National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Horseshoe Bend National Military Park

Natural Resource Report NPS/SECN/NRR—2015/981

ON THE COVER
Photo of the Tallapoosa River, viewed from Horseshoe Bend National Military Park
Photo Courtesy of Elle Allen

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This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Contents

Figures

Figures (continued)

Figures (continued)

Page

Figures (continued)

Page

Tables

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Plates

Appendices

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Abbreviations

ADEM – Alabama Department of Environmental Management
Ala. – Alabama
API – Air Pollution Index (kilograms or pounds; calculated as total pounds of the six most hazardous air pollutants (arsenic, benzene, carbon tetrachloride, lead, and mercury)
AQI – Air Quality Index (of the EPA; scale from 0 to 500, with higher numbers indicating poorer air quality)
AWW – Alabama Water Watch (volunteer program of Auburn University)
ARD – automated recording device (for a study of anuran amphibians)
ASABE – American Society of Agricultural and Biological Engineers
Au-OpMA – the Auburn-Opelika metropolitan area (in adjacent Lee County)
Bd – *Batrachochytrium dendrobatidis* (chytrid fungal pathogen of amphibians)
BDSS – the Bortle Dark-Sky Scale
BMP – best management practices
cfs – cubic feet per second
cfu – colony forming units
CI – confidence interval (in statistics)
cm – centimeter
cms – cubic meters per second
CO – carbon monoxide
CO_2 – carbon dioxide, a major greenhouse gas contributing to global warming
dB(A) – A-weighted decibels, wherein a decibel is a unit of sound production; decibel(A) refers to sound production level on an A-weighted scale according to sound frequency
DO – dissolved oxygen
EFC – Environmental Flow Component
EPA –United States Environmental Protection Agency
EPMT – Exotic Plant Management Team (of the NPS)
ERMF – Environmental Research and Mapping Facility (of the University of Tennessee)
ft – feet
Ga. – Georgia
GDD – growing degree days
GIS – Geographic Information System
GeRI – Geologic Resources Inventory
GRD – Geologic Resources Division (of the NPS)
GRI – Groundwater Resources Inventory
HOBE – Horseshoe Bend National Military Park
hr – hour
Hz – cycles per second, a measure of pitch in noise analysis
I&M Program – Inventory and Monitoring Program (of the NPS)
IHA – Indicators of Hydrologic Alteration (software from the Nature Conservancy)
in – inch

IPCC –Intergovernmental Panel on Climate Change (of the United Nations)
IRMA – Integrated Resource Management Applications (National Park Service portal)
kHz (or KHz) – kilohertz, unit of alternating current or electromagnetic wave frequency equal to one thousand hertz (Hz)
km – kilometer
km^2 – square kilometer
L – liter(s)
lat. – latitude
long. – longitude
m – meter
µg/L – micrograms per liter
$mile^2$ – square mile
mg/L – milligrams per liter
mgd – million gallons per day
mya – million years ago
N – nitrogen (nutrient; excessive enrichment can degrade water quality)
NAAQS – National Ambient Air Quality Standards (of the EPA)
NADP – National Atmospheric Deposition Program (of the EPA)
NCSU CAAE – North Carolina State University Center for Applied Aquatic Ecology
NH_4^+N – ammonium (inorganic form of nitrogen, ionized from ammonia; excessive enrichment can degrade water quality)
NLCD – National Land Cover Database
NOAA – National Oceanic and Atmospheric Organization
$NO_3^- + NO_2^-$ – nitrate + nitrite (inorganic forms of nitrogen; excessive enrichment can degrade water quality)
NO_x – nitrate + nitrite (inorganic forms of nitrogen; excessive enrichment can degrade water quality)
NPC – Not possible for the National Park Service to control
NPDES – National Pollutant Discharge Elimination System
NPS – National Park Service
NRC – Natural Resource Condition
NRCA – Natural Resource Condition Assessment
NRS – National Resource Strategy (of parks in the NPS)
NTU – nephelometric turbidity units
NWI – National Wetlands Inventory
NWS – National Weather Service (of NOAA)
O_3 – ozone
P – Phosphorus (nutrient; excessive enrichment can degrade water quality)
Pa – Pascal, a unit of pressure: 1 Pa = the pressure of 1 newton per square meter
PDSI – Palmer Drought Severity Index (PDSI, a scale ranging from -3 to +3; sometimes called the Palmer Drought Index)
$PM_{2.5}$ – particulate matter, diameter $\leq$ 2.5 µm (air pollutant)
PM_{10} – particulate matter, diameter $\leq$ 10 µm (air pollutant)

ppb – parts per billion
ppm – parts per million
RSS – Resource Stewardship Strategy
SECN – Southeast Coast Network (of the National Park Service)
SSHS – Saffir/Simpson Hurricane Scale
SO_2 – sulfur dioxide (air pollutant)
SoC – species of concern (endangered, threatened, etc. - federal and/or state)
SOP – standard operating procedure
spec. cond. – specific conductivity
SSHS – Saffir/Simpson Hurricane Scale
STORET – Storage and Retrieval Environmental Data System (of the EPA)
TD – tropical depression
TDS – total dissolved solids
TKN – total Kjeldahl nitrogen
TMDL – total maximum daily load
TN – total nitrogen
TP – total phosphorus
TS – Tropical storm
TSS – total suspended solids
TWP – Tallapoosa Watershed Project (of Auburn University)
UC – unacceptable condition (referring to water quality)
USDA – United States Department of Agriculture
USDI – United States Department of the Interior
USGS – United States Geological Survey
VCP – variable-circular plot technique (for studying bird communities)
VES – visual encounter survey (in amphibian and reptile studies)
yr – year
≡ – is (or are) defined as

Executive Summary

The two major goals of this report were (i) to inventory the natural resources of Horseshoe Bend National Military Park (HOBE, or the park) in eastern Alabama, including synthesis of available information and collection of geospatial data layers and maps; and (ii) to develop a set of indicators, quantitative insofar as possible, for natural resource conditions that can be tracked over time. The natural resources that were evaluated include climate, air quality, geology and soils, groundwater, surface water, terrestrial and wetland biota, and species of special concern.

Horseshoe Bend is a small park (8.3 square kilometers [km^2], or 2,040 acres) in Tallapoosa County within the middle Tallapoosa River basin. Its natural resources include mixed hardwood/pine forests mixed with grassy fields, two perennial streams, several intermittent streams, and wetlands that mostly occur as narrow fringes of swamp forest along the Tallapoosa River. An approximately 6-km (3.7-mile) segment of that river flows through the park and is its most prominent natural feature; indeed, the park is named for a “horseshoe-like” bend in the river. Horseshoe Bend has excellent soundscape and lightscape features and is described by park staff as minimally affected by noise or light pollution. The airshed has moderate ozone levels that may adversely affect both human health and the park vascular plant communities. Visibility is poor because of compromised air quality, and the park also lies in an area that is especially prone to acid deposition by nitrogen and sulfur species.

The Middle Tallapoosa River basin is predominantly rural with mostly forested land cover. Unfortunately, Tallapoosa County has a relatively high poverty level, and the park is also threatened by rapid population growth of the Auburn-Opelika metropolitan area in adjacent Lee County. Horseshoe Bend is a popular park that was visited by approximately100,000 people in 2012, comparable to or lower than the number of visitors estimated for previous years. Park trails are well-used; in 2012 there were an average of 17 visitors per km of trail per day (27 visitors per mile of trail per day). Although more than half of the soil categories in Horseshoe Bend are moderately eroded, there is little evidence of soil erosion along the trails, or of streambank erosion.

The Tallapoosa River segment that traverses Horseshoe Bend lies between dams and hydropower facilities at two run-of-river impoundments, ~32 km (20 miles) upstream, and ~40 km (25 miles) downstream. Since the upstream dam was installed in 1982, the river segments downstream have been subjected to changes in river flow from as low as zero to 45.3 cubic meters per second (m^3/sec; or 16,000 cubic feet per second, cfs). River flow is routinely extreme and is regulated by the Alabama Power Company on a daily basis. The upper Tallapoosa River system also has been targeted as a potential source of potable water for Atlanta, Ga. Water quality of the river in HOBE is characterized by ample dissolved oxygen and desirable pH to support beneficial aquatic life, but high turbidity and moderate nutrient levels are suggestive of land disturbance and nutrient pollution from upstream watershed development.

The terrestrial and aquatic biota of Horseshoe Bend are not well known other than species lists. Based on the available lists, the park contains rich vascular plant floras, with 230 and 227 taxa in terrestrial and wetland/aquatic habitats, respectively. However, the natural floras are being compromised by exotic/ invasive species including six highly invasive terrestrial species

(Bermudagrass - *Cynodon dactylon*, Chinese lespedeza - *Lespedeza cuneata*, Chinaberry - *Melia azedarach*, Chinese yam - *Dioscorea oppositifolia*, kudzu - *Pueraria montana* var. *lobata*, and mimosa - *Albizia julibrissin*) and three highly invasive wetland species (Chinese privet - *Ligustrum sinense*, Japanese honeysuckle - *Lonicera japonica*, and Aleppo milletgrass - *Sorghum halepense*). A total of 251 taxa of vertebrate fauna have been reported to occur in the park. With 66 native herpetofauna species, Horseshoe Bend leads other SECN parks in amphibian and reptile species richness. Its bird fauna are also species-rich, slightly higher than the number of species reported for another SECN park that is a globally Important Bird Area. In fact, 16 taxa identified as priority species in the South Atlantic Migratory Bird Initiative Implementation Plan were recently found in Horseshoe Bend. The mammalian fauna species list, in contrast, includes only 22 documented native species, although 10-11 more are suspected to occur in the park; and at least 16% of the total mammalian fauna taxa (5 species) are exotic/invasive.

Aside from invasive exotic taxa, park staff has identified several species of special management concern. Prescribed fires at five-year intervals are being used to encourage re-establishment of longleaf pines along the ridgeline for a more balanced ecosystem. Recently invasive coyotes may be adversely affecting other predators in the park such as gray foxes. Wild turkeys and white-tailed deer appear to be over-populated in the park north of the river, but over-hunted in the area south of the river. Unfortunately, none of these species has been quantified or assessed for health and stressors.

The larger Mobile River watershed, which contains the Tallapoosa River and Horseshoe Bend, historically was home to many endemic species including fishes, mussels, aquatic snails, turtles, aquatic insects and crustaceans. During the past two centuries, watershed development has led to species extinctions at a rate unparalleled elsewhere in the mainland U.S. and various aquatic and wetland species are now threatened or endangered. The habitat fragmentation imposed by the Harris and Lake Martin dams, along with two other dams on the lower Tallapoosa River, have affected faunal diversity, species distributions, and fisheries. The river serves as a transportation corridor for exotic/ invasive species. In contrast, various endemic species appear to have been locally extirpated, including most fish species of concern that are sensitive to extreme artificial hydrologic fluctuations and/or degrading water quality. Thus, only 25 native species are listed as presently still occurring in Horseshoe Bend, and these species are broadly tolerant of disturbance and other human impacts.

Present natural resource concerns are higher sedimentation to surface waters from increased upstream clear-cutting, pollution from agriculture and silviculture, and atmospheric deposition of pollutants from larger cities in the state and from the Atlanta metropolitan area of Georgia. While the middle Tallapoosa sub-basin, at present, is only about 5% urbanized, the combined pressures of anticipated increased development in both the upper and middle basins are expected to increase land disturbance and water pollution including excessive suspended sediments, nutrients, fecal bacteria, and toxic substances. Although the overall potential for nonpoint source impairment in the middle sub-basin has been evaluated as low, more than half of the sub-watersheds in this sub-basin were estimated by the state environmental agency to have moderate potential of nonpoint source impairment because of runoff from forestry practices, clear-cutting, and sedimentation.

In selecting the suite of indicators that were developed for natural resource status at Horseshoe Bend, a foremost consideration was to ensure insofar as possible that the indicators are scientifically sound, clear to the general citizenry, and logistically assessable for park personnel with minimal time and additional resources required. We also strived to ensure that the indicators meet the specific needs of this park as described by park staff. A total of 58 indicators were used to evaluate the 16 categories of natural resources for which sufficient information was available to allow some level of assessment. The overall condition of five categories were rated as *good*; six were evaluated to be in *fair* condition; and five were in *poor* condition, as shown by the Report Card for Natural Resource Conditions in Horseshoe Bend:

Natural Resource Category	Indicator(s)	HOBE Grades
Climate	5	*poor*
Human Population Surrounding the Park	5	*poor*
Visitation - Human Population in the Park	3	*fair*
Land Use / Land Cover	2	*good*
Air Quality	8	*fair*
Soundscape	3	*good*
Lightscape	1	*good*
Soil and Streambank Erosion	4	*fair*
Surface Water Hydrology	2	*poor*
Surface Water Quality	7	*fair*
Vascular Flora	4	*fair*
Fish	2	*poor*
Herpetofauna	2	*good*
Birds	5	*good*
Mammals	1	*poor*
Species of Special Management Concern	4	*fair*

The Report Card is evenly distributed with *good* (5), *fair* (6), and *poor* (5), rating an overall “C.” Importantly, of these 16 categories of natural resources, most are not possible for the National Park Service to control. Only a few categories, within the park biota, can be even partly controlled by park staff.

Major knowledge gaps prevented or seriously restricted evaluation of the present condition of several natural resource categories. These gaps, and efforts needed to fill them, include:

- *Streambank Erosion* - A study should be conducted to develop a channel stability index for the Tallapoosa River in the park.
- *Surface Water Hydrology* - The RSS planned for Horseshoe Bend is expected to identify additional hydrologic targets, such as an indicator for tracking undesirable high water conditions over time, and an indicator to assess changes in flows of the springs in the park.

- *Groundwater Supply* - A monitoring well is needed near Horseshoe Bend within the Piedmont aquifer that underlies the park, to provide the data needed to assess aquifer drawdown over time.
- *Surface Water Quality* - Data for the parameters selected as indicators should be collected at least monthly to enable reliable assessment of water quality conditions over time, from one station on each stream in the park. In addition, data are needed for fecal coliform bacteria and chlorophyll *a* (suspended algal biomass in the Tallapoosa River within Horseshoe Bend).
- *Stream Sediment Quality* - Information is needed to enable assessment of the quality of stream sediments in Horseshoe Bend, focusing on toxic substances such as mercury and PCBs, to address an identified concern of park staff.
- *Groundwater Quality* - Information is lacking on groundwater quality in or near the park. Monthly sampling at least every other year is needed to characterize the pH and track concentrations of contaminants such as nitrate+nitrite, sulfide, and metals (e.g., iron, aluminum, manganese).
- *Stream Macroinvertebrate Communities* - Stream macroinvertebrates should be assessed at five-year intervals as an important biological component of Horseshoe Bend.
- *Ecological Studies* - Concerted studies of key vascular plant communities and key species of interest are needed, including quantitative abundance data and maps. The species-level studies should emphasize the dominant terrestrial and wetland vascular plants in each of the general habitat types found in the park; the common Category #1 and Category #1 Alert invasive vascular plants of most concern to park staff; and any other exotic/invasive fauna of major concern to park staff.
- *Population Studies* - Species of special management concern, including wild turkeys, coyotes, and white-tailed deer, should be assessed for food availability, hunting/ poaching pressure, disease, and effects on the park ecosystem.
- *Updated Biota Surveys* - Vouchered species lists should be updated on a decadal basis to assist in tracking the biological resource conditions in the park.
- *Analysis Over Time of the Cumulative and Synergistic Effects of Pressures from Climatic, Land Use, and Exotic/Invasive Species Changes* - The rate of climate warming in this century is projected to be from 2.5- to 5.8-times higher than the rate measured during the 1900s. Temperatures are expected to increase by 2.58°C to 4.58°C. Watershed development is expected to accelerate; for example, an average 255% increase in housing density is projected by 2100 in lands surrounding national parks throughout the nation. The Au-OpMA, near the park, is rapidly growing. Exotic/invasive species generally are favored by disturbances such as these. The cumulative, synergistic effects of such changes are predicted to dramatically impact ecosystem function and biodiversity in national parks. In fact, it has been estimated that 30% of the parklands may lose their present biomes by as early as 2030.

We have recommended various additional efforts by the Southeast Coast Network which, together with the present and planned I&M Program protocols, will greatly strengthen understanding about how each of these pressures affects Horseshoe Bend natural resources. The resulting databases will make it possible for the Network to consider climatic, land use, and exotic/invasive species changes more realistically – through integrative rather than separate analyses of cumulative/ synergistic impacts over time. Ultimately, that approach offers the best hope of restoring and protecting the natural resources of Horseshoe Bend.

1. NRCA Background Information

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

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

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

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

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

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

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

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

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

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

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

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

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

Over the next several years, the National Park Service plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm.

NRCA Reporting Products…

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

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

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

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

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

2. Introduction and Setting

2.1. Introduction

Horseshoe Bend National Military Park (HOBE), located in east-central Alabama in Tallapoosa County, is a small park (826 hectares, or 2,040 acres; Figures 1 and 2) traversed by the Tallapoosa River, a tributary of the Mobile River. It is about 32.2 kilometers (km; or 20 miles) downstream from the Harris Dam at the outflow of the Harris Lake impoundment, and about 9.7 km (6 miles) upstream from the Lake Martin impoundment. The park is easily accessible from State Highway 49, 8 km (5 miles) south of New Site (population ~765 as of 2012) and 19.3 km (~12 miles) north of Dadeville (population ~4,300). The largest nearby human population center is Alexander City (population ~16,000) about 13 miles west, adjacent to Lake Martin. Birmingham (metropolitan area population 1,136,650 as of 2012; Godwin 2013) lies about 145 km (90 miles) northwest, Montgomery (metropolitan area population 377,149 as of 2012) is about 113 km (70 miles) southwest, and Atlanta, Georgia is about 177 km (110 miles) northeast.

Horseshoe Bend lies at the southern end of the Piedmont Plateau, in a transitional area between the Piedmont and Coastal Plain physiographic provinces, but is characterized mostly by Piedmont geology and hydrology (Rasmussen et al. 2009). Its low, rolling hills reach an elevation from ~183-217 m (600-711 ft.) above mean sea level. Its soils are clay-rich, and its major surface water body is the Tallapoosa River. The park area (~826 hectares or 2040 acres) consists mostly of mixed hardwood forest uplands (83%, or 688 hectares [1,700 acres]); the remainder is ecologically disturbed (mowed battlefield area and recovering farmlands, ~55 hectares or 136 acres), and wetlands (10% of the park area, or 88 hectares [204 acres]; Rasmussen et al. 2009; Plate 1). Much of the park area was farmed for more than 100 years, and various open fields are sites of historic battles.

Horseshoe Bend is under the jurisdiction of the National Park Service and is one of the four dedicated War of 1812 parks in the NPS system along with Fort McHenry National Monument in Baltimore, Perry's Victory & International Peace Memorial in Ohio, and Chalmette National Battlefield in New Orleans. The park is the site of the Battle of Horseshoe Bend, where Major General Andrew Jackson's forces annihilated about 900 of 1,000 Creek Native Americans on 27 March 1814. The Creek War began as a civil war within the Creek (Muscogee) Native American nation, between the Upper Creeks who wished to strike against U.S. expansionists and return to a traditional way of life and the Lower Creeks who sought not to aggravate the U.S. government and attempted to assimilate themselves into white culture. In February 1813, friction among the Creeks intensified when a group of Upper Creeks, known as the Red Sticks, killed seven frontier families after being told erroneously that the United States and the Creek Nation were at war. After a Creek tribal council tried and executed the Creeks responsible for the killings, angered Red Sticks set out to destroy white settlements and opposing Creeks. Several months later at Burnt Corn Creek in Alabama, Red Sticks retaliated against a group of American soldiers and plundered their munitions. This exchange broadened the Creek Civil War to include American forces. Incited to fight, William Weatherford, a Red Stick leader, ordered his warriors to assault an American stockade, Fort Mims, on the Alabama River on 30 August 1813. Although Weatherford attempted to restrain his warriors, the Red Sticks killed about 500 people.

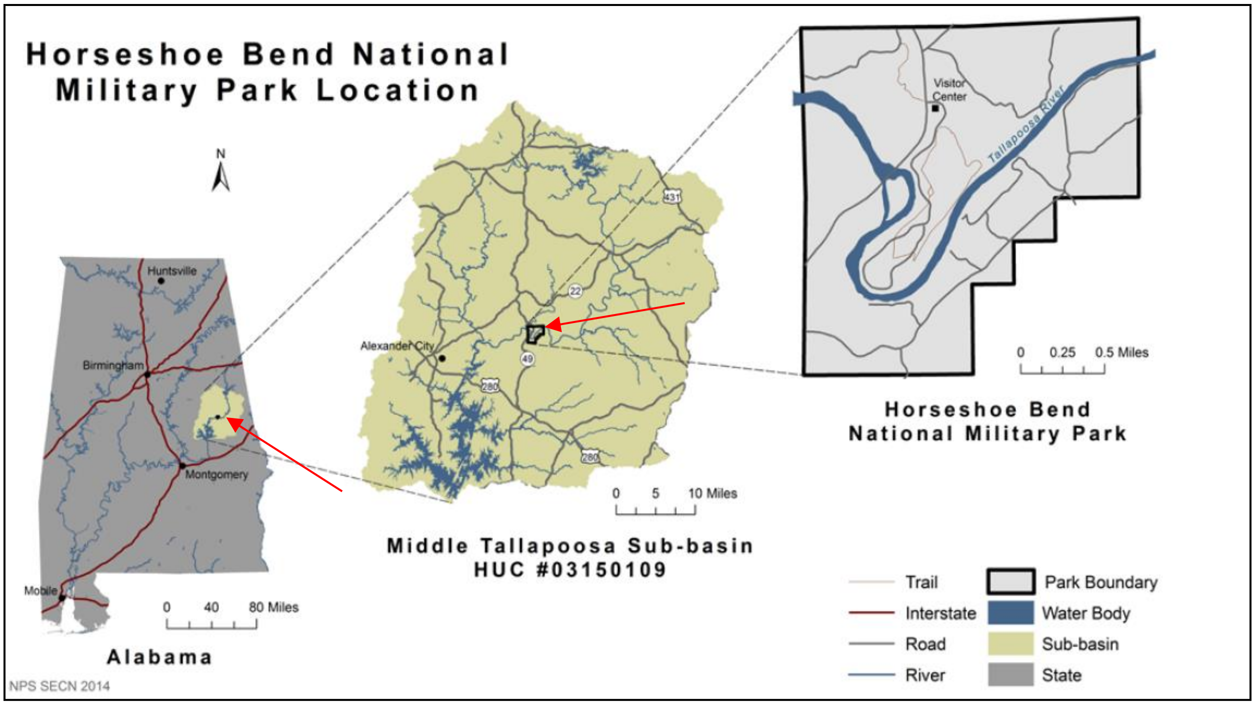

Figure 1. Maps showing the location of HOBE. (Left – black dot ≡ park location in Alabama; middle – middle Tallapoosa River watershed or sub-basin [park boundary in black]; and right – close-up of park) in east-central Alabama between Harris Lake and Lake Martin (direction of water flow is from north to south. From the NPS SECN (2014).

Jackson, an expansionist who saw the opportunity to secure Creek land, demanded “retaliatory vengeance” (Schafer 2003). In November of 1813, Jackson led an advance on the Creeks, and ~500 Creeks were killed during the battles of Tallushatchee and Talladega in Alabama (Figure 2). Although the Creeks defeated Tennessee militiamen in three minor engagements in January 1814, they finally were overcome in the Battle of Horseshoe Bend. In DeVivo (2004), it was stated that, “Never before or since in the history of the United States have so many Native Americans lost their lives in a single battle. This battle ended, for all time, the power of the lands Creek Nation.” The Creek Confederacy was broken. Its defeat opened the way for settlement in Alabama and other parts of what historically was referred to as “the old Southwest.” Creek lands were subsequently were added to the United States and opened for settlement.

The National Park Service currently maintains a Visitors Center and museum, a 4.5-km (2.8-mile) nature trail, a 4.8-km (3-mile) tour road, picnic areas, and the battlefield. Grasslands and cleared grass fields associated with battlefields and park facilities can be found in the central regions of the park; the “Battlefield Area” has large open areas of well-mowed grasses interspersed with patches of mixed forest. In the visitor’s area, a paved road can be used to reach various observation posts; there is also a Battlefield Hiking Trail and a Nature Hiking Trail. A network of several miles of service roads traverses the non-visitors area.

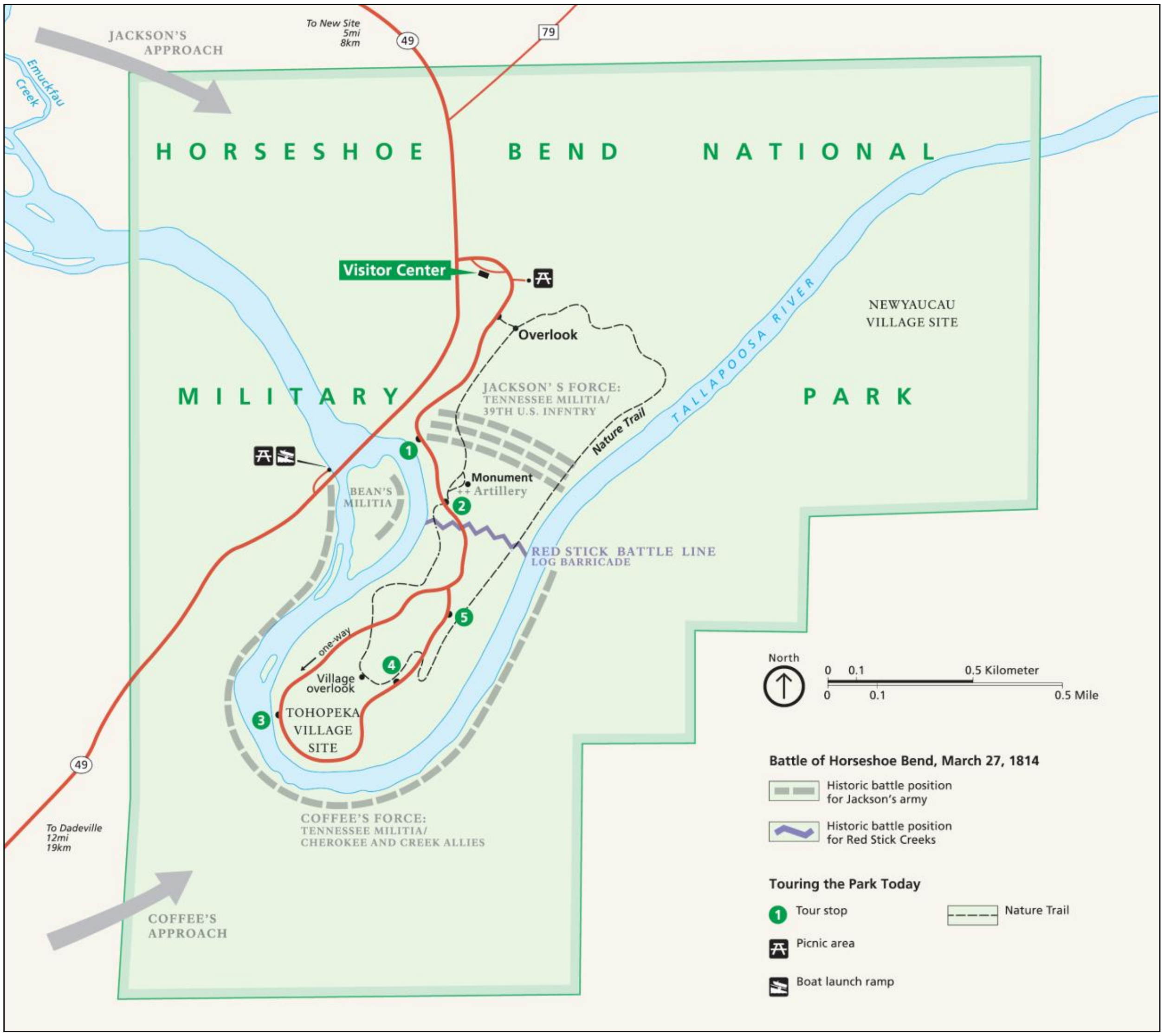

Figure 2. Map showing features of the battle at Horseshoe Bend (1814) within the park. The green border shows the boundaries of the present-day park. Other park features are also shown (NPS 2015e).

Plate 1. The tranquil present-day setting of the bloody Battle at Horseshoe Bend. Approximately 900 of 1,000 Creek Native Americans were annihilated here by Jackson's forces on 27 March 1814 (NPS 2015e).

Enabling Legislation and Potential for Expansion

As early as August 1907, Alabama state legislature voted to petition the U.S. Congress to establish Horseshoe Bend Battle Park to memorialize a battle site of "great patriotic and educatory value" (Cummings and Gebhard 1996). Congress voted in April 1914 to appropriate $5,000 to erect a small stone monument on the battleground, but petitions to establish a military park at the site were rejected in 1909, 1911, 1913, and 1914 because the "national significance" of the event was in doubt (Cummings and Gebhard 1996). Also during this period, a controversy erupted over who owned the battle site and who would control the region's emerging hydroelectric technology. Benjamin Russell, a local industrialist, began to build his own dam near Alexander City. In 1911, the Alabama Power Company, which planned to build its own dam on the river at Cherokee Bluff, brought suit against Russell and was successful at having construction stopped. In 1923, the Alabama Power Company purchased Horseshoe Bend from Russell. The company's president, Thomas Martin, whose great-grandfather had fought with Jackson's army in 1814, recommended to the Power Company's board of directors that no action on a dam should be taken until every effort to win congressional approval for a national park had been expended (Martin 1959).

After much research, Martin succeeded in convincing Congress of the significance of the battle. A Congressional Act approved on 25 July 1956 (70 Stat. 651 - first section, 16 U.S.C. § 430ff) provided that when at least 2.02 square kilometers (km^2; or 500 acres) of non-Federal lands known as the Horseshoe Bend Battle Ground had been acquired and transferred to the Federal Government, the area would be dedicated as the Horseshoe Bend National Military Park. On 11 June 1957, in accord with the second section of that act (16 U.S.C. § 430gg), the Secretary of the Interior approved a map of 8.26 km^2 (2,040 acres) on the Horseshoe Bend Battleground for the park. The Alabama state legislature provided $150,000 to purchase part of the area, and the remaining ~2.27 km^2 (560 acres) were donated by the Alabama Power Company. The deeds for the land were presented to the Secretary of the Interior on 24 April 1959 (Cummings and Gebhard 1996). With the requirements of both sections of the Act having been met, on 11 August 1959 President Eisenhower issued Proclamation No. 3308 (73 Stat. c72, 16 U.S.C. 430 ii 24 F.R. 6607) to establish the park. HOBE was dedicated March 27, 1964 on the 150th anniversary of the Battle of Horseshoe Bend, thus culminating more than 50 years of effort.

2.2. Geographic Setting

The park elevation ranges from 165 meters (m; or ~540 feet, ft.) to more than 183 m (600 ft.) on river hills (Dusi and Dusi 1997). Land use within park boundaries is primarily forested by upland and floodplain mixed hardwoods and pines. The Tallapoosa River basin is characterized by high physiographic diversity. It flows 415 km from the Piedmont uplands in western Georgia and eastern Alabama, crosses the Fall line in another set of large falls prior to impoundment, and continues across the Coastal Plain, joining with the Coosa River to form the mainstem Alabama River. The Middle Tallapoosa sub-basin, which includes Horseshoe Bend, has an area of 1,527.3 km^2 (589.7 square miles, mi^2) and includes all lands and surface waters that drain to the Tallapoosa River between the confluence of the Tallapoosa and Little Tallapoosa Rivers and Martin Dam (Figure 1; CH2MHill 2005).

The North Carolina State University Center for Applied Aquatic Ecology (NCSU CAAE) analyzed land use/land cover in the Middle Tallapoosa River sub-basin (Hydrologic Unit Code [HUC] #03150109), which includes Horseshoe Bend, using the most recent National Land Cover (NLCD) data, from 2011 (the most recent data available), for comparison with land use/land cover in 2001 and 2006 (Tables 1 and 2). The CAAE also generated a new land use-land cover map for this sub-basin using the following procedure: The sub-basin boundary (HUC) Geographic Information System (GIS) data layer was provided by the US Geological Survey (USGS), and NLCD for 2006 were downloaded from the USGS Seamless Data Distribution System (USGS 2015b). Using the Spatial Analyst extension of ArcGIS 9.1, the land use classification system was modified to include eight general categories: (1) urban areas, (2) row crop agriculture, (3) animal agriculture, (4) forests, (5) grasslands, (6) water, (7) wetland, and (8) barren/disturbed. Once the grid was reclassified, the Spatial Analyst “tabulate area” function was used to calculate the area of each land class within the sub-basin surrounding Horseshoe Bend. This analysis indicated that the park is in a mostly rural setting, mainly consisting of forested land cover (~70%) which helps to provide favorable conditions for good water quality (CH2MHill 2005; Tables 1 and 2, Figure 3). The remainder is mostly grassland (~9%), pasture/hay agriculture (~9%), urban development (5%), and water (~5%), with wetlands comprising only about 1.4% of the land cover. While the data for percentages of land use/land cover categories were similar in 2001 and 2006, in 2011 there was slightly more urban/developed land, less pasture/hay and forest versus more grassland, and less barren/rock area. This information provided a baseline from which to assess future watershed changes that may affect the park’s natural resources.

Table 1. Previous land use/land cover, 10-15 yr ago: As of 2001 and 2006, area and percent cover of each land use class in the middle Tallapoosa sub-basin (#03150109), from analysis by the NCSU CAAE. The National Land Cover data (NLCD) for 2001 were downloaded from the United States Geological Survey (USGS) Seamless Data Distribution System (USGS 2015b). Note that “forest” here includes silviculture.

Land Cover Type	Urban/ Developed	Pasture/ Hay	Row Crops	Forest	Grassland	Water	Wetland	Barren/ Rock	Total
2001									
km^2	206.3	382.6	0.8	2,835.1	379.8	201.9	58.8	52.10	4,117.4
$miles^2$	79.7	147.7	0.3	1,094.5	146.7	77.9	22.7	20.2	1,589.7
% of Total	5.0%	9.30%	0.02%	68.88%	9.20%	4.90%	1.40%	1.30%	100%
2006									
km^2	209	337.4	0.3	2,835.1	379.8	201.9	58.8	52.10	4,117.4
$miles^2$	80.7	130.2	0.3	1,060.4	211.3	78.2	22	6.6	1,589.7
% of Total	5.10%	8.20%	0.01%	66.70%	13.30%	4.90%	1.40%	0.40%	100%

Table 2. Land use/land cover information. As of 2011, area and percent cover of each land use class in the middle Tallapoosa sub-basin (03150109), from analysis by the NCSU CAAE. The NLCD for 2011 were downloaded from the USGS Seamless Data Distribution System (USGS 2015b).

Land Cover Type (2011)	Urban/ Developed	Pasture/ Hay	Row Crops	Forest	Grassland	Water	Wetland	Barren/ Rock	Total
Area (km2)	214.9	331.2	0.3	2,621.1	674.9	202.8	57.0	15.2	4,117.4
Area (miles2)	83.0	127.9	0.1	1,012.0	260.6	78.3	22.0	5.8	1,589.7
% of Total	5.22%	8.04%	0.01%	63.66%	16.40%	4.93%	1.38%	0.37%	100%

The Environmental Research and Mapping Facility (ERMF) at the University of Tennessee – Chattanooga (2007) was retained by the National Park Service to develop and maintain a GIS Base Map for Horseshoe Bend (Figure 4). The ERMF conducted data surveys, field data collection, and additional file processing and development to derive geospatial files and metadata. Tasks included verification of digitized topographical map components and development of distinct data processing layers including contours, the river and creeks, structures, paved roads, dirt roads, monuments, and the park boundaries. Primary forest distributions were developed. Existing fire management maps were digitized to show 26 burn units within the park. Distinct data layers were also developed for the visitor center/administration building, maintenance building, three houses, a boat ramp, two picnic shelters, three interpretative shelters, a barricade location, water-sewage-electrical lines, hiking trails (4.8 km or 3 miles), dirt fire roads (19.3 km or 12 miles), wooden fencing, three drilled water wells, USGS boundary markers, and interpretative stops along the main tour road within the park. The information, and scanned historic documents are available on an auto-run compact disc application.

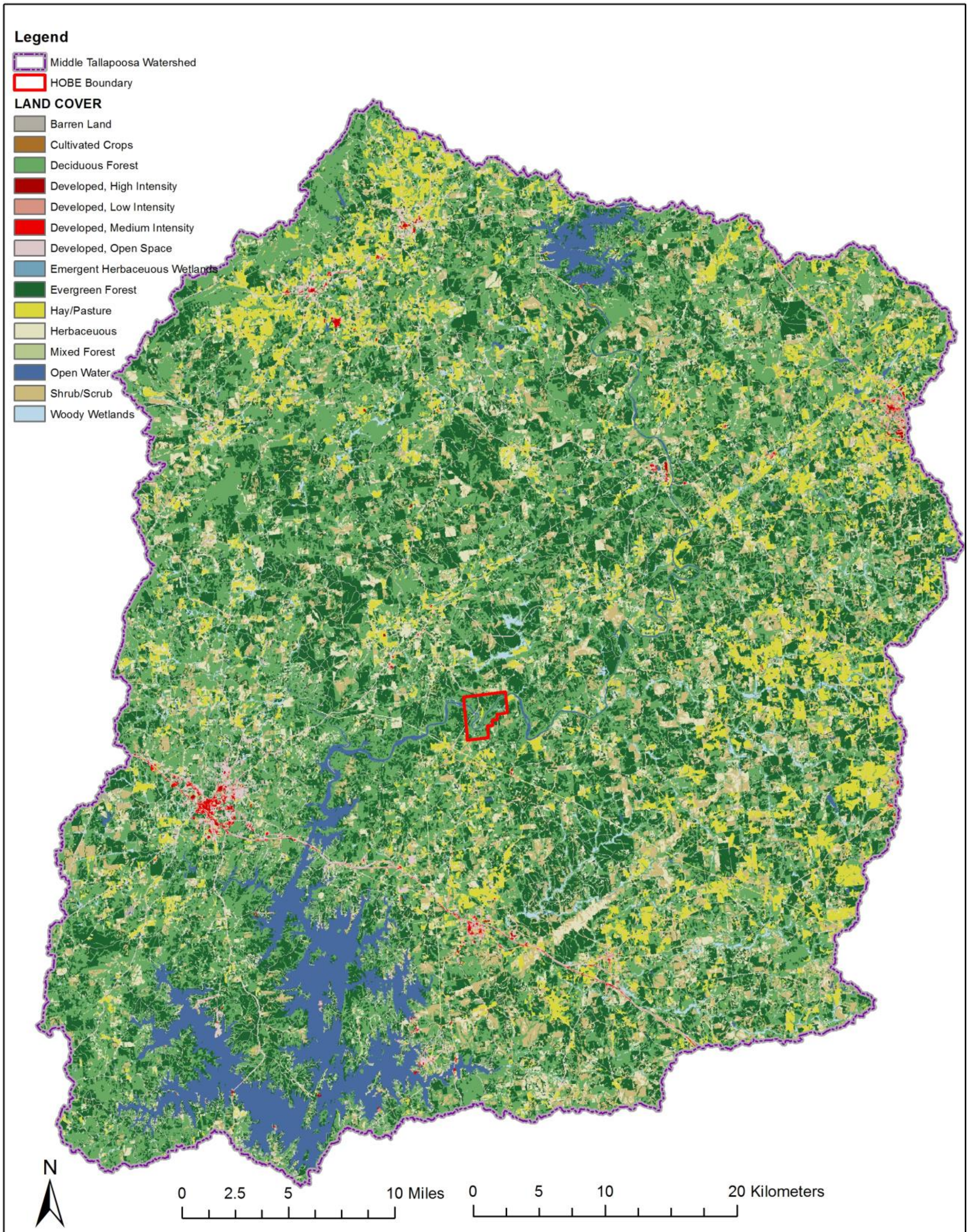

Figure 3. Map of land use/land cover (2011 NLCD in GIS, first available in 2014) in the Middle Tallapoosa sub-basin (#03150109) that includes HOBE (red outline). Map: NCSU CAAE (S. Flood).

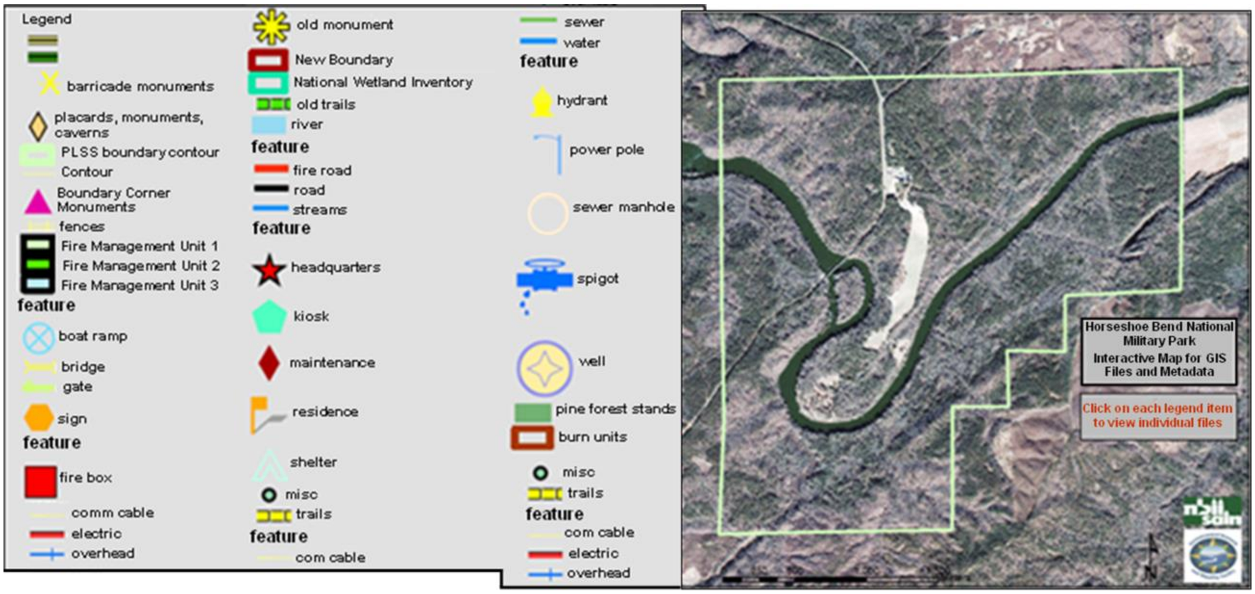

Figure 4. Interactive map for GIS files and metadata, created by the Environmental Research and Mapping Facility (ERMF 2007) at the University of Tennessee - Chattanooga.

2.3. Demographics

The Middle Tallapoosa River basin is sparsely populated (Figure 5). The estimated population of Tallapoosa County in 2011 was 41,623 people with 71.2% Caucasian, 26.9% African-American, 0.4% Native American, and 0.5% Asian. About 78% of persons age 25 or older were high school graduates; 17.1% had a Bachelor’s degree or higher. The area is economically depressed, with a median household income of $39,400 (only about 2/3 of the national average). Unemployment is high (11.5%; Economic Profile System-Human Dimensions Toolkit [EPS-HDT] 2012), and 17.1% of the population (more than 7,000 people) are below poverty level (U.S. Census Bureau 2015) This percentage is higher than the national average reported for those years, at 13.8%.

