis montana*	White wood-sorrel	Present in Park	Native
Oxalidaceae	*Oxalis stricta*	Upright yellow wood-sorrel	Present in Park	Native
Oxalidaceae	*Oxalis violacea*	Violet wood-sorrel	Present in Park	Native
Ginkgoaceae	*Ginkgo biloba*	Maidenhair tree	Present in Park	Non-Native
Hamamelidaceae	*Hamamelis virginiana*	American witch-hazel	Present in Park	Native
Hamamelidaceae	*Liquidambar styraciflua*	Sweet gum	Present in Park	Native
Platanaceae	*Platanus occidentalis*	Sycamore	Present in Park	Native
Juglandaceae	*Carya alba*	Mockernut hickory	Present in Park	Native
Juglandaceae	*Carya cordiformis*	Bitter-nut hickory	Present in Park	Native
Juglandaceae	*Carya glabra*	Sweet pignut hickory	Present in Park	Native
Juglandaceae	*Carya laciniosa*	Big shellbark hickory	Present in Park	Native
Juglandaceae	*Carya ovalis*	Red hickory	Present in Park	Native
Juglandaceae	*Carya ovata*	Shag-bark hickory	Present in Park	Native
Juglandaceae	*Carya pallida*	Sand hickory	Present in Park	Native
Juglandaceae	*Juglans cinerea*	Butternut	Present in Park	Native
Juglandaceae	*Juglans nigra*	Black walnut	Present in Park	Native
Juncaceae	*Juncus coriaceus*	Leathery rush	Present in Park	Native
Juncaceae	*Juncus debilis*	Weak rush	Present in Park	Native
Juncaceae	*Juncus effusus*	Soft rush	Present in Park	Native
Juncaceae	*Juncus interior*	Inland rush	Present in Park	Native
Juncaceae	*Juncus subcaudatus*	Woods-rush	Present in Park	Native
Juncaceae	*Juncus tenuis*	Slender rush	Present in Park	Native
Juncaceae	*Luzula acuminata*	Hairy woodrush	Present in Park	Native
Juncaceae	*Luzula bulbosa*	Southern woodrush	Present in Park	Native
Juncaceae	*Luzula echinata*	Wood rush	Present in Park	Native
Boraginaceae	*Cynoglossum virginianum* var. *virginianum*	Wild comfrey	Present in Park	Native
Boraginaceae	*Lithospermum canescens*	Hoary puccoon	Present in Park	Native
Boraginaceae	*Lithospermum latifolium*	American gromwell	Present in Park	Native
Boraginaceae	*Myosotis arvensis*	Field forget-me-not	Present in Park	Non-Native
Boraginaceae	*Myosotis macrosperma*	Largeseed forget-me-not	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Boraginaceae	*Myosotis verna*	Spring forget-me-not	Present in Park	Native
Lamiaceae	*Blephilia ciliata*	Downy woodmint	Present in Park	Native
Lamiaceae	*Blephilia hirsuta* var. *hirsuta*	Hairy pagoda-plant	Present in Park	Native
Lamiaceae	*Clinopodium vulgare*	Field basil	Present in Park	Native
Lamiaceae	*Collinsonia canadensis*	Canada horse-balm	Present in Park	Native
Lamiaceae	*Cunila origanoides*	Common dittany	Present in Park	Native
Lamiaceae	*Glechoma hederacea*	Ground ivy	Present in Park	Non-Native
Lamiaceae	*Hedeoma pulegioides*	American false-pennyroyal	Present in Park	Native
Lamiaceae	*Isanthus brachiatus*	False pennyroyal, fluxweed	Present in Park	Native
Lamiaceae	*Lamium amplexicaule*	Common deadnettle	Present in Park	Non-Native
Lamiaceae	*Lamium purpureum*	Purple deadnettle	Present in Park	Non-Native
Lamiaceae	*Lycopus virginicus*	Virginia bugleweed	Present in Park	Native
Lamiaceae	*Marrubium vulgare*	Common hoarhound	Present in Park	Non-Native
Lamiaceae	*Monarda clinopodia*	Basil bee-balm	Present in Park	Native
Lamiaceae	*Monarda fistulosa*	Wild bergamot	Present in Park	Native
Lamiaceae	*Perilla frutescens*	Beef-steak plant	Present in Park	Non-Native
Lamiaceae	*Physostegia virginiana*	Obedient-plant	Present in Park	Native
Lamiaceae	*Prunella vulgaris*	Self-heal	Present in Park	Native
Lamiaceae	*Pycnanthemum incanum*	Hoary mountain-mint	Present in Park	Native
Lamiaceae	*Pycnanthemum pycnanthemoides*	Southern mountain-mint	Present in Park	Native
Lamiaceae	*Salvia lyrata*	Lyre-leaf sage	Present in Park	Native
Lamiaceae	*Salvia urticifolia*	Nettle-leaf sage	Present in Park	Native
Lamiaceae	*Scutellaria elliptica*	Hairy skullcap	Present in Park	Native
Lamiaceae	*Scutellaria elliptica* var. *hirsuta*	Hairy skullcap	Present in Park	Native
Lamiaceae	*Scutellaria incana*	Hoary skullcap	Present in Park	Native
Lamiaceae	*Scutellaria ovata*	Heartleaf skullcap	Probably Present	Native
Lamiaceae	*Scutellaria serrata*	Showy skullcap	Present in Park	Native
Lamiaceae	*Stachys nuttallii*	Nuttall's hedge-nettle	Present in Park	Native
Lamiaceae	*Teucrium canadense*	Candad germander	Present in Park	Native
Lamiaceae	*Teucrium canadense* var. *canadense*	Canada germander	Present in Park	Native