The population density in the county averages 22 people per km2 (58 people per mi2), and 75% of the population lives in a rural setting (Advameg, Inc. 2014). The population increased 23% from 1970 to 2010, but decreased by 0.34% over the past decade (2000-2010; Moonshadow Mobile 2012; EPS-HDT 2012). Employment has also been stagnant, increasing by only 1% from 1970 to 2010. A landscape dynamics analysis by the NPS (SECN Program Manager Joe DeVivo, pers. comm., August 2013) showed that the human population in the 25 km area surrounding the park had a net increase in the past 20 years of only 1.1%.

Although the immediate area surrounding the park is still rural and low in human population density, an identified concern of park staff is the burgeoning population of adjacent Lee County (Superintendent Mr. Doyle Sapp, pers. comm., April 2013; and see Chapter 4). Only about 64 km (40 miles) southeast of the park, the Auburn-Opelika metropolitan area (Au-OpMA) in Lee County (population 147,257 as of 2012) is the 11th fastest growing metropolitan area in the nation. The Au-OpMA grew 2.6% in human population from July 2011-July 2012 (Alabama Media Group 2015). This represented the highest growth anywhere in the state. By comparison, the Montgomery metropolitan area lost 1,413 residents and the Birmingham-Hoover metropolitan area grew only slightly. Lee County has a high population density of 91.1 people per km^2 (236 people per $mile^2$ as of 2011 (Advameg 2015).

It has now become economically advantageous for farmers in eastern Tallapoosa County to sell their lands for development. Development was first proposed along the park boundary in 2007. Park staff are concerned that the rapid increase in nearby urbanization will result in increased highway traffic; increased air, water, land, light, and noise pollution; and other urban sprawl issues (Superintendent Mr. Doyle Sapp, pers. comm., April 2013; and see NPS 2008). The Strategic Plan for Horseshoe Bend (2008-2012; NPS 2012) also identifies the increasing population of neighboring Lee County as a threat to the rural setting of the park.

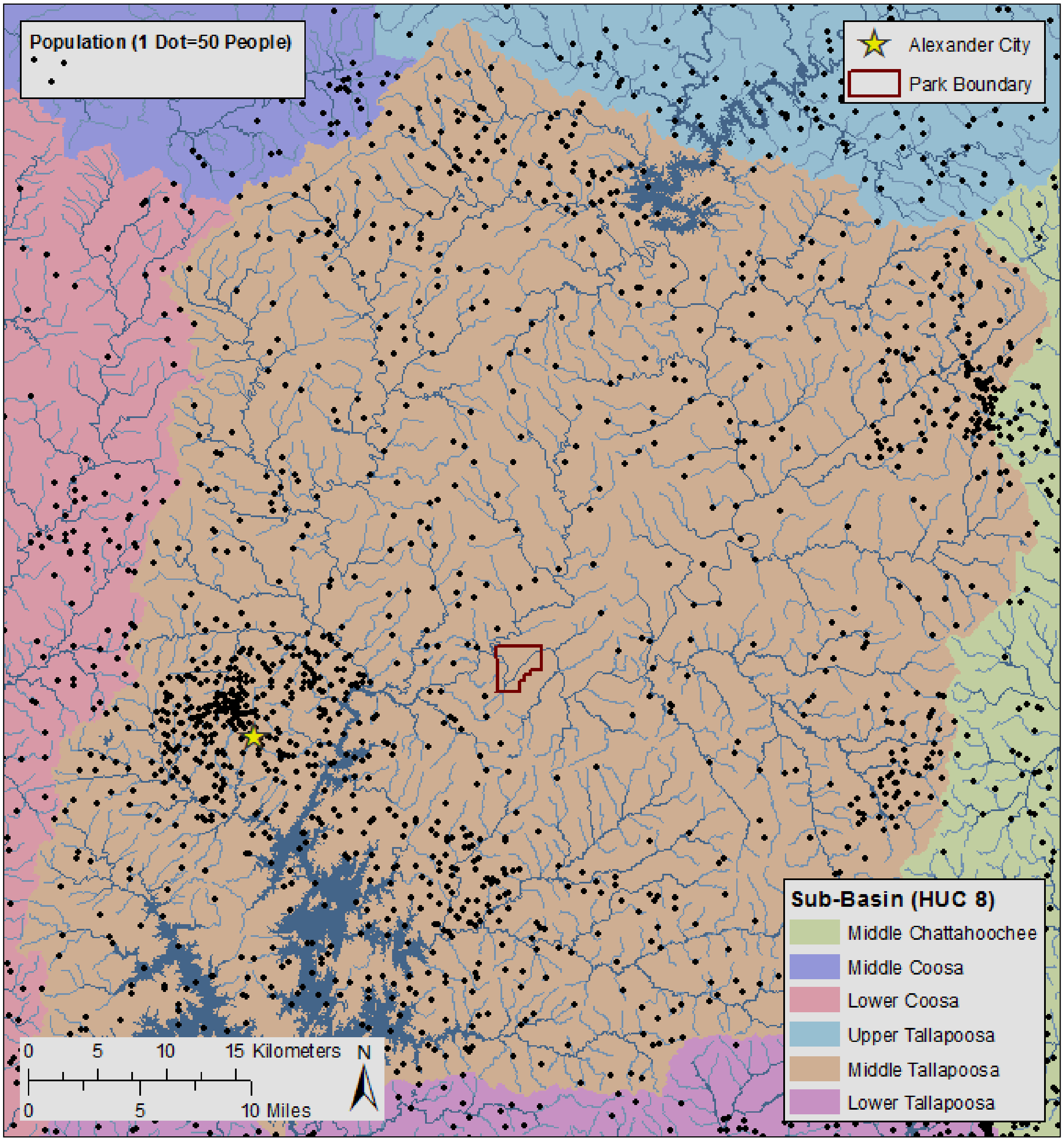

Figure 5. The Middle Tallapoosa River basin human population. Map shows the sparse population as of 2010 (black dots), Horseshoe Bend National Military Park (red), and the only population center near the park (Alexander City). Map: NCSU CAAE (S. Flood).

2.4. Visitation Statistics

The National Park Service (2008) reported that each year one million travelers on Highway 49 pass through the park, on average. The park itself has been estimated to average approximately 100,000 visitors per year as recreational visitors (Rasmussen et al. 2009). Of that population, about 70,000 visitors use the Tour Road, Nature Trail and park grounds; 15,000 visitors use the Tallapoosa River access; 25,000 people make use of the park's amenities (visitors center, bookstore, auditorium); and an estimated 26,000 people benefit from special events and programs.

The National Park Service has gathered statistics for the number of recreationists in the park, and the data show a decrease in recreating visitors during the period from 2001 to 2012 (Figure 6). The median number of visitors annually over that period was 71,149. An additional figure provided by former Horseshoe Bend Chief Ranger J. Cahill shows the number of visitors who used the boat ramp over roughly the same period (2003-2011; Figure 7).

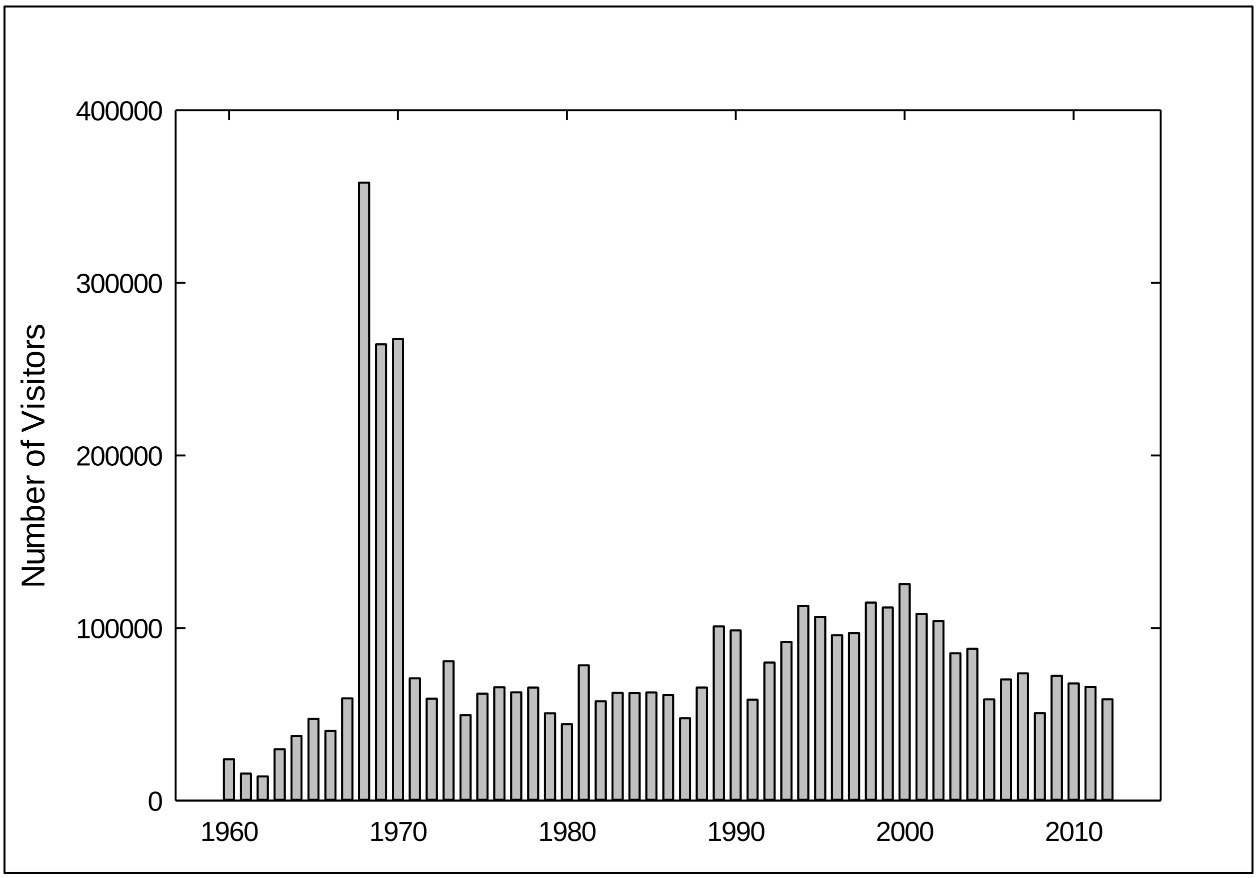

Figure 6. Visitation statistics for total recreationists per year in the park (NPS 2015i).

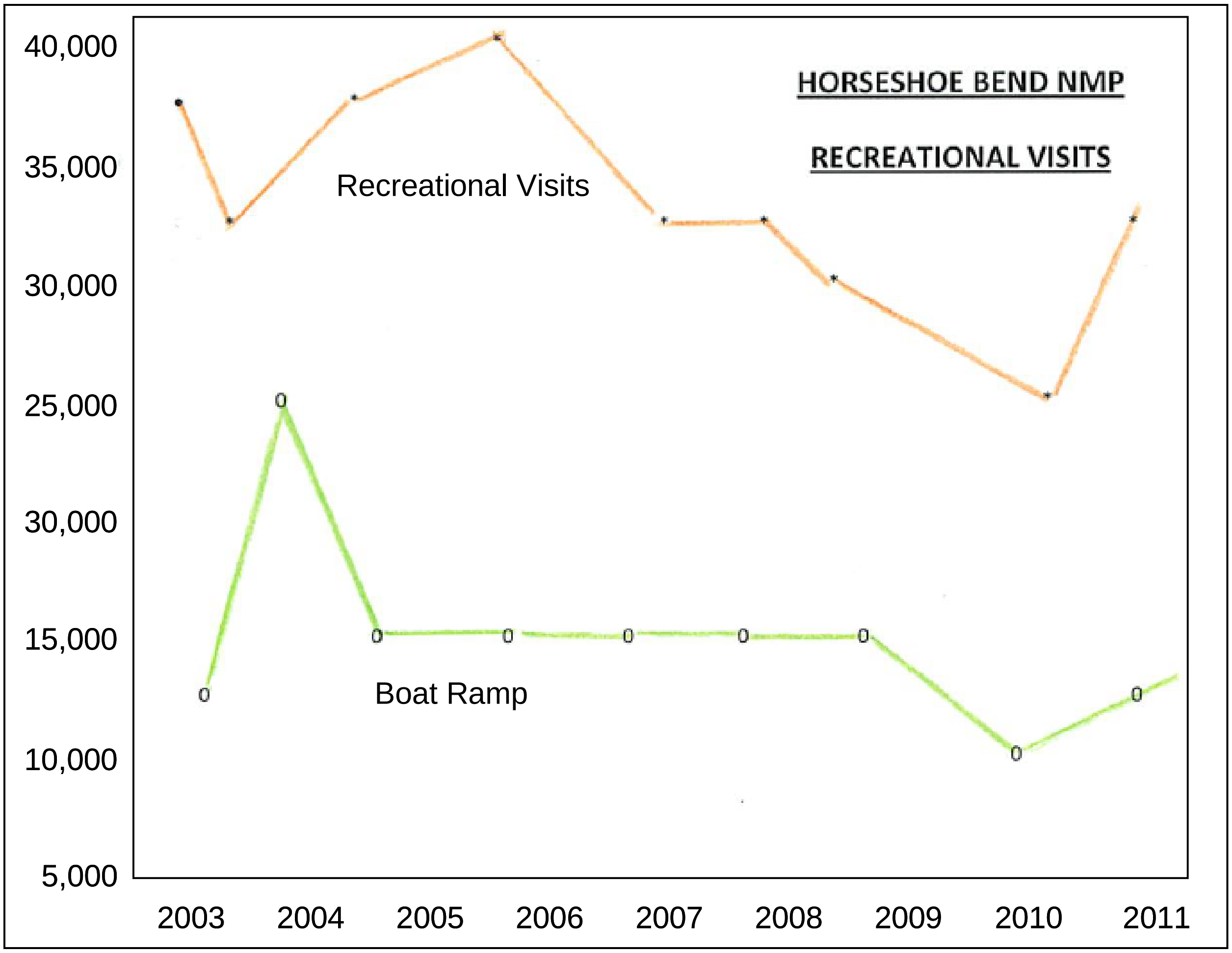

Figure 7. Visitors to the Park for recreation or use of the boat ramp (2003–2011). Source: former HOBE Chief Ranger Jim Cahill, 2011.

2.5. Watersheds

Horseshoe Bend is located within the middle Tallapoosa basin (HUC 013150109).The Tallapoosa River is a major tributary within the Mobile River basin (113,959 km^2, or 44,000 miles^2), which is the 6th largest river basin in the U.S. (Burkholder and Rothenberger 2010; Figure 8). From its headwaters in northwest Georgia (four counties west of the City of Atlanta, Georgia), the Tallapoosa River flows 314 km (195 miles) south-southwest through Alabama (16 counties) until it joins the Coosa River near Montgomery to form the Alabama River.

In Alabama, the Tallapoosa River basin (12,121 km^2 or 4,680 miles^2) lies within the Piedmont (with Horseshoe Bend) and Coastal Plain physiographic provinces. Its physiography reflects a geologic history of mountain building in the Appalachian Mountains together with long periods of repeated land submergence in the Coastal Plain province (https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/chapt-21.pdf, last accessed in May 2015).. The Piedmont has well-dissected uplands with rounded inter-stream areas to the north, and substantial erosional and weathering resistance of underlying geologic units. The stream patterns are predominantly dendritic (Journey and Atkins 1996).

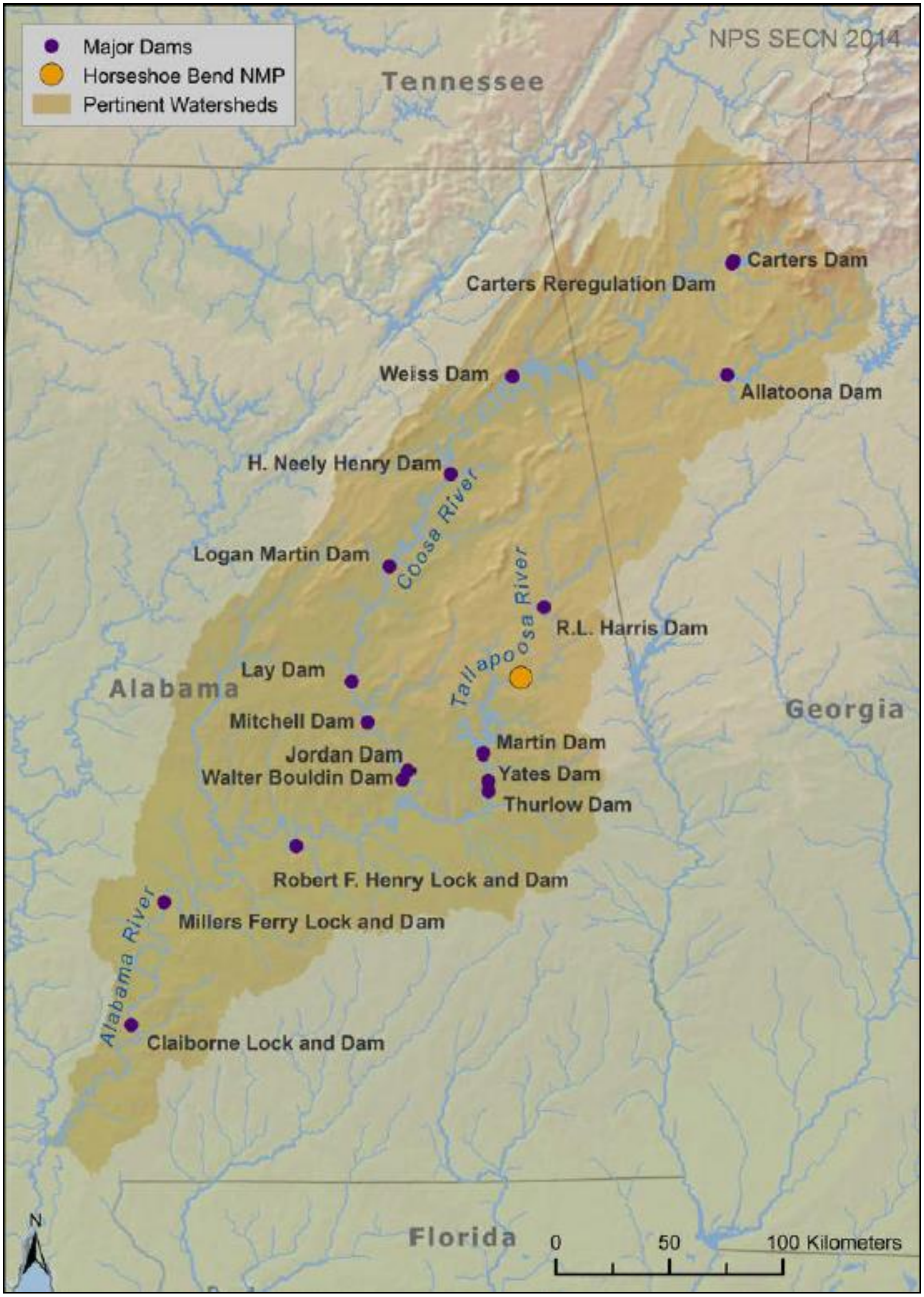

Figure 8. Map of the Tallapoosa River watershed showing the various locks and dams (National Atlas of the United States 2006).

2.6. GIS Data Layers

2.6.1. Data Selection and Acquisition

Data files available from NPS GIS personnel were pared down to those relevant to natural resource management concerns. An FTP site was set up for file transfer from NPS personnel to the CAAE server. Data considered necessary for specific analytical or display purposes, but unavailable from NPS files, were obtained from external databases. The databases that provided national or statewide data for use in assessing Horseshoe Bend included:

- National Land Cover Database 2006 (NLCD2006) provided through Multi-Resolution Land Characterization (MRLC) consortium (USGS 2015a);
- Statewide hydrology, elevation, geographic names and government unit file were obtained from the Geospatial Data Gateway (USDA NRCS 2014);
- National Wetlands Inventory (NWI), Critical Habitat, National Wildlife Refuge Boundaries, and Wilderness Preserve Boundaries were obtained from U.S. Fish and Wildlife (USFWS 2015);
- Landfill, Land Application Sites and 305(b) and 303(d) waterbody listings for 2010 were obtained from Alabama Dept. of Environmental Management (ADEM 2015);
- 2010 U.S. Census Population Density data obtained from U.S. Census Bureau (U. S. Census Bureau 2015b)

All of the above websites were last accessed in May 2015.

NPScape should also be mentioned here: It is a landscape dynamics monitoring project of the National Park Service that produces and delivers to parks a suite of landscape-scale datasets, maps, reports, and other products to inform resource management and planning at local, regional, and national scales. Initial analyses include six major categories (population, housing, roads, land cover, pattern, and conservation status) that broadly address the environmental drivers, natural attributes, and conservation context of the parks. In aggregate, these measures contribute to assessments of current natural resource status, potential threats, and conservation vulnerability and opportunity (NPS 2014b).

2.6.2. Data Oversight and Database Management

Each file was accessed and reviewed for spatial reference and availability/correctness of metadata. Where necessary, files were copied and post-processed to merge into a cohesive database for across-the-board integration in map-making and analyses. Aerial imagery was examined in ArcMap and orthorectified where necessary.

Organizational efforts were made to maintain copies of NPS data in an “unadulterated” form digitally segregated from data that had been geoprocessed or created by the CAAE, while maintaining a logical directory structure. We separately maintained oversight of CAAE GIS systems (software and hardware), GIS computer hardware upkeep and maintenance, troubleshooting/updating of ArcGIS software, and, as needed, addressed any other database management requirements for spatial data amassed by CAAE staff. All of the GIS data we have gathered are listed in Appendix 1.

2.6.3. Map Generation

Maps depicting various geographic themes were developed for Horseshoe Bend, including soils, geology, hydrology, wetlands, population density, impervious surfaces, urban encroachment and social trails, and land use coverage/change in the park, sub-watershed, and/or overall river basin. The maps were designed to address points of interest specific to the park, and to illustrate geographic positioning of known site localities and/or regional relationships.

3. Natural Resources Inventory

3.1. Climate

Climate is defined as the long-term pattern and processes of weather events for a given location (UGA 2015). Climate is one of the most significant influences dictating biotic components anywhere on Earth.

Weather and climate are key drivers for ecosystem patterns and processes, affecting both biotic and abiotic components alike. Understanding the role of climate as a forcing agent for other vital signs (e.g., plant and animal communities) is a critical component of network monitoring. Continuous weather monitoring is [also] a key factor in separating the effects of climate from the effects of human-induced disturbance on plant and animal community and population dynamics (White 2011).

The Tallapoosa watershed has a moist, temperate climate, with mean annual precipitation ranging from 124 to 135 cm (49 to 53 inches) per year (USGS 1997, Georgia Environmental Protection Division 1998). The state in general has relatively mild winters, hot summers, and year-round precipitation (Alabama Humanities Foundation 2012). Precipitation occurs mostly as rainfall that is fairly evenly distributed throughout the year except for a distinct dry season from mid-summer to late fall (Georgia Environmental Protection Division [GA EPD] 1998). Precipitation typically is highest in March and lowest in October. The mean annual temperature is about16.1°C (61°F; GA EPD 1998).

Summary climate data for Horseshoe Bend are presented in annual reports published by the Southeast Coast Network, available online in the NPS's NRInfo portal (http://nrinfo.nps.gov). Limited climate data, used for these NPS reports (e.g., Wright 2012), are available from three stations near Horseshoe Bend (Table 3, Figure 9); much more complete data records are available from the National Oceanic and Atmospheric Administration for the City of Montgomery, 113 km (70 miles) southeast of the park. The location of the state at mid-latitudes near the Gulf of Mexico produces the often-turbulent weather patterns that commonly bring tornadoes and hurricanes to the state. Evaporation and transpiration account for approximately 76 cm (30 in) of rainfall, resulting in about 45.7 cm (18 in) annually available for streamflow and percolation to groundwater. A dry season typically occurs from mid-summer to late fall, whereas maximal precipitation and flow occur in March. Prevailing winds are from the south in most months, except from the northeast or north from September to January. Average wind speed is highest, about13.8 km (8.5 miles) per hour, in March.

Table 3. Location of relevant weather stations near HOBE, station network affiliation and additional metadata for weather stations used in this report. NL indicates information was not listed in the station metadata documentation. dd = decimal degrees; RH = relative humidity (from Wright 2012a).

Distance (km[mi])	Station Name	National Network	Station ID	Lat (dd)	Long (dd)	County	Elev. (ft)	Start Date
19.0 [11.8]	Alexander City	COOP	10160	32.95	-85.95	Tallapoosa	640.1	10/1/1969
28.6 [17.8]	Lafayette 2W	COOP	14502	32.9	-85.4333	Chambers	740.2	6/1/1948
66.6 [41.4]	Anniston Metro Airport (RH only)	COOP	10272	33.5833	-85.85	Calhoun	594.2	11/1/1928

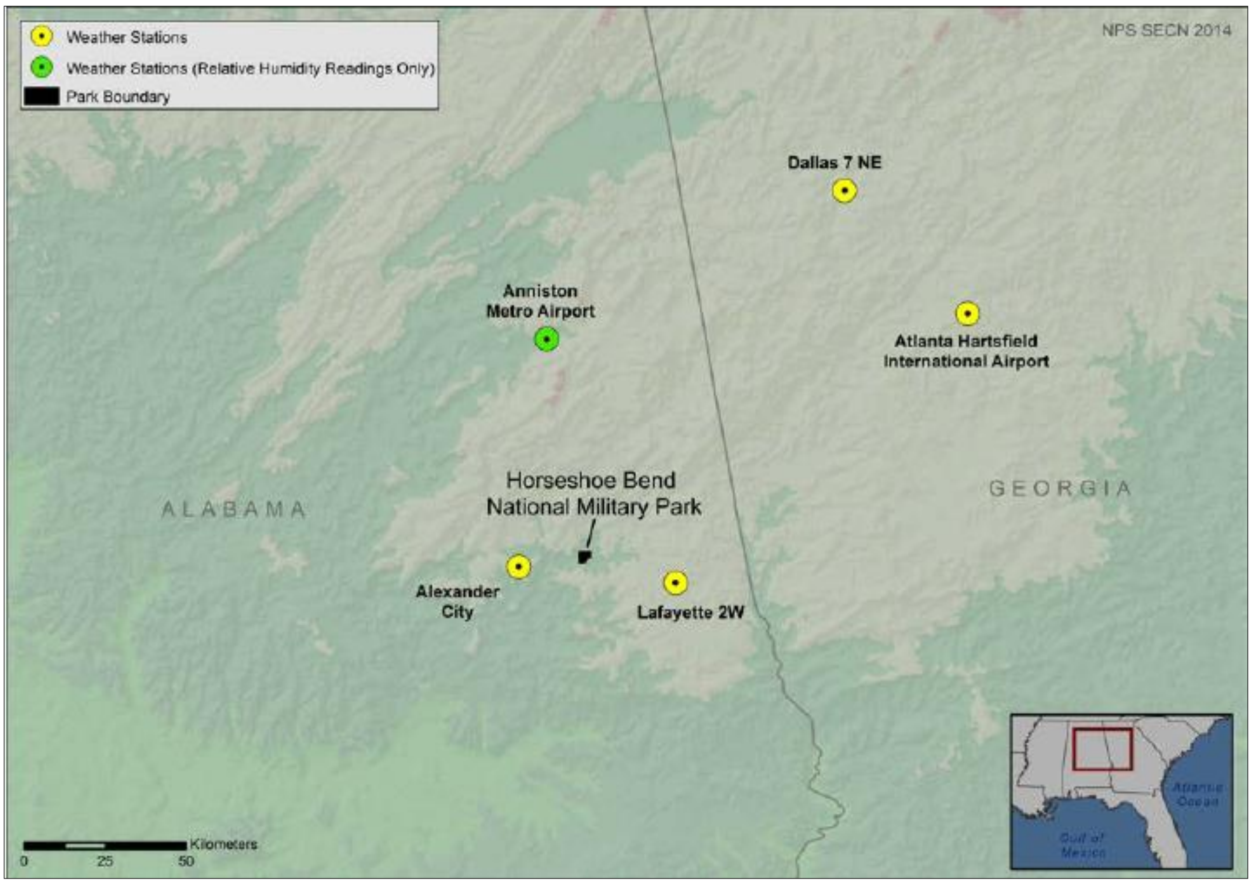

Figure 9. Weather stations near Horseshoe Bend National Military Park, Alabama (from Wright 2011).

3.1.1. Temperature

Data from the National Weather Service of the NOAA provides excellent information on changes in temperature, precipitation, and drought conditions over time. Its historic record for the Atlanta area covers the period from 1895 to 2012 (NOAA 2015a). The mean annual temperature across that entire 118-year period was 16.9°C (62.5°F) (Figure 10). The graph shows two periods of temperature increase separated by a period of declining temperatures. When the period from the 1960s to the present was considered, there was an increase of 0.2°C (+0.3°F) per decade (Figure 11). The mean annual temperature was slightly less, 16.3°C (61.4°F). The summer season (June-August) also showed an increasing trend in temperature over the period from 1960° through 2012, and over the past decade as well (2003-2012; Figures 12 and 13, respectively).

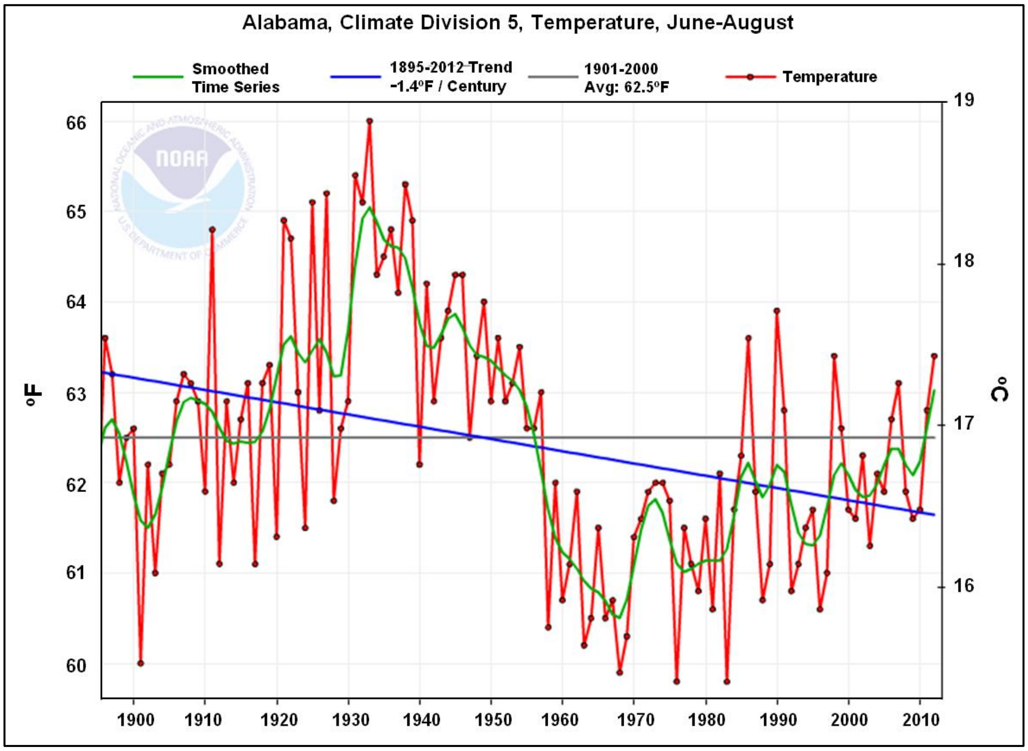

Figure 10. Mean annual temperature in the Division 5 area of Alabama, including Horseshoe Bend National Military Park, from 1895 to 2013, hereafter referred to as NOAA NWS (NOAA 2015).

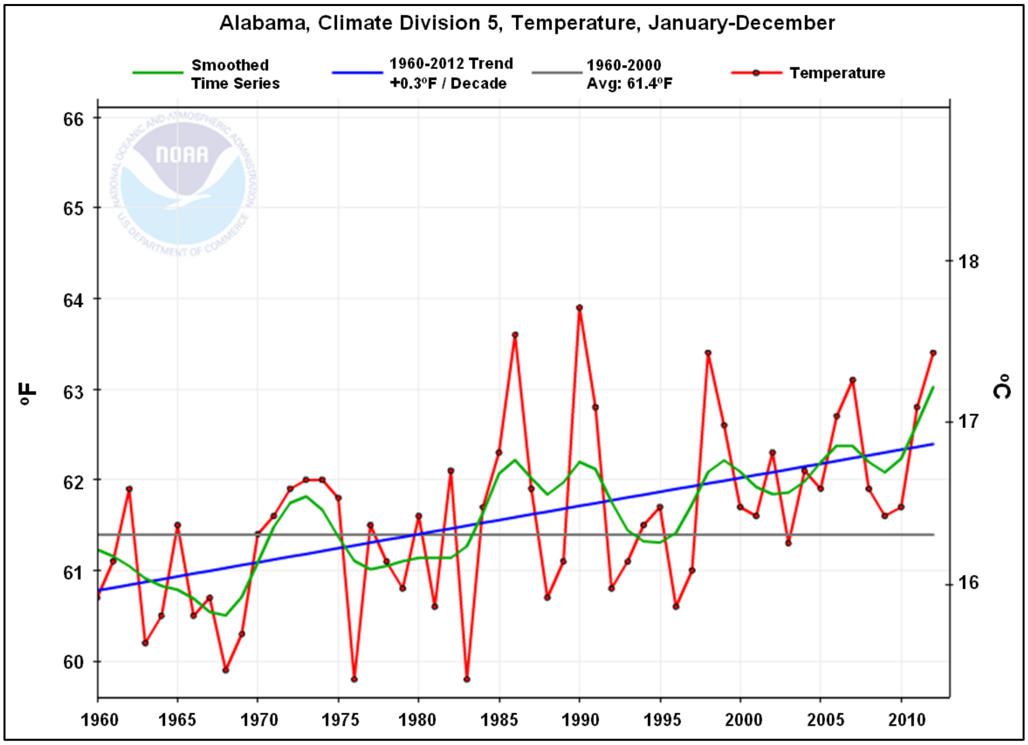

Figure 11. Increasing trend in mean annual temperature in Division 5 of Alabama, including Horseshoe Bend National Military Park, from 1960 to 2013. From the NOAA NWS.

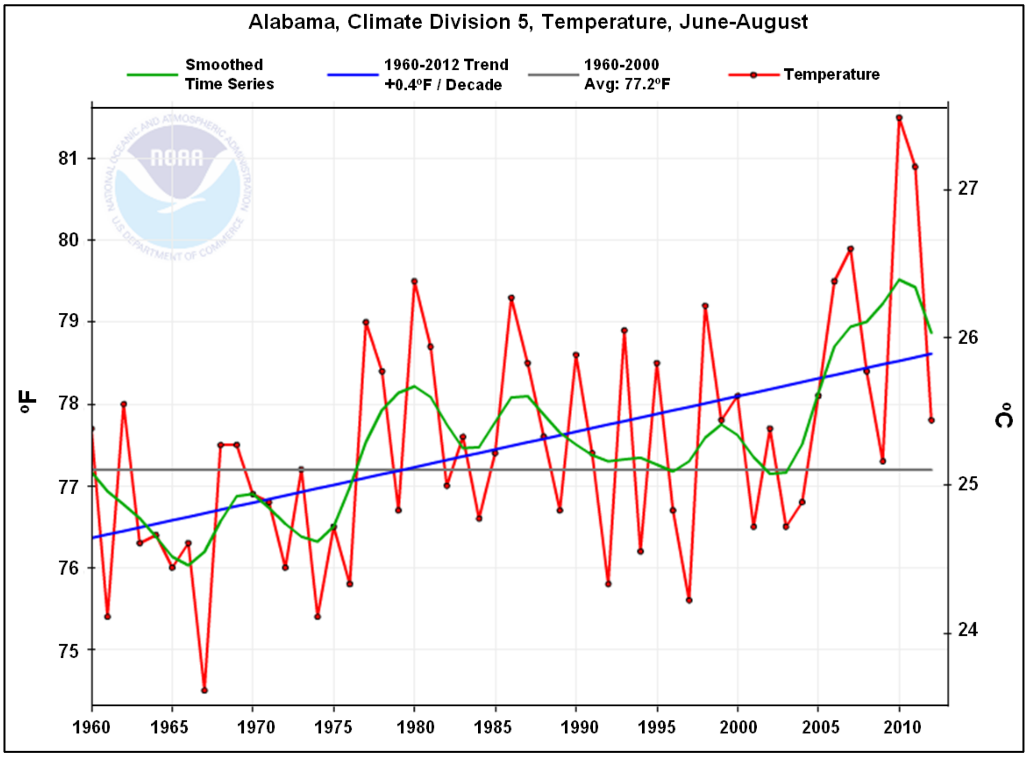

Figure 12. Increasing trend in mean summer temperature in Division 5 of Alabama, including Horseshoe Bend National Military Park, from 1960 to 2012. The overall average was 25.1°C, or 77.2°F (NOAA NWS).

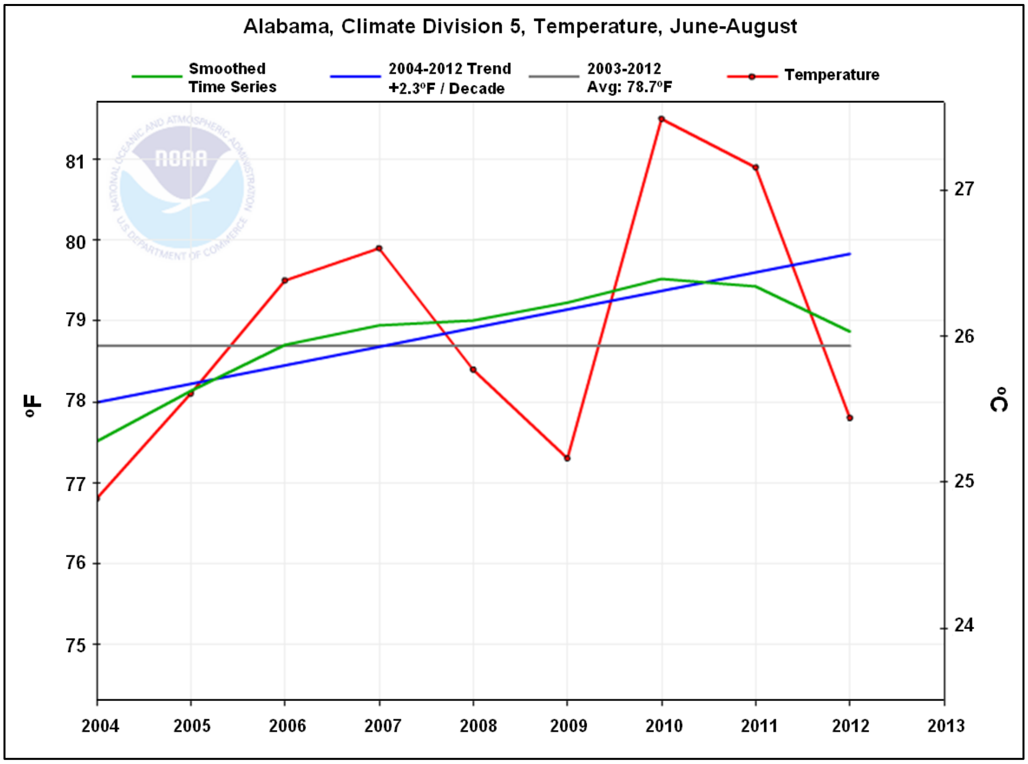

Figure 13. Increasing trend in the mean summer temperature in Division 5 of Alabama, including Horseshoe Bend National Military Park, from 2004 to 2012. From NOAA NWS.

3.1.2. Precipitation

The annual average precipitation from 1895 to 2012 in the Division 5 area of Alabama showed an increasing trend (+1.9 cm or +0.73 inches per decade, and +0.23 cm or +0.09 inches per decade, respectively; Figures 14 and 15). In the past decade (2003 through 2012), however, mean summer precipitation showed a decreasing trend of -23.27 cm (-9.16 inches; Figure 15).

Overall, both annual and summer precipitation are increasing, long-term (1960s on) and within the past decade; mean annual precipitation has increased; and summer precipitation is decreasing. Collectively, the data suggest that increasing temperatures and decreasing precipitation in the warm season will lead to a decrease in available water at Horseshoe Bend and an increase in drying which may, in turn, promote more frequent and/or severe drought conditions.

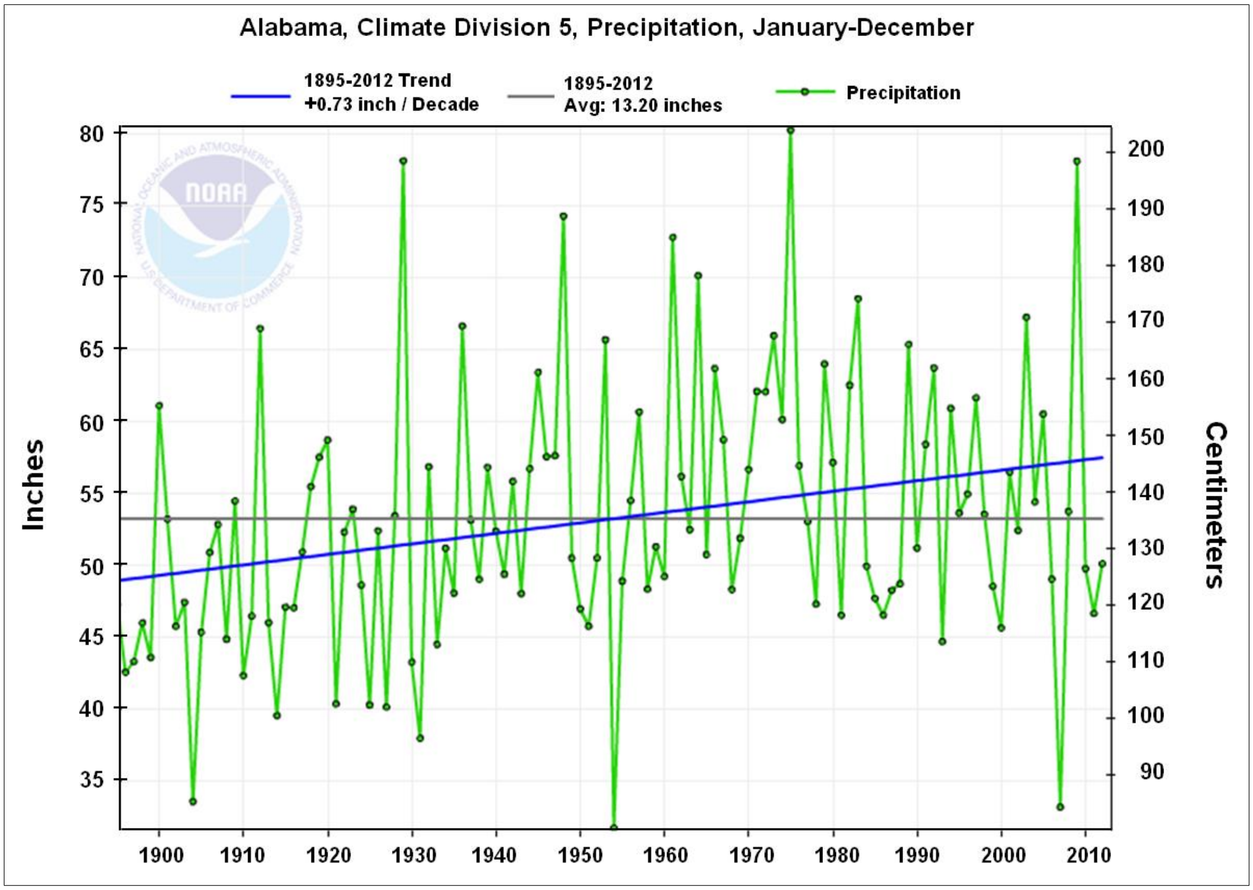

Figure 14. Increasing trend in mean annual precipitation within the Division 5 area of Alabama, including Horseshoe Bend National Military Park, from 1895 through 2012. The mean annual precipitation was 135.2 cm (53.21 inches) over that period, suggesting an increase of +1.85 cm (+0.73 inches) per decade (NOAA NWS).