Lamiaceae	*Trichostema dichotomum*	Forked bluecurls	Present in Park	Native
Verbenaceae	*Phryma leptostachya*	Lopseed	Present in Park	Native
Verbenaceae	*Verbena urticifolia*	White vervain	Present in Park	Native
Lauraceae	*Lindera benzoin*	Spicebush	Present in Park	Native
Lauraceae	*Sassafras albidum*	Sassafras	Present in Park	Native
Agavaceae	*Yucca filamentosa*	Common yucca	Present in Park	Native
Dioscoreaceae	*Dioscorea oppositifolia*	Chinese yam	Present in Park	Non-Native
Dioscoreaceae	*Dioscorea quaternata*	Fourleaf yam	Present in Park	Native
Dioscoreaceae	*Dioscorea villosa*	Yellow yam	Present in Park	Native
Iridaceae	*Belamcanda chinensis*	Blackberry lily	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Iridaceae	*Hypoxis hirsuta*	Eastern yellow stargrass	Present in Park	Native
Iridaceae	*Iris cristata*	Crested dwarf iris	Present in Park	Native
Iridaceae	*Sisyrinchium albidum*	White blue-eyed grass	Present in Park	Native
Iridaceae	*Sisyrinchium angustifolium*	Pointed blue-eyed-grass	Present in Park	Native
Liliaceae	*Allium cernuum*	Nodding onion	Present in Park	Native
Liliaceae	*Allium tricoccum*	Wild leek	Present in Park	Native
Liliaceae	*Allium vineale* ssp. *vineale*	Wild garlic	Present in Park	Non-Native
Liliaceae	*Amianthium muscitoxicum*	Fly-poison	Present in Park	Native
Liliaceae	*Chamaelirium luteum*	Devil's-bit	Present in Park	Native
Liliaceae	*Clintonia umbellulata*	White bluebead-lily	Present in Park	Native
Liliaceae	*Convallaria majuscula*	Convallaria	Present in Park	Native
Liliaceae	*Erythronium americanum*	Yellow trout-lily	Present in Park	Native
Liliaceae	*Hemerocallis fulva*	Orange daylily	Present in Park	Non-Native
Liliaceae	*Lilium canadense*	Canada lily	Present in Park	Native
Liliaceae	*Maianthemum canadense*	False lily-of-the-valley	Present in Park	Native
Liliaceae	*Maianthemum racemosum* ssp. *racemosum*	False Solomon's-seal	Present in Park	Native
Liliaceae	*Medeola virginiana*	Indian cucumber-root	Present in Park	Native
Liliaceae	*Melanthium parviflorum*	Small-flowered false helleborne	Present in Park	Native
Liliaceae	*Polygonatum biflorum* var. *commutatum*	King Solomon's seal, King Solomon's-seal, smooth Solomon's seal	Present in Park	Native
Liliaceae	*Prosartes lanuginosa*		Present in Park	Native
Liliaceae	*Prosartes maculata*		Present in Park	Native
Liliaceae	*Streptopus lanceolatus* var. *roseus*	Twistedstalk	Present in Park	Native
Liliaceae	*Trillium erectum*	Stinking benjamin	Present in Park	Native
Liliaceae	*Trillium grandiflorum*	Large-flowered wakerobin	Present in Park	Native
Liliaceae	*Trillium sulcatum*	Furrowed wakerobin	Present in Park	Native
Liliaceae	*Trillium undulatum*	Painted trillium	Present in Park	Native
Liliaceae	*Uvularia grandiflora*	Large-flowered bellwort	Present in Park	Native
Liliaceae	*Uvularia perfoliata*	Perfoliate bellwort	Present in Park	Native
Liliaceae	*Uvularia sessilifolia*	Sessile-leaf bellwort	Present in Park	Native
Smilacaceae	*Smilax bona-nox*	Saw greenbrier	Present in Park	Native
Smilacaceae	*Smilax ecirrata*	Upright carrionflower	Present in Park	Native
Smilacaceae	*Smilax glauca*	Glaucous-leaved greenbrier	Present in Park	Native
Smilacaceae	*Smilax herbacea*	Smooth carrion-flower	Present in Park	Native
Smilacaceae	*Smilax hugeri*	Huger's carrion-flower	Present in Park	Native
Smilacaceae	*Smilax pulverulenta*	Downy carrion-flower	Present in Park	Native
Smilacaceae	*Smilax rotundifolia*	Common greenbrier	Present in Park	Native
Smilacaceae	*Smilax tamnoides*	Bristly greenbrier	Present in Park	Native
Linaceae	*Linum usitatissimum*	Common flax	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Linaceae	*Linum virginianum*	Virginia flax	Present in Park	Native
Lycopodiaceae	*Huperzia lucidula*	Shining clubmoss	Present in Park	Native
Lycopodiaceae	*Huperzia porophila*	Rock clubmoss	Present in Park	Native
Lycopodiaceae	*Lycopodium clavatum*	Running clubmoss	Present in Park	Native
Lycopodiaceae	*Lycopodium digitatum*	Shining clubmoss	Present in Park	Native
Lycopodiaceae	*Lycopodium obscurum*	Tree clubmoss	Present in Park	Native
Lycopodiaceae	*Lycopodium tristachyum*	Deep-root clubmoss	Present in Park	Native
Annonaceae	*Asimina triloba*	Pawpaw	Present in Park	Native
Magnoliaceae	*Liriodendron tulipifera*	Tulip tree	Present in Park	Native
Magnoliaceae	*Magnolia acuminata*	Cucumber magnolia	Present in Park	Native
Magnoliaceae	*Magnolia fraseri*	Fraser magnolia	Present in Park	Native
Magnoliaceae	*Magnolia macrophylla*	Bigleaf magnolia	Present in Park	Native
Magnoliaceae	*Magnolia tripetala*	Umbrella magnolia	Present in Park	Native
Malvaceae	*Hibiscus syriacus*	Rose-of-sharon	Present in Park	Non-Native
Malvaceae	*Malva neglecta*	Common mallow	Present in Park	Non-Native
Malvaceae	*Sida spinosa*	Prickly fanpetals	Present in Park	Native
Tiliaceae	*Tilia americana*	American basswood	Present in Park	Native
Tiliaceae	*Tilia americana* var. *americana*	American basswood	Present in Park	Native
Tiliaceae	*Tilia americana* var. *heterophylla*	White basswood	Present in Park	Native
Onagraceae	*Circaea lutetiana* ssp. *canadensis*	Intermediate enchanter's nightshade	Present in Park	Native
Onagraceae	*Epilobium coloratum*	Purple-leaf willow-herb	Present in Park	Native
Onagraceae	*Gaura biennis*	Biennial gaura	Present in Park	Native
Onagraceae	*Ludwigia alternifolia*	Bushy seedbox	Present in Park	Native
Onagraceae	*Oenothera biennis*	Common evening-primrose	Present in Park	Native
Ophioglossaceae	*Botrychium dissectum*	Cutleaf grape-fern	Present in Park	Native
Ophioglossaceae	*Botrychium virginianum*	Rattlesnake fern	Present in Park	Native
Ophioglossaceae	*Ophioglossum vulgatum*	Southern adderstongue, Southern adder's-tongue	Present in Park	Native
Orchidaceae	*Aplectrum hyemale*	Puttyroot	Present in Park	Native
Orchidaceae	*Corallorrhiza odontorhiza*	Autumn coral-root	Present in Park	Native
Orchidaceae	*Corallorrhiza wisteriana*	Spring coralroot	Present in Park	Native
Orchidaceae	*Cypripedium acaule*	Pink lady's-slipper	Present in Park	Native
Orchidaceae	*Cypripedium parviflorum*	Small yellow lady's-slipper	Present in Park	Native
Orchidaceae	*Cypripedium parviflorum* var. *pubescens*		Present in Park	Native
Orchidaceae	*Galearis spectabilis*	Showy orchis	Present in Park	Native
Orchidaceae	*Goodyera pubescens*	Downy rattlesnake-plantain	Present in Park	Native
Orchidaceae	*Hexalectris spicata*	Crested coralroot	Present in Park	Native
Orchidaceae	*Isotria verticillata*	Large whorled pogonia	Present in Park	Native
Orchidaceae	*Liparis liliifolia*	Large twayblade	Present in Park	Native
Orchidaceae	*Listera smallii*	Kidney-leaf twayblade	Probably	Native

Family	Scientific Name	Common name	Occurrence	Nativity
			Present	
Orchidaceae	*Malaxis unifolia*	Green adder's-mouth	Present in Park	Native
Orchidaceae	*Platanthera ciliaris*	Yellow fringed orchid	Present in Park	Native
Orchidaceae	*Platanthera clavellata*	Small green woodland orchid	Present in Park	Native
Orchidaceae	*Platanthera flava*	Pale green orchid	Present in Park	Native
Orchidaceae	*Platanthera lacera*	Green fringed orchid	Present in Park	Native
Orchidaceae	*Spiranthes cernua*	Nodding ladies'-tresses	Present in Park	Native
Orchidaceae	*Spiranthes lacera* var. *gracilis*	Southern slender ladies'tresses	Present in Park	Native
Orchidaceae	*Spiranthes ovalis*	Lesser ladies'-tresses	Present in Park	Native
Orchidaceae	*Spiranthes praecox*	Greenvein ladiestresses, greenvein ladies'-tresses	Present in Park	Native
Orchidaceae	*Spiranthes vernalis*	Twisted ladies'-tresses	Present in Park	Native
Orchidaceae	*Tipularia discolor*	Crippled cranefly	Present in Park	Native
Fumariaceae	*Adlumia fungosa*	Climbing fumitory	Present in Park	Native
Fumariaceae	*Corydalis sempervirens*	Pale corydalis	Present in Park	Native
Papaveraceae	*Sanguinaria canadensis*	Bloodroot	Present in Park	Native
Cupressaceae	*Juniperus virginiana* var. *virginiana*	Eastern redcedar	Present in Park	Native
Pinaceae	*Pinus echinata*	Arkansas pine	Present in Park	Native
Pinaceae	*Pinus rigida*	Pitch pine	Present in Park	Native
Pinaceae	*Pinus virginiana*	Virginia pine	Present in Park	Native
Pinaceae	*Tsuga canadensis*	Eastern hemlock	Present in Park	Native
Plantaginaceae	*Plantago lanceolata*	English plantain	Present in Park	Non-Native
Plantaginaceae	*Plantago major*	Great plantain	Present in Park	Native
Plantaginaceae	*Plantago rugelii*	Black-seed plantain	Present in Park	Native
Plantaginaceae	*Plantago virginica*	Pale-seeded plantain	Present in Park	Native
Polygalaceae	*Polygala sanguinea*	Field milkwort	Present in Park	Native
Polygalaceae	*Polygala senega*	Seneca snakeroot	Present in Park	Native
Polygonaceae	*Polygonum arifolium*	Halberd-leaf tearthumb	Present in Park	Native