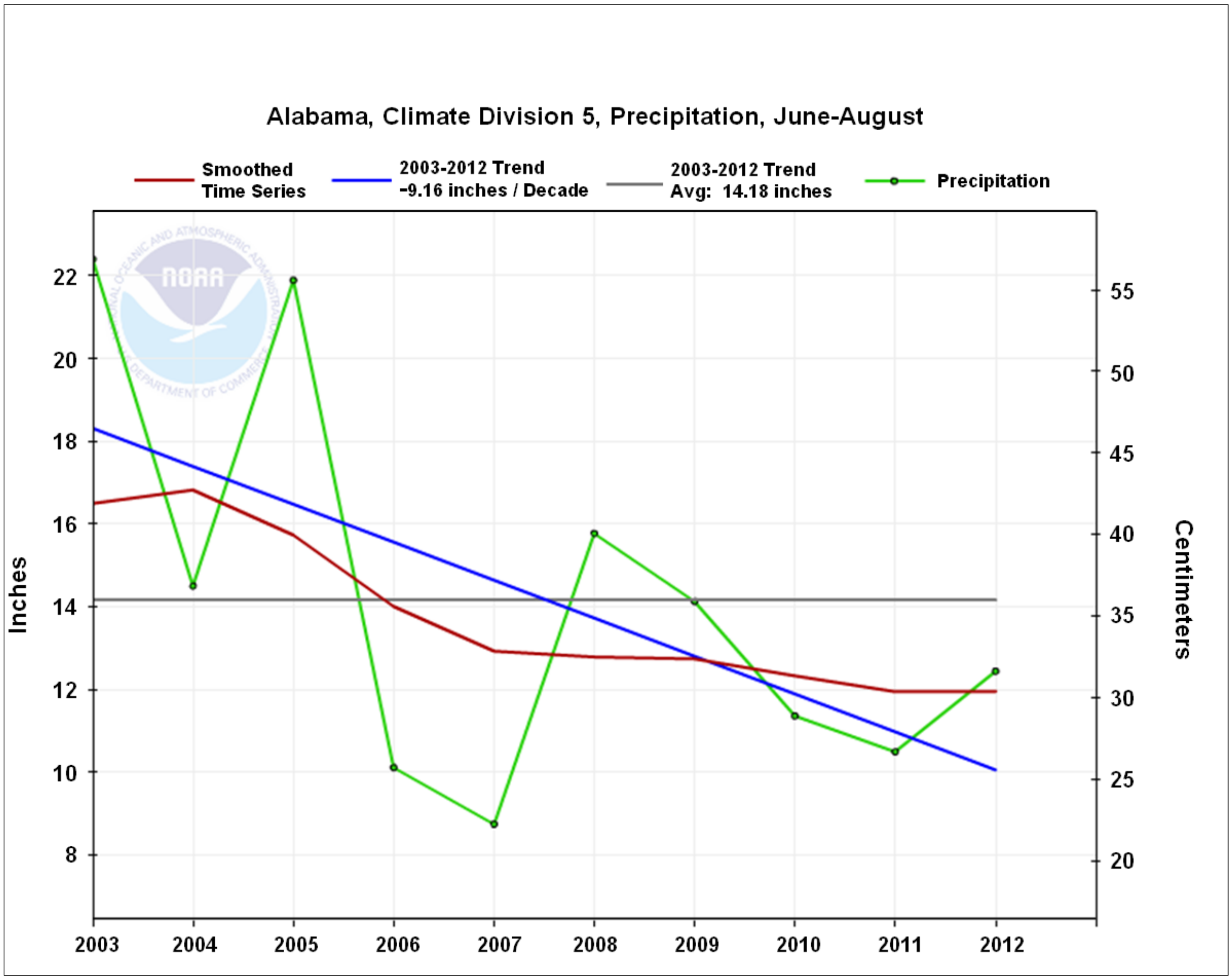

Figure 15. Mean summer precipitation (June through August) in the Division 5 area of Alabama during 2003 to 2012 showing a decrease of 23.27 cm, or -9.16 inches). From NOAA NWS.

3.1.3. Moisture

Drought severity in the region of Alabama that includes Horseshoe Bend was assessed (1896 through 2012) using the PDSI, a scale ranging from -3 to +3, which assesses the duration and intensity of long-term drought-inducing circulation patterns (Dai et al. 2004, Dai 2011a,b). Since long-term drought is cumulative, the intensity of drought during the present month depends on the present weather patterns along with the cumulative conditions for previous months. Palmer Drought Severity Index values rank the severity of a given drought (Table 4). The indicated “classes” were used to assign a monthly PDSI value from 1930 to 2012, and the proportion of months in each class for each 9-year period was determined (Figure 16). Drought severity was highly variable over time, but the data show a strong increase in the proportion of months that were in the abnormally dry and excessively dry classes since 1896.

Table 4. Palmer Drought Severity Index (PDSI) scale. From Dai et al. (2004).

Scale Interval	**Class Description**
-3 or less	Severely dry
-2 to less than -3	Excessively dry
-1 to less than -2	Abnormally dry
-1 to less than 1	Slightly dry/favorably moist
1 to less than 2	Abnormally wet
2 to less than 3	Wet
3 or greater	Excessively wet

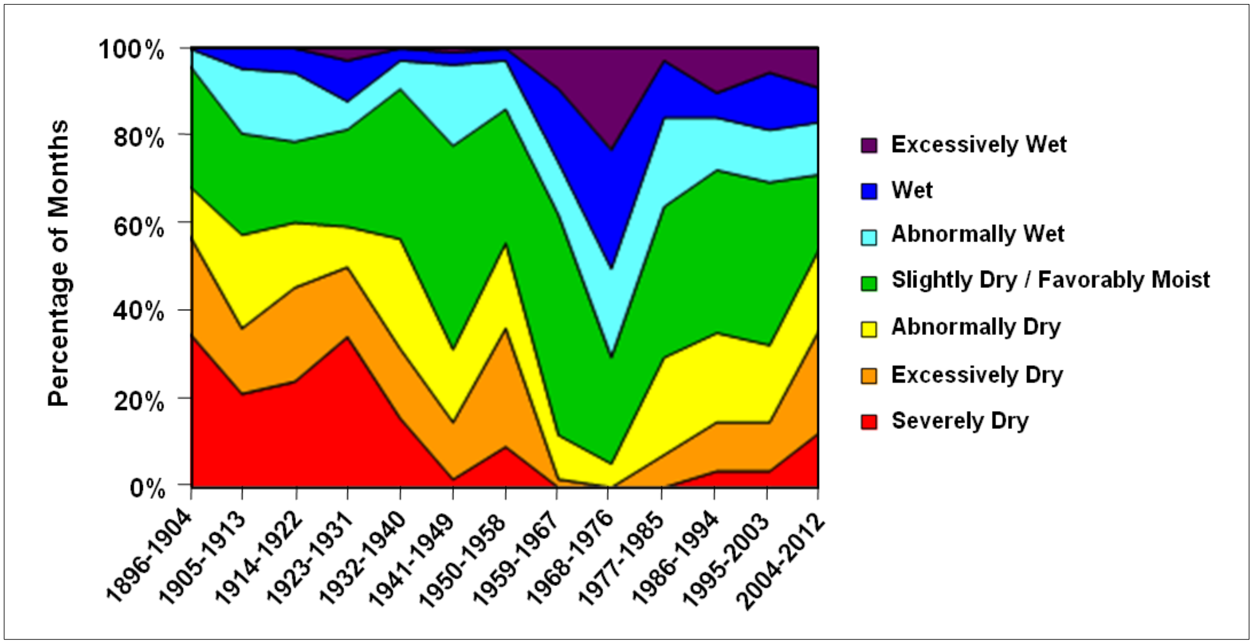

Figure 16. PDSI values for the Division 5 area of Alabama over nine-year periods from 1896 through 2012. Data from the Southeast Regional Climate Center (SERCC).

3.1.4. *Phenology (Growing Degree Days)*

Phenology is the study of the effects of changes in the seasonal variation of temperature and precipitation on biological processes, reflected in the timing of reproduction, flowering, and the length of the growing season (NOAA NWS). We assessed changes in phenology as growing degree days (GDDs), defined as the total amount of time in an annual cycle when the temperature is above 4.4^{o}C (40^{o}F), roughly equivalent to the growing season when non-evergreen plants are able to photosynthesize. The monthly mean temperature for Division 5 of Alabama over time (1930 to 2012) was used to estimate the approximate number of GDDs per month:

$$GDD = (Tm - 40)\ Dm$$

Where GDD = Growing degree days, Tm = monthly mean temperature, and Dm = number of days in month. The GDDs for each month were added to estimate the GDDs per year, and these values were plotted over time to assess long-term changes in the numbers of GDDs in the Atlanta area (Figures 17 and 18). Using the approach of Dorr et al. (2009), we also considered phenology within the context of a calendar year by selecting an arbitrary GDD threshold of 1200 and then estimating the data at which that number of GDDs was reached. This would be similar to estimating the specific date when a phenologic event such as cherry trees flowering in March or April. The total monthly accumulated GDD through March 31st was calculated by multiplying the mean daily temperature by the number of days in a month, and the difference from 1200 was determined. The number of days required to reach the 1200 GDD was estimated as the slope of the line for the approximate month. If the difference was positive, the exact date where 1200 was achieved was estimated as the slope of the line between the total GDD for March and the total for April. If the difference was negative, the same procedure was used between February and March. In this way, the calendar date when the 1200 GDD was achieved was calculated for each year (Figure 19). The annual GDDs in the Division 5 area of Alabama have decreased since the 1930s. However, the approximate date when 1200 GDD was reached for each year since 1930 has increased by several days (Figure 20). Thus, the phenology in the Division 5 area may be advancing, but the annual variation for GDD is high so that the R^2 value is weak. The analysis indicates that species found in warmer climates may, in time, be able to expand into the region, whereas more northern species may be limited.

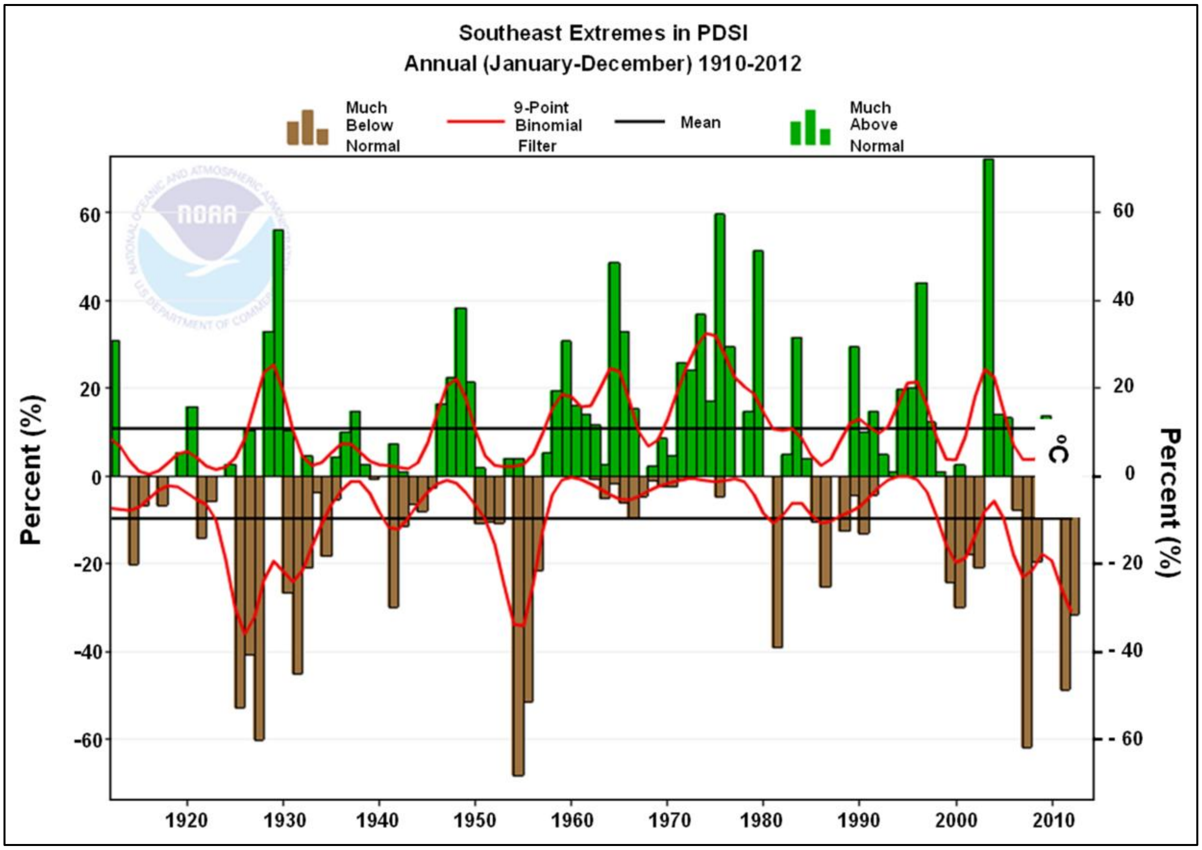

Figure 17. PDSI values for the Division 5 area of Alabama from 1896 to 2012. Data from NOAA NWS.

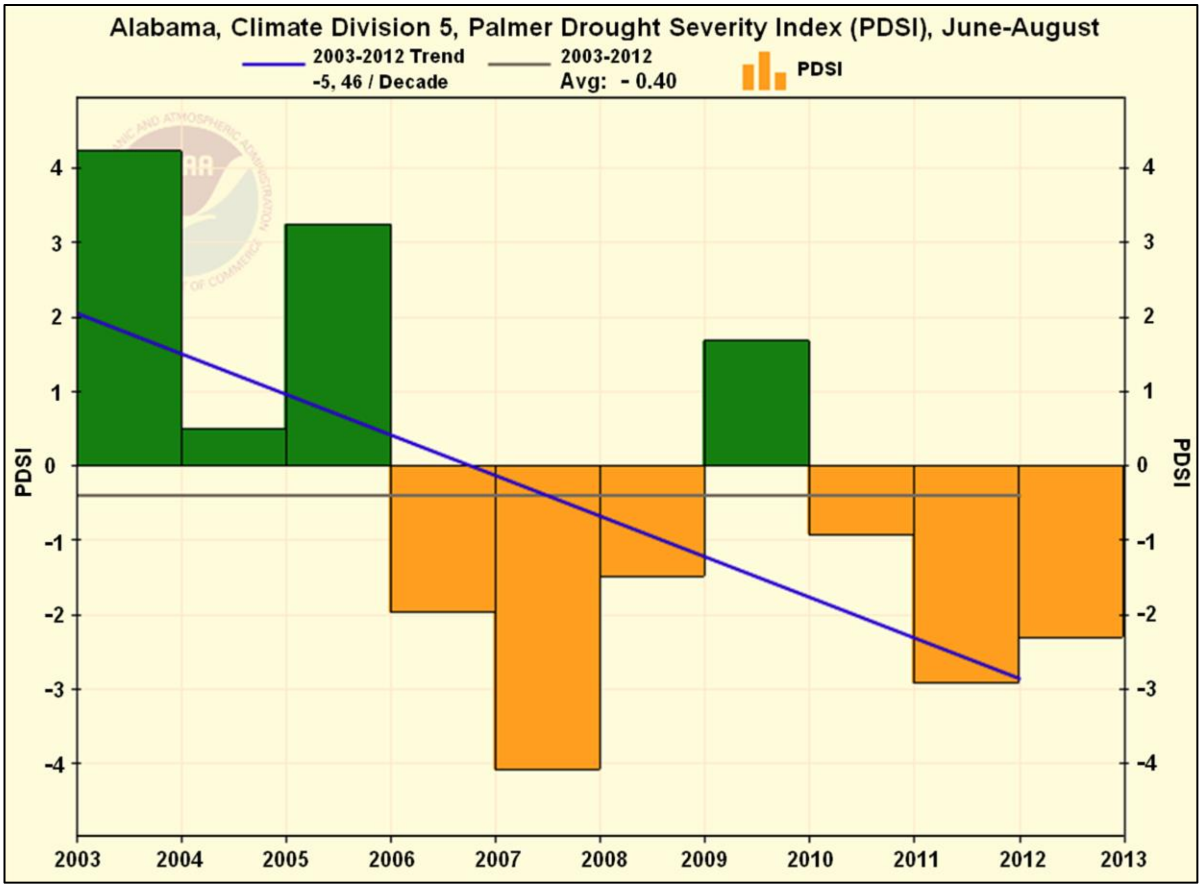

Figure 18. PDSIs over the past decade (2003-2012) in the Alabama Climate Division 5, showing a decrease. Data from NOAA NWS.000

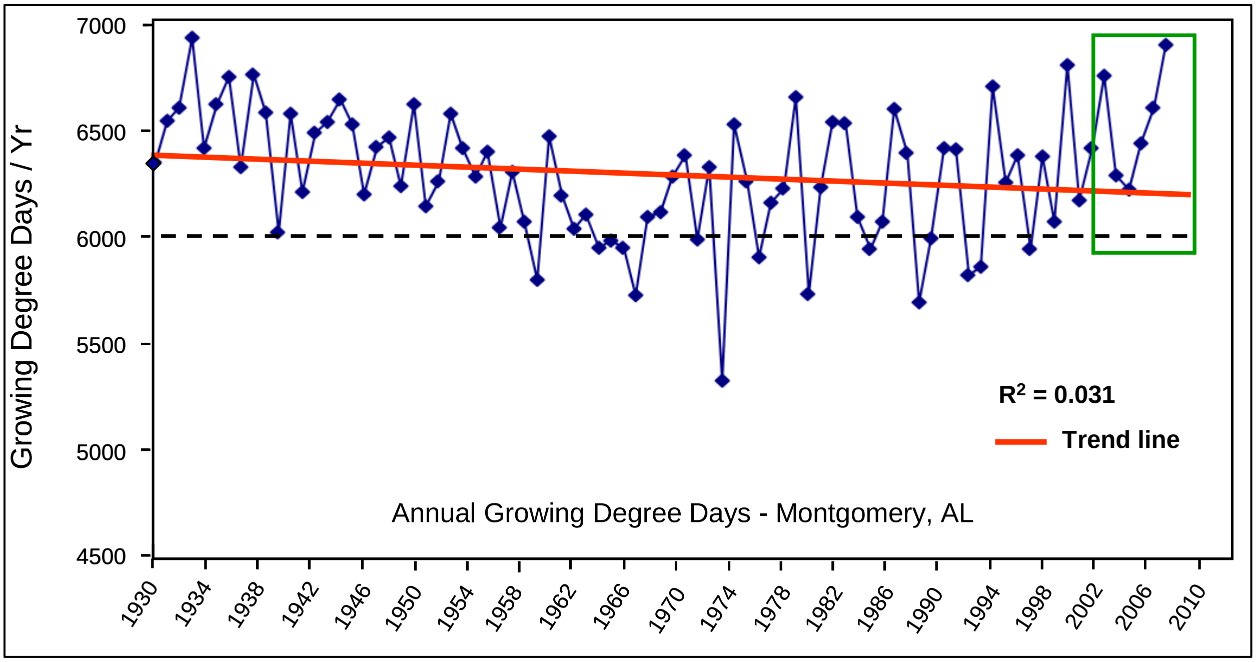

Figure 19. The GDDs per year for the Division 5 area of Alabama from 1930 through 2012. The long-term mean annual number of GDDs is 5,984 (dashed line). The data suggest that the GDD has decreased from 1930-2012, but increased in the past decade (green box). Data from the SERCC.

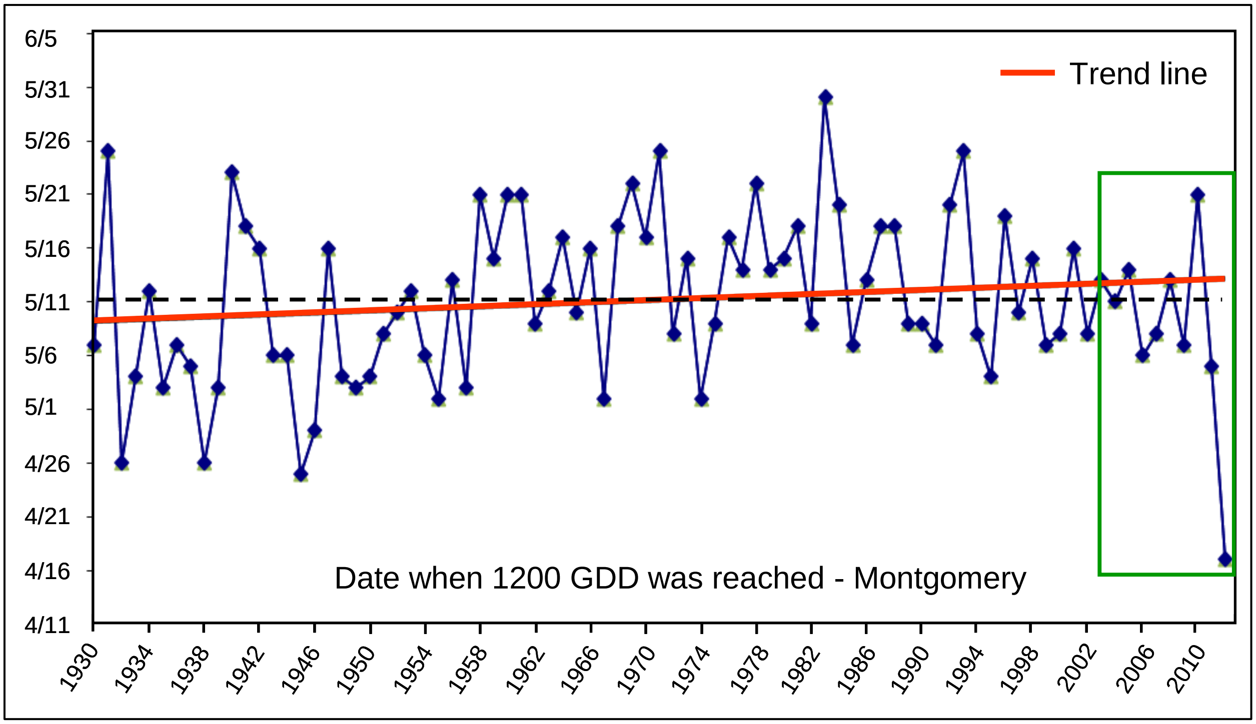

Figure 20. Approximate date when 1200 GDD was reached for each year in the Division 5 area of Alabama in 1930 through 2012. Dashed line = long-term mean approximate date when 1200 GDD was reached (5/12). The GDD apparently has increased by several days since the 1930s, but has decreased in the past decade (green box). Data from the SERCC.

3.1.5. Extreme Weather Events

Storm tracks within a 161-km (100-mile) radius of Atlanta were acquired from 1851 to 2012 from the NOAA National Weather Service. Each storm was rated as a tropical depression (TD), a tropical storm (TS), or a Category 1-4 hurricane. Storms categorized as tropical depressions have maximum sustained winds of 61 km/hr (38 miles per hour, mph) or less. Tropical storms have maximum sustained winds of 63 to 117 km/hr (39 to 73 mph; U.S. Department of Commerce 2001). The Saffir/Simpson Hurricane Scale (SSHS; Table 5) rates and categorizes hurricanes on a scale of 1 to 5 based on wind speeds (Blake et al. 2007), and a major hurricane is rated as a 3, 4, or 5 on the SSHS. Storms that occurred on successive days were combined into one storm event, and the event was assigned the most severe storm rating that it received). The data were considered by decade, and also by the total per month over the period from 1930 through 2012.

Table 5. The Saffir/Simpson Hurricane Scale (SSHS - Blake et al. 2007).

Typical Characteristics of Hurricanes by Category					
Scale Number (Category)	**Wind Speed (mph)**	**Millibars**	**Inches**	**Surge (feet)**	**Damage**
1	74 - 95	> 979	> 28.91	4 to 5	Minimal
2	96 - 110	965 - 979	28.50 - 28.91	6 to 8	Moderate
3	111 - 130	945 - 964	27.91 - 28.47	9 to 12	Extensive
4	131 - 155	920 - 944	27.17 - 27.88	13 to 18	Extreme
5	> 155	< 920	< 27.17	> 18	Catastrophe

Of the 24 storms in total from 1930 through 2012, all were tropical depressions and tropical storms except for two level-1 hurricanes and one level-2 hurricane (Figure 21). Most storms in the Atlanta area have occurred during August - September (Figure 22). The total number was similar from the 1930s through the 1990s, then increased within the past decade (Figure 23).

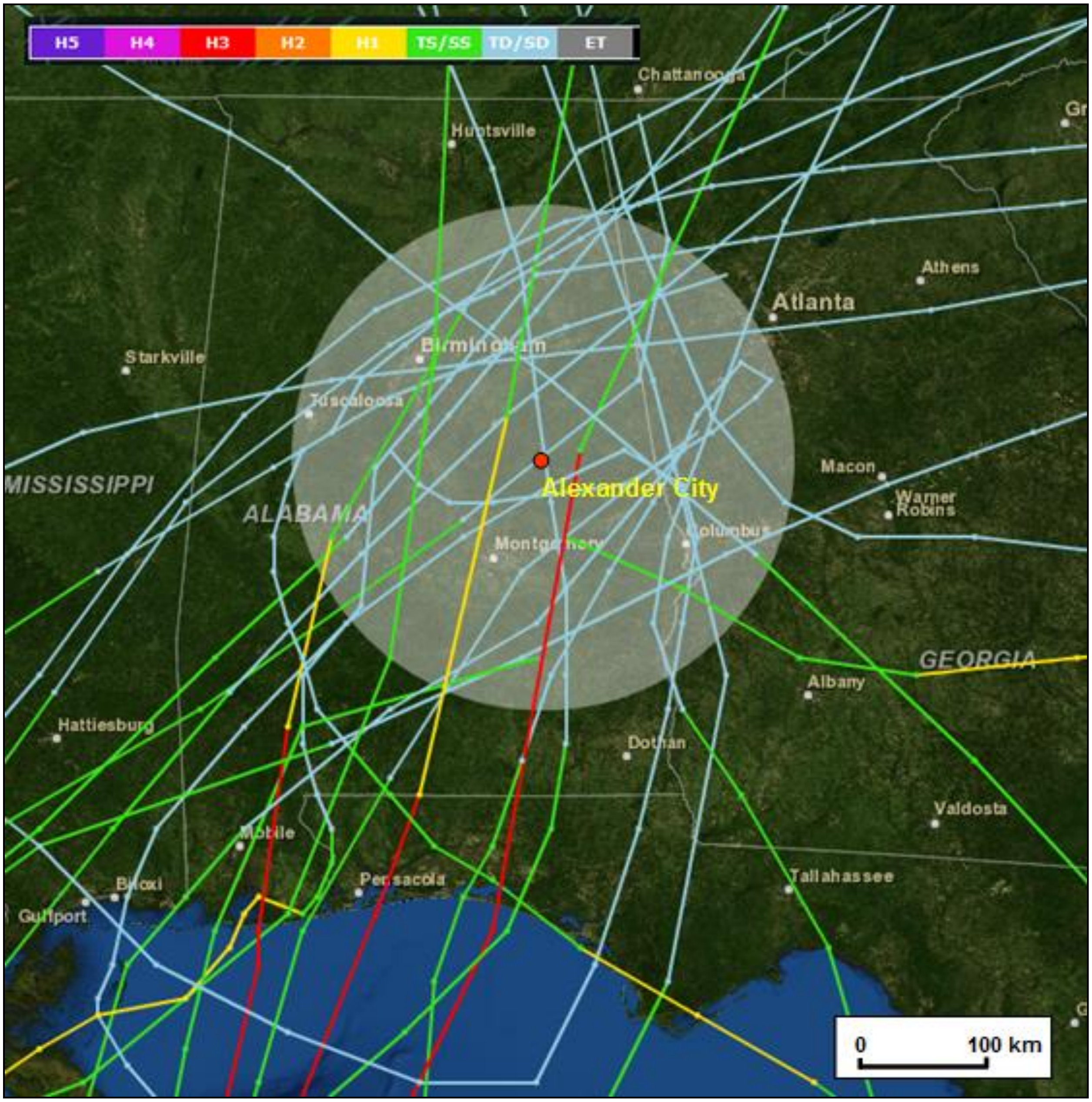

Figure 21. Map showing tracks of 24 tropical storms (1930–2012) that passed within 161 km (100 miles) of Alexander City, Alabama (NOAA 2015b).

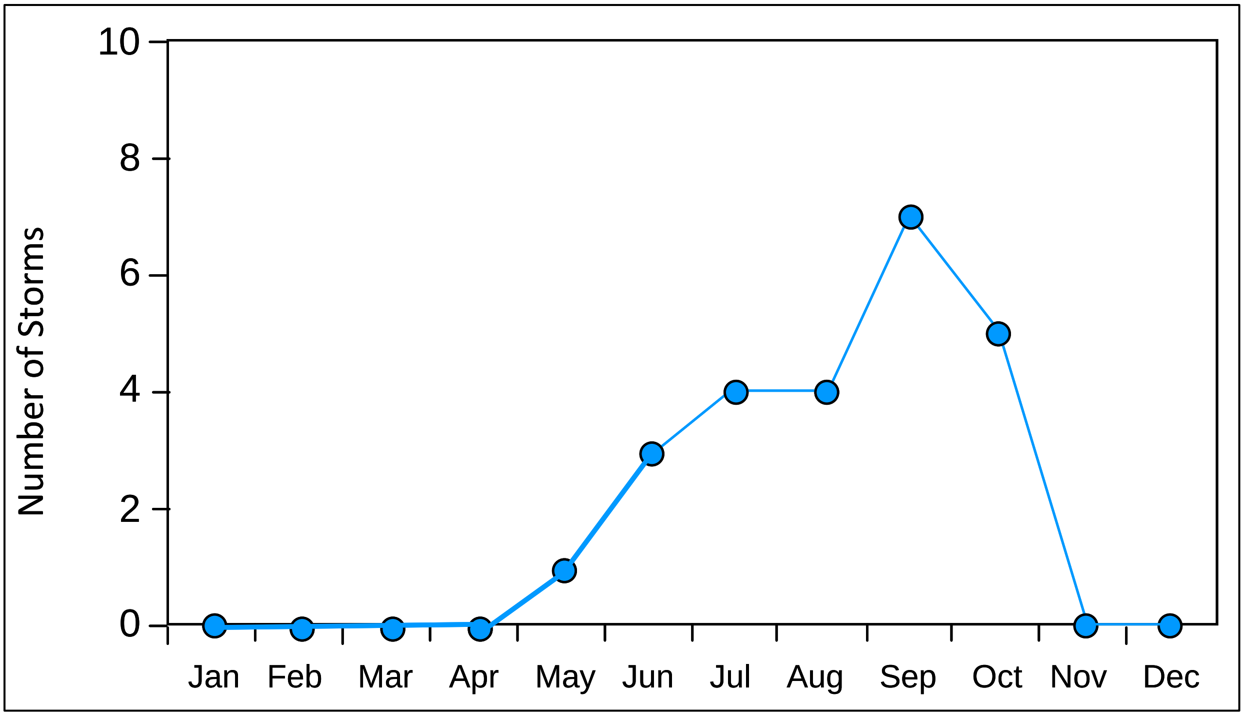

Figure 22. The total number of major and minor storms per month (1930 to 2012) that occurred within 161 km (100 miles) of Alexander City, Alabama.

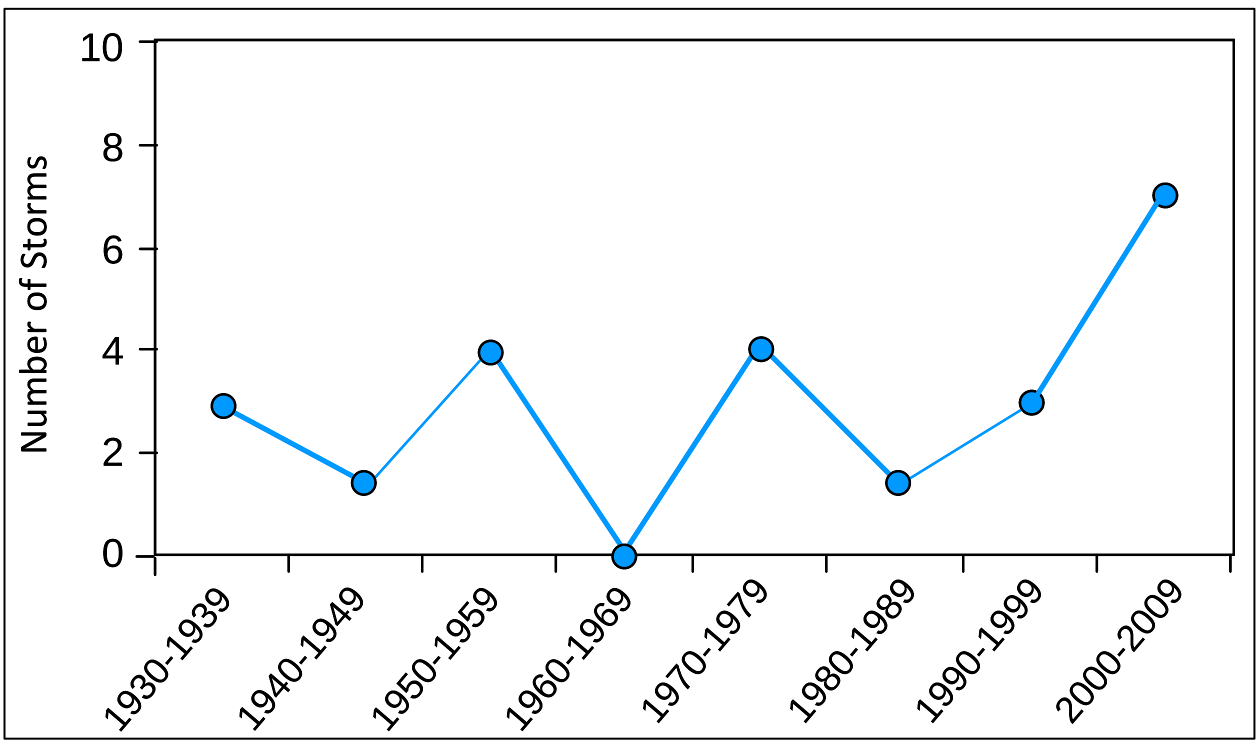

Figure 23. The number of storms per decade (1930 to 2009 - the latest year for which complete data were available) that occurred within 161 km (100 miles) of Alexander City, Alabama.

3.2. Air Quality

3.2.1. Federal Criteria for Major Air Pollutants, and a Federal Index Scale

The EPA maintains NAAQS under the federal Clean Air Act (EPA 2014). The Clean Air Act has set standards for six "criteria" pollutants (including two categories for one of these, particulate matter) (Table 6). The regulatory air quality standards are health-based, and concentrations above the standards are considered unhealthy for sensitive groups. For example, the eight-hour ozone standard is attained when the average of the fourth highest concentration measured is equal to or below 0.08 parts per million (ppm; 0.085 ppm with the EPA rounding convention), averaged over three years. The standards for the six criteria pollutants are fairly straightforward except for the particle pollution ($PM_{2.5}$) standard: To be in compliance with the federal air $PM_{2.5}$ standard, an area must have an annual arithmetic mean concentration of less than or equal to 15 µg $PM_{2.5}/m^3$. An additional requirement imposed a stricter standard for fine particulate matter as of 2007, wherein the 98th percentile 24-hour concentration must be $\leq$ 35 µg $PM_{2.5}/m^3$ to protect sensitive groups (Table 6).

Ozone is monitored in March through October, since that period is when ozone production mostly occurs (EPA 2004). This pollutant is a serious health concern because it attacks the mammalian respiratory system, causing coughs, chest pain, throat irritation, increased susceptibility to respiratory infections, and impaired lung functioning. In fact, moderate ozone levels can interfere with performance of normal daily activities by people who have asthma or other respiratory diseases. Of more concern than acute affects are chronic effects of repeated exposure to ozone, which can lead to lung inflammation and permanent scarring of lung tissue, loss of lung function, and reduced lung elasticity. Fine particulate matter ($PM_{2.5}$) is produced by various sources including industrial combustion, residential combustion, and vehicle exhaust, or when combustion gases are chemically transformed into particles. Research has indicated that $PM_{2.5}$ is a human health concern because it can penetrate into sensitive areas of the lungs and cause persistent coughs, phlegm, wheezing, more serious respiratory and cardiovascular disease, cancers, and premature death at particle levels well below the existing standards (Schwela 2000, EPA 1994a). Mounting evidence indicates that $PM_{2.5}$ enhances delivery of other pollutants and allergens deep into lung tissue where the effects are exacerbated. Especially sensitive groups include children, the elderly, and people with cardiovascular or lung diseases such as asthma. $PM_{2.5}$ also impairs visibility and contributes to haze in the humid conditions that characterize the eastern Alabama climate (EPA 1994a).

Table 6. National ambient air quality (AQ) standards (NAAQS, 40 CFR part 50), set by the EPA (October 2011) for six principal ("criteria") pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient AQ standards: Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (EPA 2014).

Pollutant [Final Rule Cited]		**Primary/ Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide [76 FR 54294, Aug 31, 2011]		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead [73 FR 66964, Nov 12, 2008]		primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ (1)	Not to be exceeded
Nitrogen Dioxide [75 FR 6474, Feb 9, 2010], [61 FR 52852, Oct 8, 1996]		primary	1-hour	100 ppb	98th percentile, average over 3 years
		primary and secondary	Annual	53 ppb (2)	Annual Mean
Ozone [73 FR 16436, Mar 27, 2008]		primary and secondary	8-hour	0.075 ppm (3)	Annual fourth highest daily maximum 8-hr concentration, averaged over 3 years
Particle pollution Dec 14, 2012	$PM_{2.5}$	primary	Annual	12 $\mu g/m^3$	annual mean, averaged over 3 years
		secondary	Annual	15 $\mu g/m^3$	annual mean, averaged over 3 years
		primary and secondary	24-hour	35 $\mu g/m^3$	98th percentile, average over 3 years
	PM_{10}	primary and secondary	24-hour	150 $\mu g/m^3$	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide [75 FR 35520, Jun 22, 2010], [38 FR 25678, Sept 14, 1973]		primary	1-hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

[1] Final rule signed October 15, 2008. The 1978 lead standard (1.5 $\mu g/m^3$ as a quarterly average) remains in effect until 1 yr after an area is designated for the 2008 standard, except that in areas designated nonattainment, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

[2] The official level of the annual NO_2 standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hr standard.

[3] Final rule, signed March 12, 2008. The 1997 ozone standard (0.08 ppm, annual fourth highest daily maximum 8-hour concentration, averaged over 3 yr) and related implementation rules remain in place. In 1997, the EPA revoked the 1-hour ozone standard (0.12 ppm, not to be exceeded more than once per yr) in all areas, although some areas have continued obligations under that standard ("anti-backsliding"). The 1-hour ozone standard is attained when the expected number of days per calendar year with maximum hourly average concentrations higher than 0.12 ppm is 1 day or less.

[4] Final rule signed June 2, 2010. The 1971 annual and 24-hour SO_2 standards were revoked in that same rulemaking. However, these standards remain in effect until 1 yr after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, wherein the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

The EPA's Air Quality Index (AQI) scale (from 0 to 500 with lower values indicating less pollution) was designed to help inform the general citizenry about potential health impacts from air quality degradation (Tables 7 and 8). The AQI is designed to provide accurate, timely, easily understandable information about daily levels of air pollution with a uniform system for the major air pollutants regulated under the Clean Air Act. The index allows the general citizenry to assess whether air pollution levels in the location of interest are Good, Moderate, Unhealthy for Sensitive Groups, or worse. For example, an AQI value of 50 indicates good air quality with low potential for adverse public health effects, whereas an AQI of more than 300 indicates hazardous air quality. An AQI less than 100 generally is used as the acceptable level set by the EPA to protect public health (Air Now 2015). Information is also provided about precautions that should be taken if air pollution levels are Unhealthy or worse. It should be noted that the state of Alabama relies on the federal standards for air quality (Alabama Department of Environmental Management [AL DEM] 2013a).

Table 7. EPA's Air Quality Index (AQI) criteria (modified from GA DNR 2007b, EPA 2009)

Maximum Pollutant Concentration								
$PM_{2.5}$ (24hr) µg/m^3	PM_{10} (24hr) µg/m^3	SO_2 (24hr) ppm	O_3 (8hr) ppm	CO (8hr) ppm	NO_2 (1 hr) ppm	AQI Value	Descriptor (color-coded)	EPA Health Advisory
≤ 15.4	≤ 54	≤ 0.034	≤ 0.064	≤ 4.4	None	**0-50**	**GOOD**	Air quality satisfactory; little or no risk from air pollution
15.5 - 40.4	55-154	0.035 - 0.144	0.065 - 0.084	4.5 - 9.4	None	**51 - 100**	**MODERATE**	Air quality acceptable, but for some pollutants there may be a moderate health concern for a small number of unusually sensitive people
40.5 - 65.4	155 - 254	0.145 - 0.224	0.085 - 0.104	9.5 - 12.4	None	**101 - 150**	**UNHEALTHY for Sensitive Groups**	Sensitive groups (people with lung or heart disease) are at greater risk from exposure to particulate pollution, ozone
65.5 - 150.4	255 - 354	0.225 - 0.304	0.105 - 0.124	12.5 - 15.4	None	**151 - 200**	**UNHEALTHY**	Everyone may begin to sustain health effects; members of sensitive groups may experience more serious health impacts
150.5 - 250.4	355 - 424	0.305 - 0.604	0.125 - 0.374	15.5 - 30.4	0.65 - 1.24	**201 - 300**	**VERY UNHEALTHY**	AQI values trigger a health alert; everyone sustain more serious health effects. If related to high ozone, If related to high ozone, restricted to morning or late evening to minimize exposure
250.5 - 500.4	425 - 604	0.605 - 1.004	None	30.5 - 50.4	1.25 - 2.04	**301 - 500**	**HAZARDOUS**	AQI values over 300 trigger health warnings of emergency conditions; the entire populace is more likely to be affected

Table 8. The Air Quality Index (AQI) of the EPA (1994) translated into actions that citizens can take to protect their health from potentially harmful levels of major air pollutants. From EPA (2009).