Polygonaceae	*Polygonum aviculare*	Prostrate knotweed	Present in Park	Non-Native
Polygonaceae	*Polygonum caespitosum* var. *longisetum*	Oriental ladysthumb	Present in Park	Native
Polygonaceae	*Polygonum convolvulus*	Black bindweed	Present in Park	Non-Native
Polygonaceae	*Polygonum cuspidatum*	Japanese knotweed	Present in Park	Non-Native
Polygonaceae	*Polygonum pensylvanicum*	Pennsylvania smartweed	Present in Park	Native
Polygonaceae	*Polygonum persicaria*	Lady's thumb	Present in Park	Non-Native
Polygonaceae	*Polygonum punctatum*	Dotted smartweed	Present in Park	Native
Polygonaceae	*Polygonum sagittatum*	Arrow-leaved tearthumb	Present in Park	Native
Polygonaceae	*Polygonum scandens*	Climbing false-buckwheat	Present in Park	Native
Polygonaceae	*Polygonum virginianum*	Virginia knotweed	Present in Park	Native
Polygonaceae	*Rumex acetosella*	Sheep sorrel	Present in Park	Non-Native
Polygonaceae	*Rumex crispus*	Curly dock	Present in Park	Non-Native
Polygonaceae	*Rumex obtusifolius*	Bitter dock	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Aspleniaceae	*Asplenium montanum*	Mountain spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium pinnatifidum*	Lobed spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium platyneuron*	Ebony spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium resiliens*	Black-stem spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium rhizophyllum*	Walking-fern spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium ruta-muraria*	Wallrue spleenwort	Present in Park	Native
Aspleniaceae	*Asplenium trichomanes*	Maidenhair spleenwort	Present in Park	Native
Blechnaceae	*Woodwardia areolata*	Netted chainfern	Present in Park	Native
Dennstaedtiaceae	*Dennstaedtia punctilobula*	Eastern hay-scented fern	Present in Park	Native
Dennstaedtiaceae	*Pteridium aquilinum*	Bracken fern	Present in Park	Native
Dryopteridaceae	*Athyrium filix-femina*	Common ladyfern	Present in Park	Native
Dryopteridaceae	*Athyrium filix-femina* ssp. *asplenioides*	Asplenium ladyfern	Present in Park	Native
Dryopteridaceae	*Cystopteris bulbifera*	Bulblet fern	Present in Park	Native
Dryopteridaceae	*Cystopteris protrusa*	Lowland brittle fern	Present in Park	Native
Dryopteridaceae	*Deparia acrostichoides*	Silvery spleenwort	Present in Park	Native
Dryopteridaceae	*Diplazium pycnocarpon*	Glade fern	Present in Park	Native
Dryopteridaceae	*Dryopteris campyloptera*	Mountain woodfern	Present in Park	Native
Dryopteridaceae	*Dryopteris goldiana*	Goldie's woodfern	Present in Park	Native
Dryopteridaceae	*Dryopteris intermedia*	Evergreen woodfern	Present in Park	Native
Dryopteridaceae	*Dryopteris marginalis*	Marginal wood-fern	Present in Park	Native
Dryopteridaceae	*Onoclea sensibilis*	Sensitive fern	Present in Park	Native
Dryopteridaceae	*Polystichum acrostichoides* var. *acrostichoides*	Christmas fern	Present in Park	Native
Dryopteridaceae	*Woodsia appalachiana*	Appalachian cliff fern	Present in Park	Native
Dryopteridaceae	*Woodsia obtusa*	Blunt-lobe woodsia	Present in Park	Native
Lygodiaceae	*Lygodium palmatum*	Climbing fern	Present in Park	Native
Osmundaceae	*Osmunda cinnamomea*	Cinnamon fern	Present in Park	Native
Osmundaceae	*Osmunda claytoniana*	Interrupted fern	Present in Park	Native
Osmundaceae	*Osmunda regalis* var. *spectabilis*	Royal fern	Present in Park	Native
Polypodiaceae	*Pleopeltis polypodioides* ssp. *michauxiana*	Resurrection fern	Present in Park	Native
Polypodiaceae	*Polypodium virginianum*	Rock polypody	Present in Park	Native
Pteridaceae	*Adiantum pedatum*	Northern maidenhair-fern	Present in Park	Native
Pteridaceae	*Cheilanthes alabamensis*	Alabama lipfern	Present in Park	Native
Pteridaceae	*Cheilanthes lanosa*	Hairy lipfern	Present in Park	Native
Pteridaceae	*Pellaea atropurpurea*	Purple-stem cliff-brake	Present in Park	Native
Thelypteridaceae	*Phegopteris hexagonoptera*	Broad beech fern	Present in Park	Native
Thelypteridaceae	*Thelypteris noveboracensis*	New york fern	Present in Park	Native
Primulaceae	*Lysimachia quadrifolia*	Whorled loosestrife	Present in Park	Native
Primulaceae	*Lysimachia tonsa*	Southern loosestrife	Present in Park	Native
Primulaceae	*Samolus valerandi* ssp. *parviflorus*	Seaside brookweed	Present in Park	Native
Berberidaceae	*Berberis thunbergii*	Japanese barberry	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Berberidaceae	*Caulophyllum thalictroides*	Blue cohosh	Present in Park	Native
Berberidaceae	*Podophyllum peltatum*	May apple	Present in Park	Native
Menispermaceae	*Cocculus carolinus*	Carolina coralbead	Present in Park	Native
Menispermaceae	*Menispermum canadense*	Canada moonseed	Present in Park	Native
Ranunculaceae	*Actaea pachypoda*	White baneberry	Present in Park	Native
Ranunculaceae	*Actaea racemosa* var. *racemosa*		Present in Park	Native
Ranunculaceae	*Anemone quinquefolia*	Wood anemone	Present in Park	Native
Ranunculaceae	*Anemone virginiana* var. *virginiana*	Tall thimbleweed	Present in Park	Native
Ranunculaceae	*Aquilegia canadensis*	Wild columbine	Present in Park	Native
Ranunculaceae	*Clematis catesbyana*	Satincurls	Present in Park	Native
Ranunculaceae	*Clematis terniflora*	Japanese virgin's-bower	Present in Park	Non-Native
Ranunculaceae	*Clematis viorna*	Vase-vine leatherflower	Present in Park	Native
Ranunculaceae	*Clematis virginiana*	Virginia virgin-bower	Present in Park	Native
Ranunculaceae	*Delphinium tricorne*	Dwarf larkspur	Present in Park	Native
Ranunculaceae	*Hepatica nobilis* var. *acuta*	Sharp-lobed hepatica	Present in Park	Native
Ranunculaceae	*Hepatica nobilis* var. *obtusa*	Roundlobed hepatica	Present in Park	Native
Ranunculaceae	*Hydrastis canadensis*	Golden-seal	Present in Park	Native
Ranunculaceae	*Ranunculus abortivus*	Kidney-leaved buttercup	Present in Park	Native
Ranunculaceae	*Ranunculus acris*	Tall butter-cup	Present in Park	Non-Native
Ranunculaceae	*Ranunculus allegheniensis*	Allegheny mountain buttercup	Present in Park	Native
Ranunculaceae	*Ranunculus bulbosus*	Bulbous buttercup	Present in Park	Non-Native
Ranunculaceae	*Ranunculus hispidus*	Hispid buttercup	Present in Park	Native
Ranunculaceae	*Ranunculus hispidus* var. *hispidus*	Bristly buttercup	Present in Park	Native
Ranunculaceae	*Ranunculus recurvatus*	Blisterwort	Present in Park	Native
Ranunculaceae	*Thalictrum clavatum*	Mountain meadow-rue	Present in Park	Native
Ranunculaceae	*Thalictrum dioicum*	Early meadowrue	Present in Park	Native
Ranunculaceae	*Thalictrum pubescens*	Tall meadow-rue	Present in Park	Native
Ranunculaceae	*Thalictrum revolutum*	Waxleaf meadowrue	Present in Park	Native
Ranunculaceae	*Thalictrum thalictroides*	Windflower	Present in Park	Native
Ranunculaceae	*Trautvetteria caroliniensis* var. *caroliniensis*	Carolina bugbane	Present in Park	Native
Elaeagnaceae	*Elaeagnus umbellata* var. *parvifolia*	Autumn olive, oleaster	Present in Park	Non-Native
Rhamnaceae	*Ceanothus americanus*	New jersey tea	Present in Park	Native
Rhamnaceae	*Frangula caroliniana*	Carolina buckthorn	Present in Park	Native
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper	Present in Park	Native
Vitaceae	*Vitis aestivalis*	Summer grape	Present in Park	Native
Vitaceae	*Vitis aestivalis* var. *bicolor*	Summer grape	Present in Park	Native
Vitaceae	*Vitis cinerea*	Pigeon grape	Present in Park	Native
Vitaceae	*Vitis cinerea* var. *baileyana*	Graybark grape	Present in Park	Native
Vitaceae	*Vitis cinerea* var. *floridana*	Florida grape	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Vitaceae	*Vitis labrusca*	Fox grape	Present in Park	Native
Vitaceae	*Vitis rotundifolia*	Muscadine grape	Present in Park	Native
Vitaceae	*Vitis vulpina*	Winter grape	Present in Park	Native
Crassulaceae	*Sedum pulchellum*	Widowscross	Present in Park	Native
Crassulaceae	*Sedum ternatum*	Wood stonecrop	Present in Park	Native
Hydrangeaceae	*Hydrangea arborescens*	Wild hydrangea	Present in Park	Native
Hydrangeaceae	*Philadelphus hirsutus*	Streambank mock-orange	Present in Park	Native
Rosaceae	*Agrimonia gryposepala*	Tall hairy groovebur	Present in Park	Native
Rosaceae	*Agrimonia parviflora*	Swamp agrimony	Present in Park	Native
Rosaceae	*Agrimonia pubescens*	Soft agrimony	Present in Park	Native
Rosaceae	*Agrimonia rostellata*	Woodland agrimony	Present in Park	Native
Rosaceae	*Amelanchier arborea*	Downy serviceberry	Present in Park	Native
Rosaceae	*Amelanchier canadensis*	Canadian serviceberry	Present in Park	Native
Rosaceae	*Amelanchier laevis*	Allegheny service-berry	Present in Park	Native
Rosaceae	*Aruncus dioicus*	Common goatsbeard	Present in Park	Non-Native
Rosaceae	*Chaenomeles speciosa*	Flowering quince	Present in Park	Non-Native
Rosaceae	*Crataegus calpodendron*	Pear hawthorn	Present in Park	Native
Rosaceae	*Crataegus flabellata*	Fanleaf hawthorn	Present in Park	Native