AQI Value	Actions To Protect Your Health From Particle Pollution	Actions to Protect Your Health From Ozone	Actions To Protect Your Health From Carbon Monoxide	Actions to Protect Your Health From Sulfur Dioxide
Good (0-50)	None	None	None	None
Moderate (51-100*)	Unusually sensitive people should consider reducing prolonged or heavy exertion.	Unusually sensitive people should consider reducing prolonged or heavy outdoor exertion.	None	None
Unhealthy for Sensitive Groups (101-150)	The following groups should reduce prolonged or heavy outdoor exertion: - People with heart or lung disease - Children and older adults Everyone else should limit prolonged or heavy exertion.	The following groups should reduce prolonged or heavy outdoor exertion: - People with lung disease, such as asthma - Children and older adults - People who are active outdoors	People with heart disease, such as angina, should reduce heavy exertion and avoid sources of carbon monoxide such as heavy traffic.	People with asthma should consider reducing exertion outdoors.
Unhealthy (151-200)	The following groups should avoid all physical outdoors: - People with heart or lung disease - Children and older adults Everyone else should avoid prolonged or heavy exertion.	The following groups should avoid prolonged or heavy outdoor exertion: - People with lung disease such as asthma - Children and older adults - People who are active outdoors Everyone else should limit prolonged outdoor exertion.	People with heart disease, such as angina, should reduce moderate exertion and avoid sources of carbon monoxide such as heavy traffic	Children, asthmatics, and people with heart disease should reduce exertion outdoors
Very Unhealthy (201-300)	The following groups should remain indoors and keep activity levels low: - People with heart or lung disease - Children and older adults Everyone else should avoid all physical activity outdoors.	The following groups should avoid all outdoor exertion: - People with lung disease, such as asthma - Children and older adults - People who are active outdoors Everyone else should limit outdoor exertion.	People with heart disease, such as angina, should avoid exertion and sources of carbon monoxide such as heavy traffic	Children, asthmatics, and people with heart or lung disease should avoid outdoor exertion. Everyone else should reduce exertion outdoors.

3.2.2. National Park Service Indices for Air Quality

The National Park Service (2011) has developed guidance for assessing AQ conditions within its parks, including information for evaluating O_3 as related to plant responses. The Air Resources Division of the National Park Service used all available monitoring data over the 2005-2009 five-year period to generate interpolations for the parks throughout the continental U.S., including parks such as Horseshoe Bend that do not have on-site monitoring. The National Park Service then determined an index for each type of air quality data considered, including ozone concentrations and exposures (mean annual fourth highest eight-hour [hr] ozone concentrations), nitrogen wet deposition, sulfur wet deposition, and visibility condition (Group 50 visibility minus estimated annual average natural conditions, where Group 50 is the mean of the 40th to 60th percentiles of observed measurements in deciview). Park AQ interpolated values are then assigned to one of three condition categories for each NPS AQ index:

- Air quality is in good condition
- Air quality is in moderate condition
- Air quality is a significant concern

The following procedures are taken from National Park Service (2011):

3.2.2.1. <u>Ozone Condition:</u>

The O_3 human health standard (EPA 2008) requires that the three year average of the fourth highest daily maximum eight-hour average ozone concentrations measured at each monitor within the area of interest over each year must not exceed 75 parts per billion (ppb). Accordingly, the National Park Service assigned five-year average values as in Table 9:

Table 9. The NPS ranks for ozone concentrations to protect human health in air quality condition assessment (NPS 2011).

Ozone Condition (Human Health)	Ozone Concentration
Significant Concern	≥ 76 ppb
Moderate	61-75 ppb
Good	≤ 60 ppb

Note that the “moderate” and “good” conditions are assigned to parks with average five-year, fourth highest eight-hour ozone concentrations > 80% of the standard and < 80% of the standard, respectively.

The National Park Service has incorporated vegetation sensitivity, as well as human health, into its park air quality rating, in consideration of the fact that some plant species have been shown to be more sensitive to O_3 than humans so use of an O_3 standard for humans would not be sufficiently protective of those plant species. The National Park Service completed a risk assessment in 2004 that rated parks at low, moderate, or high risk for ozone injury to vegetation based on the presence of sensitive plant species, O_3 exposures, and environmental conditions (especially soil moisture). For O_3 condition assessment, parks that were evaluated at high risk are moved into the next worse condition category. For example, a park with an average O_3 concentration of 72 ppb, but evaluated at high risk for vegetation injury, would be moved from "moderate condition" to "significant concern."

The National Park Service also developed a method for rating O_3 condition considering only plant response, based on the EPA's proposed approach; use of the metric W126 for a secondary O_3 standard designed to protect vegetation. The W126 measures cumulative O_3 exposure over the growing season and is considered a better predictor of plant response than the eight-hour human health standard metric. A similar metric, SUM06, also measures cumulative exposure. The thresholds below for both metrics are based on recommendations from an expert workgroup (Table 10): W126 in the range of 7-13 ppm-hr would protect growth effects to tree seedlings in natural forest stands, whereas W126 ranging from 5-9 ppm-hr would protect plants in natural ecosystems from foliar injury (Heck and Cowling 1997, EPA 2007).

Table 10. The NPS ranks for ozone concentrations to protect sensitive plant species in air quality condition assessment. (NPS 2011).

Ozone Condition (Ecological)	Ozone Exposure - W126	Ozone Exposure - SUM06
Significant Concern	> 13 ppm-hr	>15 ppm-hr
Moderate	7-13 ppm-hr	8-15 ppm-hr
Good	< 7 ppm-hr	<8 ppm-hr

3.2.2.2. Nitrogen and Sulfur Conditions:

Wet deposition is calculated by multiplying the N or S concentration in precipitation by a normalized precipitation amount (note: dry deposition data are not available). Factors considered in rating the deposition condition include natural background deposition estimates (~.25 kilograms per hectare per year [kg/ha/yr] for either N or S), and deposition effects on ecosystems. Certain sensitive ecosystems respond to levels of N or S deposition at ~1.5 kg per ha per hr, whereas information is not available indicating that wet deposition of < 1 kg/ha/yr causes ecosystem harm. Therefore, the NPS ranks parks with wet N or S deposition as in Table 11: Note that the basis for the level of deposition ranked as "significant concern" was not given by the National Park Service (2011). Values for parks with ecosystems that are potentially more sensitive to N or S are adjusted up one category.

Table 11. The NPS ratings for wet deposition of nitrogen (N) or sulfur (S) in air quality condition assessment, in order to protect park ecosystems (NPS 2011).

Deposition Condition	Wet Deposition of N or S (kg/ha/yr)
Significant Concern	> 3
Moderate	1-3
Good	<1

3.2.2.3. Visibility Condition:

This rating is based on the deviation of the current Group 50 visibility conditions from the estimated Group 50 natural visibility conditions, where Group 50 is the mean of the visibility observations within the range from the 40^{th} through the 60^{th} percentiles. Current visibility is estimated from interpolating the five-year averages of the Group 50 visibility. Visibility is expressed in terms of a haze index (derived from calculated light extinction - see report #EPA-454/B-03-005), in deciviews (dv):

Visibility = present Group 50−estimated Group 50 visibility
Condition visibility under natural conditions

The dv ranges for these categories were described as somewhat subjective but selected to reflect, insofar as possible, the variation in visibility conditions across the monitoring network. The NPS criteria for visibility were finalized as shown in Table 12:

Table 12. The NPS ratings for visibility in air quality condition assessment. (NPS 2011).

Visibility Condition	Current Group 50 - Estimated Group 50 Natural (dv)
Significant Concern	> 8
Moderate	2-8
Good	< 2

3.2.3. Air Quality in the Park and Vicinity

Based on the AQI, air quality in the Alexander City, Ala. area near Horseshoe Bend was evaluated as having *good* air quality 98.94% of the time (days) in 2013 thus far, and 97.57% of the time in 2012 (Table 13; Homefacts 2015a). Air quality was moderate, and therefore still acceptable for sensitive groups, only 6.94% of the time in 2014, and considering the past decade, the highest percentage of moderate air quality days occurred in that year. Of the two largest population centers nearest Horseshoe Bend to the west - therefore, potential influences on the park's air quality - Montgomery had better air quality than Birmingham (Homefacts 2015b). Air quality was good in Montgomery 91.82 to 97.05% of the time over the past ~seven years (2008 to 2014), with the remainder of the time classified as moderate. In contrast, over the past ~seven years, air quality in Birmingham was good 79.10 to92.58% of the time, moderate 7.42 to 20.28% of the time, and unhealthy for sensitive groups up to 0.61% of the time. For all three population centers, violations of the priority criteria standards occurred for ozone and $PM_{2.5}$; Birmingham also had a small number of violations of the carbon monoxide (CO) and sulfur dioxide (SO_2) standards.

Table 13a. The overall Air Quality Index (AQI) percentage levels for Alexander City, Alabama (Homefacts 2015a,b)

Air Quality Index (AQI)	Percentage Levels
GOOD	93.06 %
MODERATE	6.94 %
UNHEALTHY FOR SENSITIVE GROUPS	0.00 %
UNHEALTHY	0.00%
VERY UNHEALTHY	0.00 %
HAZARDOUS	0.00 %

Pie Chart

Table 13b. The 2014 Air Quality Index (AQI) for Alexander City, Alabama, also showing levels of the top six criteria pollutants. Numbers in the two tables show the number of days violations occurred for each priority pollutant (Homefacts 2015a,b)

Pollutant	Stat. Lat. & Long.	Good %	0-50	51-100	101-150	151-200	201-300	301-500
Ozone	32.4986, -86.1366	97.21%	209	6	0	0	0	0
CO	33.5653, -86.7964	100.00%	274	0	0	0	0	0
NO_2	33.5214, -86.8441	98.90%	270	3	0	0	0	0
SO_2	33.5531, -86.815	98.53%	269	4	0	0	0	0
PM10	33.5783, -86.7739	98.88%	265	3	0	0	0	0
PM2.5	33.5531, -86.815	60.00%	135	90	0	0	0	0

Table 13c. The 2013 Air Quality Index (AQI) for Alexander City, Alabama, also showing levels of the top six criteria pollutants. Numbers in the two tables show the number of days violations occurred for each priority pollutant (Homefacts 2015a,b)

Pollutant	Stat. Lat. & Long.	Good %	0-50	51-100	101-150	151-200	201-300	301-500
Ozone	32.4986, -86.1366	97.96%	240	5	0	0	0	0
CO	33.5653, -86.7964	100.00%	365	0	0	0	0	0
NO_2	33.5531, -86.815	100.00%	31	0	0	0	0	0
SO_2	33.5531, -86.815	99.73%	363	1	0	0	0	0
PM10	32.4071, -86.2564	100.00%	89	0	0	0	0	0
PM2.5	33.2813, -85.8022	84.75%	100	18	0	0	0	0

The AQI for Montgomery in 2012 was evaluated as 9% less than the average AQI for Alabama, and 56.7% greater than the national average (Area Vibes 2015; Table 14). An air "pollution index" (API) was also available for the two larger cities, calculated as the sum of the most hazardous air pollutants (arsenic, benzene, carbon tetrachloride, lead, and mercury) in kilograms (pounds). The pollution indices indicate that Birmingham had ~9.1-fold more air pollution by weight of these hazardous substances than Montgomery, ~4.3-fold more air pollution than the average for the state, and 2.9-fold more air pollution than the national average.

Table 14. Air Quality Index (AQI) and Air Pollution Index (API; pounds in parentheses) for Montgomery and Birmingham, Alabama in 2012, also showing the statewide and national averages (Areavibes.com 2015).

Location	AQI	Median API in kg (lbs)	Days Measured (for AQI)	Evaluation
Montgomery	38	939,911 (2,072,150)	246	209 - *good* 37 - *moderate* 0 - Other
Birmingham	58	8,617,439	336	118 - *good* 202 - *moderate* 16 - *poor* for sensitive groups
Alabama (mean)	42	2,025,117 (4,464,618)	--	--
National (mean)	37	3,004,568 (6,623,939)	--	--

The Birmingham area has improved in air quality after years of violations. There are no coal-fired power plants in the vicinity of Horseshoe Bend, but several lie to the west (Southern Alliance for Clean Energy 2002; Figure 24). In 1999, Alabama ranked third in the U.S. in per capita premature deaths attributable to PM_{10} and $PM_{2.5}$ from power plants, and Birmingham was among the top ten cities for highest death rates in the U.S. from power plant fine particulate matter air pollution. The Birmingham and Montgomery metropolitan areas were both in violation of the national health standard for ground level ozone (Southern Alliance for Clean Energy 2002). Montgomery has since made progress, and in January 2013 the EPA reported that for the first time in 30 years, Birmingham met federal air quality standards.

Acid deposition is another air quality issue of concern for SECN parks to the east in the Atlanta, Ga. area. Acid precipitation can adversely affect or kill aquatic life and harm human health (Abelson 1987, Herlihy et al. 1991, Baker and Christensen 1992), and can act synergistically with ozone to harm human health as well (Abelson 1987). The major pollutants from coal-fired power plants, including those involved in acid deposition (SO_2, mostly from coal-fired power plants, and NO_x from coal-fired power plants, car exhausts and other sources) can be transported long distances across airsheds (Schwela 2000).

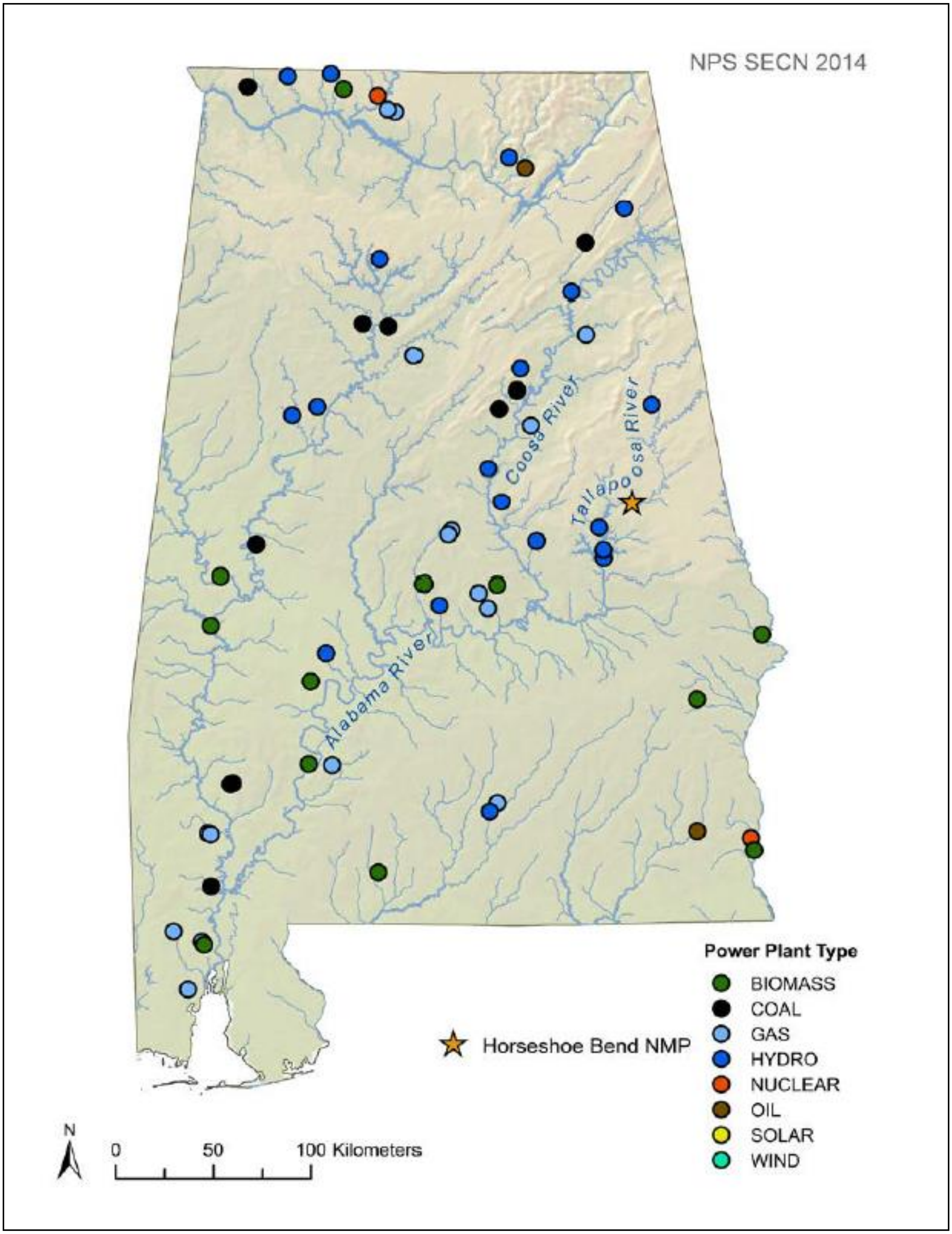

Figure 24. Map of power plants in Alabama (data from EISPC 2014).

Sullivan et al. (2011) assessed the threat of acid deposition to national parks across the nation, including Horseshoe Bend. First, they compiled and mapped data for total sulfur and total nitrogen emissions from the EPA (2002 National Emissions Inventory dataset - tons per mile^2 per year); from the NADP for wet deposition (2001-2003 - kg/hectare/yr); and from the 12-km Community Multiscale Air Quality (CMAQ) Model projections for dry deposition for 2002. Then, they ranked the 32 NPS networks and also the individual parks within each network considering four metrics (not further defined or explained): Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and an overall metric, Summary Risk to acid deposition. This analysis indicated that the Network ranked at the top of the second highest quintile in Pollutant Exposure among the NPS networks. Emissions and deposition of S and N within the Network were evaluated as fairly high. The SECN Ecosystem Sensitivity ranking was Very Low, in the bottom quintile among the networks, and at the bottom of the second lowest quintile in Park Protection because it has only limited amounts of protected lands. The Network's overall Summary Risk ranking was relatively low among the networks.

More specifically, Horseshoe Bend lies along the area of outermost influence from the Birmingham metropolitan area and other sources of air pollution to the north/northwest and east. As of 2001, the area including the park was estimated to have sustained >5 to < 10 kg/hectare/yr of total sulfur emissions and total nitrogen emissions (Figure 25). Sullivan et al. (2011) ranked Horseshoe Bend High (second highest ranking of five) for Pollutant Exposure, and Moderate (third highest ranking) for Ecosystem Sensitivity, Park Protection, and overall Summary Risk from acid deposition.

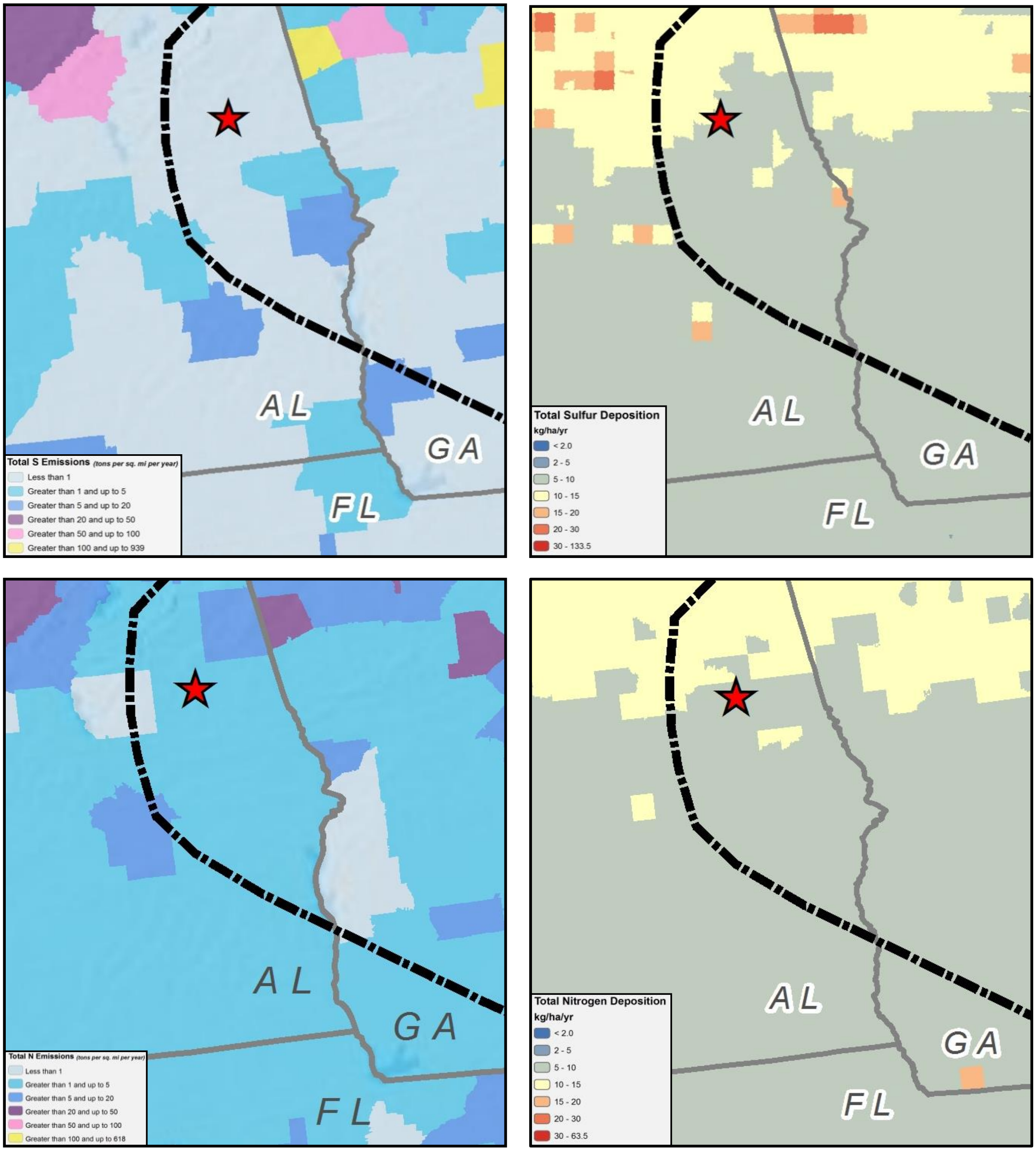

Figure 25. Map of total sulfur (S) and total nitrogen (N) emissions (both oxidized forms as nitrogen oxides and reduced forms as ammonia) by county as of 2002 in the vicinity of HOBE (star; and black line ≡ portion of the SECN boundary delineation). The data are given in units of tons per square mile per year (a,b) versus units of kilograms per hectare per year (c,d). Data source for a and b: National Emissions Inventory (EPA 2010). Data source for c and d: Wet deposition values were derived from interpolated measured values from NADP (3-yr average centered on 2002); dry deposition values were derived from 12-km CMAQ model projections for 2002. From Sullivan et al. (2011) - but note that although this document was recently published, the data used for the publication were from 2002. In the ensuing decade, two major point sources of air pollutants significantly reduced their emissions.

Air quality is a concern in the park. Horseshoe Bend is within a Class II airshed under the Clean Air Act, wherein modest increases in air pollution are allowed beyond baseline levels for particulate matter, sulfur dioxide, nitrogen and nitrogen dioxide, provided that the NAAQS, established by the EPA, are not exceeded. Although the cities to the west have improved in air quality within the past few years, in 2008 the federal ozone primary standard was lowered to 0.075 ppm for the eight-hour averaging time, fourth maximum value, averaged over three years (Federal Register, Vol. 63, No. 60). Because of that change imposing stricter requirements, there is concern that the Birmingham area may not remain in compliance.

Not surprisingly, several air quality issues were identified for Horseshoe Bend by DeVivo et al. (2008), including potential aerial deposition of (toxic) metals, high risk of foliar injury based on air quality conditions, and Sum06 and W126 indices that frequently or consistently surpassed the NPS air quality thresholds identified in Tables 9-12. Overall, the National Park Service has evaluated the air quality of Horseshoe Bend to be of significant concern based on the four NPS indices (Figure 26).

It should also be noted that the park occasionally can be affected by smoke from wildland fires considerable distances away. For example, in 2007 the National Weather Service reported that significant wildland fires which developed across southern Georgia and northern Florida in mid-April through May of 2007 pushed a smoke plume into central Alabama. The resulting hazy and smoky conditions lasted several days.

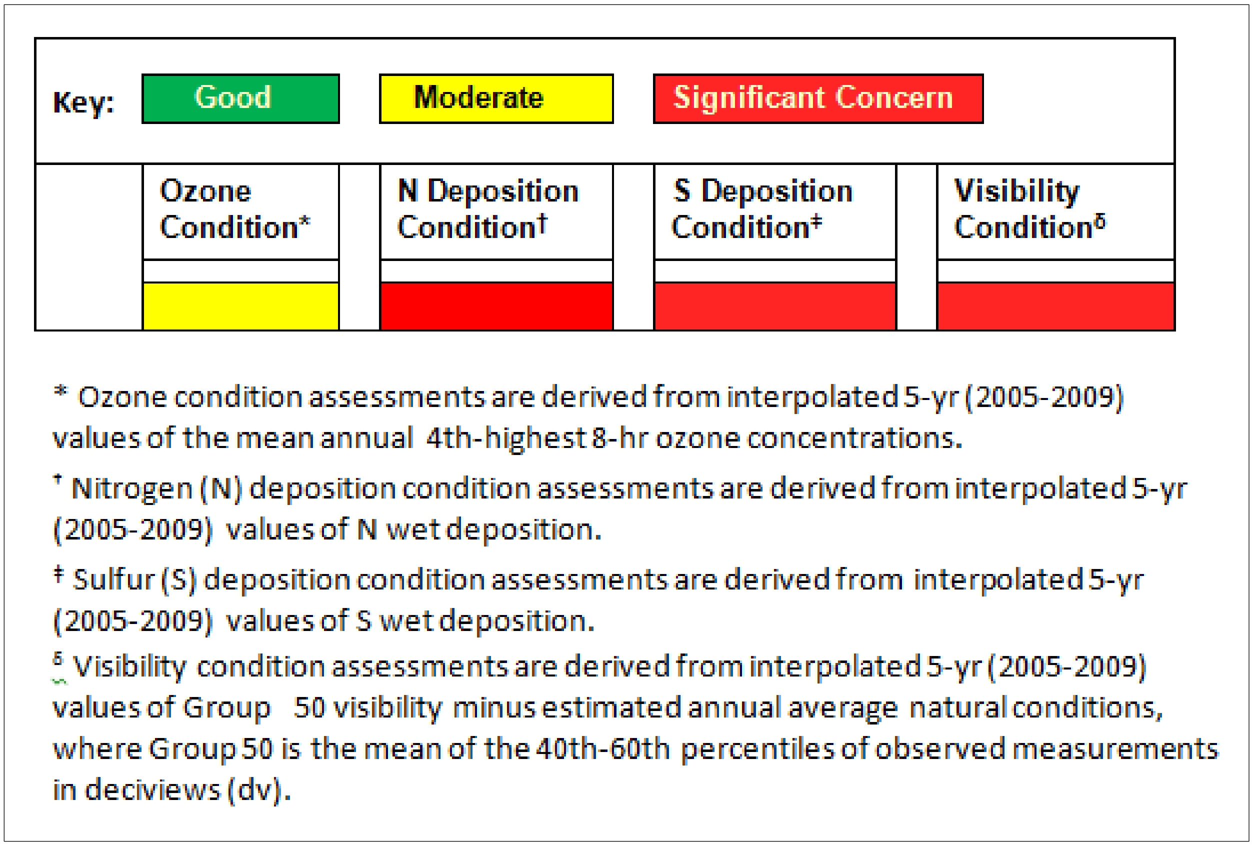

Figure 26. Evaluation of air quality conditions (2005–2009) at HOBE (NPS 2014a). Air quality condition is represented by color: Good = Green, Moderate = Yellow and Significant Concern = Red.

3.3. Soundscape

3.3.1. Some Definitions and Interpretations

Sound is defined as an auditory sensation perceived by humans, and created by pressure variations that move in waves through a medium such as air or water (NPS 2015e). Sound is measured in terms of frequency and amplitude. Noise is defined as sound(s) that is unwanted or inappropriate in an environment. Frequency (sometimes referred to as pitch; units, hertz [Hz]) is the number of times per second that a sound pressure wave repeats itself. Humans with normal hearing can hear sounds ranging from 20 to 20,000 Hz; bats can hear up to 120,000 Hz. Amplitude is defined as the relative strength of sound waves (or transmitted vibrations), perceived as loudness or volume. Amplitude, or the sound pressure level (intensity), is measured in decibels (dB). The terms dB(A) or dB(C) designate two frequency-response functions (weighting characteristics) that filter sounds detected by a microphone in a sound level meter. Each emphasizes or de-emphasizes sounds of certain pitches relative to others (Figure 27).

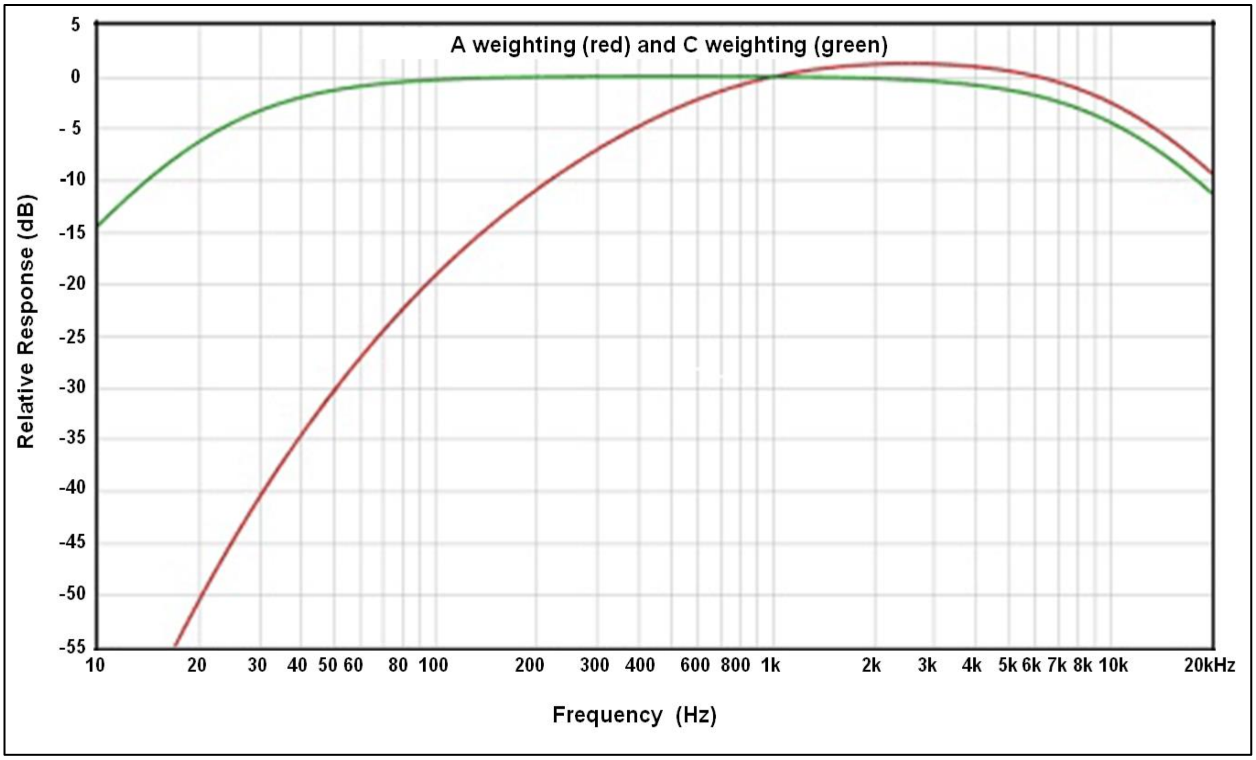

Figure 27. Influence of A- and C-weighting curves on the relationship between dB and frequency (pitch, Hz; modified from http://www.sengpielaudio.com/calculator-dba-spl.htm, last accessed in May 2015).

The "A" weighting, germane to Horseshoe Bend, filters out the low frequencies and slightly emphasizes upper-middle frequencies at ~2 to 3 kilohertz (kHz). A-weighting, used to assess noise impacts on wildlife, measures hearing risk and compliance with Occupational Safety and Health Administration and Mine Safety and Health Administration regulations that specify permissible noise exposures as a time-weighted average sound level or daily noise "dose" that can be tolerated without appreciable health risks. Thus, the World Health Organization has recommended that outdoor environmental noise should not exceed 55 dB(A) and 40 dB(A) for daytime and nighttime activity, respectively, to prevent potential adverse psychosocial and physiological effects. For perspective, the lower threshold of human hearing is 0 dB; moderate sound levels (e.g. normal speaking voice) are less than 60 db; a typical suburban area is ~50-60 dB(A); thunder is ~100 dB(A); and a military jet flying at ~100 m above ground level is ~120 dB(A; NPS: see above website, and Crocker 1997).

Because dB are on a logarithmic scale, an increase of 10 dB causes a doubling of perceived loudness and represents a ten-fold increase in sound level. Sound levels adjusted for human hearing are expressed as dB(A). "Soundscape" is used here in accord with the NPS definition, that is, the human perception of these physical sound resources. The acoustical environment is the combination of all of the acoustic resources within a given area, including both natural and non-natural (human-caused) sounds. Thus, it is important to consider the entire acoustical environment in efforts to protect natural sounds.

Sound is an important component of natural park ecosystems; the acoustical environment influences a wide array of animal behavior, such as finding desirable habitat and mates, avoiding predators, protecting young, and establishing territories (Lynch et al. 2011, and references therein; NPS 2015c). National parks in all regions of the U.S. are under increasing noise pressure from ground transportation, air transportation, and other human activities (Monroe et al. 2007, Lynch et al. 2011). For example, noise levels in park transportation corridors are ~1,000-fold higher than natural sound levels (Barber et al. 2009). Noise from airplanes can cause as much as a 70% reduction in the size of the hunting area where predatory animals are able to hear their prey (Barber et al. 2009, Bell et al. 2009). There is no question that parks are becoming noisier from human activities, even in remote areas, in conflict with the fact that ~70% of Americans have indicated that one of the most important reasons for preserving national parks is to provide opportunities to experience natural peace and the sounds of nature (Haas and Wakefield 1998). The problem is growing to the extent that national parks are presently sustaining what has been described as "an ongoing acoustic assault" by human-related noise (see above website). Thus, the National Park Service has determined that "Increasingly, careful consideration of the impacts of human-generated noise on wildlife is a critical component of management for healthy ecosystems in our parks (NPS 2015c)."

Wildlife, like humans, is stressed by the increasing noise and must adapt. As examples, robins in suburban and urban environments are now singing at night in order to be heard by other members of their population (Fuller et al. 2007); males of at least one frog species have adapted to traffic noise by calling at a higher pitch, although females have been shown to prefer lower-pitched calls which apparently are indicative of larger, more "fit" males; bats avoid hunting in areas with road noise (Barber et al. 2009, Parris et al. 2009). Noise stress can exacerbate the impacts of other stressors in national parks, with important ramifications for wildlife populations.

3.3.2. The Horseshoe Bend Soundscape

Human-related environmental noise reaches Horseshoe Bend from sources such as aircraft, construction, trains, and road traffic. The NPS Management Policies and Director's Order #47, *Sound Preservation and Noise Management*, call for and direct the protection of the natural ambient soundscape so as to minimize and optimally manage noise, defined as unwanted sound, especially dissonant human-caused sounds. However, most noise sources measured in national parks (e.g., highways, airplane traffic) originate outside park boundaries, beyond NPS management jurisdiction (Lynch et al. 2011). The National Park Service recognizes that no single metric is adequate to characterize acoustic resources; thus, the Natural Sounds and Night Skies Division of the National Park Service works with several metrics and considers SPL data, spectral data, audibility data, source identification data, and meteorological data (Lynch et al. 2011). Horseshoe Bend is a predominantly rural area, with generally minor noise pollution. Data on the soundscape of Horseshoe Bend are not available, but Superintendent Doyle Sapp (pers. comm., April 2013) described human-related environmental noise (e.g. from Highway 49) as minimal, and stated that the park is generally very quiet.

3.4. Lightscape

Light pollution is considered here as the upward "spill" of light that is scattered and reflected by water vapor, dust, and other particles to create "sky glow" (NPS 2007; NPS 2014c). The National Park Service uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night.

The 2006 NPS Management Policies directs the NPS to conserve natural lightscapes, in part because protection of natural darkness is important for ecological integrity and sustainability - that is, the natural lightscape is critical for maintaining nocturnal habitat. Light from cities can be visible from more than ~322 km (200 miles) away (NPS 2007, and references therein). Thus, to maintain a natural nocturnal lightscape, it is essential to minimize the sky glow from artificial light. There is clear evidence that human health is adversely impacted by artificial light at night. Although research on light pollution's effect on wildlife is relatively sparse, the available studies suggest that artificial light also adversely affects the natural environment and the biological rhythms of flora and fauna. Nocturnal predators are especially affected, with "cascading" effects on prey species. Many bird species migrate at night and, thus, are prone to disorientation by artificial lights. Some biomes are more sensitive than others, such as wetlands, ponds, and shorelines.

The National Park Service is committed to minimizing light from park facilities at night, and to restricting the use of artificial light insofar as possible. As with noise pollution, the problem of artificial light pollution at night is caused by sources beyond National Park Service control. The burgeoning light pollution of the eastern U.S. has been increasing over time (Figure 28), although Horseshoe Bend thus far is at sufficient distance from urban centers to remain somewhat insulated from light pollution impacts. This observation has been made by park staff, unfortunately with little quantitative data. Although various instruments are available for measuring light in the night sky (NPS 2012b), few such data have been collected as of yet for national parks in much of the SECN. As an alternative for providing baseline information, here we consider the Bortle Dark-Sky Scale (BDSS, range 1-9). It was developed to assess light pollution using a numerical scale that is easily understood by the general citizenry, policymakers, etc. (Table 15). Truly dark skies typically have a BDSS of 7.1 to 7.5. According to Superintendent Doyle Sapp (30 April 2013), Horseshoe Bend is minimally impacted by light pollution, and its habitat generally is equivalent to typical, truly dark skies.

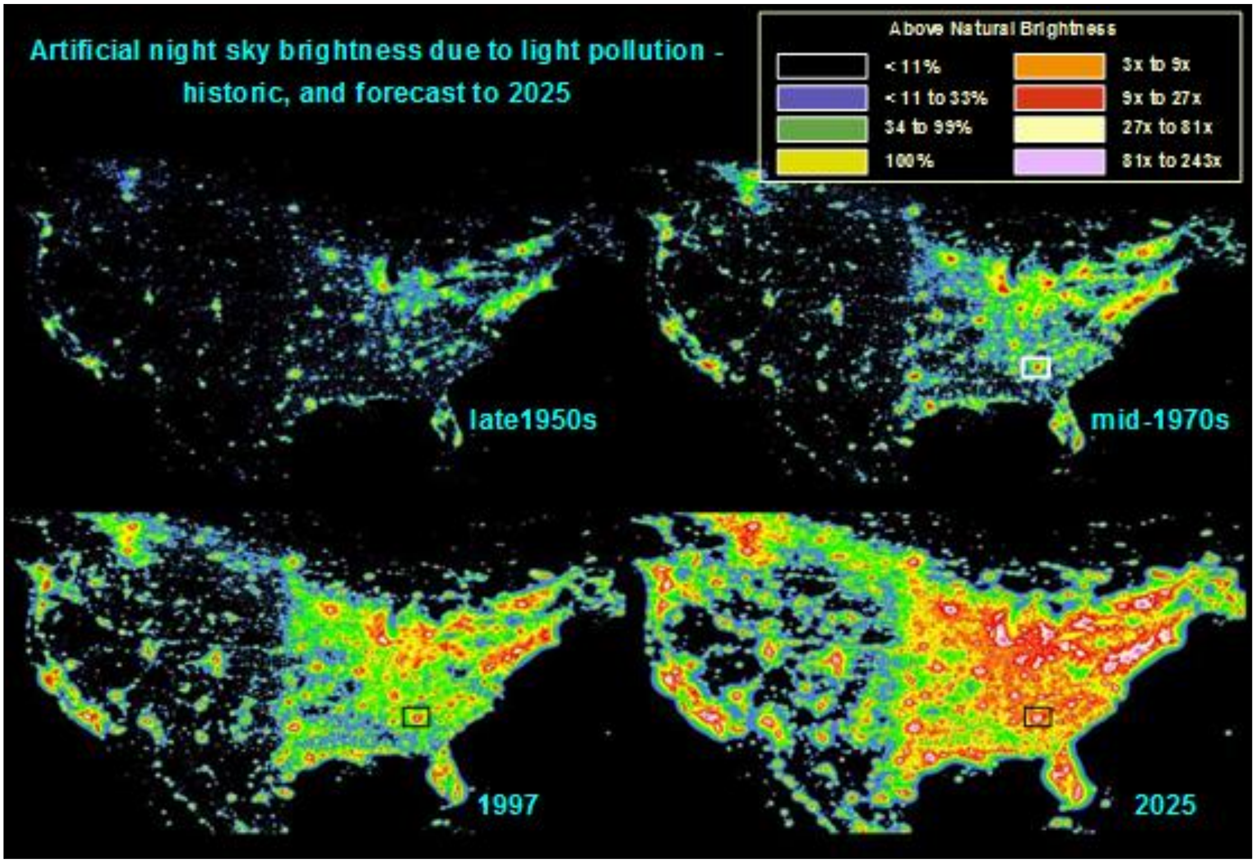

Figure 28. Artificial night sky brightness due to light pollution in the 1950s, 1970s, 1997, and projected to 2025. Modified from Cinzano et al. (2001).

Table 15. The Bortle Dark-Sky Scale for assessing artificial light pollution. The column labeled "Naked-eye Limiting Magnitude" indicates the dimmest stars visible under each class of light pollution. The larger the magnitude number, the dimmer the star. Each whole number represents a factor of 5 in brightness - thus, a magnitude-5 star appears to be five-fold brighter than a magnitude 6 star, whereas a magnitude-4 star appears to be ten-fold brighter than a magnitude-6 star (see Bortle 2001a,b; Big Sky Astronomy Club 2014).