Rosaceae	*Crataegus uniflora*	Dwarf hawthorn	Present in Park	Native
Rosaceae	*Duchesnea indica*	Indian mock-strawberry	Present in Park	Non-Native
Rosaceae	*Fragaria virginiana*	Virginia strawberry	Present in Park	Native
Rosaceae	*Geum canadense* var. *canadense*	Canada avens	Present in Park	Native
Rosaceae	*Geum vernum*	Spring avens	Present in Park	Native
Rosaceae	*Geum virginianum*	Pale avens	Present in Park	Native
Rosaceae	*Malus angustifolia*	Southern crabapple	Present in Park	Native
Rosaceae	*Malus pumila*	Apple	Present in Park	Non-Native
Rosaceae	*Photinia melanocarpa*	Black chokeberry	Present in Park	Native
Rosaceae	*Porteranthus trifoliatus*	Bowman's-root	Present in Park	Native
Rosaceae	*Potentilla canadensis*	Canada cinquefoil	Present in Park	Native
Rosaceae	*Potentilla norvegica* ssp. *monspeliensis*	Norwegian cinquefoil	Present in Park	Native
Rosaceae	*Potentilla recta*	Sulphur cinquefoil	Present in Park	Non-Native
Rosaceae	*Potentilla simplex*	Old-field cinquefoil	Present in Park	Native
Rosaceae	*Prunus americana*	American plum	Present in Park	Native
Rosaceae	*Prunus angustifolia* var. *angustifolia*	Chickasaw plum	Present in Park	Native
Rosaceae	*Prunus persica*	Peach	Present in Park	Non-Native
Rosaceae	*Prunus serotina* var. *serotina*	Black cherry	Present in Park	Native
Rosaceae	*Pyrus communis*	Common pear	Present in Park	Non-Native
Rosaceae	*Rosa carolina* var. *carolina*	Carolina rose	Present in Park	Native
Rosaceae	*Rosa multiflora*	Multiflora rose	Present in Park	Non-Native
Rosaceae	*Rosa setigera*	Prairie rose	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Rosaceae	*Rosa virginiana*	Virginia rose	Present in Park	Native
Rosaceae	*Rosa wichuraiana*	Memorial rose	Present in Park	Non-Native
Rosaceae	*Rubus allegheniensis*	Allegheny blackberry	Present in Park	Native
Rosaceae	*Rubus allegheniensis* var. *allegheniensis*	Allegheny blackberry	Present in Park	Native
Rosaceae	*Rubus argutus*	Sawtooth blackberry	Present in Park	Native
Rosaceae	*Rubus canadensis*	Smooth blackberry	Present in Park	Native
Rosaceae	*Rubus cuneifolius*	Sawtooth blackberry	Present in Park	Native
Rosaceae	*Rubus flagellaris*	Sand blackberry	Present in Park	Native
Rosaceae	*Rubus hispidus*	Sand blackberry	Present in Park	Native
Rosaceae	*Rubus occidentalis*	Black raspberry	Present in Park	Native
Rosaceae	*Rubus odoratus*	Purple flowering raspberry	Present in Park	Native
Rosaceae	*Rubus pensilvanicus*	Pennsylvania blackberry	Present in Park	Native
Rosaceae	*Spiraea prunifolia*	Bridal-wreath	Present in Park	Non-Native
Rosaceae	*Waldsteinia fragarioides*	Barren strawberry	Present in Park	Native
Saxifragaceae	*Boykinia aconitifolia*	Brook saxifrage	Present in Park	Native
Saxifragaceae	*Heuchera americana*	American alumroot	Present in Park	Native
Saxifragaceae	*Heuchera parviflora*	Little-leaved alumroot	Present in Park	Native
Saxifragaceae	*Heuchera pubescens*	Downy alumroot	Present in Park	Native
Saxifragaceae	*Heuchera villosa* var. *villosa*	Hairy alumroot	Present in Park	Native
Saxifragaceae	*Mitella diphylla*	Two-leaf bishop's-cap	Present in Park	Native
Saxifragaceae	*Saxifraga michauxii*	Michaux's saxifrage	Present in Park	Native
Saxifragaceae	*Tiarella cordifolia*	Heart-leaved foam-flower	Present in Park	Native
Rubiaceae	*Cephalanthus occidentalis*	Common buttonbush	Present in Park	Native
Rubiaceae	*Diodia virginiana*	Larger button-weed	Present in Park	Native
Rubiaceae	*Galium aparine*	Catchweed bedstraw	Present in Park	Native
Rubiaceae	*Galium circaezans*	Wild licorice	Present in Park	Native
Rubiaceae	*Galium lanceolatum*	Lanceleaf wild licorice	Present in Park	Native
Rubiaceae	*Galium latifolium*	Purple bedstraw	Present in Park	Native
Rubiaceae	*Galium pilosum*	Hairy bedstraw	Present in Park	Native
Rubiaceae	*Galium tinctorium*	Stiff marsh bedstraw	Present in Park	Native
Rubiaceae	*Galium triflorum*	Sweet-scent bedstraw	Present in Park	Native
Rubiaceae	*Houstonia caerulea*	Azure bluets	Present in Park	Native
Rubiaceae	*Houstonia canadensis*	Canadian summer bluet	Present in Park	Native
Rubiaceae	*Houstonia longifolia*	Longleaf bluet	Present in Park	Native
Rubiaceae	*Houstonia purpurea*	Purple bluet	Present in Park	Native
Rubiaceae	*Mitchella repens*	Partridge-berry	Present in Park	Native
Rubiaceae	*Sherardia arvensis*	Blue fieldmadder	Present in Park	Non-Native