Class	Color Key	Naked-eye Limiting Magnitude	Sky Descrip-tion	Milky Way (MW)	Astronomical Objects	Zodiacal Light/ Constellations	Airglow and Clouds	Night Time Scene
1		7.6 - 8.0	Excellent, truly dark skies	MW shows great detail and light from the Scorpio/Sagittarius region - casts obvious shadow on the ground	M33 (Pinwheel Galaxy) is an obvious object	Zodiacal light has an obvious color and can stretch across the entire sky	Bluish airglow is visible near the horizon and clouds appear as dark blobs against the backdrop of the stars	The brightness of Jupiter and Venus is annoying to night vision; ground objects are barely lit and trees and hills are dark
2		7.1 - 7.5	Typical, truly dark skies	Summer MW shows great detail and has veined appearance	M33 is visible with direct vision, as are many globular clusters	Zodiacal light bright enough to cast weak shadows after dark and has an apparent color	Airglow may be weakly apparent and clouds still appear as dark blobs	Ground is mostly dark, but objects projecting into the sky are discernible
3		6.6 - 7.0	Rural sky	MW still appears complex, dark voids and bright patches and meandering outline are all visible	Brightest Globular Clusters are distinct, but M33 only visible with averted vision; M31 (Andromeda Galaxy) obviously visible	Zodiacal light is striking in spring and autumn, extending 60 degrees above the horizon	Airglow is not visible and clouds are faintly illuminated, except at the zenith	Some light pollution evident along the horizon; ground objects are vaguely apparent
4		6.1 - 6.5	Rural/ suburban transition	Only well above the horizon does the MW reveal any structure; fine details lost	M33 is difficult to see, even with averted vision; M31 still readily visible	Zodiacal light is clearly evident, but extends less than 45 degrees after dusk	Clouds faintly illuminated except at the zenith	Light pollution domes are obvious in several directions; sky is noticeably brighter than the terrain
5		5.6 - 6.0	Suburban sky	MW appears washed out overhead and is lost completely near the horizon	The oval of M31 is detectable, as is the glow in the Orion Nebula	Only hints of zodiacal light in spring and autumn	Clouds are noticeably brighter than the sky, even at the zenith	Light pollution domes are obvious to casual observers; ground objects are partly lit
6		5.1 - 5.5	Bright suburban sky	MW only apparent overhead and appears broken as fainter parts are lost to sky glow	M31 is detectable only as a faint smudge; Orion Nebula is seldom glimpsed	Zodiacal light is not visible; constellations are seen and not lost against a starry sky	Clouds anywhere in the sky appear faintly bright as they reflect back light	Sky from horizon to 35 degrees glows with grayish color; ground is well lit
7		4.6 - 5.0	Suburban/ urban transition	MW is totally invisible or nearly so	M31 and the Beehive Cluster are rarely glimpsed	The brighter constellations are clearly recognizable	Clouds brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color

Table 15 (continued). The Bortle Dark-Sky Scale for assessing artificial light pollution. The column labeled “Naked-eye Limiting Magnitude” indicates the dimmest stars visible under each class of light pollution. The larger the magnitude number, the dimmer the star. Each whole number represents a factor of 5 in brightness - thus, a magnitude-5 star appears to be five-fold brighter than a magnitude 6 star, whereas a magnitude-4 star appears to be ten-fold brighter than a magnitude-6 star (see Bortle 2001a,b; Big Sky Astronomy Club 2014).

Class	Color Key	Naked-eye Limiting Magnitude	Sky Descrip-tion	Milky Way (MW)	Astronomical Objects	Zodiacal Light/ Constellations	Airglow and Clouds	Night Time Scene
8		4.1 - 4.5	City sky	MW is not visible at all	The Pleiades Cluster is visible, but very few other objects can be detected	Dimmer constellations lack key stars	Clouds brilliantly lit	Entire sky background has an orangish glow and it is bright enough to read at night
9		4.0 at best	Inner city sky	MW is not visible at all	Only the Pleiades Cluster is visible to all but the most experienced observers	Only the brightest constellations are discernible and they are missing stars	Clouds brilliantly lit	Entire sky background has a bright glow, even at the zenith

3.5. Geology and Soils

3.5.1. Geologic Resources

The information for Section 3.5.1 of this Natural Resources Inventory is largely taken from the scoping summary document (KellerLynn 2013), along with Miller (1990) and Rasmussen et al. (2009). Horseshoe Bend is located in a transitional area where the eastern Blue Ridge physiographic province meets the Northern Piedmont Upland physiographic province, in the immediate vicinity of the Brevard Zone which is a large strike-slip fault zone that was last active ~325 million years ago (mya; KellerLynn 2013). Horseshoe Bend is on the northwest side of the Brevard Zone (Figure 29). The Piedmont province is characterized by complex sequences of igneous and metamorphic rocks, collectively called crystalline rocks, of Paleozoic to Precambrian age (Journey and Atkins 1996, USGS 1997; Appendix 1). The bedrock materials are granite, gneiss, and schists. The metamorphic rocks, which originally were sedimentary, volcanic and volcaniclastic, have been altered by several stages of regional metamorphism to slate, phyllite, schist, gneiss, quartzite, and marble. They are extensively folded and faulted. The igneous rocks are intrusive, comprised mostly of granites with lesser amounts of diorite and gabbro. These rocks are characterized by a complex outcrop and subsurface distribution pattern.

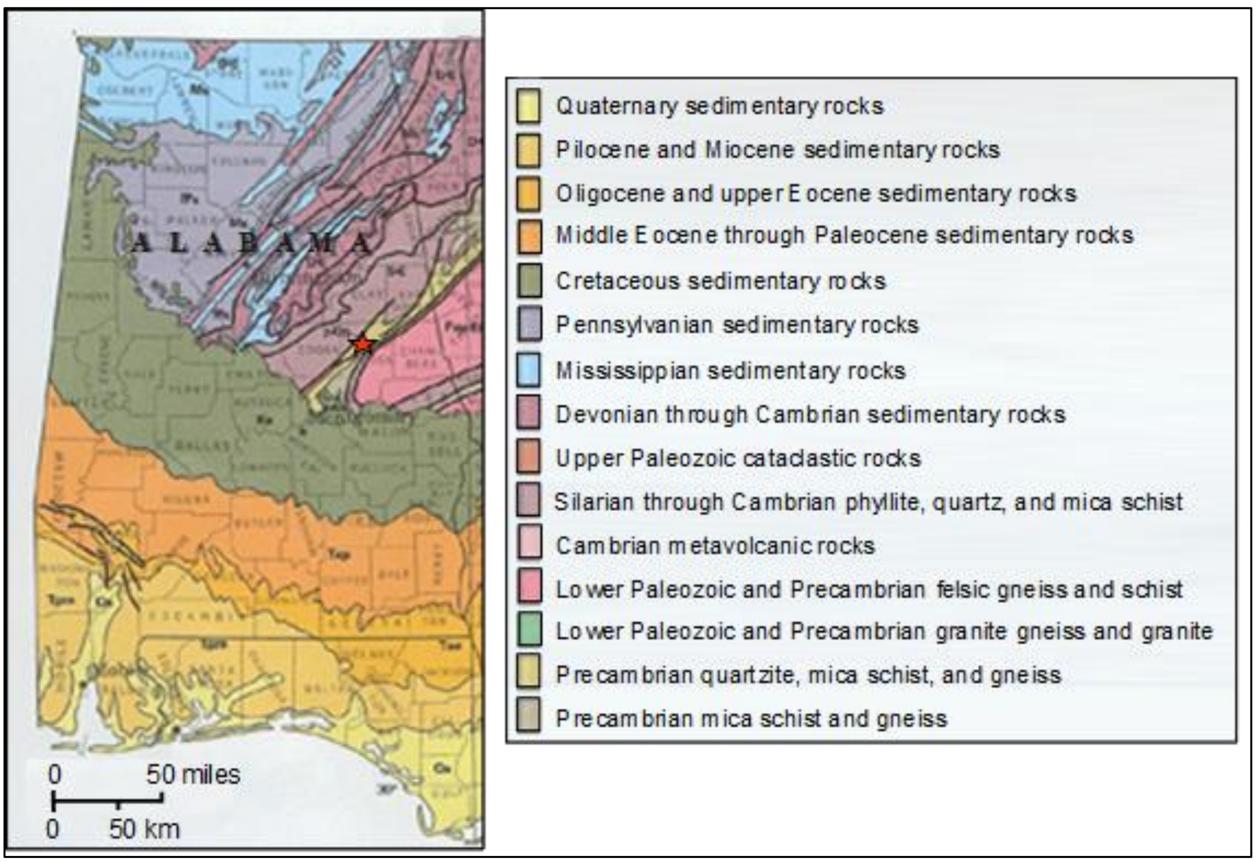

Figure 29. Map of the geology of the general Park area (star - HOBE, including quartzite, mica schist, and gneiss; green lines - faults). Modified from Miller (1990).

The Piedmont contains major fault zones that generally trend northeast-southwest and form the boundaries between the major rock groups (Journey and Atkins 1996, GA EPD 1998). The crystalline igneous and metamorphic rocks mostly are covered by a layer of weathered rock and soil called regolith, which ranges from about a meter to more than 45.7 m (a few feet to more than 150 ft) in thickness, depending on the type of parent rock, the topography, and the hydrogeologic history. From the land surface, the regolith consists of a porous, permeable soil zone that grades downward into a clay-rich, relatively impermeable zone that overlies and grades into porous, permeable saprolite. This formation is often referred to as a transition zone (Heath 1989), and it, in turn, grades downward into unweathered bedrock. The massive granite and gabbro rocks generally are poorly fractured and have a thin soil cover, whereas the schists and gneisses are moderately to highly fractured. Weathering of the rocks is erratic and usually deep (Journey and Atkins 1996).

The Geologic Resources Inventory (GeRI), administered by the NPS GRD, recently completed a geologic scoping meeting and summary document for Horseshoe Bend, along with a digital geologic map and a Geologic Resources Inventory report. Jacksons Gap Group (phyllite, schist, and quartzite) is part of the Brevard Zone (Szabo et al. 1988). Emuckfaw Group (schist and gneiss) and Kowaliga Gneiss are part of the Blue Ridge province. Zana Granite intruded the Kowaliga Gneiss in the vicinity of the park. The Emuckfaw Zana Group was named for exposures along Emuckfaw Creek, northwest of Horseshoe Bend. The Brevard Zone contains many different rock types juxtaposed by numerous faults. The underlying bedrock consists of a complex mix of metamorphic and igneous rocks, mainly gneiss and schists (the latter mostly characterizing Horseshoe Bend; Figure 30) but extremely fine-grained rocks such as phyllite and metamorphosed volcanic tuff, ash, and flows are common in some areas, and locally quartzite and marble are also present (Rasmussen et al. 2009). As examples, the Katy Creek and Abanda faults bound the Jacksons Gap Group of rocks (Steltenpohl et al. 1990). The Jacksons Gap Group contains phyllite, schist, and quartzite. Quartzite, which is very resistant to weathering, forms distinctive ridges such as Cherokee Ridge in the area. Phyllite, which is more easily eroded than quartzite, forms ravines. Movement along faults in the Brevard Zone caused the rocks of the Blue Ridge, such as the Emuckfaw Group and Kowaliga Gneiss, to rise up in the Horseshoe Bend area. These units slope to the east, with the Emuckfaw Group overlying the Kowaliga Gneiss (Neathery and Reynolds 1975).

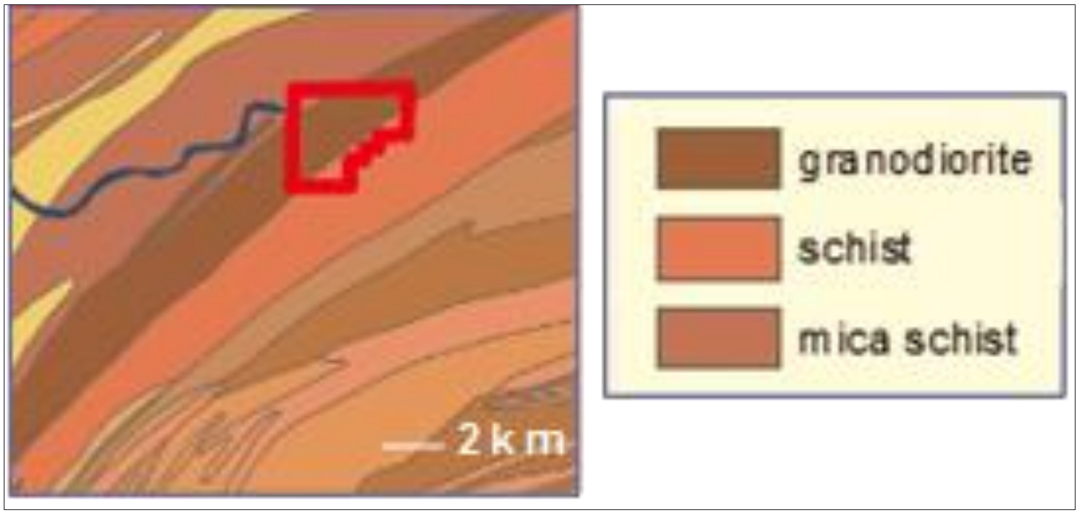

Figure 30. Map of simplified geology of the Park showing granodiorite, schist, and mica schist. From the NCSU CAAE (S. Flood).

All rocks within the park are Paleozoic in age (542 to 251 mya). Most metamorphic rocks were once sediments; some were originally igneous or volcanic, and some contain ore-bearing mineralized zones (Rasmussen et al. 2009). All of the metamorphic rocks have been intruded by igneous rock that varies from felsic (light in color, with large quantities of silica) to mafic (dark in color, with large amounts of ferromagnesian minerals). Large igneous intrusions consist of granite, quartz monzonite, and gabbro. Smaller intrusions such as dikes and sills consist of both felsic and mafic rocks, including syenite, andesite, diabase, and pegmatite. The rocks are displaced by several major fault zones as mentioned, some of which extend for hundreds of kilometers. Shearing along large fracture zones has also produced siliceous, intensely fractured rocks such as mylonite or phyllonite.

Horseshoe Bend contains one rock shelter, Wilson's Rock, which occurs in overhanging bedrock on the western side of the park. Rock shelters usually form from weathering of crystalline bedrock. There is occasional seismic activity in the general area, such as an earthquake of magnitude 2.3 on the Richter scale that occurred on 15 October 2012 ~100 km (60 miles) north of the park (USGS 2013b). Mining activities have not been conducted in the park, except for gravel that previously was mined from a pit to supply road materials. The pit, not used for many years, has mature trees growing on it. Any fossils that may occur in the park are Quaternary in age (past 2.6 million years) and associated with Tallapoosa River deposits. If present, these fossils (algal cysts, pollen, leaves, wood etc.) could be used for paleoclimatological and paleoecological studies (Tweet et al. 2009).

3.5.2. Soils and Erosion

The Piedmont province includes soils that have been derived in place through weathering of the varied igneous and metamorphic rocks; and floodplains or recently deposited soils of stream bottoms. Soils form 93.7% and water forms 6.3% of the park area, and consist mainly of well-drained reddish loams and clays.

The clay-rich soils of the Tallapoosa watershed are almost entirely within the southern Piedmont major land-resource area (previously called a soil province; Appendix 1). The soils developed mostly from gneiss schist, mica schist, and phyllite. The soils have a gravelly sandy loam surface layer and a yellowish red to red, loamy to clayey subsoil, with higher mica content than typical for the southern Piedmont (Journey and Atkins 1996, GA EPD 1998). Most of the area has slopes of less than 10%, but the slopes cover a wide range. The dominant soils have deep red clay subsoil and occur mostly on the broader ridges. Steeper hillsides are mostly shallow soils overlying soft bedrock of mica schist and phyllite, and these soils have a gravelly fine sandy loam surface layer and yellowish red loamy subsoil.

Three soils comprise more than 40% of the total area with soil coverage. These include ToA, the Toccoa fine sandy loam (0-2%, occasionally flooded = 18.4%); PrDZ, the Pacolet-Rion complex (15-25% slopes, moderately eroded, stony = 13.5%), and PrEZ, the Pacolet gravelly sandy loam (6-15% slopes, moderately eroded = 11.7%; Figure 31). Of the 21 soil types included in Horseshoe Bend, 12 (57%) are characterized as moderately eroded, and six (29%) are described as rarely to frequently flooded. The soils of the floodplains province represent stream bottomland recently deposited from overflow water. This soil material has been washed from contiguous upland areas, and there is considerable textural variation in these soils (Smith and Avery 1910).

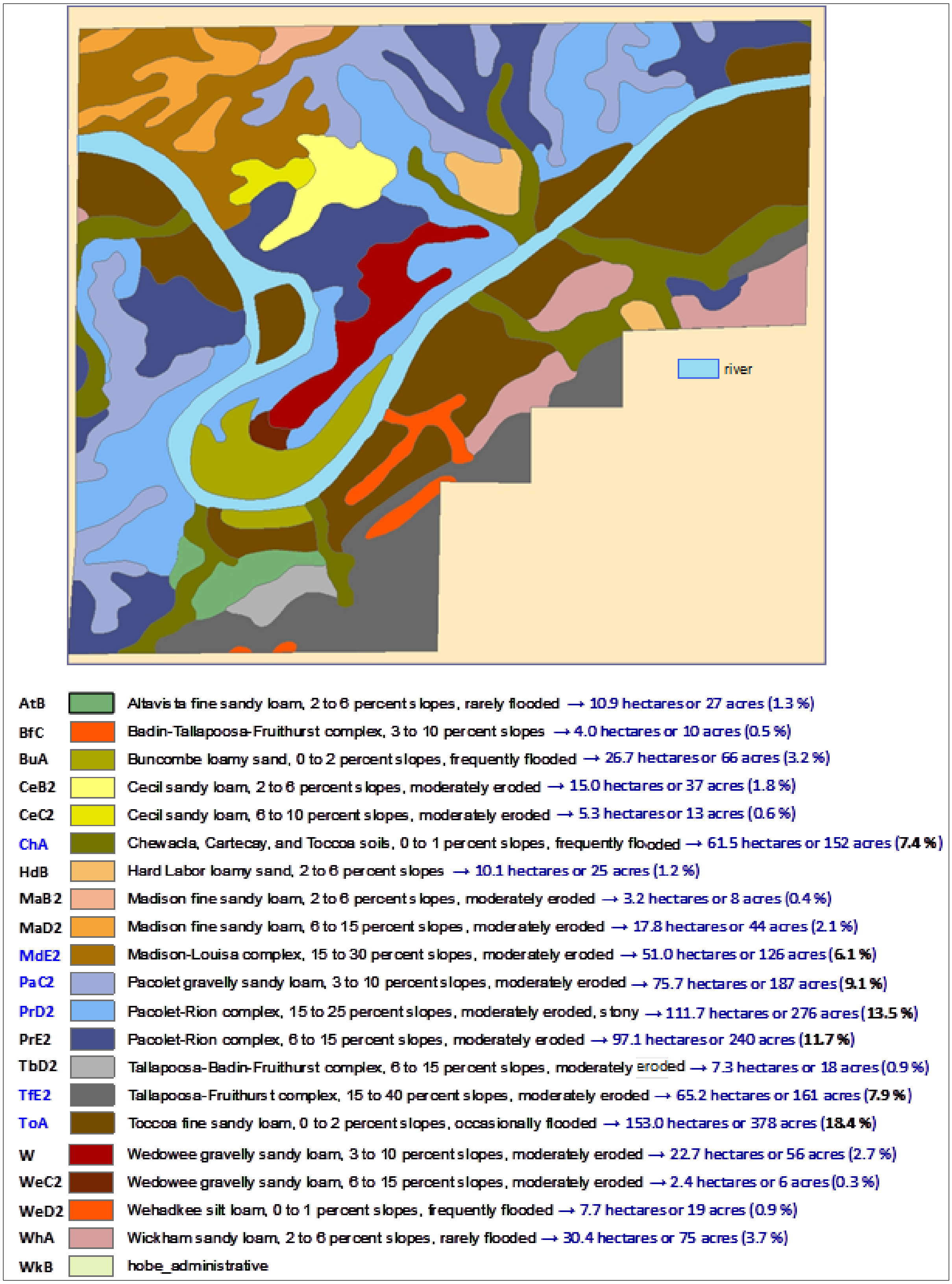

Figure 31. Simplified map of 21 soils in the Park (blue - most abundant). From the NCSU CAAE.

3.5.2.1. General Soil Erodibility:

At present the banks along the Tallapoosa River within the park are minimally disturbed by natural streambank erosion or sloughing (KellerLynn 2013). The stream bank along the river at the Tohopeka Village site appears less stable than other areas and may be related to removal of trees (Brown et al. 2004). As mentioned above, however, more than half of the soils in the park are characterized as moderately eroded, and nearly a third are occasionally to frequently flooded, indicating that water levels commonly change (and see Section 3.6 of this Report). Both characteristics typify the three most abundant soils in Horseshoe Bend (ToA, PrDZ, and PrEZ).

Streambank erosion occurs when stream channels widen to accommodate and transport increased, sudden ("flash-flood" or "flashy") runoff and higher stream flows from developed areas with elevated impervious area (GA DNR 2001). The runoff events scour and undercut the lower areas of the streambank, causing steeper banks to "slump" and collapse during moderate and major storms. The soil loss from eroded banks contributes to already-high sediment loads, much of which is deposited during larger storms. Trees along the streambanks become weakened as the erosion progresses, so that some of their major roots are exposed and they can be more easily uprooted and washed away, further destabilizing the streambank. The floodplain elevation for the stream commonly increases as the watershed is developed, due to higher peak flows. This problem is exacerbated by building and filling in floodplain areas. Thus, over time as the upper and middle Tallapoosa River watershed continue to sustain activities such as silviculture, clear-cutting, and other land disturbance for development, streambank erosion along the Tallapoosa River is expected to increase.

3.6. Water Resources

The middle Tallapoosa River drains mostly rural and forested lands between dams and hydropower facilities at two run-of-river impoundments: Harris Lake is 32 km (20 miles) upstream near Linville, AL, built and operated by the Alabama Power Company), and Lake Martin's dam near Alexander City, ~40 km (25 miles) downstream. The Alabama Power Company regulates water release and river flow entirely for electrical purposes at Harris Dam, 56 km (35 miles) above the park boundary. The present water release regime causes extreme river fluctuations, typically more than 1 m (several ft.) per day (NPS 2008). More specifically, peak power generation activities at the R.L. Harris Dam has been described to result in two high water events per day, causing river levels to fluctuate as much as 1.5- 1.8 m (5-6 ft.; DeVivo 2004). Thus, since the upstream dam was constructed in 1980, the river segments downstream, including the park area, have been subjected to changes in river flow from as low as zero to 453 cubic meters per second (cms; or 16,000 cubic feet per second, cfs). The park has no control over this highly regulated, often-extreme artificial flow regime. The dam likely is also partially responsible for increased flooding during heavy rains, when the captured water of Harris Lake is released too rapidly to the downstream Tallapoosa River (NPS 2008). Such severe floods threaten the natural lowland ecosystems of the park, as well as the stability of its roads, trails, and cultural resources (NPS 2008). Because of this highly stressed situation, the Tallapoosa River was in the Top Ten Most Endangered Rivers in America for 2003 (American Rivers 2012).

The upper Tallapoosa River system additionally has been targeted as a potential source of potable water for Atlanta, Ga. through interbasin transfer (GA DNR EPD 1998). The ongoing “water wars” between Georgia, Alabama, and Florida create what the Horseshoe Bend Strategic Plan (NPS 2008) described as “a tremendous unknown to the flow quantity of the Tallapoosa River as it traverses the park.”

A 5.9-km (3.7-mile) segment of the Tallapoosa River flows through Horseshoe Bend. In this area the river is a relatively deep channel marked by several shoals, habitat features that characteristically support high faunal diversity (Irwin and Freeman 2002). The horseshoe-like bend in the Tallapoosa River is an entrenched (incised) meander that cut into phyllite bedrock as the channel shifted over time. The meander likely formed under conditions of rapid vertical uplift or lowering of base level (Neuendorf et al. 2005). The park also contains a small spring-fed perennial and several intermittent streams that only flow during flood events. Nevertheless, park staff has expressed concerns about runoff problems from springs that affect a parking lot near the battlefield (Rasmussen et al. 2009). The park’s wetlands have not been well characterized, but they were recently delineated using GIS and occur as narrow fringes of swamp forest mostly along the river.

The town of New Site now supplies water for the park. The water is chlorinated and, thus, is not a risk from fecal bacteria. Groundwater resources in the park appear to be plentiful, but data are not available to assess groundwater quantity or quality.

3.6.1. Surface Water

3.6.1.1. Hydrology:

Hydrologic features such as stream flow characteristics provide what have been described as:

“some of the most appropriate and useful indicators for assessing aquatic ecosystem integrity, and for monitoring environmental changes over time.[They] also provide key support data for other vital signs indicators including water quality, threatened and endangered aquatic species, wetlands, and riparian habitat. The hydrologic output of a watershed is a function of land characteristics, human use, weather and climate conditions, urbanization, and soil characteristics. Hydrologic variation plays a key part in structuring the biotic diversity within river ecosystems by controlling critical habitat conditions within the river channel, the floodplain, and hyporheic zones…” (Gregory et al. 2012).

The Tallapoosa River, the major perennial water body within Horseshoe Bend, is a fifth-order stream with a rock, silt, sand and gravel bottom interspersed with patches of organic matter (Burkholder and Rothenberger 2010). Some riffle areas occur, as well as areas of woody debris. Its flow is controlled mainly by water released by the R.L. Harris Dam below Lake Wedowee to the north. Other surface water resources in the park include two small springs: One emerges from a hill about 0.8 km (0.5 mile) from the top of Battlefield Hill, to the east (Figure 32, #1). A second small spring originates from a series of seeps near the second hill of the battlefield, and then becomes a small perennial stream (sometimes called Whale Creek; Jones et al. 2010) near visitor’s Stop 1 (Figure 32, #2). ERMF (2007) mapped the locations of various intermittent streams in the park (Figure 32).

Figure 32. Map of streams in the Park (boundary in white), which are intermittent except for those indicated by numbers. Modified from NPS SECN (2014); and see Appendix 1.

A comprehensive analysis of surface water quantity is lacking for HOBE (Jones et al. 2010). USGS gaging station 02414715 on the Tallapoosa River in HOBE (drainage area 5,330 km^2 or 2,058 miles^2) is listed by the USGS as located at the small community of New Site, Alabama (Figure 33). This station has been in operation since 1985, unfortunately post-construction of the Harris Dam. The next closest USGS gaging station upstream from the park is at Wadley, Alabama (#02414500; drainage area 4,338 km^2 or 1,675 miles^2), more than 30 km (19 miles) distant. This station has valuable historic information pre-dam construction, as it has been in operation since 1923. Therefore, Jones et al. (2010) considered both stations in their hydrologic analysis, summarized as follows.

Figure 33. USGS stream gaging stations in and near the Park. From the NPS SECN (2014).

Prior to construction of the Harris Dam, maximum discharge at the Wadley USGS station was ~1,897 cms (~67,000 cfs). Since the dam has been in place, maximum discharge greater than 2,832 cms (100,000 cfs) has been recorded (in May 2003). Maximum discharge at Horseshoe Bend also exceeded 2,832 cms in May 2003. Flow duration curves indicate that prior to dam construction, there was a less than-1% probability that average daily flow would exceed 1,133 cms (40,000 cfs), and there was a greater than-50% probability that the average daily flow would be less than ~142 cms (5,000 cfs). Post-dam construction, there was a less than-1% probability that the average daily flow would exceed 567 cms (20,000 cfs), and there was a greater than-50% probability that the average daily flow would be less than 142 cms (5,000 cfs). However, high flow events may occur at higher probabilities than indicated, since the data fell above the predicted distribution of high flow return frequency (log Pearson III analysis). Although the two USGS stations were somewhat similar in their recordings of flow events, the land area drained at New Site near Horseshoe Bend is ~1,000 km^2 (~385 $miles^2$) more than at the Wadley station. Thus, high flow events during 1987-1991 reached a maximum of ~1,700 cms (60,000 cfs) at Wadley, versus 2,265 cms (80,000 cfs) at New Site/ Horseshoe Bend (Jones et al. 2010).

The NPS Vital Signs Monitoring Program evaluated stream flow variation and the magnitude and timing of specific flow at both USGS gaging stations on the Tallapoosa River during 2010. Flow patterns were characterized within the context of USGS stream flow, the Nature Conservancy's (2009) Indicators of Hydrologic Alteration (IHA) software, and program Flow (Dowd 2011; Table 16). The IHA software used single-period daily values in cfs to calculate nonparametric and parametric statistical metrics including mean monthly flow values and extreme event characterization and timing. IHA was also used to calculate EFCs, used to characterize natural flow and departures from natural conditions. EFCs characterize flow events that have become typical (over a long period such as many years) since perturbations such as diversions or development occurred (Table 16). The EFC procedure used by Gregory et al. (2012) set initial high flows as 75% of daily flows for the period of record used, and included the following three definitions:

- small floods ≡ events with a two-year return interval;
- large floods ≡ events with a 10-year return interval; and
- extreme low flows ≡ less than 10% of all flows for the period.

Table 16a. Indicators of Hydrologic Alteration Metrics and Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

Parameter Type	Definition	Potential Ecosystem Influences
Median Monthly Flow Conditions	Median daily value for each calendar month	• Habitat availability for aquatic organisms • Soil moisture availability for plants • Availability of water for terrestrial animals • Availability of food/cover for furbearing mammals • Reliability of water supplies for terrestrial animals • Access by predators to nesting sites • Water temperature, oxygen levels, photosynthesis in water column
Extreme Flow Conditions	1 to 90 day minimum and maximum flows	• Balance of competitive, ruderal, and stress- tolerant organisms • Creation of sites for plant colonization • Structuring of aquatic ecosystems by abiotic vs. biotic factors • Structuring of river channel morphology and physical habitat conditions • Soil moisture stress in plants • Dehydration in animals • Anaerobic stress in plants • Volume of nutrient exchanges between rivers and floodplains • Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments • Distribution of plant communities in lakes, ponds, floodplains • Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
Magnitude of Extreme Flow Conditions	Magnitude of 1 to 90 day high and low	• Compatibility with life cycles of organisms • Predictability/avoidability of stress for organisms • Access to special habitats during reproduction or to avoid predation • Spawning cues for migratory fish • Evolution of life history strategies, behavioral mechanisms

Table 16b. Indicators of Environmental Flow Components, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

Parameter Type	Definition	Potential Ecosystem Influences
Monthly Low Flows	Median low flow daily value for each calendar month	• Provide adequate habitat for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)

Table 16c. Indicators of Hydrologic Alteration Metrics, including potential ecosystem influences modified from the IHA User's manual (The Nature Conservancy 2009).

Extreme Low Flow and Low Flow Pulses	Frequency, duration and timing of low flows and low flow pulses	• Enable recruitment of certain floodplain plant species • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High Flow Pulses	Frequency, duration and timing of high flow pulses	• Shape and physical character of river channel, including pools and riffles • Determine size of streambed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries • Influences bedload transport, channel sediment textures, and duration of substrate disturbance high pulses
Small Floods	Frequency, duration and timing of small floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (i.e., insects) • Enable fish to spawn in floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplains

The algorithm makes three passes through the data: The 1st pass each day is assigned to either low flow or high flow initial event types; on the 2nd pass all days initially assigned as high flows are re-assigned to 1, 2, or 3 high flow classes (small floods, high flow pulses etc.); and for the 3rd pass, some of the initial low flow days are re-assigned to the extreme low flow class (the Nature Conservancy 2009 - IHA User's Manual). Annual stream flow features were described within historical flow context using the Flow program (Dowd 2011) which produces daily flow graphs (median monthly flow, interquartile range, and daily flow. Data were also interpreted within the context of existing resource data as defined by Horseshoe Bend staff.

3.6.1.2. Flow Conditions at the Wadley Gaging Station, Baseline Year 2010:

From a special "baseline" study during 2010, Gregory et al. (2012) reported that as would be expected, flow was highest in winter and early spring (especially February-March, due to late winter/ early spring rains), and lowest during late summer through early autumn (Figure 34). Based on IHA analysis, monthly median flow and low flow ranged from 6.9 cms (245 cfs - September) to 143.7 cms (5,080 cfs – February; Table 17). Low flow ranged from 11.3 cms (398 cfs - September) to 83.8 cms (2,960 cfs – February; Table 17). The minimum 1- to 90-day extreme flow ranged from 4.9 cms (173 cfs - 1 day) to 16.3 cms (575.3 cfs - 90 day; Table 18). The maximum 1- to 90-day extreme flow ranged from 192.3 cms (6,792 cfs - 90 day) to 512.5 cms (18,100 cfs - 1 day; Table 18). The peak extreme low flow condition (5.5 cms or 193 cfs - 13 events) lasted 1 day, whereas the peak in high flow pulse (148.1 cms or 5,230 cfs - 10 events) lasted 4 days (Table 19). Two small floods lasting 11.5 days occurred in March-April, with peak flow at 494.1 cms (17,450 cfs; Table 19). The park plans to build upon these data in subsequent years in order to better characterize hydrologic conditions in Horseshoe Bend.

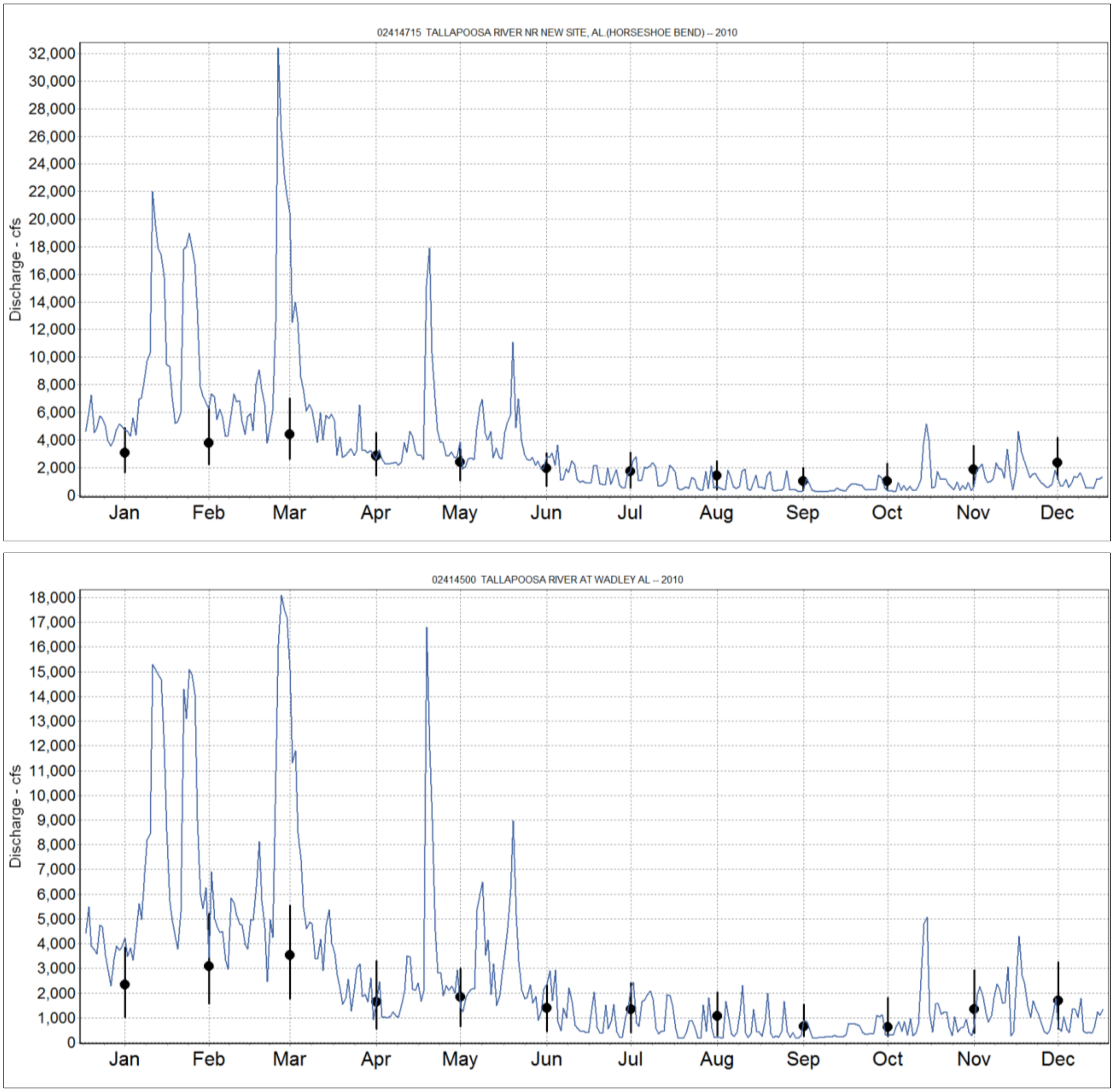

Figure 34. Daily flow in 2010 (blue line), median monthly flow (dots 2010 data), and interquartile range (error bars) for the Tallapoosa River at Wadley (upper panel) and New Site (nearest HOBE - lower panel).

Table 17. Monthly median and low flow magnitudes (in cfs) for the two USGS gaging stations nearest HOBE during 2010. Metrics were calculated using the IHA (The Nature Conservancy 2009) from daily data. Darker blue indicates higher flow magnitude; ** ≡ missing data.

Flow Magnitude	USGS ID	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Median	2414500	4,420	5,080	4,980	1,910	2,310	1,725	1,000	399	245	680	1,160	1,050
	2414715	5,580	6,730	6,570	3,000	3,430	2,460	1,480	561	357	544	1,140	1,190
Low	2414500	2,635	2,960	2,690	1,780	2,045	1,600	1,150	502	398	663	1,160	1,035
	2414715	3,570	**	3,790	2,895	2,740	2,160	1,480	561	399	615	1,140	1,160

Table 18. Extreme flow magnitudes (cfs, 1-day to 90-day) at the two upstream USGS gaging stations nearest HOBE during 2010. These metrics were calculated using IHA software (The Nature Conservancy 2009).

Flow Magnitude	USGS ID	1-day	3-day	7-day	30-day	90-day
Minimum	02414500	173	177	203	386.9	575.3
	02414715	249	257	269	461.4	675.8
Maximum	02414500	18,100	17,600	15,300	8,709	6,792
	02414715	32,400	27,330	21,540	11,160	8,821

Table 19. EFCs (The Nature Conservancy 2009) for flows (in cfs) at the USGS gaging stations nearest HOBE during 2010. Timing refers to the date of the first peak event.

	Extreme Low Flow				High Flow Pulses				Small Flood			
USGS ID	Frequency	Peak (cfs)	Duration (days)	Timing	Frequency	Peak (cfs)	Duration (days)	Timing	Frequency	Peak (cfs)	Duration (days)	Timing
02414500	13	193	1	5-Sep	10	5,230	4	10-May	2	17,450	11.5	8-Apr
02414715	6	283.5	1.5	26-Sep	11	5,950	3.5	4-May	1	32,400	17	12-Mar

3.6.1.3. Flow Conditions at the New Site Station Nearest Horseshoe Bend, Baseline Year 2010:
The flow pattern is similar at New Site as at Wadley, although usually much greater in magnitude (Figure 33). In 2010 the flow at New Site was highest in winter (especially February-March), and lowest during late summer through early autumn (Table 17, Figure 34). Based on IHA analysis, monthly median flow and low flow ranged from 10.1 cms (357 cfs - September) to 190.6 cms (6,730 cfs – February; Table 17). Low flow ranged from 11.3 cms (399 cfs - September; identical to that at the Wadley gaging station) to 107.3 cms (3,790 cfs - March; Table 17; note that February data were not available). The minimum 1- to 90-day extreme flow ranged from 7.1 cms (249 cfs - 1 day) to 19.1 cms (675.8 cfs - 90 day; Table 18). The maximum 1- to 90-day extreme flow ranged from 249.8 cms (8,821 cfs - 90 day) to 917.5 cms (32,400 cfs - 1 day; Table 18). The peak extreme low flow condition (8.0 cms or 283.5 cfs) lasted 1.5 days, whereas the peak in high flow pulse (168.5 cms or 5,950 cfs) lasted 3.5 days (Table 19). One small flood lasting 17 days occurred in March, with peak flow at 917.5 cms (32,400 cfs, almost double that at the Wadley station; Table 19).

3.6.1.4. Flow Conditions at the Two Upstream USGS Stations Nearest Horseshoe Bend, 2012:
Data for these EFCs were collected again at the two USGS stations in 2012 (Jones and Gregory 2013, NPS 2013a). Major findings were generally consistent with the 2010 baseline year, except that March, rather than February, had the highest median monthly flow, and August, rather than September, had the lowest median monthly flow (Figure 35, Table 20; note that low flow monthly conditions were not available in the two cited documents). In the drier year of 2012, the minimum 1- to 90-day extreme flows at the two stations were much lower (40% and 50% less at the Wadley and New Site stations, respectively) than in the 2010 baseline year (Tables 18 and 21). Maximum 1- to 90-day extreme flows during 2010 and 2012 were fairly comparable at the Wadley station (1 day - 2012: 512.6 cms or 18,100 cfs vs. 2012: 436.1 cms or 15,400 cfs).

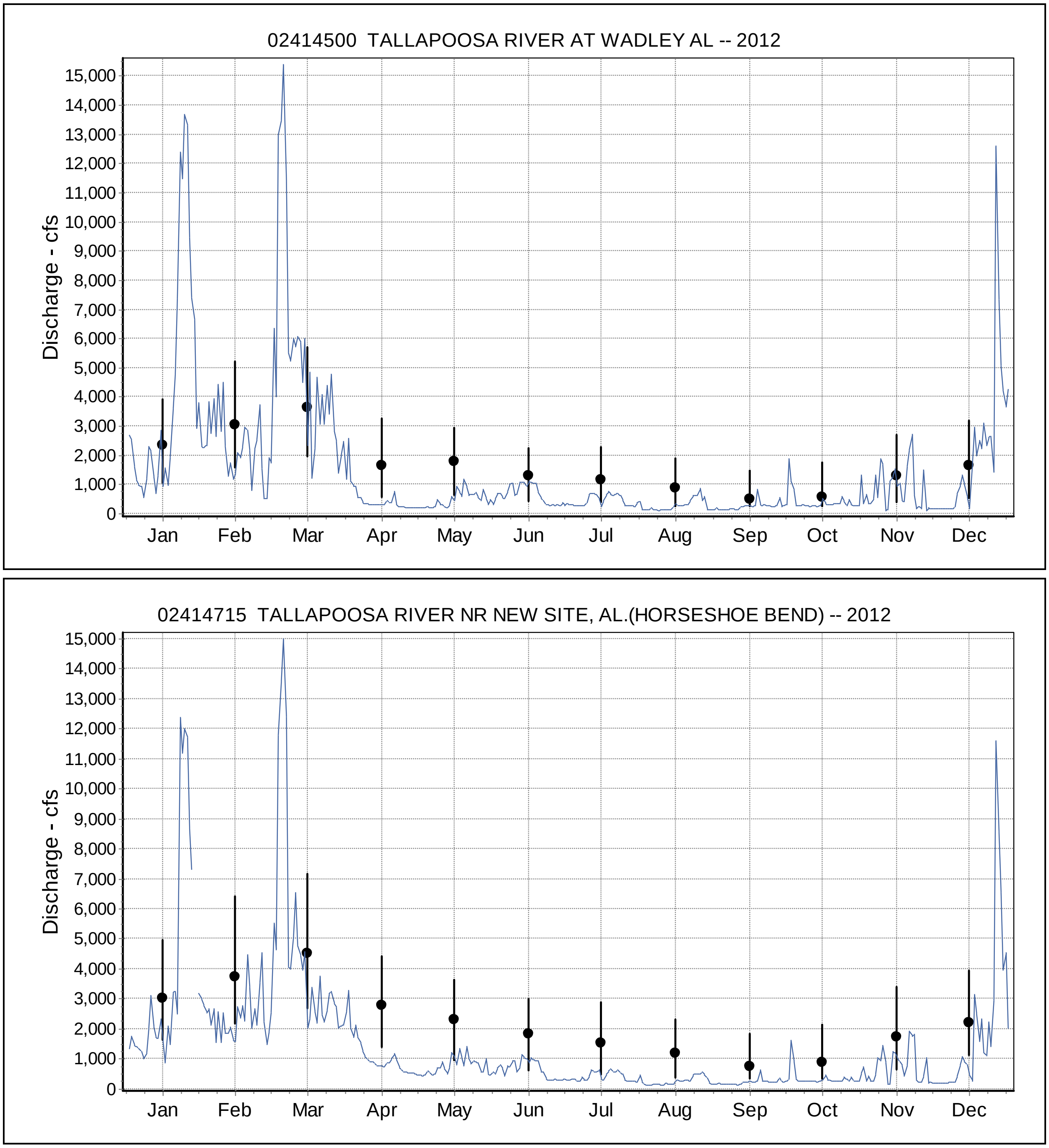

Figure 35. Daily flow in 2012 (blue line), historical median monthly flow (dots - 2012 data), and interquartile range (error bars) for the Tallapoosa River near Wadley (upper panel) and near New Site (Horseshoe Bend; lower panel). From Jones and Gregory (2013).

However, the maximum 1- to 90-day extreme flow in 2012 (1 day - 424.8 cms or 15,000 cfs) was less than half that during baseline year 2010 (917.5 cms or 32,400 cfs; Tables 18 and 21). The peak extreme low flow condition at the New Site station (424.8 cms or 15,000 cfs) was less than half that during baseline year 2010 (917.5 cms or 32,400 cfs; Tables 18 and 21). The peak extreme low flow condition at the New Site station nearest Horseshoe Bend (6.9 cms or 243 cfs) lasted 3 days; thus, this EFC was both lower than in baseline year 2010 and lasted twice as long (Tables 19 and 22). In contrast, the peak high flow pulse (328.5 cms or 11,600 cfs) during 2012 was about double that in 2010 (168.5 cms or 5,950 cfs) and lasted about a third longer (3.5 days in 2010 vs. 5 days in 2012). The frequency of extreme low flows and of high flow pulses differed from those in the baseline year especially at the New Site station (Table 22). In 2012, extreme low flows occurred 11 times at Wadley (USGS gaging station #02414500) and 18 times at New Site nearest Horseshoe Bend (USGS gaging station #02414715). The duration of high flow pulses was longest at the New Site station, as expected. Overall, daily flows were generally below the median for most of 2012, and were below the 25th percentile in April and much of August-October.

Table 20. Monthly median flow magnitudes (in cfs) for the Tallapoosa River in 2012, upstream from HOBE at the two USGS gaging stations. Median flow was calculated with IHA (The Nature Conservancy 2009) using daily USGS data. Darker blue color indicates higher flow magnitude. From NPS (2013) and Jones and Gregory (2013).

USGS ID	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2414500	2,300	2,270	4,490	313.5	442	641.5	397	152	261	301	545.5	1,440
2414715	1,950	2,230	3,280	729	572	622.5	335	201	227	269	630	1,090

Table 21. The 1- to 90-day extreme flow magnitudes (USGS data, cfs) for the Tallapoosa River in 2012, upstream from HOBE at the two nearest USGS gaging stations. Metrics were calculated using Indicators of Hydrologic Alteration software (The Nature Conservancy 2009).

Flow Magnitude	USGS ID	1-day	3-day	7-day	30-day	90-day
Minimum	2414500	104	128	135.4	234	314.8
	2414715	123	133.3	141.9	216.5	275.4
Maximum	2414500	15,400	13,970	10,740	5,266	3,914
	2414715	15,000	13,670	9,847	4726	3,644

Table 22. Environmental Flow Components for flows (in cfs) for the Tallapoosa River in 2012, upstream from HOBE at the two nearest USGS gaging stations. Timing refers to the average date (i.e., average of Julian dates) of a peak event if more than one occurred (NC ≡ timing was not calculated due to the distribution of Julian dates). From NPS (2013a) and Jones and Gregory (2013).

	Extreme Low Flow				High Flow Pulses				Small Flood			
USGS ID	Frequency	Peak (cfs)	Duration (days)	Timing	Frequency	Peak (cfs)	Duration (days)	Timing	Frequency	Peak (cfs)	Duration (days)	Timing
02414500	11	159	2	9/1	12	4480	1	NC	0	NC	NC	NC
02414715	18	243	3	10/19	5	11600	5	NC	0	NC	NC	NC

3.6.1.5. Wetlands:

Wetlands are defined as transitional lands between terrestrial and permanent (deeper) standing-water habitats (Cowardin et al. 1979). The water table in wetlands is at or near land surface, or the land is covered at times by shallow water. In the Tallapoosa River basin, most wetlands are forested floodplain systems, maintained by the natural flooding regime of rivers and streams (CH2MHILL 2005). This description is characteristic of the woody wetlands in Horseshoe Bend, which occur as narrow fringes along the Tallapoosa River (Figure 36). More than 20% of the vegetative cover in these wetlands consists of forest or shrub vegetation (Burkholder and Rothenberger 2010). The wetlands have not been well characterized, but a recent survey of plant species indicates that there is a rich diversity of wetland and aquatic plant species in the park (below).

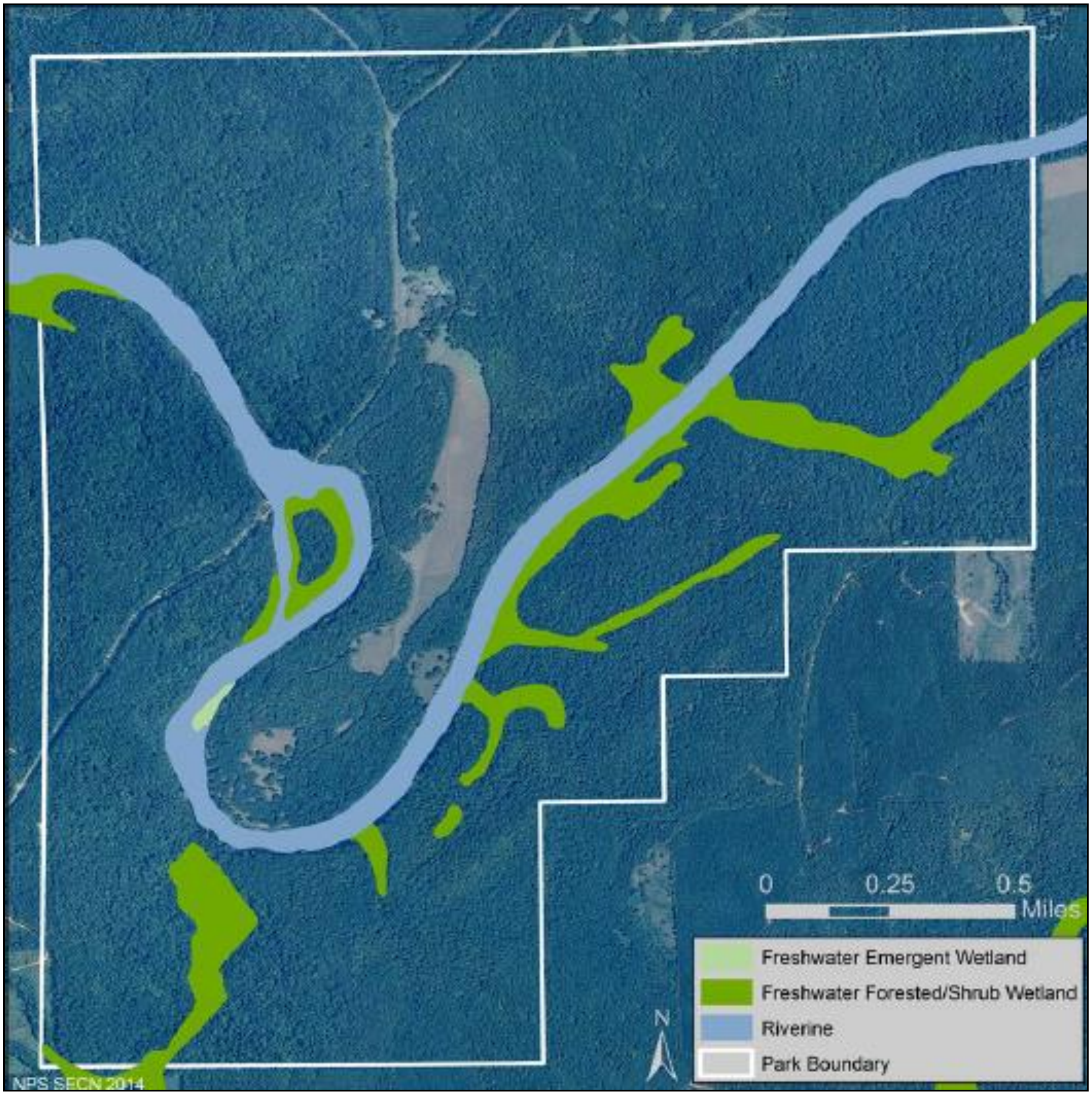

Figure 36. Map of wetland locations in the park. Map also shows the Tallapoosa River ('riverine,' in blue; USFWS 2011).

3.6.1.6. Surface Water Quality Criteria:

Following the Clean Water Act (33 U.S.C. 1251 et seq., the Federal Water Pollution Control Act as amended through P.L. 107-303, November 27, 2002), the state of Alabama has developed various standards (criteria) applicable to the surface waters of Horseshoe Bend with designated use for Fish and Wildlife (ADEM 2008b, 2013b). The description for the Fish and Wildlife use classification states that the "best usage of waters [is for] fishing, propagation of fish, [other] aquatic life, and wildlife, and any other usage except for swimming and water contact sports or as a source of water supply for drinking or food-processing purposes" (ADEM 2013b). For this designated use, the state has ambient water quality standards for common water quality parameters such as dissolved oxygen (DO), pH, turbidity, fecal bacteria, and enterococci bacteria (Table 23).

Other recommended guidelines for acceptable water quality have been published by the U.S. EPA (2000, 2002), Mallin (2000), and Mallin et al. (2006; e.g. Table 24). The Clean Water Act requires the U.S. EPA to develop criteria (or recommendations) for water, designed to protect aquatic life. The criteria are supposed to reflect accurately the up-to-date scientific knowledge. Whereas the State of Alabama has imposed regulations, a U.S. EPA water quality criterion is not a regulation; it does not impose legally binding requirements on the U.S. EPA or the states. States have discretion to adopt approaches that differ from the U.S. EPA water quality criteria, but these criteria are meant to provide useful guidance.

Table 23. In-stream water quality standards for non-coastal surface waters with designated use as Fish and Wildlife (ADEM 2013b).

Parameter	Acceptable Conditions
Temperature	Maximum shall not exceed 90°F [32°C]; maximum in-stream temperature rise above ambient due to the addition of artificial heat by a discharger shall not exceed 5°F.
DO	For a diversified warm water biota, including game fish, daily concentrations shall not be less than 5 mg/L at all times, except that under extreme conditions due to natural causes, it may range between 5 mg/L and 4 mg/L, provided that water quality is favorable in all other parameters.
pH	Sewage, industrial wastes, or other wastes shall not cause the pH to deviate more than one unit from the normal or natural pH. The pH should be greater than 6.0 and less than 8.5.
Turbidity	There shall be no turbidity of other than natural origin that causes substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses. In no case shall turbidity exceed 50 Nephelometric units [NTU] above background. Background is interpreted as the natural condition of the receiving waters, without influence of human or human-induced causes.
Fecal Coliform Bacteria	Shall not exceed a geometric mean (g.m.) of 1,000 colonies [cfu] per 100 mL, nor exceed a maximum of 2,000 colonies per 100 mL in any sample. The geometric mean shall be calculated from no less than five samples collected over a 30-day period at intervals not less than 24 hours. For incidental water contact during June through September, water quality is acceptable when a survey by controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform densities do not exceed 200 colonies per 100 mL.
Toxic, color-producing, odor-producing, and other deleterious substances from wastes	Only such amounts, whether alone or in combination with other substances or wastes, as will not cause acute or chronic toxicity to fish, wildlife, and [other] aquatic life, as demonstrated by effluent toxicity testing or by application of numeric criteria given in Rule 335-6-10-.07, or adversely affect the aesthetic value of the water.

Table 24a. Summary of Alabama state standards for acceptable water quality in waters classified as Fish and Wildlife designated use, and of conditions for acceptable water quality recommended by other sources (ADEM 2013b).

Parameter	ADEM	Other Recommendation(s) or Guideline(s)	HOBE
DO	$\geq$ 5 mg/L; or $\geq$ 4 m/L in extreme conditions	$\geq$ 4 mg/L (U.S. EPA 2000)	Limited data - some violations (down to 3.4 mg/L)
pH	> 6.0, < 8.5	> 6.5, and < 9.0 (U.S. EPA 2000)	Limited data - pH as low as 6.0
Turbidity	< 50 NTU above background	5.7 NTU (25th percentile, all streams; all seasons for Level III Nutrient Ecoregion IX, sub-ecoregion #45 (U.S. EPA 2000)	44% of samples were in compliance (2010-2011 data)
Escherichia coli	< 548 cfu/100 mL (g.m.);< 2,507 cfu/100 mL in any sample	235 cfu/100 mL for data collected with insufficient frequency to calculate g.m.s by the State's criteria (general recreational use; U.S. EPA 2003)	Data not available
Nutrients	-----	25th percentiles, all streams, all seasons for Level III Nutrient Ecoregion IX, sub-ecoregion #45; 30 µg TP/L, 234 µg TKN/L, 177 µg NO_x/L, 411 µg TN/L (calculated as TKN + NO_x; U.S. EPA 2000)[a]	84% of NO_x, 100% of TP, and 53% of TKN samples would conform (2010-2011 data)
Chlorophyll *a* (chl*a*, corrected)	-----	25th percentile, all streams, all seasons for Level III Nutrient Ecoregion IX, sub-ecoregion #45: 3.3 µg chl*a*/L (F)[a,b] or 3.5 µg chl*a*/L (S)[a,b]	84% of samples would conform (2010-2011 data)
Biochemical Oxygen Demand (BOD)	-----	< 3.0 mg/L as the 5-day BOD (BOD_5) (Mallin et al. 2006)	Data not available
Total suspended solids (TSS)	-----	< 25 mg/L; and < 10 mg/L increase from a sudden spike (U.S. EPA 2000)	Limited data - TSS < 25 mg/L

[a] U.S. EPA's (2000b) recommendation for acceptable conditions for nutrients, turbidity, and suspended algal biomass as chlorophyll *a* concentration (corrected for pheopigments), for streams within level III nutrient ecoregion IX, sub-ecoregion #45, which includes HOBE. These recommendations were based on the 25th percentile of all available streams data for the previous decade; alternatively, if reference (minimally impacted) streams were available, U.S. EPA (2000) recommends use of the 75th percentile of the data from those streams. Note that TP ≡ total phosphorus, TN ≡ total nitrogen, and TKN ≡ total Kjeldahl nitrogen.

[b] F ≡ fluorometric technique; S ≡ spectrophotometric technique.

[c] Dissolved concentrations; equations express the total recoverable concentration depending on the water ardness or pH. Please note that this historic procedure for calculating heavy metals concentrations in developing freshwater criteria have been replaced by use of the Biotic Ligand Model (BLM), wherein he available toxicity data, when evaluated using the procedures described in the Guidelines for eriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, indicate that freshwater aquatic life should be protected if the 24-hr average and 4-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the BLM (see http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#mm , last accessed in August 2013).

[d] Water quality guidelines (reference condition, 25th percentile – also see Byrne 2004). CMC ≡ the criterion maximum concentration; CCC ≡ the criterion continuous concentration, within a pH range of 6.5-9.

Table 24b. Summary of Alabama state standards for acceptable water quality for toxic metals in waters classified as Fish and Wildlife designated use, and of conditions for acceptable water quality recommended by other sources (ADEM 2013b)(U.S. EPA 2000, 2002[d]).

Toxic metals (µg/L)	ADEM	Other Recommendation(s) or Guideline(s)		HOBE
Aluminum	Equations[c]	CMC 750	CCC 87	Data not available
Cadmium	Equations[c]	CMC 2	CCC 0.25	Data not available
Chromium III	Equations[c]	CMC 570	CCC 74	Data not available
Chromium IV	Equations[c]	CMC 16	CCC 11	Data not available
Copper	Equations[c]	CMC 13	CCC 9	Data not available
Lead	Equations[c]	CMC 65	CCC 2.5	Data not available
Mercury	Equations[c]	CMC 1.4	CCC 0.77	Data not available
Nickel	Equations[c]	CMC 470	CCC 52	Data not available
Zinc	Equations[c]	CMC 120	CCC 120	Data not available

[a] U.S. EPA's (2000b) recommendation for acceptable conditions for nutrients, turbidity, and suspended algal biomass as chlorophyll *a* concentration (corrected for pheopigments), for streams within level III nutrient ecoregion IX, sub-ecoregion #45, which includes HOBE. These recommendations were based on the 25th percentile of all available streams data for the previous decade; alternatively, if reference (minimally impacted) streams were available, U.S. EPA (2000) recommends use of the 75th percentile of the data from those streams. Note that TP ≡ total phosphorus, TN ≡ total nitrogen, and TKN ≡ total Kjeldahl nitrogen.

[b] F ≡ fluorometric technique; S ≡ spectrophotometric technique.

[c] Dissolved concentrations; equations express the total recoverable concentration depending on the water ardness or pH. Please note that this historic procedure for calculating heavy metals concentrations in developing freshwater criteria have been replaced by use of the Biotic Ligand Model (BLM), wherein he available toxicity data, when evaluated using the procedures described in the Guidelines for eriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, indicate that freshwater aquatic life should be protected if the 24-hr average and 4-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the BLM (see http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#mm , last accessed in August 2013).

[d] Water quality guidelines (reference condition, 25th percentile – also see Byrne 2004). CMC ≡ the criterion maximum concentration; CCC ≡ the criterion continuous concentration, within a pH range of 6.5-9.

3.6.1.7. Potential Pollution Sources:

The Middle Tallapoosa River basin includes a total of 153 point source (National Pollutant Discharge Elimination System, NPDES) dischargers (133 industrial, 20 municipal; ADEM 2013c). Data are not available for the current permitted flows. There are also 15 active minor NPDES discharges into the Tallapoosa River above Lake Martin. The only NPDES point source above Horseshoe Bend is ~40 river km (25 river miles) upstream and poses no immediate threat to the park. Nevertheless, sewage spills have affected tributaries close by in the sub-basin (see Burkholder and Rothenberger 2010). ADEM monitors some sites along the Tallapoosa River, although not near the park, for mercury content in fish and occasionally has reported fish consumption advisories.

Nonpoint source pollution from airsheds and land occurs from human activities such as urban development, agriculture, silviculture, various other industries, and other land use practices. It is the major source of pollution in many U.S. watersheds, and can carry toxic substances, suspended sediments, excessive nutrients, and microbial pathogens into receiving waters (e.g. U.S. EPA 2001, Burkholder et al. 2006). Local nonpoint pollution sources in the watershed include suburban/urban runoff and air pollution from the small population centers and agricultural and silvicultural operations upstream from the park. The upper watershed has been used for agriculture, industrialized animal production (mainly poultry), gold mining and, more recently, for timber production and harvest (CH2MHill 2005). Concern has been raised that water quality in the Middle Tallapoosa sub-basin may be adversely affected by agricultural runoff from upstream livestock and chicken production (DeVivo 2004, CH2MHill 2005, ADEM 2006).

In addition to nonpoint water and air pollution from local sources, toxic contaminants, dust/particulates, and other pollutants may be carried into the park area and upstream Tallapoosa waters from larger cities in the state, and from Atlanta, Ga., by prevailing winds. The risk of foliar ozone injury to plants at Horseshoe Bend has been evaluated as moderate, and is considered to affect both wetland and terrestrial species (see Figure 26). Other air pollution, notably N and S deposition, have been assessed as being of significant concern for park natural resources, and these pollutants would also affect Horseshoe Bend surface waters (NPS 2014d. They can cause acidification (both N and S), over-fertilization of soils (N), and over-enrichment of surface waters (N; process known as eutrophication). These air pollutants can help to drive natural land and water ecosystems out of balance, causing shifts from beneficial to undesirable flora and fauna such as microbial pathogens and exotic/invasive species (Burkholder and Glibert 2013). Air pollutants such as S and N can also adversely affect essential ecosystem services such as air and water purification, decomposition and detoxification of waste materials, climate regulation, regeneration of soil fertility, production, and biodiversity (NPS 2012).

About 15 years ago, the overall potential for nonpoint source impairment in the Middle Tallapoosa River sub-basin was evaluated as low, based on estimates of sedimentation rates, animal unit densities, and pasture land (ADEM 2000). However, pollution from increased industrial development of the Tallapoosa watershed is a park concern, as is clear-cutting for timber and for development (Burkholder and Rothenberger 2010). Other concerns about pollution sources have been expressed by Horseshoe Bend staff as follows (Rasmussen et al. 2009):

- Possible contamination of the Tallapoosa River by the upstream and downstream hydroelectric power plants;
- Significant agriculture upstream from the park that contributes substantial suspended sediments and other pollutants to the river;
- Septic drain fields, including four housing units that feed into a septic tank and drainage field, and a septic tank for the maintenance building; and
- Two aboveground storage tanks at the maintenance building, still in Horseshoe Bend although others have been removed.

The Tallapoosa River Basin Management Plan (CH2MHILL 2005) described water quality and general habitat concerns identified by stakeholders for various segments of the Tallapoosa River and certain tributaries within the Middle Tallapoosa watershed, including microbial pathogen contamination, erosion and siltation, clay turbidity, nutrient over-enrichment, excessive phytoplankton biomass (as chlorophyll *a*) in impoundments. Water quality and habitat integrity measures within the Middle Tallapoosa sub-basin were evaluated as generally achieving use classification standards (CH2MHILL 2005), likely reflecting the fact that the land is mostly forested. However, supporting data for this evaluation are, and were, extremely sparse. The results from a Tallapoosa River basin surface water quality assessment (ADEM 2000), now dated by nearly a decade, rated the overall potential for nonpoint pollution source impairment as low, based on estimates of sedimentation rates, animal unit densities, and pastureland. One smaller watershed within the middle Tallapoosa sub-basin (03150109040, located above Horseshoe Bend) was listed as a priority NPS-watershed because of only a "fair" assessment rating due to erosion and sedimentation from silvicultural practices (CH2MHILL 2005).

Overall, based on a recent watershed condition assessment, present water quality concerns in Horseshoe Bend include sedimentation from increased clear-cutting, pollution from agriculture and silviculture, and atmospheric deposition of dust/particulates, toxic contaminants, and other pollutants from larger cities to the west (Montgomery, Birmingham) and from Atlanta, Ga. (Burkholder and Rothenberger 2010). Although the Middle Tallapoosa River watershed is only ~5% urbanized at present, the combined pressures of anticipated increased development in the upper and middle basins are expected to increase land disturbance and water pollution including excessive suspended sediments, nutrients, fecal bacteria, and toxic substances. The present overall potential for nonpoint source impairment of surface waters in the area has been evaluated as low, but more than half of the sub-watersheds in this sub-basin were considered by ADEM to have moderate potential for nonpoint source impairment due to runoff from forestry practices, clear-cutting, and sedimentation.

3.6.1.8. <u>Surface Water Quality at Horseshoe Bend:</u>
The park's sewage is treated on-site with septic tanks. Park sewer lines for septic tanks, which previously caused problems from leakage, recently were replaced and aboveground storage tanks were replaced with double-wall containers.

The Tallapoosa River Basin Management Plan (CH2MHill 2005) described water quality and general habitat concerns identified by stakeholders for various segments of the Tallapoosa River and certain tributaries within the Middle Tallapoosa watershed, including microbial pathogen contamination, erosion and siltation, clay turbidity, nutrient over-enrichment, excessive phytoplankton biomass (as chlorophyll *a*) in impoundments. Water quality and habitat integrity measures within the Middle Tallapoosa sub-basin were evaluated as generally achieving use classification standards (CH2MHill 2005), likely reflecting the fact that land use is mostly forested. However, supporting data for this evaluation are, and were, extremely sparse. The results from a Tallapoosa River basin surface water quality assessment (ADEM 2000), now dated by nearly a decade, rated the overall potential for nonpoint pollution source impairment as low, based on estimates of sedimentation rates, animal unit densities, and pastureland. One smaller watershed within the middle Tallapoosa sub-basin (03150109040, located above Horseshoe Bend) was listed as a priority NPS-watershed because of a "fair" assessment rating caused by erosion and sedimentation from silvicultural practices (CH2MHill 2005).

Recent water quality data for Horseshoe Bend, taken within the past ~15 years (since 2000), are sparse for parameters other than temperature but, nevertheless, the available data include most of the past ~15 years (2000-2007 and 2010-2011; Table 25). The older data taken during that period indicate that, except for several violations of the pH criterion, parameters were at acceptable conditions (Figures 37-39). Recent data from ADEM (April through October 2011) indicate that some conditions were unacceptable on several dates, including turbidity, chlorophyll *a*, NO_x, TKN, total dissolved solids (TDS), and TSS (Table 26). Data are not available for algal abundance/composition, fecal bacteria, or toxic substances.

Table 25. Dates of water quality sampling, and parameters sampled in surface waters of the park, considering information from 2000 - present. For older data, see Burkholder and Rothenburger (2010).

Station	Duration	*n*	Parameters
Alabama Water Watch (AWW) Boat Ramp, site #07001001	Jan 2000 - Feb 07*	127	Water temperature, salinity, alkalinity, hardness, turbidity, pH, DO
Tallapoosa Watershed Project (TWP) Just downstream from Boat Ramp station - Auburn Univ.	Feb 04 - Dec 05	29	TP, soluble reactive phosphorus (SRP), TN, TSS
ADEM - boat ramp	Apr 10 - Oct 11	19-337	Temperature, turbidity, Specific Conductance, pH, DO, chl*a*, NO_x, NH_4^+N, TKN, TP, SRP, BOD_5, chloride, total dissolved solids (TDS), TSS, alkalinity

* The dataset was initiated in June of 1993, but this Report emphasizes data from 2000 on.

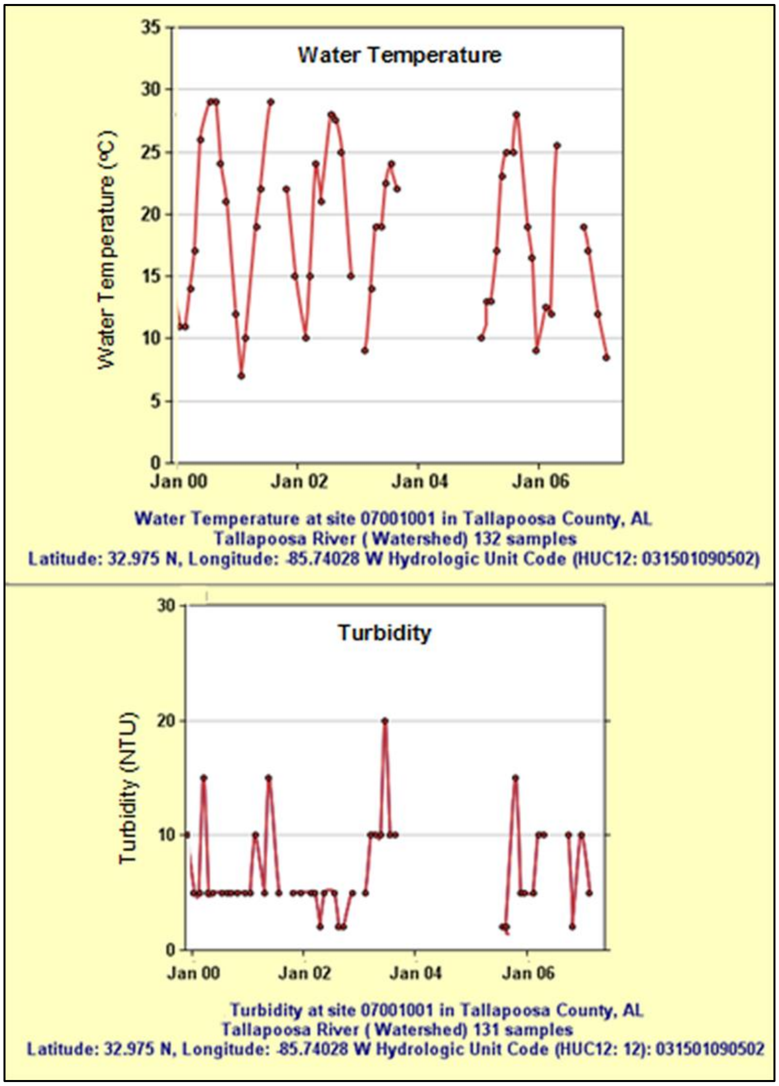

Figure 37. Water temperature and turbidity (upper and lower panels, respectively) in the Tallapoosa River at HOBE (Boat Ramp station, January 2000 - February 2007) from a monthly sampling program by volunteer citizens in the Alabama Water Watch (AWW).

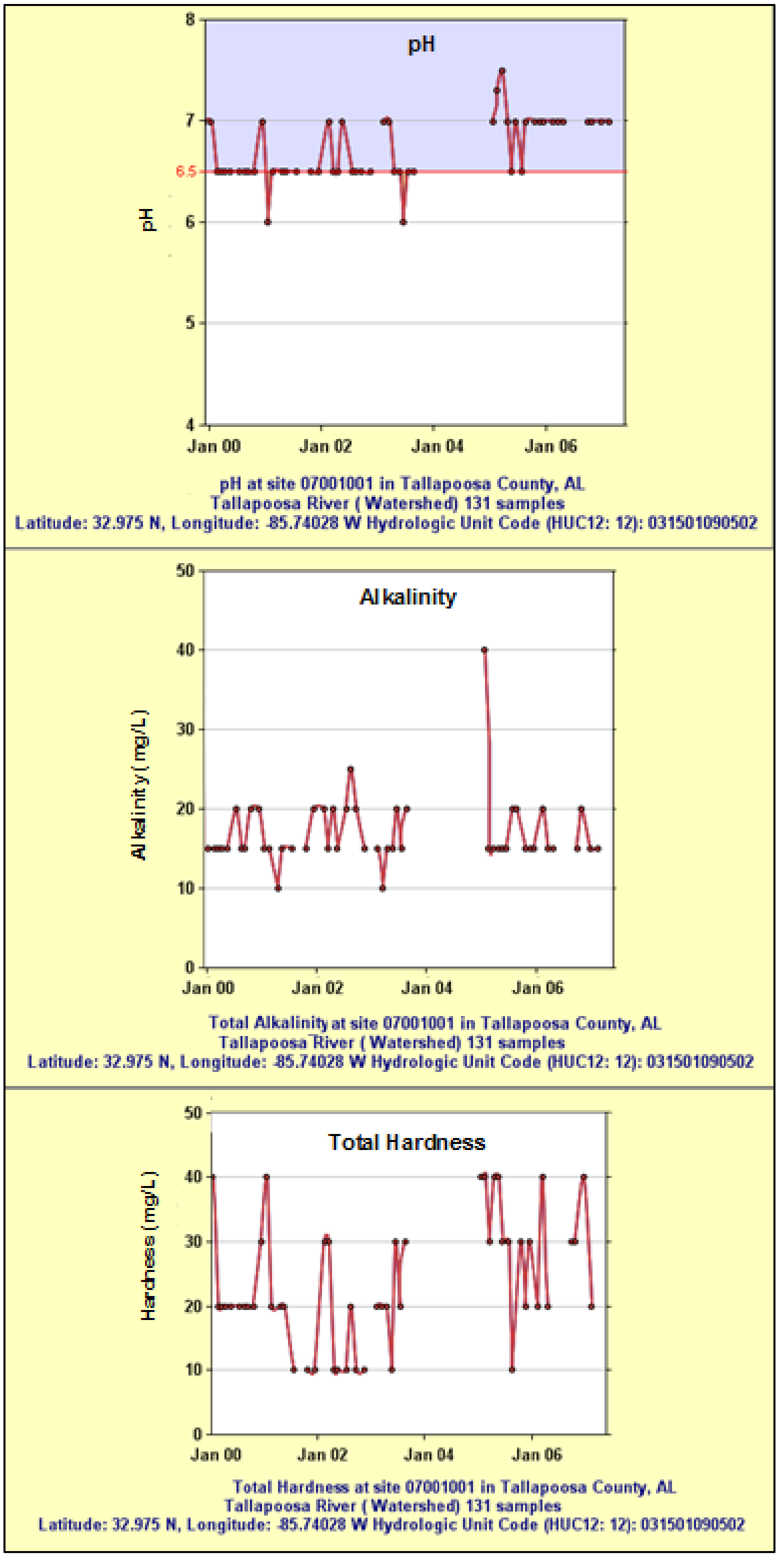

Figure 38. Water pH, alkalinity, and hardness (upper, middle, and lower panels, respectively) for the Tallapoosa River at HOBE (Boat Ramp station, January 2000 - February 2007) from a sampling program by volunteer citizens in the AWW.

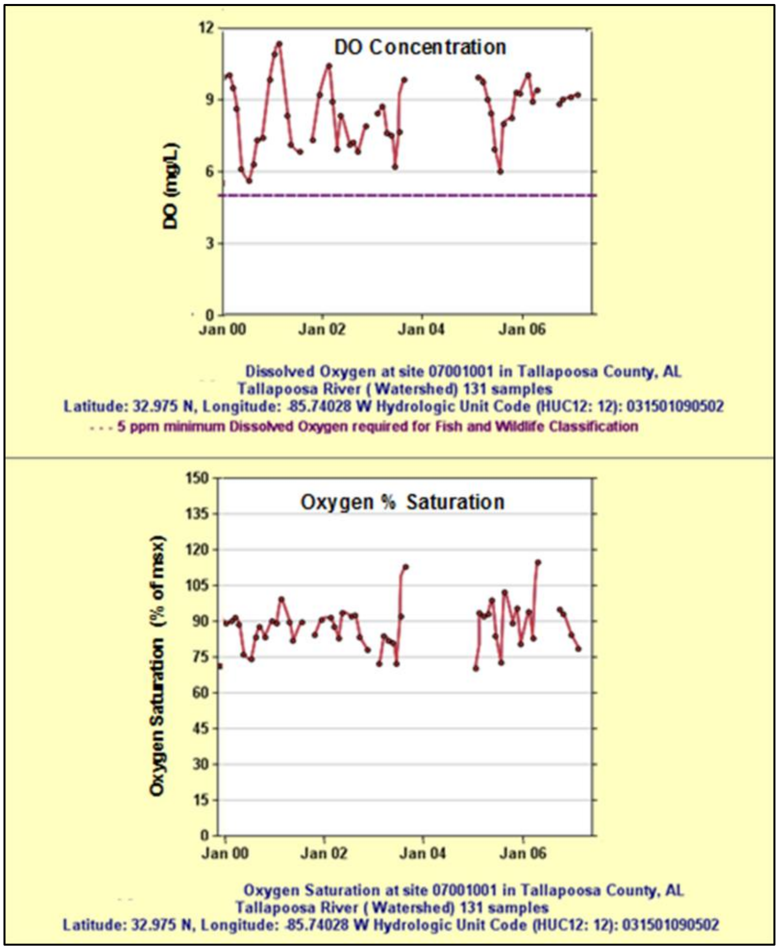

Figure 39. DO as concentration and percent saturation (upper and lower panels, respectively) for the Tallapoosa River at HOBE (Boat Ramp station, January 2000 - February 2007) from a sampling program by volunteer citizens in the AWW.

Table 26. Water quality conditions during the past decade based on data collected by ADEM: Parameters measured at the boat ramp station in HOBE (ADEM #3952 -Tallapoosa River; lat. 32.97734, long. -85.73968) (sampling dates per year ranged from 8 to 13)[a]. Note that UC ≡nd ≡ not detectable. Value underlined in bold ≡ in violation of state standard (ADEM 2013b); values shaded in bold ≡ data exceeded recommended values for acceptable water quality (EPA 2000).

Parameter	Date	*n*	Mean (range)	Median	UC (#)
Temperature (^{o}C)	Apr 10 - Oct 11	337	28.9 (14.9 - **32.5**)	29.3	3
Turbidity (NTU)	Apr 10 - Oct 11	25	**6.0** (0.3 - **12.5**)	5.8	14
Spec. cond. (µmhos/cm, field)	Apr 10 - Oct 11	337	44.1 (33.9 - 48.7)	44	---
DO (mg/L0	Apr 10 - Oct 11	237	7.3 (6.4 - 10.2)	7.3	---
pH	Apr 10 - Oct 11	337	6.9 (6.5 - 7.2)	6.9	---
chlorophyll *a* (mg/m^3)	Apr 10 - Oct 11	19	1.7 (nd-**7.5**)[b]	0.7	3
$NO_3^-N + NO_2^-N$ (NO_x, µg/L)	Apr 10 - Oct 11	19	114 (nd - **223**)[b]	134	3
TKN (µg/L)	Apr 10 - Oct 11	19	**234** (nd - **625**)[b]	202	9
TP (µg/L)	Apr 10 - Oct 11	19	14 (9 - 21)	13	---
SRP (µg/L)	Apr 10 - Oct 11	19	7 (3 - 19)	6	---
BOD_5 (mg/L)	Apr 10 - Oct 11	19	all nd[c]	---	---
Chloride (mg/L)	Apr 10 - Oct 11	19	2.5 (1.9 - 3.5)	2.5	---
TDS (mg/L)	Apr 10 - Oct 11	19	36.5 - (4 - 98)	34	---
TSS (mg/L)	Apr 10 - Oct 11	19	2.3 (nd - 9)[b]	1	---
Alkalinity, carbonate as $CaCO_3$ (mg/L)	Apr 10 - Oct 11	19	14 (9 - 20.8)	13.4	---

[a] More than 50% of samples were below detection or below the reporting limit with the analytical technique used; thus, statistical interpretation was not attempted.

[b] Abbreviations: °C degrees – Celsius; NTU – nephelometric turbidity units; spec. cond. – specific conductivity, NOx – nitrate-N + nitrite-N; NH4+N – ammonium-N; TKN – total Kjeldahl nitrogen; TP – total phosphorus; SRP – soluble reactive phosphorus; BOD5 – 5-day biochemical oxygen demand; TDS – total dissolved solids; TSS – total suspended solids; and $CaCO_3$ –calcium carbonate.

[c] All values reported less than the level of detection or less than the detection limit were replace with 1/2 the value, following Ellis and Gilbert (1980) and Zirschky et al. (1985), except that TSS mdl – 1.

3.6.2. Groundwater

3.6.2.1. Groundwater Quantity:

Knowledge of groundwater supplies and quality is critically important to enable sound assessment of the status of water resources in most ecosystems:

> Groundwater level and groundwater quality data are essential for water resource assessment and management. Water level measurements from observation wells are the principal source of information about the hydrologic stresses on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time; develop groundwater models and forecast trends; and design, implement, and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley, 2001). Groundwater quality data are necessary to ensure that public water supplies meet health standards; deterioration of groundwater quality may be virtually irreversible, and treatment of contaminated groundwater can be expensive (Alley 1993) [in USGS 2008].

Unfortunately, however, little is known about groundwater supplies in the park. The regional geology controls the aquifer types present, and influences the natural quantity and quality of the groundwater. The aquifers underlying the park and vicinity are fairly well known: A surficial aquifer system, not a principal aquifer, covers the state (USGS 2008). The important aquifer underlying east-central Alabama is the substantial Piedmont-Blue Ridge Aquifer System, which consists of a fractured, crystalline-rock aquifer (within metamorphic and igneous rocks) with little or no primary porosity or permeability, and overlying unconsolidated material called regolith which generally acts as a porous-media aquifer (Miller 1990, Chapman and Peck 1997, Rasmussen et al. 2009; Figure 40). In some locations a transition zone also occurs, which lies between the regolith and unweathered crystalline bedrock (Chapman and Peck 1997). The regolith includes (i) mostly saprolite, a layer of variable thickness (up to ~46 m or 150 ft. in places) of earthy, decomposed rock developed by weathering of the bedrock, along with (ii) soil that develops on the upper part of the saprolite; and, mainly in-stream valleys, (iii) overlying alluvium. The mineralogy and texture of the rocks forming the Piedmont and Blue Ridge Aquifer System differ, resulting in substantial local differences in the occurrence and availability of groundwater. Nevertheless, the overall hydraulic characteristics of the aquifers in this system are similar (Miller 1990). Various textural and structural properties in the rocks control permeability features, whereas hydraulic head gradients and recharge are influenced by topography and climatic factors.

Water levels in the aquifers fluctuate seasonally, and generally rise in winter/spring because of increased recharge from precipitation and less evapotranspiration and pumping (Leeth et al. 2005). The magnitude of fluctuations varies substantially across seasons and year to year depending on climatic conditions and human use, which influences the amount of ground-water in storage and the rate of discharge (Taylor and Alley 2001). As storage is depleted within the radius of pumping influence from a well, the water level declines and forms a "cone of depression" around the well. In areas with high concentrations of wells, multiple cones of depression form and effect water level declines across large areas. These declines can change the groundwater flow direction, reduce flow to streams, capture water from a stream or adjacent aquifer, and/or alter groundwater quality (USGS 2008).

As described by Miller (1990), water in the rocks of the Piedmont and Blue Ridge Aquifer System generally is unconfined. Locally, artesian conditions exist when wells penetrate deeply buried fractures that are hydraulically connected to recharge areas at higher altitudes or in places where the regolith is clayey and forms a confining unit. Water enters the ground in recharge areas, which generally include all land surfaces except the lower parts of valleys. The water percolates vertically downward through the unsaturated zone. Once it reaches the saturated zone (water table), it moves laterally to points of discharge as springs, seeps, baseflow to streams, and seepage to lakes. The water table is essentially a subdued replica of surface topography; thus, the depth to the water table varies, depending largely on topography and less so on precipitation. On hills and steep ridges, the water table lays tens to hundreds of meters below land surface. In contrast, in valleys and adjacent to lakes, ponds and wetlands, the water table is at or near the land surface. Water movement in the bedrock is restricted entirely to flow through fractures.