Salicaceae	*Salix humilis*	Tall prairie willow	Present in Park	Native
Salicaceae	*Salix humilis* var. *tristis*	Prairie willow	Present in Park	Native
Salicaceae	*Salix nigra*	Black willow	Present in Park	Native
Santalaceae	*Pyrularia pubera*	Buffalo-nut	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Viscaceae	*Phoradendron leucarpum*	American mistletoe	Present in Park	Native
Aceraceae	*Acer negundo*	Box elder	Present in Park	Native
Aceraceae	*Acer pensylvanicum*	Striped maple	Present in Park	Native
Aceraceae	*Acer rubrum*	Red maple	Present in Park	Native
Aceraceae	*Acer rubrum* var. *trilobum*	Red maple	Present in Park	Native
Aceraceae	*Acer saccharum*	Sugar maple	Present in Park	Native
Aceraceae	*Acer saccharum* var. *saccharum*	Sugar maple	Present in Park	Native
Anacardiaceae	*Rhus aromatica* var. *aromatica*	A fragrant sumac, fragrant sumac	Present in Park	Native
Anacardiaceae	*Rhus copallinum*	Winged sumac	Present in Park	Native
Anacardiaceae	*Rhus glabra*	Smooth sumac	Present in Park	Native
Anacardiaceae	*Toxicodendron radicans*	Poison ivy	Present in Park	Native
Hippocastanaceae	*Aesculus flava*	Yellow buckeye	Present in Park	Native
Rutaceae	*Ptelea trifoliata*	Wafer-ash	Present in Park	Native
Rutaceae	*Ptelea trifoliata* ssp. *trifoliata* var. *mollis*	Wafer-ash	Present in Park	Native
Simaroubaceae	*Ailanthus altissima*	Tree-of-heaven	Present in Park	Non-Native
Acanthaceae	*Ruellia caroliniensis* ssp. *caroliniensis* var. *caroliniensis*	Carolina wild petunia	Present in Park	Native
Acanthaceae	*Ruellia purshiana*	Pursh's wild-petunia	Present in Park	Native
Bignoniaceae	*Bignonia capreolata*	Crossvine	Present in Park	Native
Bignoniaceae	*Campsis radicans*	Trumpet creeper	Present in Park	Native
Oleaceae	*Forsythia viridissima*	Forsythia	Present in Park	Non-Native
Oleaceae	*Fraxinus americana*	White ash	Present in Park	Native
Oleaceae	*Fraxinus pennsylvanica*	Green ash	Present in Park	Native
Oleaceae	*Ligustrum amurense*	Amur privet	Present in Park	Non-Native
Oleaceae	*Ligustrum sinense*	Chinese privet	Present in Park	Non-Native
Orobanchaceae	*Conopholis americana*	Squaw-root	Present in Park	Native
Orobanchaceae	*Epifagus virginiana*	Beechdrops	Present in Park	Native
Orobanchaceae	*Orobanche uniflora*	One-flowered broomrape	Present in Park	Native
Scrophulariaceae	*Agalinis tenuifolia*	Slender false-foxglove	Present in Park	Native
Scrophulariaceae	*Aureolaria flava*	Yellow false-foxglove	Present in Park	Native
Scrophulariaceae	*Aureolaria laevigata*	Entire-leaf yellow false foxglove	Present in Park	Native
Scrophulariaceae	*Aureolaria pedicularia*	Fernleaf yellow false-foxglove	Present in Park	Native
Scrophulariaceae	*Aureolaria virginica*	Downy false-foxglove	Present in Park	Native
Scrophulariaceae	*Chelone glabra*	White turtlehead	Present in Park	Native
Scrophulariaceae	*Gratiola virginiana*	Roundfruit hedge-hyssop	Present in Park	Native
Scrophulariaceae	*Melampyrum lineare*	American cow-wheat	Present in Park	Native
Scrophulariaceae	*Melampyrum lineare* var. *latifolium*	American cowwheat	Present in Park	Native
Scrophulariaceae	*Mimulus alatus*	Sharp-wing monkeyflower	Present in Park	Native
Scrophulariaceae	*Paulownia tomentosa*	Princess tree	Present in Park	Non-Native

Family	Scientific Name	Common name	Occurrence	Nativity
Scrophulariaceae	*Pedicularis canadensis* ssp. *canadensis*	Canadian lousewort	Present in Park	Native
Scrophulariaceae	*Penstemon calycosus*	Longsepal beardtongue	Present in Park	Native
Scrophulariaceae	*Penstemon canescens*	Gray beardtongue	Present in Park	Native
Scrophulariaceae	*Penstemon digitalis*	Talus slope penstemon	Present in Park	Native
Scrophulariaceae	*Penstemon pallidus*	Pale beardtongue	Present in Park	Native
Scrophulariaceae	*Verbascum blattaria*	Moth mullein	Present in Park	Non-Native
Scrophulariaceae	*Verbascum thapsus*	Great mullein	Present in Park	Non-Native
Scrophulariaceae	*Veronica arvensis*	Corn speedwell	Present in Park	Non-Native
Scrophulariaceae	*Veronica officinalis* var. *officinalis*	Common gypsyweed	Present in Park	Native
Scrophulariaceae	*Veronica serpyllifolia* ssp. *serpyllifolia*	Thymeleaf speedwell	Present in Park	Non-Native
Convolvulaceae	*Calystegia sepium*	Hedge bindweed	Present in Park	Non-Native
Convolvulaceae	*Calystegia spithamaea*	Low false bindweed	Present in Park	Native
Convolvulaceae	*Convolvulus arvensis*	Field bindweed	Present in Park	Non-Native
Convolvulaceae	*Ipomoea hederacea*	Ivyleaf morning-glory	Present in Park	Non-Native
Convolvulaceae	*Ipomoea pandurata*	Big-root morning-glory	Present in Park	Native
Convolvulaceae	*Ipomoea purpurea*	Tall morning-glory	Present in Park	Non-Native
Cuscutaceae	*Cuscuta gronovii*	Scaldweed	Present in Park	Native
Hydrophyllaceae	*Hydrophyllum canadense*	Bluntleaf waterleaf	Present in Park	Native
Hydrophyllaceae	*Hydrophyllum macrophyllum*	Largeleaf waterleaf	Present in Park	Native
Hydrophyllaceae	*Hydrophyllum virginianum*	Shawnee salad	Present in Park	Native
Hydrophyllaceae	*Phacelia bipinnatifida*	Fernleaf phacelia	Present in Park	Native
Hydrophyllaceae	*Phacelia purshii*	Miami-mist	Present in Park	Native
Polemoniaceae	*Phlox amplifolia*	Large-leaved phlox	Present in Park	Native
Polemoniaceae	*Phlox carolina*	Thick-leaved phlox	Present in Park	Native
Polemoniaceae	*Phlox divaricata*	Wild blue phlox	Present in Park	Native
Polemoniaceae	*Phlox maculata*	Spotted phlox	Present in Park	Native
Polemoniaceae	*Phlox paniculata*	Fall phlox	Present in Park	Native
Solanaceae	*Physalis heterophylla* var. *heterophylla*	Clammy groundcherry	Present in Park	Native
Solanaceae	*Physalis virginiana* var. *virginiana*	Virginia groundcherry	Present in Park	Native
Solanaceae	*Solanum carolinense* var. *carolinense*	Carolina horsenettle	Present in Park	Native
Solanaceae	*Solanum ptychanthum*	Nightshade	Present in Park	Native
Clusiaceae	*Hypericum gentianoides*	Orange-grass st. John's-wort	Present in Park	Native
Clusiaceae	*Hypericum hypericoides* ssp. *hypericoides*	St. Andrew's cross	Present in Park	Native
Clusiaceae	*Hypericum hypericoides* ssp. *multicaule*	St. Andrew's cross	Present in Park	Native
Clusiaceae	*Hypericum mutilum*	Slender st. John's-wort	Present in Park	Native
Clusiaceae	*Hypericum punctatum*	Common St. John's-wort	Present in Park	Native
Sparganiaceae	*Sparganium americanum*	American bur-reed	Present in Park	Native
Typhaceae	*Typha latifolia*	Broad-leaf cattail	Present in Park	Native

Family	Scientific Name	Common name	Occurrence	Nativity
Moraceae	*Morus rubra* var. *rubra*	Red mulberry	Present in Park	Native
Ulmaceae	*Celtis occidentalis*	Common hackberry	Present in Park	Native
Ulmaceae	*Celtis tenuifolia*	Dwarf hackberry	Present in Park	Native
Ulmaceae	*Ulmus alata*	Winged elm	Present in Park	Native
Ulmaceae	*Ulmus americana*	American elm	Present in Park	Native
Ulmaceae	*Ulmus rubra*	Slippery elm	Present in Park	Native
Urticaceae	*Boehmeria cylindrica*	False nettle	Present in Park	Native
Urticaceae	*Laportea canadensis*	Wood nettle	Present in Park	Native
Urticaceae	*Pilea pumila*	Canada clearweed	Present in Park	Native
Cistaceae	*Lechea racemulosa*	Illinois pinweed	Present in Park	Native
Cucurbitaceae	*Sicyos angulatus*	One-seed bur-cucumber	Present in Park	Native
Passifloraceae	*Passiflora lutea*	Yellow passionflower	Present in Park	Native
Violaceae	*Hybanthus concolor*	Green violet	Present in Park	Native
Violaceae	*Viola affinis*	Sand violet	Present in Park	Native
Violaceae	*Viola bicolor*	Field pansy	Present in Park	Native
Violaceae	*Viola blanda*	Smooth white violet	Present in Park	Native
Violaceae	*Viola canadensis* var. *canadensis*	Canadian white violet	Present in Park	Native
Violaceae	*Viola conspersa*	American bog violet	Present in Park	Native
Violaceae	*Viola cucullata*	Marsh blue violet	Present in Park	Native
Violaceae	*Viola hastata*	Halberd-leaved yellow violet	Present in Park	Native
Violaceae	*Viola hirsutula*	Southern wood violet	Present in Park	Native
Violaceae	*Viola macloskeyi* ssp. *pallens*	Smooth white violet	Present in Park	Native
Violaceae	*Viola palmata* var. *palmata*	Violet	Present in Park	Native
Violaceae	*Viola pedata*	Bird's-foot violet	Present in Park	Native
Violaceae	*Viola pubescens*	Downy yellow violet	Present in Park	Native
Violaceae	*Viola pubescens* var. *pubescens*	Smooth yellow violet	Present in Park	Native
Violaceae	*Viola rotundifolia*	Roundleaf violet	Present in Park	Native
Violaceae	*Viola sagittata*	Arrow-leaved violet	Present in Park	Native
Violaceae	*Viola sororia*	Common blue violet	Present in Park	Native
Violaceae	*Viola striata*	Striped violet	Present in Park	Native

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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