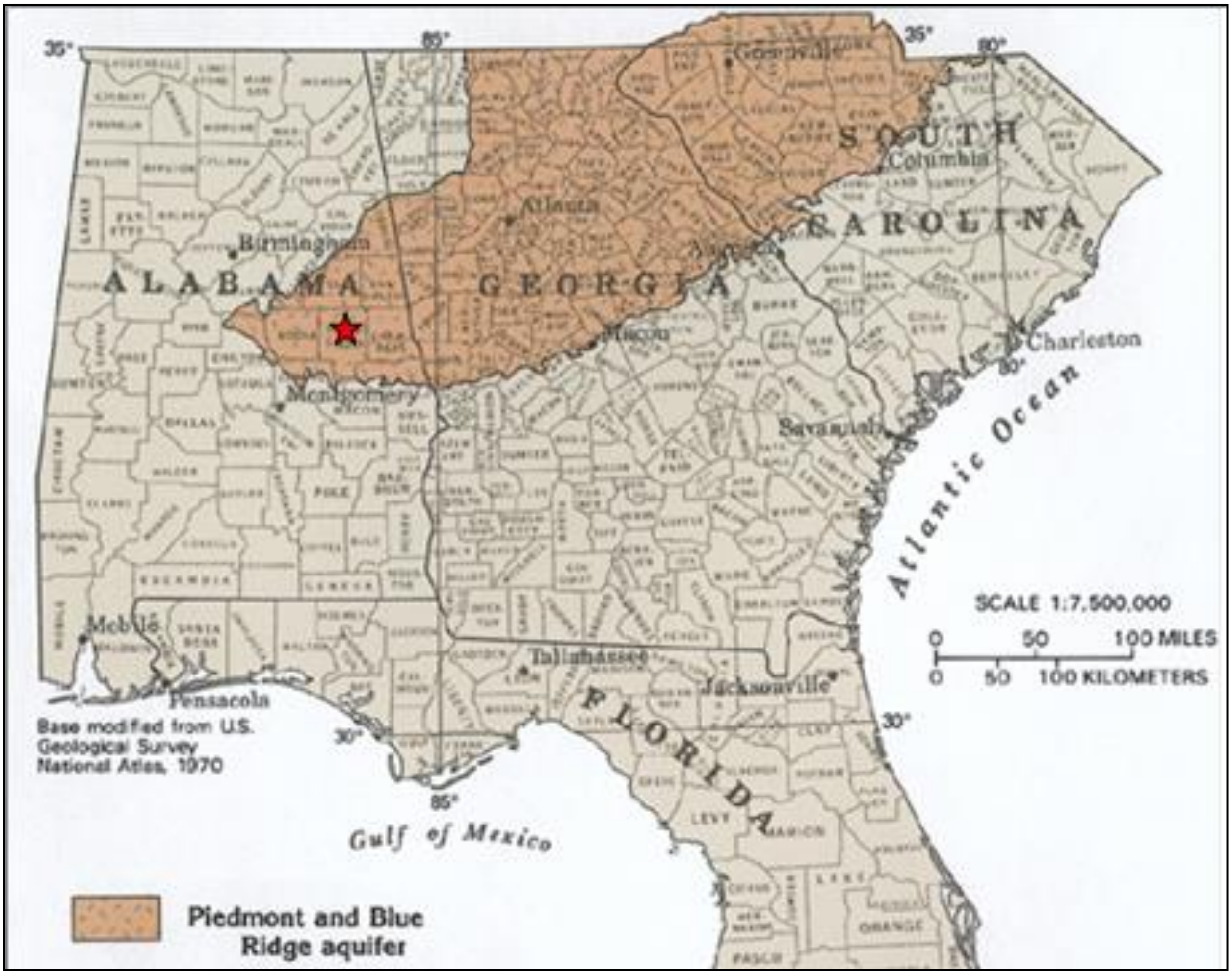

Figure 40. The Piedmont and Blue Ridge Aquifer System: Crystalline-rock aquifers underlie the rolling hills of the Piedmont physiographic province and the rugged mountains of the Blue Ridge physiographic province in a band that extends from east-central Alabama northeastward through western South Carolina. From Miller (1990), with permission.

More specifically to Horseshoe Bend, the two basic types of aquifers in the Tallapoosa River basin are porous-media aquifers wherein groundwater can be obtained from the regolith, and fracture-conduit aquifers wherein groundwater can be obtained from fractures in the rock (Miller 1990). The porous-media aquifers are shallow and typically consist of unconsolidated or poorly consolidated sediments (Journey and Atkins 1996, USGS 1997). Most groundwater occurs within soil, alluvium, and saprolite derived from rocks of various age, and the water moves through interconnected pore spaces between sediment grains. The porous-media aquifers generally are only suitable for domestic use. The fracture-conduit aquifers are deeper, and formed in areas of igneous and metamorphic rocks. The crystalline rocks formed under intense heat and pressure; thus, they have few primary pore spaces, and the porosity and permeability of the unweathered and unfractured bedrock are extremely low (Miller 1990). Groundwater mostly moves through fractured or broken rock, and through openings between cleavage plains. Contact zones between crystalline-rock types are favorable places for the location of wells yielding large volumes of water. Well yields typically vary from 3.8-95 L (1-

25 gallons) per minute, but may exceed 1,893 L (500 gallons) per minute. Overall, most groundwater storage occurs in the overlying weathered rock (regolith or saprolite), whereas the fracture-conduit aquifer usually has low storage capacity (Journey and Atkins 1996). Water levels in fracture-conduit aquifers respond rapidly to pumping and seasonal precipitation changes, with lowest annual water levels usually in fall after the dry summer, and highest water levels early in spring after recharge from winter rains.

Groundwater/surface water interactions within the Tallapoosa River basin are substantial, based on information for the Tallapoosa River at the Georgia-Alabama state line (Journey and Atkins 1996): The unit area mean annual baseflow due to groundwater discharge is ~0.01 cms per km^2 (0.902 cfs per $mile^2$). The mean annual contribution of baseflow (groundwater) to the total flow in the Tallapoosa River was estimated to be ~15.1 cms (534 cfs), or ~51% of the total annual flow. More specifically, however, very little is known about groundwater quantity or quality in Horseshoe Bend. The park presently has no wells for monitoring. On the grounds there is an inactive well house (latitude 32.97932, longitude -85.74007) and an inactive PVC well (latitude 32.98077, longitude -85.73133) that is welded shut but is not capped (Rasmussen et al. 2009). In addition, there is an old, capped, sealed well that was previously used for aquaculture, located between the picnic area and river/nature trail in what was probably a gravel quarry (latitude 32.97195, longitude -85.73465).

The Monitoring Well Network within the Network includes two wells within 100 km (62 miles) from the park in south-central/southeastern Alabama (Figure 41), but both are in the Southeastern Coastal Plain aquifer, not the Piedmont and Blue Ridge and, so, are inappropriate for extrapolation to conditions in Horseshoe Bend. The closest well to Horseshoe Bend among this network that also lies within the Piedmont and Blue Ridge Aquifer System is USGS #334207084254801 (well name, 10DD02; latitude 33.70194, longitude −84.43000). The well depth is ~104 m (341 ft.). The well has been sampled from 17 November 1973 to the present, and 13,658 observations had been taken between the start data and 31 December 2011, the last observation used for analysis by Wright (2012). Trend analysis indicated a significant negative trend in groundwater level of the period of record ($p = 0.0003$; Wright 2012; Figure 42). It is important to mention, however, that this well is within the influence of the Atlanta, Georgia metropolitan area, and therefore differs substantially from the park area in its higher water demand from the much larger surrounding local population.

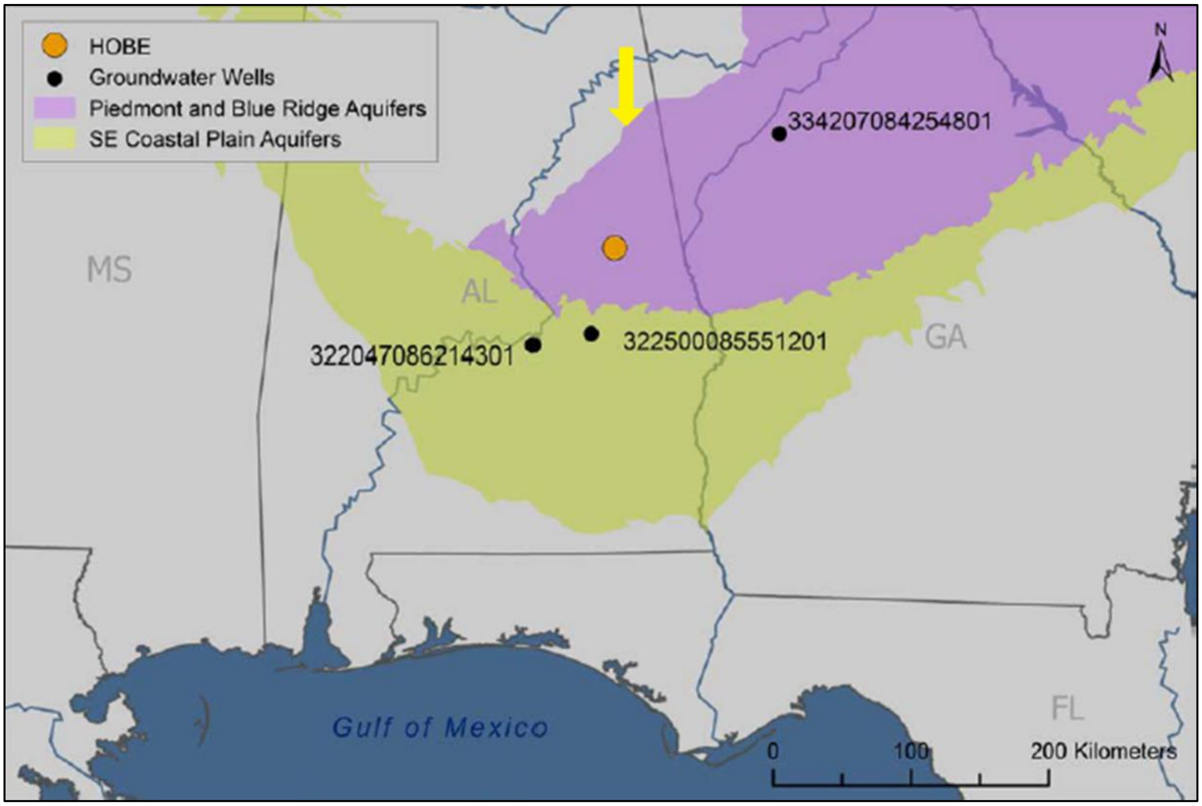

Figure 41. Map showing the locations of the USGS monitoring wells (black dots; USGS well numbers) near HOBE (orange dot). Of the three wells, only the well shown in northern Georgia lies in the Piedmont and Blue Ridge crystalline-rock aquifers (Miller 1990), as does the park. Yellow arrow ≡ statistically significant negative trend in groundwater level over the period of record at that well. Modified from the NPS SECN (2014).

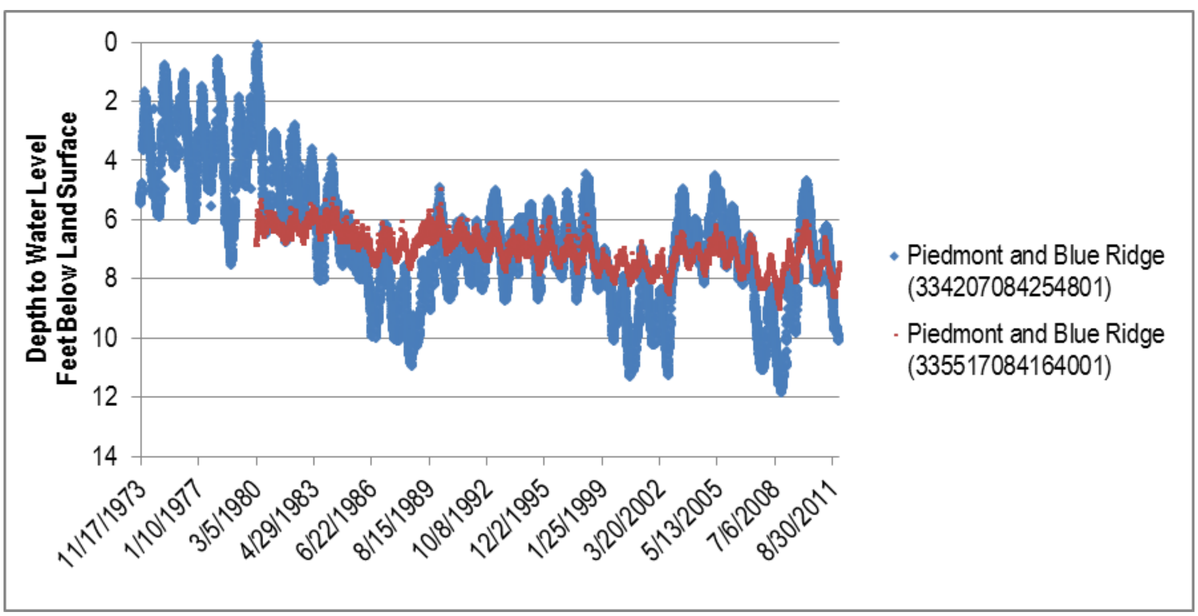

Figure 42. Mean depth to water level (feet - NGVD 1929) over time (1973-2011) for the well nearest Horseshoe Bend National Military Park (#334207084254801; blue line) within the Piedmont and Blue Ridge Aquifer System, showing the substantial decrease. From Wright (2012).

3.6.2.2. Groundwater Quality:
Miller (1990, p.4) provided a general description for the Piedmont and Blue Ridge Aquifer System, unfortunately dated now by more than 20 years:

"The quality of water from the Piedmont and Blue Ridge aquifers generally is suitable for drinking and other uses practically everywhere."

Concentrations of dissolved constituents except for fluoride, iron, manganese, and, locally, sulfate seldom exceed state and federal drinking water standards. Wells yielding water containing large concentrations of these constituents possibly penetrate mineralized zones, although large iron concentrations may be due to the action of iron-fixing bacteria. Oxidation and filtration usually will alleviate problems of large iron and manganese concentrations, and render the water potable. Rarely, radioactive minerals occur in concentrations sufficient to create water quality problems.

In 2000, however, the USGS collected limited data on pH in the middle Tallapoosa River basin near Horseshoe Bend and reported that, of 38 samples collected, 31 (65%) were in compliance (pH 6.5-9.0; ADEM 2013b). Thus, up-to-date groundwater quality data are needed for this park. Two programs were developed by Dr. J. Dowd at the University of Georgia to support groundwater analyses of national parks in the Network, and are described in detail in Rasmussen et al. (2009). Both save data to *Excel* spreadsheets. Program *GWInput* automates input of groundwater data. Users first select the park from the drop-down menu NPS ID. Information entered must be keyed to a unique well name, beginning with the four-character code for the park. Program *UpdateSW* was designed to assist in management and interpretation of groundwater data, and updates daily or realtime USGS streamflow or groundwater data by using the Internet to update selected gage sites. This program also can graph the data, and can be used to evaluate temporal trends for each well. *UpdateSW* can be used to download data from the USGS National Water Information Service (NWIS) database, the national archive for hydrologic data (USGS 2015c). Groundwater data can be accessed from the NWIS database using http://water.usgs.gov/waterwatch/ (USGS 2015c).

3.7. Biological Resources and Management

3.7.1. Attributes Used in Assessment

The NPS Omnibus Management Act of 1998, and other reinforcing policies and regulations, require park managers "to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources" (Title II, Sec. 204). A first step toward meeting that mandate is to inventory the species diversity of park biota. This information is valuable because measures of community composition are often good indicators of abiotic variability, disturbance, and/or other stressors (Byrne et al. 2011b). Understanding changes in species distributions is integral to informed management of species and their habitats - changes in species distributions over time provide valuable insights at local and landscape scales about how species respond to influences such as changing land use, climate, hydrology, or habitat quality/availability. Climate change, for example, influences the distribution, phenology, population demographics, and abundance of individual species. In turn, the cascading effects through altered species interactions and altered food web structure can impact ecosystem processes (Montoya and Raffaelli 2010). It is also valuable to capture the number of species (species richness) and their relative abundance (species evenness or dominance) within a given community (here, Horseshoe Bend). These two components describe the species diversity, often communicated as various diversity indices.

Diversity, defined as "the variety and abundance of species in a defined unit of study" (Magurran 2004, p.8 in Byrne et al. 2011b), is a community property that is broadly related to trophic structure, productivity, stability (McIntosh 1967, McNaughton 1977), immigration/emigration (Colwell and Lees 2000), and ecological condition (i.e., ecological integrity as defined by Karr and Chu 1995). Diversity indices respond differently to various mechanisms that influence community structure, so the National Park Service uses a suite of alpha-diversity indices (the diversity of species within a defined area, community or ecosystem - Whittaker 1972) in order to fully characterize diversity in SECN parks (Haedrick 1975; Boyle et al. 1984 in Byrne et al. 2011b; Table 27).

Table 27. Alpha-diversity indices for species richness (data: observations identified to the species-level) used by the Network; notes also add interpretations from other sources as indicated. Modified from Byrne et al. (2011b).

Index	Notes
Native Species Richness, Sobs	Value is a positive integer that indicates the number of native species in the sample. Intuitive. Good discriminant ability if the sampling effort is comparable; sensitive to sample size, occurrence of rare or cryptic species (with low detectability); does not account for relative abundances (Chao 1984, 1987).
Chao1	Values indicate an estimate of species richness; abundance-based estimate; works well with dataset containing several infrequent observations (Chao 1984, 1987).
Chao2	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate; works well with dataset containing several infrequent observations (Chao 1984, 1987).
Abundance-based coverage, ACE	Values indicate an estimate of species richness; abundance-based estimate (Chao and Lee 1992, Chazdon et al. 1998).
Incidence-based coverage, ICE	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate (Lee and Chao 1994, Chazdon et al. 1998).
Jackknife 1, Jack1	Values indicate an estimate of total species richness (including species not present in the sample); incidence-based estimate; the higher the value, the higher the species richness. This procedure requires no assumptions regarding the data distribution (Burnham and Overton 1978, 1979; Heltshe and Forrester 1983).
Jackknife 2, Jack2	Values indicate an estimate of species richness, incidence-based (Smith and van Belle 1984).
Y, Boot	Values indicate an estimate of species richness, incidence-based (Smith and van Belle 1984).
Fisher's α, α	Value is a positive integer and indicates a relative estimate of species richness (Fisher et al. 1943); good discriminant ability, low sensitivity to sample size, and robust to deviations in the assumed distribution (Kempton and Taylor 1974, Wolda 1983, Hayek and Buzas 1997, Kempton 2002); abundance-based estimate.
Q static, Q	Value is a positive integer and indicates a relative estimate of species richness (Kempton and Taylor 1974, 1976); good discriminant ability and low bias with small samples (Kempton and Wedderburn 1978), model fit is irrelevant to index performance (Magurran 1988); value is not weighted toward abundant or rare species; abundance-based estimate.

* Community attribute: Richness (Sobs, Chao1, Chao2, ACE, ICE, Jack1, Jack2, Boot, α, Q), Evenness (Evar, E1/D, E', EG); and Dominance (DBP).

Table 27 (continued). Alpha-diversity indices for species richness (data: observations identified to the species-level) used by the Network; notes also add interpretations from other sources as indicated. Modified from Byrne et al. (2011b).

Index	Notes
Smith and Wilson, Evar	Values range from 0 (no evenness) to 1 (perfectly even and all species exist in relatively equal abundance); weighs common species more heavily than rare species (desirable in certain cases; Simpson 1949, Smith and Wilson 1996).
Smith and Wilson 1/D, E1/D	Values range from 0 (no evenness) to 1 (perfectly even and all species exist in relatively equal abundance); weighs rare and abundant species equally (desirable in certain cases; Simpson 1949, Smith and Wilson 1996).
Camargo, E'	Values range from 0 (no evenness) to 1 (perfectly even and all species exist in relatively equal abundance); performs well at estimating intermediate values of evenness in comparison to the other indices; weighs rare and abundant taxa equally (desirable in certain cases; Camargo 1992).
Gini, Eg	Values range from 0 (no evenness to 1 (perfectly even and all species exist in relatively equal abundance; Gini 1912); good discriminant ability and low sensitivity to sample size (Lexerød and Eid 2006).
Berger-Parker, DBP	Values range from 0 (no single species dominance) to 1 (sample is strongly dominated by a single species; Berger and Parker 1970); describes the proportional dominance of the single most abundant species; low sensitivity to sample size but poor discriminant ability (Magurran 2004) - not used for across-years or across-sites comparisons.

* Community attribute: Richness (Sobs, Chao1, Chao2, ACE, ICE, Jack1, Jack2, Boot, α, Q), Evenness (Evar, E1/D, E', EG); and Dominance (DBP).

3.7.2. Horseshoe Bend Biota Assessment – Overview

The biota at Horseshoe Bend are generally known only through species lists. In recognition of this substantial knowledge gap, the Network has begun to characterize the amphibians, birds, and mammals of the park, and also have surveyed for a chytrid fungus (*Batrachochytrium dendrobatidis*) that causes amphibian disease worldwide (Byrne and Moore 2011; Byrne et al. 2011b).

According to the NPS Certified Species List (2013b - modified for vascular plant flora to include recent taxonomic changes), a total of 706 taxa have been reported to occur in Horseshoe Bend.

These include 251 fauna (32 amphibians, 39 reptiles, 26 fish, 122 birds, and 32 mammals) and 455 taxa of vascular flora (228 terrestrial plants, 224 wetland plants, and three aquatic plants; Appendix 2). Note that these total numbers of vascular plant and animal taxa differ markedly from the figures given in the Strategic Plan for the park (NPS 2008), which lists the number of known plant species at 901 and the number of known animal species at 354, for a total of 1,255 species. The reason for these considerable discrepancies - almost two-fold higher species numbers in the 2008-2012 Strategic Plan than in the NPS Certified Species List for Horseshoe Bend (NPS 2008 and NPS 2013b, respectively) - is uncertain but likely is due to the fact that the species lists for the park are mostly unvouchered, and/or were compiled from historic as well as present information. Similar discrepancies for the vascular flora of two other parks, Kennesaw Mountain National Battlefield Park and Ocmulgee National Monument, were reflected in the NPS Certified Species List (2013b) versus vouchered, recent lists compiled by Zomlefer et al. (2010, 2013). This information collectively suggests that Horseshoe Bend, like other SECN parks, is in need of an updated, vouchered Certified Species List for its flora and fauna. A recent, vouchered species list unfortunately is not yet available for

Horseshoe Bend, so at present the best-available information is the NPS Certified Species List (2013b). As vouchered, updated species lists for this park become available, the new information should replace the summaries given here.

According to the NPS Certified Species List (2013b), six Species of Concern (SoC s): one amphibian, two reptiles, and three birds) can be found in the park (Table 28). At least 33 other SoCs have been reported in Tallapoosa County (Alabama Natural Heritage Program 2012) but not in Horseshoe Bend, suggesting that these species may have occurred there historically but were extirpated (Table 29). These include 13 plants (12 higher vascular plants + 1 moss), 12 fish, two amphibians, three reptiles, and three birds. In addition, three mammalian species, the American black bear (*Ursus americanus*), red wolf (*Canis rufus*), and mountain lion (*Puma concolor*), likely have been extirpated from the park. Black bear sightings have been reported from Tallapoosa County, but there apparently is no established, self-sustaining population (Alabama Natural Heritage Program 2012). Various sensitive macroinvertebrates likely also have been extirpated, such as bivalve mollusks and certain crayfish (Table 29).

Table 28. Species of concern (SoCs) reported to occur in HOBE (Alabama Natural Heritage Program 2011, NPS 2013b).

Biota Group	Species	Common Name	Status[a]
Amphibians	*Rana sylvatica*	Wood frog	S2, G5
Reptiles	*Lampropeltis getula*	Common kingsnake	SP, S4, G5T5[b]
	Masticophis flagellum	Coachwhip (snake)	SP, S3, G5
Birds	*Dendroica petechia*	Yellow warbler	SP, S2B, G5
	Falco sparverius	American kestrel	SP, S3B, S5N, G5
	Vireo solitarius	Solitary vireo	SP, S3B, S4N, G5

[a] State of Alabama: E, endangered; T, threatened; R, rare (Alabama Department of Conservation and Natural Resources)

[b] As *Lampropeltis getula getula*

Table 29. Other plant SoCs reported to occur in Tallapoosa County (Alabama Natural Heritage Program 2012, Appendix 3), but not found in HOBE according to the NPS Certified Species List (2013b) and other information.*

			SoC Listing(s)		
Biota Group	**Scientific Name**	**Common Name**	**State**	**Federal**	**Status**
Plants (13)	*Amphianthus pusillus*	granite pool sprite	S1	G2	LT
	Baptisia metacarpa	Apalachicola wild indigo	S2	G2	
	Cyperus granitophilus	granite-loving flatsedge	S2	G3G4Q	
	Cypripedium kentuckiense	southern lady's-slipper	S1	G3	
	Hypericum nudiflorum	pretty St. John's-wort	S2	G5	
	Isoetes virginica	Piedmont quillwort	S2	G3	
	Juncus georgianus	Georgia rush	S1	G4	
	Matelea baldwyniana	Baldwin's milkvine	S1	G3	
	Phacelia dubia var. *georgiana*	outcrop smallflower phacelia	S2	G5T3	
	Pyrularia pubera	buffalo-nut	S2	G5	
	Rudbeckia triloba var. *pinnatiloba*	pinnate-lobed blackeyed Susan	S2S3	G5T3	
	Rhynchospora globularis var. *saxicola*	Stone Mountain beakrush	S1	G3Q	
	Selaginella rupestris	ledge spike-moss	S2	G5	
Fish (12)	*Crystallaria asprella*	crystal darter	S3	G3	SP
	Cyprinella gibbsi	Tallapoosa shiner	S3	G4	
	Etheostoma chuckwachatte	lipstick darter	S2	G2G3	SP
	Etheostoma tallapoosae	Tallapoosa darter	S3	G4	
	Fundulus bifax	stippled studfish	S2	G2G3	
	Hiodon tergisus	Mooneye	S3S4	G5	
	Hybopsis lineapunctata	lined chub	S3	G3G4	
	Notropsis uranoscopus	skygazer shiner	S2	G3	
	Percina palmaris	bronze darter	S3	G4	

* Four invertebrate SoCs were also reported by the Alabama Natural Heritage Program (2012) to occur in Tallapoosa County, including *Cambarus englishi* (Tallapoosa crayfish), *Cambarus halli* (slackwater crayfish), Pyganodon cataract (easter floater - mussel), and Toxolasma parvum (lilliput - mussel). It is not known whether these species occur in HOBE, as the NPS Certified Species List for that park does not include invertebrate taxa.

Table 29 (continued). Other plant SoCs reported to occur in Tallapoosa County (Alabama Natural Heritage Program 2012, Appendix 3), but not found in HOBE according to the NPS Certified Species List (2013b) and other information.*

			SoC Listing(s)		
Biota Group	**Scientific Name**	**Common Name**	**State**	**Federal**	**Status**
Fish (12) (continued)	*Percina shumardi*	river darter	S3	G5	
	Percina smithvanizi	muscadine darter	S2	G2G3	
	Polyodon spathula	paddlefish	S3	G4	CNGF, SP
Amphibians (2)	*Desmognathus monticola*	seal salamander	S5	G5	SP
	Plethodon websteri	Webster's salamander	S3	G3	
Reptiles (3)	*Graptemys nigrinoda nigrinoda*	black-knobbed sawback (turtle)	S3	G3T3Q	SP
	Graptemys pulchra	Alabama map turtle	S3	G4	SP
	Plestiodon inexpectatus	southeastern five-lined skink	S3	G5	SP
Birds (3)	*Columbina passerine*	common groung-dove	S3	G3	SP
	Picoides borealis	red-cockaded woodpecker	S2	G3	SP
	Scolopax minor	American woodcock	S3B, S5N	G5	GB

* Four invertebrate SoCs were also reported by the Alabama Natural Heritage Program (2012) to occur in Tallapoosa County, including *Cambarus englishi* (Tallapoosa crayfish), *Cambarus halli* (slackwater crayfish), Pyganodon cataract (easter floater - mussel), and Toxolasma parvum (lilliput - mussel). It is not known whether these species occur in HOBE, as the NPS Certified Species List for that park does not include invertebrate taxa.

The larger Mobile River watershed, which contains the Tallapoosa River and Horseshoe Bend, was once home to many endemic species including aquatic insects and crustaceans, aquatic snails, mussels, fishes, and turtles (Burkholder and Rothenberger 2010, and references therein). During the past two centuries, watershed development has led to species extinctions at a rate unparalleled elsewhere in the U.S. mainland and various aquatic and wetland species are now threatened or endangered. The habitat fragmentation imposed by the Harris and Lake Martin dams, along with two other dams on the lower Tallapoosa River, have affected faunal diversity, species distributions, and fisheries. For example, shoals of the Tallapoosa River support populations of Cahaba lily (Hymenocallis coronaria), which has a limited distribution and requires swift current to flourish. This wetland plant has been eliminated from portions of its native range by impoundments, and is not listed among the park flora. Two protected mussel species, the finelined pocketbook (Lamsilis atilis) and the ovate clubshell (Pleurobema perovatum), are thought to be rare although present within park boundaries, but their ability to re-colonize the Tallapoosa, including park waters, is impeded by the impoundments along the river. Sensitive macroinvertebrates such as bivalve mollusks are "barometers" of aquatic ecosystem health. There is no information on their present status in the park. CH2M HILL (2005) reported that native mussels were becoming rare in the middle reach of the Tallapoosa mainstem which includes Horseshoe Bend. Three of the four endemic fish species known from the Tallapoosa basin are on the park species list, including the lipstick darter (Etheostoma chuckwachatte), the Tallapoosa shiner (Cyprinella gibbsi), and the mottled sculpin (Cottus bairdi).

In contrast to the paucity of SoCs in Horseshoe Bend, the park contains 46 exotic/invasive taxa comprising 39 vascular plants (23 terrestrial, 16 wetland), and seven vertebrate animal species (one fish, three birds, three mammals), as well as an unknown number of invertebrate taxa including at least two highly damaging species (see Section 3.7.9 below). Major concerns have been expressed by park staff about exotic/ invasive species problems.

3.7.3. Vascular Flora

The National Park Service (2012) describes plant communities as:

> *"The primary drivers for a range of ecological processes…integral to the proper function of park ecosystems. They serve as the foundation for food webs and wildlife habitat for many species, and function as a carbon sink, produce oxygen, cycle nutrients and energy through an ecosystem, influence the local climate, improve water quality, and moderate flooding and erosion."*

Prior to European settlement, most of the Tallapoosa River basin was forested, but the entire watershed has sustained varying degrees of logging and extensive clearing for agriculture (Tallapoosa Basin Plan, Section 2 - River Basin Characteristics; see https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/tallapoosa.pdf, chapter 2, and https://epd.georgia.gov/tallapoosa-river-basin-watershed-protection-plan, last accessed in May 2015). The native forests in the Piedmont were dominated by deciduous hardwoods and mixed stands of pines and hardwoods. The wetlands originally were forested as well, and were mostly in the floodplains of streams and rivers. Those still remaining are maintained by the natural flooding regime.

Horseshoe Bend lies near the northern boundary of longleaf pine (*Pinus palustris*), and historically the floodplains and drainages consisted of mixed hardwoods, while patches of longleaf pine grew along the ridgetops. The hillsides and ridgelines also had a climax beech (*Fagus* spp.*)*-oak (*Quercus* spp.)-hickory (*Carya* spp.) forest, mixed with ash (*Fraxinus* spp.), walnut (*Juglans* spp.), and chestnut (*Castanea* spp.; DeVivo 2004). Since the battle of 1814, the vegetation was altered extensively by human settlement, logging, and the introduction of exotic species until the park was established in 1959 (NPS 2000). Many agricultural fields are now managed in loblolly pine or are undergoing ecological succession, and some of the park is also maintained through mowing as open grasslands.

Using the NPS Certified Species List as a starting point, we determined terrestrial versus wetland status following Godfrey and Wooten (1981a,b), the USDA Plants Database (also called the PLANTS Database or National Plants Database) of USDA's Natural Resources Conservation Service (USADA NRCS 2015), and The National Wetland Plant List (Lichvar 2012; USACE 2015). We checked all scientific and common names for discrepancies, and indicated the PLANTS Database recent changes to scientific names. As mentioned, 431 taxa of vascular flora have been reported from Horseshoe Bend, including 216 terrestrial plants, 212 wetland plants (many with broad mesic-hydric tolerance), and three aquatic plants (Appendix 2). The Network conducted plant surveys of Horseshoe Bend during summer 2011, and the data summary is expected to be available shortly, including a vegetation map inventory (NPS 2012). Thus far, however, there has been no ecological study of the park flora. Its three general habitat types include woodlands, wetlands, and ongoing ecologically disturbed areas, as follows:

3.7.3.1. Woodlands:

As mentioned, most of Horseshoe Bend (83%, or 688 hectares [1,700 acres]) is medium-aged, second growth upland mixed hardwood forest (Rasmussen et al. 2009). In many places, pines have displaced the climax hardwoods that historically were present (Watson 2005). Thus, the forests that cover most of the park have been modified by disturbance into secondary growth hardwoods and mixed hardwood-pine growth. Chief Ranger J. Cahill (pers. comm., 2009) described a shift in Horseshoe Bend forests from historic [longleaf] pine stands to "takeover" by sweetgum and [other] hardwoods. The flora has also been altered by exotic/invasive species (see Section 3.7.9 below). The forests of Horseshoe Bend most recently have been described as mostly consisting of mesic beech-oak hickory (American beech, *Fagus grandifolia*; oaks such as the white oak - *Quercus alba,* the southern red oak - *Q. falcata,* and the post oak - *Q. stellata*; and hickory, *Carya alba*) with some loblolly pine (*Pinus taeda*; Watson 2005).). Other abundant tree species can include sweetgum (*Liquidambar styraciflua*) and tulip tree (*Liriodendron tulipifera*; modified from Zomlefer et al. 2010 based on authors' observations). Habitats in drier areas and along hilltops are dominated by loblolly pine.

The understory vegetation is relatively open, commonly with sapling elms (*Ulmus alata* - winged elm, *U. americana* - American elm, and *U. rubra* - slippery elm), blueberries (*Vaccinium pallidum* -

Blue Ridge blueberry), silver bells (*Halesia diptera* - two-wing silverbell, *H. carolina* - Carolina silverbell), muscadines (*Vitis rotundifolia*), and ferns (e.g. chainfern - *Woodwardia areolata* , sensitive fern - *Onoclea sensibilis*, cinnamon fern - *Osmunda cinnamomea*, royal fern - *Osmunda regalis*). The understory shrubs also include the exotic/invasive species Chinese privet (*Ligustrum sinense*), and Japanese honeysuckle (*Lonicera japonica*; see below). Common vine species among the shrub understory are Carolina coralbead (*Cocculus carolinus*), wild yam (*Dioscorea villosa*), American ivy (*Parthenocissus quinquefolia*), greenbriers (*Smilax* spp.), noxious poison ivy (*Toxicodendron radicans*), and muscadines

The herbaceous layer of the forested areas varies depending on the soil moisture and the season. Early spring taxa include spotted geranium (*Geranium maculatum*), bedstraw (*Galium aparine*), littlebrownjug (*Hexastylis arifolia*), King Solomon's seal (*Polygonatum biflorum*), Carolina wild petunia (*Ruellia caroliniensis*), bloodroot (*Sanguinaria canadensis*), bashful wakerobin (*Trillium catesbaei*), perfoliate bellwort (*Uvularia perfoliata*), and violets (*Viola* spp.). Woodland species thrive later in the season, especially under canopy openings and along trails, and include mainly greater tickseed (*Coreopsis major*), tickrefoil (*Desmodium* spp.), panicgrass (*Dichanthelium* spp.), Carolina elephantsfoot (*Elephantopus carolinianus*), common elephantsfoot (*E. tomentosus*), American pokeweed (*Phytolacca americana*), blackseed needlegrass (*Piptochaetium avenaceum*), Christmas fern (*Polystichum acrostichoides*), Canada sanicle (*Sanicula canadensis*), kidneyleaf rosinweed *Silphium compositum*, and aster (*Symphyotrichum* spp.) (adapted from Zomlefer et al. 2010, based on authors' observations).

3.7.3.2. Wetlands:

The park's wetlands mostly occur along the Tallapoosa River. Wetlands are defined here according to Cowardin et al. (1979), as lands transitional between terrestrial and deeper-water habitats where the water table is at or near the land surface, or the land is covered by shallow water. About 10% of the park is wetlands, or ~83 hectares (204 acres). As mentioned in the above overview, a total of 212 taxa of wetland vascular plants, including five wetland ferns, occur in the park, mainly along the ~6.4- km (4-mile) segment of the Tallapoosa River that flows through Horseshoe Bend (Appendix 2). These taxa comprise ~50% of the total vascular plant taxa in Horseshoe Bend. Only about 4% of the wetland taxa (nine species) are exotic/invasive. Scattered shrubs of buttonbush (*Cephalanthus occidentalis*) are common and grasses, sedges, and rushes predominate (e.g. *Carex* spp., strawcolored flatsedge - *Cyperus strigosus*, blunt spikerush - *Eleocharis obtusa*, and *Juncus* spp.; authors' observations). Horseshoe Bend forested wetlands include both seasonally flooded, mesic lowlands and smaller areas with groundwater seepage year-round. Typical swampland trees and shrubs (red maple - *Acer rubrum*, silky dogwood - *Cornus amomum*, sourwood - *Oxydendrum arboretum*, and poison ivy) characterize the woody margins bordering open wetland areas.

3.7.3.3. Ongoing Ecologically Disturbed Habitats:

Aside from woodlands and wetlands, the remaining 7% of the park area (~58 hectares or 143 acres) consists of ongoing ecologically disturbed lands such as cleared fields, mowed battlefield areas, and cleared areas around public access sites (roadsides, parking lots, trails; Watson 2005). The flora at these sites is variable. Numerous grasses commonly include the exotic/invasive taxa Bermudagrass

(*Cynodon dactylon*), goosegrass (*Eleusine indica*), Dallas grass (*Paspalum dilatatum*), and Bahiagrass (*Paspalum notatum* var. *saurae*), and native species such as Virginia wild rye (*Elymus virginicus*) and various others. Tree and shrub borders of the cleared fields commonly include species such as red maple (*Acer rubrum*), the exotic/invasive species mimosa (*Albizia julibrissin*), eastern redbud (*Cercis canadensis*),flowering dogwood (*Cornus florida*), common honeylocust (*Gleditsia triacanthos*), and exotic/invasive Chinese privet and Chinaberry (*Melia azedarach*), Arkansas or shortleaf pine (*Pinus echinata*), loblolly pine, and water oak (*Quercus nigra*) - also with woody vines such as common trumpetcreeper (*Campsis radicans*), poison ivy, and muscadines (modified from Zomlefer et al. 2010, based on authors' observations).

3.7.3.4. Vegetation Community Survey in August 2011:

As part of the NPS Vital Signs monitoring program, the SECN Inventory & Monitoring Program (NPS 2012a) sampled 21 locations at Horseshoe Bend in 2-18 August 2011, including information on vascular plant species, frequency of occurrence, percent cover, diversity, and distribution in the groundcover, shrub, and canopy strata (Heath et al. 2014a). Vegetation communities were sampled within each stratum using hybrid methods following the North Carolina Vegetation Survey nested-subplot design (Peet et al. 1998) within a circular plot similar to that of the Forest Inventory and Analysis protocol described by Bechtold and Patterson (2005).

From the two-week survey, 172 vascular plant taxa were detected (Heath et al. 2014a). Of these, 16 species and 2 genera (rattlesnake root, Prenanthes, and Heuchera, alum root) were newly detected in Horseshoe Bend; another species, (Acer saccharum), was also described as newly reported for the park, but it was the only species of the 17 that was included in the NPS Certified Species list as of 2013 (NPS 2013a). One newly reported taxa, Japanese stiltgrass or Nepalese browntop (*Microstegium vimineum*), is invasive. The newly reported species were added to the NPS Certified Species List (Appendix 2).

This survey indicated that Horseshoe Bend had 86.5% vascular plant canopy cover across the park, and the canopy cover was fairly uniform (Heath et al. 2014a). Longleaf pine (*Pinus palustris*) had the largest average diameter at breast height of any canopy species in the park where more than two individuals were measured. The shrub stratum was dominated by sweetgum (*Liquidamber styraciflua*), which had the highest absolute and relative cover. Red maple (*Acer rubrum*) had the second highest absolute and relative shrub cover, and sweetgum and red maple were the most frequently occurring shrub species. Blue Ridge blueberry (Vaccinium pallidum) had the highest estimated seedling density at the park. The most frequently occurring species in the groundcover stratum were muscadine grape (*Vitis rotundifolia*), greenbriars (*Smilax* spp., notably cat greenbriar *Smilax glauca*), and Virginia creeper (*Parthenocisus quinquifolia*). Muscadine grape and common greenbriar (*Smilax rotundifolia*) had the highest and second highest absolute cover, respectively, in the groundcover stratum. Leaf litter was the most frequently occurring ground condition in Horseshoe Bend, and also had the highest relative and absolute cover of any ground condition.

3.7.3.5. Vegetation Community Survey in May 2012:

Using a similar approach, vegetation communities were sampled within each of three strata at 30 spatially balanced, permanent, random sites in Horseshoe Bend during 9-25 May 2012 (Heath et al.

2014b). The site locations differed somewhat from those surveyed in August 2011, and they were selected using the Reversed Randomized Quadrant-Recursive Raster algorithm (Theobald et al. 2007, as described by Byrne et al. 2013). All sampling locations were in naturally vegetated areas.

A total of 196 vascular plant taxa were detected during the May 2012 survey, including 11 newly reported species and two newly reported genera (beak sedge – *Rhynchospora*, and ragworts and groundsels – *Senecio*) for Horseshoe Bend (Heath et al. 2014b). The higher number of taxa detected in this survey relative to the August 2011 effort may reflect seasonal differences; in addition, different sites were sampled. Although more sites also were sampled in this survey than in the previous year, the number of sites examined in August 2011 had been evaluated as sufficient to capture the species richness (Heath et al. 2014a). Therefore, theoretically, increasing the number of sites should not have increased the species richness. Of the 196 taxa, 11 were newly reported species for the park, and 2 others were newly reported genera (species apparently were not possible to identify based on the available specimens). The newly reported species were added to the NPS Certified Species List (Appendix 2).

The findings from this survey were very similar to those from the August 2011 survey: The absolute canopy cover across the park was 87.8%, and the canopy was uniform. Post oak (rather than longleaf pine as in the August 2011 survey) had the highest estimated seedling density. In the shrub stratum, the highest and second highest relative cover were sweetgum and red maple/Elliott's blueberry (*Vaccinium elliotti*), respectively. Sweetgum was the most frequently occurring species in the shrub substratum as well. A second blueberry species, Blue Ridge blueberry, had the highest estimated seedling density in the park. In the groundcover stratum, muscadine grape and roundleaf greenbriar had the highest and second highest relative cover, respectively. Muscadine grape also had the highest absolute cover, whereas giant cane (*Arundinaria gigantea*) had the second highest absolute cover. The most frequently occurring species in the groundcover stratum were muscadine grape, Virginia creekper, cat greenbrier, and poison ivy (*Toxicodendron radicans*). Leaf litter was the most frequently occurring ground condition in Horseshoe Bend, and also had the highest relative and absolute cover of any ground condition.

3.7.4. Fish

The middle ~80 km (50-mile) reach of the Tallapoosa River from Harris Dam to the inflow of Lake Martin, which includes the section within Horseshoe Bend, is the only remaining Piedmont large-river habitat remaining in the state of Alabama. It represents one of the longest and highest-quality segments of Piedmont River habitat remaining in the Mobile River drainage (Lydeard and Mayden 1995). Various factors, including a subtropical climate and freshwater habitat diversity, combined to make the Mobile River basin what was once one of the most diverse natural faunistic regions throughout North America (Meador et al. 2005). Mettee et al. (1996) reported 404 fish species in the Mobile River basin and tributaries in Alabama and adjacent states. More specific to Horseshoe Bend, the Tallapoosa River basin historically was described as having 114-120 fish species (Williams 1965; Rivers of Alabama 2015) last accessed in September 2013). Watershed development and associated habitat degradation has led to the decline of fish species richness in these streams (Johnston and Maceina 2009).

The present NPS Certified Species List (NPS 2013b) indicates that there are only 26 species of fish in park waters (Appendix 2). This region of the Tallapoosa River has sustained a decline in some species such as the speckled chub (*Macryhybobsis aestivalis*), bullhead minnow (*Pimephales vigilax*), madtom catfish (*Noturus* spp.), and redhorse sucker (*Moxostoma* spp.; Freeman et al. 2001). According to the NPS Certified Species List, none of these species are present in Horseshoe Bend. Three of the four endemic fish species known from the Tallapoosa basin were included in the NPS Certified Species List for the park several years ago (2008), including the lipstick darter (*Etheostoma chuckwachatte*), the Tallapoosa shiner (*Cyprinella gibbsi*), and the mottled sculpin (*Cottus bairdi*). These species have since been removed from the NPS Certified Species List for Horseshoe Bend (NPS 2013b).

Some evidence suggests that the highly artificial flow variation imposed on the Tallapoosa River by regulation for hydropower at the Harris Dam may be severely impacting fish populations and other aquatic life in the park (NPS 2008). There is no fisheries management plan for the park (DeVivo 2004), which seems a major oversight given that the Strategic Plan for Horseshoe Bend (NPS 2008) describes the Tallapoosa River as the park's "major ecological resource." In addition, freshwater fish are important ecologically and for recreational uses. The Alabama Department of Conservation and Natural Resources conducts annual creel surveys at the Horseshoe Bend boat ramp but, clearly, additional efforts are needed to track fish populations and overall fish community health in the Tallapoosa River within the park and upstream from it. Saalfeld et al. (2012) noted that "To maintain and improve water quality, there is an increasing need to understand relationships between current land use practices (e.g., agriculture, forested/silviculture, and urban) and stream ecosystems." They assessed relationships among water quality, habitat composition, fish assemblages, and present land use practices in the Tallapoosa River basin in eastern Alabama. For all six streams examined, all fish metrics were significantly higher in streams draining forested lands than in streams draining agricultural lands. Nutrient pollution (total nitrogen and total phosphorus, TN and TP, respectively) were most descriptive of fish biotic integrity, and were negatively related to fish biotic integrity. These nutrient concentrations increased as the percentage of land use in agriculture increased. Saalfeld et al. (2012) concluded that agricultural land use practices, in particular, appear to be negatively impacting stream water quality and biota in the Tallapoosa watershed.

In addition to concerns at the fish community level, an example of the imperiled status of fish populations in the Tallapoosa basin is that of the stippled studfish (*Fundulus bifax*). This species is endemic to the Tallapoosa River system, but is not listed as present in Horseshoe Bend. It is widely considered to be at risk due to habitat degradation, and its global ranking is N2N3 (NatureServe: imperiled/ vulnerable). Its required habitat is clean water over clean sand in small or large streams. Therefore, and unfortunately not surprisingly, it apparently has been extirpated in the state of Georgia and appears to be increasingly uncommon in Tallapoosa basin waters of Alabama. Stallsmith (2013) visited 24 sites in the Alabama portion of the watershed during 2008 in an attempt to assess the current status of this killifish. Many of these sites were locations where the species had been found in 1980. Stallsmith (2013) found at least one individual from each of six different creek systems in four counties including Tallapoosa County, although sites in Horseshoe Bend were not sampled. The shrinkage in distribution was attributed to habitat degradation. Genetic analysis indicated that the existing populations are monophyletic, with low molecular variation. The author concluded (p.19) that "the future of the species is in doubt, with the six distinct populations being vulnerable to further habitat degradation and diminished gene flow."

As good news for Horseshoe Bend, wadeable stream habitat monitoring has been planned for the park. The Network has developed assessment procedures based on the USGS National Water Quality Assessment (NAWQA) program, USEPA wadeable stream assessment program and USDA protocols (NPS 2012). A combination of reach- and transect-level flow, geomorphic, and physical in-stream and riparian habitat measurements will be included. In addition, large river monitoring is planned for implementation in future years, which will utilize bank-to-bank videography along the length of the Tallapoosa River in the park. The video will be synced with GPS. From this information, a full-river map of potential sites of management concern, such as erosion features, will be generated.

3.7.5. Herpetofauna

Amphibian communities in the southeastern U.S. are widely considered to be among the most diverse in the world, and they are a valued resource in SECN parks. Several factors are attributable to population declines and localized extinctions [including] disease and anthropogenic stressors such as habitat loss and degradation, non-native predators, acid precipitation, altered hydrology and hydroperiod, ultraviolet radiation, and chemical contaminants (Collins and Storfer 2003). Given their habitat requirements, anatomy, and physiology, amphibians are considered good indicators of ecological condition...[and] amphibian communities are a priority for SECN monitoring efforts (Byrne et al. 2011a).

Amphibian communities in the southeastern U.S. are widely considered to be among the most diverse in the world, and they are a valued resource in SECN parks (Byrne and Moore 2011). According to the NPS Certified Species List (NPS 2013b), Horseshoe Bend contains 32 native species of amphibians and 34 native species of reptiles (Appendix 2). The amphibians include 20 species of frogs and toads, and 12 species of newts and salamanders. The reptiles include 8 species of lizards, 22 snakes, and nine turtles. Three SoCs are present at Horseshoe Bend: the wood frog (*Rana sylvatica*), the common kingsnake, and the coachwhip snake (Table 29). In a comparison of 16 parks including Horseshoe Bend, Tuberville et al. (2005) noted that while larger parks had higher species richness, Horseshoe Bend had an unusually rich assemblages of herpetofauna considering its small size (Figure 43). Horseshoe Bend was considered to have a high diversity of habitat types. Because it is located near the Fall line along the boundary between the Piedmont and Coastal Plain, resident herpetofauna of this park include species characteristic of both physiographic provinces.

3.7.5.1. National Park Service 2009 Study of Vocal Anuran Amphibians:

An Amphibian Community Monitoring Protocol is being produced for use in all SECN parks. The long-term objective is to determine trends in amphibian species occupancy, distribution, diversity, and community composition in each park (Byrne et al. 2011a). In the interim, Byrne et al. (2011a) described partial implementation and test application of Standard Operating Procedure (SOP) #4 of the Protocol, the ARD SOP, to monitor vocal anuran amphibians (frogs and toads) at Horseshoe Bend. Data were collected using this SOP from 22 April to 2 May 2009 at 30 spatially balanced, random locations in the park (Figure 44). To allow for park-wide inference, the park's administrative boundary was used as the sampling frame. The sampling frame was divided into a systematic 0.5-hectare grid, and the center point of each grid cell was considered the potential sampling site. A spatially balanced sample was drawn from the grid using the Reversed Randomized Quadrant-Recursive Raster algorithm (Theobald et al. 2007). Alternate points were used when selection criteria (i.e., safety and access issues) were not met. A sample size of 30 was chosen after consideration of the park's size, hypothesized variability, and logistical issues.

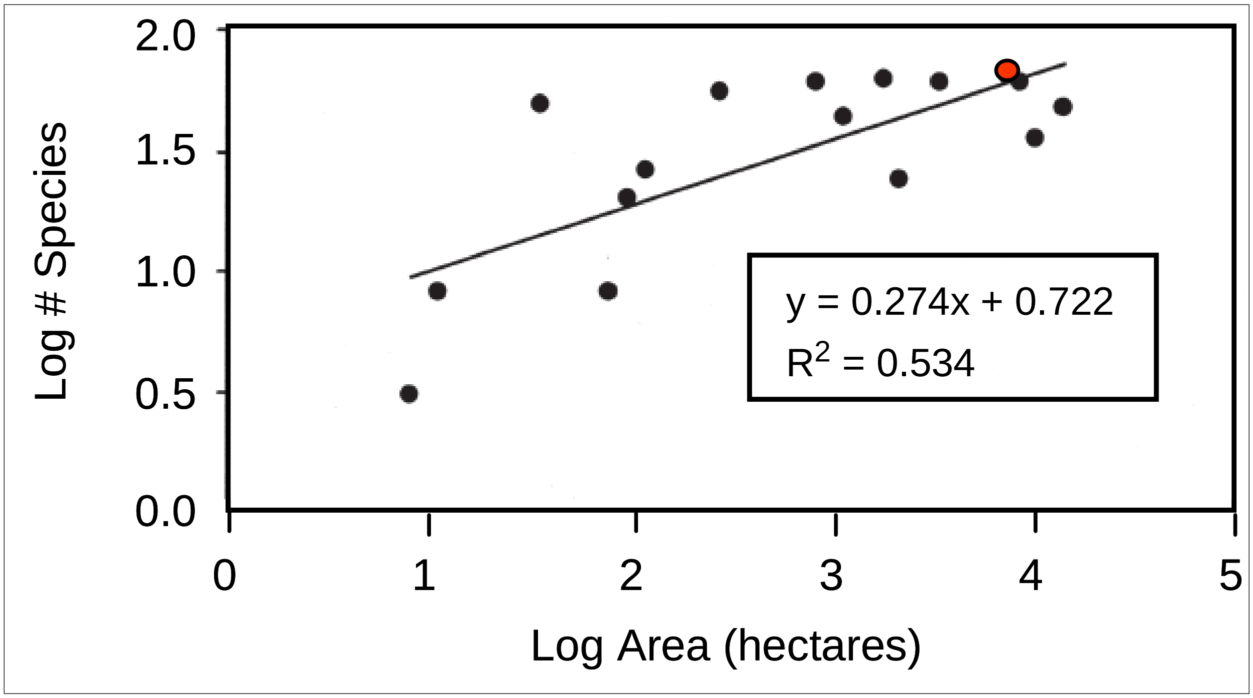

Figure 43. Relationship between land area (in hectares) and species richness, excluding exotic (introduced) species, among 16 parks within the Southeast Coast Network of the NPS, including HOBE (red dot), showing the strong positive linear relationship between (log-transformed) land area and species richness (P = 0.001). Modified from Tuberville et al. (2005).

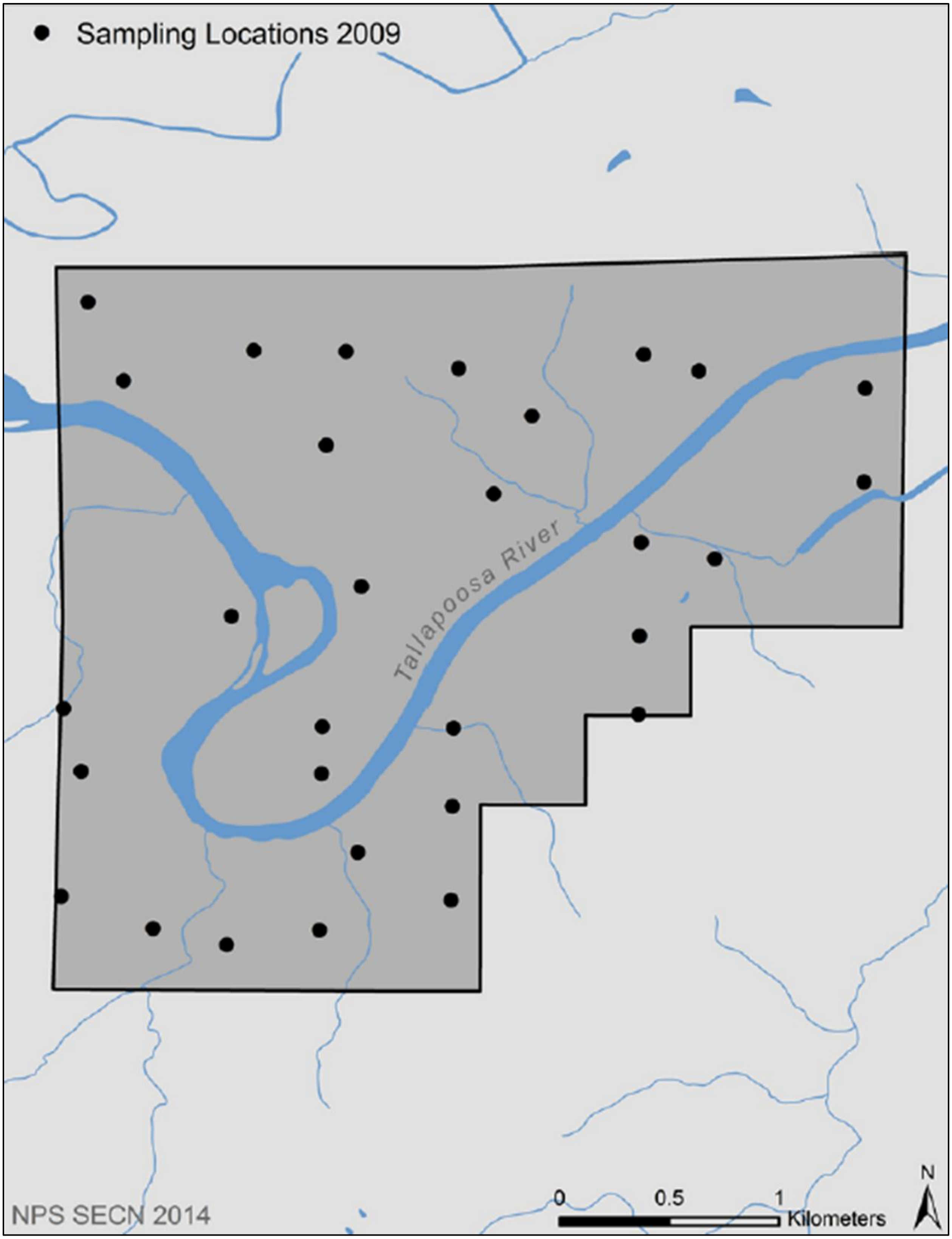

Figure 44. Spatially balanced, random sampling locations at HOBE in the 2009 studies of vocal anuran amphibians and birds. From Byrne et al. (2011a), modified by the NPS SECN (2014).

A total of 8,960 minutes were recorded by the ARDs when deployed in the park. A total of 29 samples were taken. ARDs provide only detection versus non-detection information; thus, data on abundance could not be obtained with this SOP. The species accumulation curve generated from the data was found to asymptote at a higher value than the sample size of 29 - that is, higher than the total number of samples collected - so the ARD data alone from this study were evaluated as inadequate to characterize amphibian diversity in the park. This was anticipated, as the primary goal of the study was to test the ARD technique for the overall Amphibian Community Monitoring Protocol, rather than to characterize the entire amphibian community.

In the 2009 study, seven of the 19 vocal anuran species known to occur in the park were detected, all native taxa. The most widely detected species was Fowler's toad (*Bufo fowleri*). Diversity indices were also calculated for these data as reflective of community composition (i.e., number of species (Table 30). Confidence intervals for each diversity index were estimated with a bootstrap procedure (not further described). The observed species richness (S_{obs}) was seven (95% CI: 4.19, 9.80). The ICE and Boot species richness estimates and confidence intervals were relatively consistent with one another. These estimates appeared to perform comparatively well, given the characteristics and limitations of the data, and were considered to be better estimates of true species richness than Chao2, Jack1, or Jack2 indices because of the uncertainty associated with those estimates as indicated by high CIs (Byrne et al. 2011a). The data were viewed as instructive information for when baseline values for the entire amphibian community can be generated from planned additional monitoring efforts.

Table 30. Alpha-diversity estimates for vocal anuran amphibians at HOBE based on SECN monitoring in 2009 (Byrne et al. 2011a).

Index	Symbol	Value	Lower 95% CI	Upper 95% CI	Value Interpretation
Native Spp. Richness	$\mathbf{S_{obs}}$	7.00	4.19	9.80	Number of native species detected
Chao 2	**Chao2**	9.89	7.34	30.99	Estimated true species richness (high CI)
Incidence-based Coverage	**ICE**	10.94	8.14	13.74	Estimated true species richness
Jackknife 1	**Jack1**	9.89	4.23	15.55	Estimated true species richness (high CI)
Jackknife 2	**Jack2**	12.68	8.25	17.11	Estimated true species richness
Bootstrap	**Boot**	8.21	6.72	9.70	Estimated true species richness

3.7.5.2. Survey for a Chytrid Fungus Pathogen of Amphibians:

Limited sampling on one date each in spring and fall of 2006 was conducted to assess whether an amphibian pathogen, the chytrid fungus *Batrachochytrium dendrobatidis* (Bd), was present in Horseshoe Bend (Byrne and Moore 2011). This fungus has been identified as a cause of localized declines and extinctions of amphibian populations worldwide (Fisher et al. 2009). Samples were collected throughout the park, specifically in a beaver pond, all insular streams, and at least two locations along each stream that originated outside the park.

Two pooled samples were collected in spring of 2006: One pooled sample contained pooled swabs from the southern two-lined salamander (*Eurycea cirrigera*, n = 9) and three-lined salamander

(*Eurycea guttolineata*, n = 1). The other pooled sample contained swabs from the southern cricket frog (*Acris gryllus*, n = 2), green frog (*Rana clamitans*, n = 3), and southern leopard frog (*Rana sphenocephala*, n = 3). Both pooled samples tested positive for Bd, but the actual species infected could not be determined.

Individual species samples were collected in fall of 2006, but because of the small sample size, low confidence was calculated to detect Bd in amphibians other than two species, the southern two-lined salamander and the green frog. The fungal pathogen was detected in 15% (4 of 27; 95% CIs, 1.4-28.2) of green frog samples, and in 42% (21 of 50; 95% CIs, 28.3-55.7) of southern two-lined salamander samples. There was no obvious signs of the disease in animals that tested positive for Bd, but several of the infected southern two-lined salamanders were lethargic, and their tails detached or were crushed during very light handling (Byrne and Moore 2011). In streams where the two species co-occurred, some samples from each tested positive for Bd. Positive samples for each species were also collected at locations where only one of the two species were detected. Considering the small size of the park (~825 hectares), point-pattern analysis was not considered necessary; it was assumed that the fungus is evenly distributed across the park.

3.7.5.3. National Park Service 2011 Study of Amphibians and Reptiles:

Efforts to characterize amphibian and reptile communities of Horseshoe Bend were conducted in 2011, when both ARDs for vocal anuran amphibians (11 March through 31 May) and visual encounter surveys (VESs, 2-18 August) for both amphibians and reptiles were used to collect data at the 30 spatially balanced random locations in the park (Smrekar et al. 2013). Because of prescribed burn activities, ARDs were deployed at 29 of the sites. A total of 135 vocal detections were made using the ARD recordings, wherein each detection represented an identifiable observation of a species or species group during one night of monitoring at a given sampling site.

This study detected 20 amphibian species, including vocalizations from 13 identifiable anuran species. The VESs revealed 61 post-metamorphic amphibians representing 12 species and three more taxa identified at the family or genus level, as well as 324 larval-stage amphibians within two taxa. Two species, Fowler's toad (*Bufo fowleri*) and the spring peeper (*Pseudacris crucifer*), had the highest overall frequency of occurrence, and Fowler's toad also had the highest relative abundance-based on the VESs. The spring peeper and Cope's gray treefrog (*Hyla chrysoscelis*) had the highest relative detection frequency of vocalizations during the 77-day ARD recording period. Fowler's toad, the spring peeper and the southern leopard frog, were the most widespread amphibian species in the park, found in all four quadrants. Two amphibian species were detected for the first time in Horseshoe Bend, the squirrel treefrog (*Hyla squirella*) and the spotted dusky salamander (*Desmognathus conanti*).

The 2011 VESs also resulted in detection of 261 reptiles within 15 identifiable, all native taxa (Smrekar et al. 2013). Two reptilian species were detected for the first time in Horseshoe Bend, the southeastern crowned snake (*Tantilla coronata*) and the smooth earth snake (*Virginia valeriae*). It is noteworthy that shells of the eastern box turtle (*Terrapene carolina*) occurred at 20 (70%) of the sampling sites, but only one live individual was found. The authors of the study suggested that this finding may warrant additional surveys to assess the status of this species at Horseshoe Bend.

The year 2013 marks a milestone for the National Park Service, which is now concurrently publishing both reports on its natural resources, and the data and metadata serving as the basis for the reports.

3.7.6. Birds

Birds are an important component of park ecosystems, and their high body temperature, rapid metabolism, and high ecological position in most food webs make them a good indicator of the effects of local and regional changes in ecosystems. Long-term trends in the community composition, relative abundance, distribution, and occurrences of breeding bird populations provide a measure for assessing the ecological integrity and sustainability in southeastern systems. Further, long-term patterns of these attributes in relation to changes in the structural diversity of vegetation resulting from fire and other management practices will improve our understanding of the effects of various management actions (Byrne et al. 2011b, p. ix).

As stated, 122 species of birds have been reported from Horseshoe Bend (Appendix 2). Of those, 11% (13 species) are mostly associated with wetland/aquatic habitats. Some species, such as the spotted sandpiper (*Actitis macularia*) and the Nashville warbler (*Vermivora ruficapilla*), historically have been seen only rarely (once or twice) within park boundaries. The park has three state-listed SoCs (Table 32 - the yellow warbler - *Dendroica petechia*, American kestrel - *Falco sparverius*, and solitary [blue-headed] vireo - *Vireo solitarius*), and three exotic/invasive species (see Section 3.7.9 of this Report). An Avian Conservation Implementation Plan was developed for Horseshoe Bend in 2005, in association with the North American Bird Conservation Initiative, to help identify and prioritize bird conservation opportunities, and to provide counsel about successful implementation of needed conservation activities (Watson 2005).

Byrne et al. (2011b) used the Draft SECN Landbird Community Monitoring Protocol to conduct a survey of birds in Horseshoe Bend in April and May of 2009. Data were collected at the same 30 spatially balanced random locations as for the anuran amphibian study (Figure 44). The data were collected using an adaptation of the VCP technique with distance estimation. Evaluation of sampling effort relative to the number of species detected indicated that the sample adequately characterized the bird diversity of Horseshoe Bend. Thus, these data are considered to serve as a baseline for comparison with future monitoring efforts for this Vital Sign (see Chapter 4 of this Report).

A total of 845 birds representing 53 species were detected in the spring 2009 study, all native species. In general, the data indicated that species were not aggregated and occurred uniformly across the Park. Two species were newly reported for the park, *Petrochelidon pyrrhonota* (cliff swallow) and *Dendroica petechia* (yellow warbler, an SoC). The most widely distributed species were *Cardinalis cardinalis* (northern cardinal) and *Parula americana* (northern parula), which were found at all sampling sites. The second most widely distributed species group consisted of *Melanerpes carolinus* (red-bellied woodpecker), *Vireo olivaceus* (red-eyed vireo), *Baeolophus bicolor* (tufted titmouse), *Thryothorus ludovicianus* (Carolina wren), and *Corvus brachyrhynchos* (American crow), which were detected at 87-97% of the sampling sites. It is also noteworthy that 16 species identified as priority species in the South Atlantic Migratory Bird Initiative Implementation Plan (Watson and Malloy 2006) were detected at Horseshoe Bend during the 2009 study (Appendix 2).

Observed species richness (i.e., S_{obs}) was 53 (95% CI: 48.36, 56.97; Table 31). Most species richness estimators were relatively consistent with one another, ranging from 54.52 to 63.97. The diversity indices suggested high bird species diversity at the park (α = 12.56, Q = 14.64). The sample was relatively well distributed among species, with four species composing approximately 40% of the sample. The consistent performance of the evenness/ dominance indices (i.e., E_{var}, $E_{1/D}$, E_g, and D_{BP}) suggest varied relative abundances of the species in the sample and, again, a diverse bird community at Horseshoe Bend.

Table 31. Bird alpha-diversity estimates at HOBE based on 2009 data. From Byrne et al. (2011b).

Index	Symbol	Value	Lower 95% CI	Upper 95% CI	Value Interpretation
Native Spp. Richness	$\mathbf{S_{obs}}$	53.00	48.36	56.97	Number of native species detected
Chao 1	**Chao1**	54.52	52.95	64.17	Estimated true species richness
Chao 2	**Chao2**	57.72	53.86	73.92	Estimated true species richness
Abundance-based Coverage	**ACE**	55.84	53.08	58.60	Estimated true species richness
Incidence-based Coverage	**ICE**	60.53	56.37	64.69	Estimated true species richness
Jackknife 1	**Jack1**	62.50	54.91	70.09	Estimated true species richness
Jackknife 2	**Jack2**	63.97	58.46	69.48	Estimated true species richness
Bootstrap	**Boot**	57.75	55.91	59.59	Estimated true species richness
Fisher's α	**α**	12.56	10.80	14.32	Baseline value, suggests high diversity
Q Statistic	**Q**	14.64	10.73	15.53	Baseline value, suggests high diversity
Smith and Wilson	$\mathbf{E_{var}}$	0.34	0.30	0.38	Species occur in several relative abundances –low evenness
Smith and Wilson 1/D	$\mathbf{E_{1/D}}$	0.32	0.30	0.37	Species occur in several relative abundances –low evenness
Camargo	**E'**	n.a.	-	-	Invalid calculation due to dataset (i.e., too many with few detections)
Gini	$\mathbf{E_G}$	0.35	0.29	0.39	Species occur in several relative abundances –low evenness
Berger-Parker	$\mathbf{D_{BP}}$	0.12	0.11	0.14	Sample is not dominated by a single species, diverse assemblage of species

3.7.7. Mammals

The Network has also taken recent steps to document the mammalian fauna of Horseshoe Bend by supporting a study by Webster (2010), which represents the first comprehensive survey of this important biological resource (Vital Sign; see Chapter 4 of this report). There had been no effort to document the mammalian fauna of Horseshoe Bend since dated checklists of species present or potentially present (Freeman et al. 1974, and University of California-Davis 1992, as described in Webster 2010). These checklists contained 35 terrestrial species and nine bats. Prior to Webster's (2010) work, 47 species were included on the NPS Certified Species List as assumed to be present in Horseshoe Bend, but estimated species richness was as high as 78 (Webster 2010, p.7).

In addition to gathering information from museums in Tallapoosa County and surrounding counties in intensive work, sampling in the park was conducted from 13 August through 9

October 2003, for a total of 15 man-days in the field and 2,350 trap-nights of sampling effort (Figure 45). Five major habitats were identified for mammals including stream and river edges, bottomland forest, upland mixed hardwood/pine forest, upland managed pine forest, and regularly maintained road edges and fields. Most of the field work (with Sherman live traps, pitfall traps, and extensive groundtruthing for spoor) was conducted in the more remote (gated) northeast quarter of the park, which had adequate segments of all of these habitats except for maintained road edges and fields. Many other park areas were visited at least once. Unfortunately, bats were not included in the study.

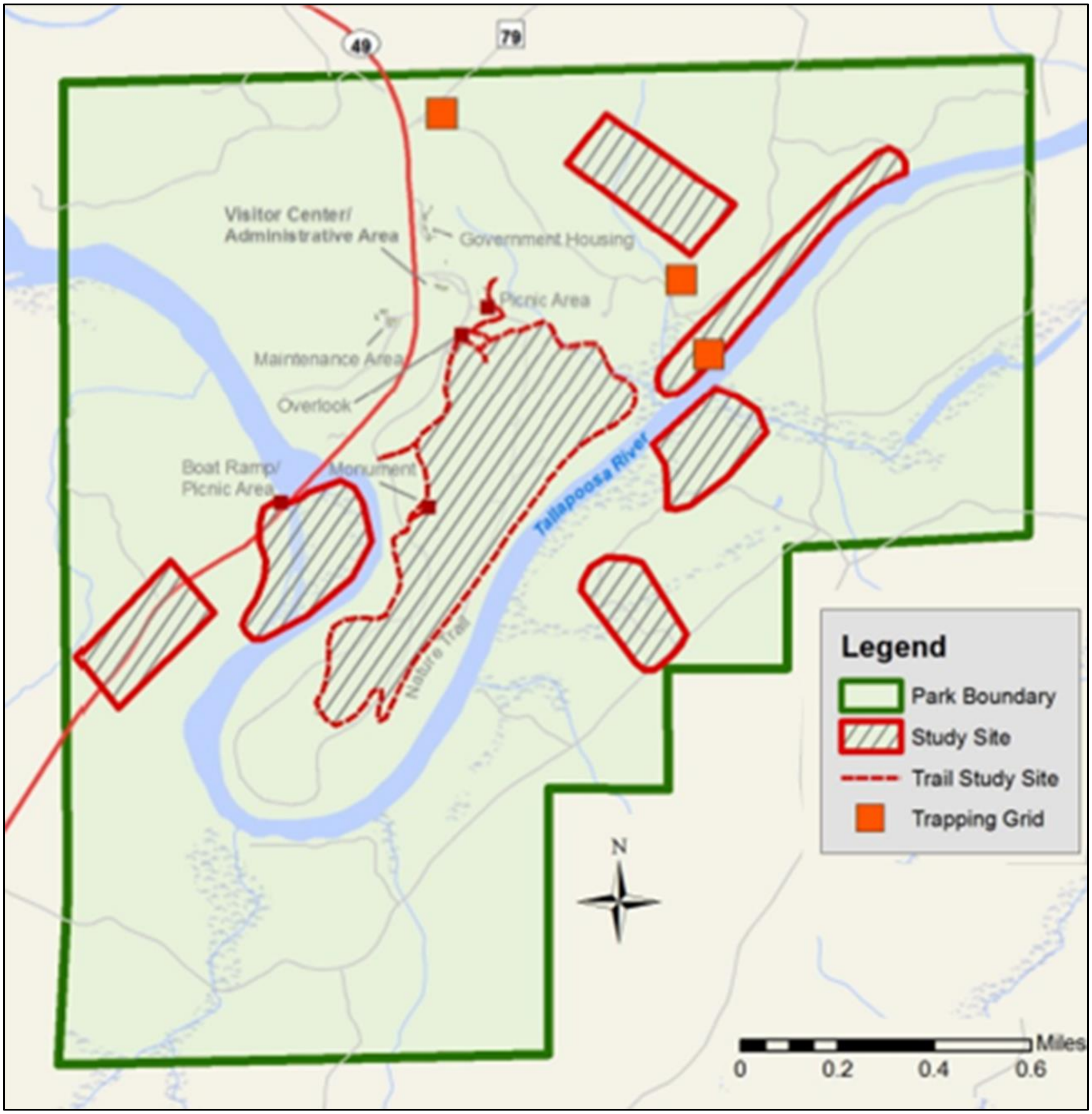

Figure 45. Map of survey sites for mammals in HOBE during August - October 2003 study. From Webster (2010).

Webster (2010) documented 24 species of terrestrial mammals from Horseshoe Bend, 22 species when domestic cattle and horses were omitted. These species have broad habitat tolerances and occupy or would be expected to occupy most of all of the five habitats. Also, the Virginia opossum (*Didelphis virginiana*) was found immediately adjacent to the park and was considered to inhabit it. An additional 11 species, widely distributed in the Southeast, were not found at Horseshoe Bend but were expected to occur there. Thus, overall, Webster's (2010) final list included 33 species, and consisted of 22 species of terrestrial mammals confirmed to inhabit Horseshoe Bend plus 11 more species that were considered likely to occur there on a permanent basis, although they were not documented during the study (Appendix 2). In addition, the domestic or feral dog (*Canis familiaris*) and striped skunk (*Mephitis mephitis*) were evaluated as likely occurring in the park on occasion, although the study did not reveal evidence of their presence.

Webster's (2010) list of mammalian species in Horseshoe Bend was comparable to the NPS Certified Species List (NPS 2013b) in its inclusion of the Virginia opossum, domestic or feral dog, striped skunk, bobcat (*Lynx rufus*), muskrat (*Ondatra zibethicus*), eastern harvest mouse (*Reithrodontomys humulis*), and red fox (*Vulpes vulpes*). With exception of the Virginia opossum, Webster (2010) listed these species as "probably present." The NPS Certified Species List (NPS 2013b) differed, however, (i) its inclusion of two bat species (bats were not tracked by Webster 2010, as noted above), and (ii) its inclusion of the eastern wood rat (*Neotoma floridana*). Webster (2010) considered the latter species among five species of mammals that "apparently are absent from Horseshoe Bend because suitable habitat is lacking;" the other four species in this grouping by Webster were the eastern fox squirrel (*Sciurus niger*), oldfield mouse (*Peromyscus polionotus*), meadow jumping mouse (*Zapus hudsonius*), and eastern spotted skunk (*Spilogale putorius*).

The NPS Certified Species List (NPS 2013b) also differed in (iii) omission of six species that Webster (2010) considered "probably present" - the southern flying squirrel (*Glaucomys volans*), the exotic/invasive house mouse (*Mus musculus*) and Norway rat (*Rattus norvegicus*), the long-tailed weasel (*Mustela frenata*), the American mink (*Neovision vision*), and the swamp rabbit (*Sylvilagus aquaticus*). In addition, the NPS Certified Species List (NPS 2013b) includes the feral horse (*Equus caballus*) as present at Horseshoe Bend. We have removed that species from Appendix 2 as requested by park staff. Thus, overall our species list for mammals at Horseshoe Bend includes 32 species, in accord with the NPS Certified Species List except for omission of the feral horse. All of these have broad habitat tolerances and widespread geographic distributions in the eastern U.S. (Webster 2010, and references therein). Our species list additionally notes that Webster's (2010) analysis indicated that six others likely are also present. Three mammalian species that historically were found throughout the eastern U.S. - the red wolf, American black bear, and mountain lion - have been extirpated from the Horseshoe Bend area. Feral pigs have not been reported in the park, although there is concern that they may establish within the next decade, and beaver damage to trees and water flow alteration has been minimal (Chief Ranger Jim Cahill, pers. comm., 2009).

3.7.8. Species of Special Management Concern

An overall National Park Service goal is to manage native species in the park to restore and maintain natural community composition, structure, and diversity. Toward that goal, and beyond efforts regarding SoCs and exotic/invasive taxa, park staff have described several species of special management concern (SSMCs), as follows.

A special focus of the park is restoration of longleaf pines (Superintendent Doyle Sapp, pers. comm., 30 April 2013). Longleaf pine forests once covered 90 million acres from Virginia to Florida, but only ~3 million acres of highly fragmented habitat remain (Ford et al. 2010, and references therein). This species typically grows in low-nitrogen, well-drained soils; it has seed dispersal timing that is fire-dependent, and longleaf pine forests have a relatively thin understory. Longleaf pines are now sparse in the park, and a management goal is to restore them along the ridgeline to historic conditions at the time of the Revolutionary War.

Information is lacking about several other SSMSc that have raised Horseshoe Bend staff concerns:

- White-tailed deer and wild turkeys appear to be *over-populated* in the park *north of the river* (Chief Ranger J. Cahill, pers. comm., 2009). Burgeoning deer populations consume forest understory species, so their grazing can lead to depressed forest regeneration. The large deer population in Horseshoe Bend may be increasingly vulnerable to starvation and disease (e.g. Davidson 2006). Population census data for these two SSMCs are needed (e.g. Alabama Division of Wildlife and Freshwater Fisheries 2008).
- White-tailed deer and wild turkeys may be *over-hunted* in the park *south of the river* because of illegal poaching and dog hunting (DeVivo 2004). Poaching is strongly suspected but data are not available. The park is working with the Alabama Department of Natural Resources on the poaching issue. Horseshoe Bend has targeted wild turkeys as a high priority for conservation.
- *Coyotes and armadillos* are recent (invasive) arrivals at the park (e.g. (Howell 1921 vs. Choate et al. 1994), and their respective impacts on Horseshoe Bend ecosystems are unknown. The coyotes may suppress fox populations, for example, via competition for food resources, and/or they may exert beneficial pressure on the deer population to bring it into balance.

3.7.9. Exotic/Invasive Species

Invasive exotic species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss as threats to global biodiversity (Scott and Wilcove 1998). Such species negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and increasing trail maintenance needs (Young et al. 2007).

Thus, exotic species are a foremost concern for national parks throughout the U.S., surely including the Southeast. As mentioned, there are at least 38 exotic species in Horseshoe Bend on the NPS Certified Species List (Table 32); these include 19 terrestrial plant species, 12 wetland plants, one fish, three birds, and three mammals. Quantitative information and maps of present distribution/coverage are lacking, although vegetation maps for the park are in progress.

3.7.9.1. Flora:

The Alabama Invasive Plant Council has ranked the most noxious of the exotic plants in the state as the Top 10 (Alabama Invasive Plant Council 2015). Similarly, the National Park Service has a *Top*

Ten Species List for the Southeast region. Both lists share three plants that are found in Horseshoe Bend, including one terrestrial plant (kudzu, *Pueraria montana* var. *lobata*) and two wetland plants (Chinese privet - *Ligustrum sinense*, Japanese honeysuckle - *Lonicera japonica*; Table 32). These plants have few natural enemies in the southeastern U.S.; they rapidly overgrow and shade out native, beneficial plant species, inhibiting their growth and displacing them in forests, fields, and/or wetlands. According to the Alabama Invasive Plant Council (2012), Kudzu has been called "the vine that ate the South" (Alabama Invasive Plant Council 2012). It continues to spread along edges of forests, pastures, roads, etc. It can grow up to 0.3 m (1 ft.) per day and covers most structures in its way, from buildings and fences to trees, road signs, and telephone poles. Chinese privet spreads by abundant seeds carried by birds and water, and its infestations grow by prolific root suckering (Alabama Invasive Plant council 2012). It tends to invade along fence rows and forested streams, and in upland forests. Its dense growth can be up to ~9 m (30 ft.) and prevents regeneration of bottomland hardwood as well as upland pine forests. For berry producers such as Chinese privet, the berries are less nutritious for wildlife than native species, but this plant has some limited value for deer browse and bird habitat. Japanese honeysuckle thrives in a wide range of habitats including fields, forests, wetlands, barrens, and various disturbed lands (NPS; see http://www.nps.gov/plants/alien/fact/loja1.htm, last accessed in May 2015). This plant has numerous growth and dispersal mechanisms, and it kills shrubs and young trees by girdling when vines twist tightly around stems and trunks, cutting off water flow through the beneficial plant.

Table 32. Exotic/ invasive taxa in HOBE, also indicating (*) Top 10 status on the Alabama Exotic Pest Plant Council (2015) Category #1 status, and Category #1 Alert status of the Alabama List of Exotic and Invasive Plants; and the NPS Top Ten Species List for national parks in the Southeast region (NPS 2015b).

Biota Group	Species	Status
Terrestrial Plants (19)	****Albizia julibrissin*** (mimosa, mimosa tree, powderpuff tree)	Category #1
	Cynodon dactylon (Bermudagrass, chiendent pied-de-poule)	Category #2
	Dioscorea oppositifolia (Chinese yam)	Category #2
	Duchesnea indica(India mockstrawberry, Indian strawberry)	
	Eleusine indica (Goosegrass, crowsfoot grass)	
	Glechoma hederacea (ground ivy)	
	Helenium amarum (sneezeweed, bitter sneezeweed, yellowdicks)	
	Lamium amplexicaule (common henbit, giraffehead, henbit)	
	****Lespedeza cuneata*** (Chinese lespedeza, sericea lespedeza)	Category #1
	****Melia azedarach*** (Chinaberry, Chinaberry tree)	Category #1
	Opuntia ficus-indica (Indian fig, Indian fig, tuna cactus)	
	Paspalum notatum var. *saurae* (bahiagrass)	
	Plantago aristata (bottlebrush Indianwheat, largebracted plantain)	
	Plantago lanceolata (narrowleaf plantain, buckhorn plantain, English plaintain)	
	Prunus mexicana (Mexican plum)	
	****Pueraria lobata*** *(Pueraria montana* var. *lobata;* kudzu*)*	Top 10, Category #1, NPS Top Ten Species
	Trifolium campestre (field [big-hop] clover, field clover, large hop clover)	
	Trifolium repens (Dutch clover, ladino clover, white clover)	
	Verbascum thapsus (big taper, common mullein, flannel mullein)	
Wetland Plants (12)	*Carya illinoinensis* (pecan)	
	Heliotropium indicum (India heliotrope, Indian heliotrope)	
	Ipomoea hederacea (ivyleaf morningglory, entireleaf morningglory)	
	****Ligustrum sinense*** (common Chinese privet, privet)	Top 10, Category #1, NPS Top Ten Species
	****Lonicera japonica*** (Japanese [Chinese] honeysuckle)	Top 10, Category #1, NPS Top Ten Species
	Paspalum dilatatum (Dallas grass, dallis grass, dallisgrass)	
	Polygonum caespitosum var. *longisetum* (oriental ladysthumb)	

Table 32 (continued). Exotic/ invasive taxa in HOBE, also indicating (*) Top 10 status on the Alabama Exotic Pest Plant Council (2015) Category #1 status, and Category #1 Alert status of the Alabama List of Exotic and Invasive Plants; and the NPS Top Ten Species List for national parks in the Southeast region (NPS 2015b).

Biota Group	Species	Status
	Rumex acetosella (red sorrel, sheep sorrel, common sheep sorrel)	
	Rumex crispus (curleydock, curly dock, narrowleaf dock)	
	Sorghum halepense (Aleppo milletgrass)	Category #2
	Verbena bonariensis (purpletop vervain)	
	Vitis rotundifolia (muscadine, muscadine grape)	
Fish (1)	*Cyprinus carpio* (European [common] carp)	
Birds (3)	*Chaetura pelagica* (chimney swift)	
	Passer domesticus (English [house] sparrow)	
	Sternus vulgaris (European starling)	
Mammals (3)	*Canis familiaris* (domestic dog, feral dog)	
	Felis catus (feral cat)	
	Vulpes vulpes (red fox)	

3.7.9.2. Fauna:

Nearly all emphasis on exotic/invasive taxa has focused on plants and, by comparison, little is known about exotic/invasive fauna at Horseshoe Bend. Nevertheless, two of the most destructive exotic/invasive species in the park are not on the NPS Certified Species List (NPS 2013b) because it does not include insects. The exotic invasive Asiatic clam, *Corbicula fluminea*, is believed to be present in the riverine ecosystem and potentially competing with native mussels (DeVivo 2004). This species, with high growth and reproduction rates, has substantially impacted other aquatic food webs and displaced native bivalve mollusc species (Stites et al. 1995). It also appears to be more adaptable to polluted environments than many native bivalves (Jenkinson 1979).

Considering terrestrial ecosystems, two insect species are high risk taxa with extreme damage potential. The southern pine beetle, *Dendroctonus frontalis*, is regarded as the most destructive forest insect pest in the southeastern U.S. (Clarke 1995), and it has killed many trees in the park (Chief Ranger J. Cahill, pers. comm., 2009). The red fire ant (*Solenopsis invicta*) originated in South America and was introduced to the U.S. in the 1930s (Porter and Savignano 1990). Since its arrival, it has infested more than ~1.2 million km^2 (~468,625 square miles, or 300 million acres) across the southern U.S., despite federal quarantine measures (Hawaii Ant Group 2007; and Defenders of Wildlife 2015). The red imported fire ant largely has displaced the two fire ant species native to the Southeast, the tropical fire ant (*Solenopsis geminata*) and the southern fire ant (*Solenopsis xyloni*; Porter and Savignano 1990). Red imported fire ants also threaten human health. In the U.S., millions of people are stung each year and more than 80 have died from hypersensitivity to the ant venom. Red imported fire ants additionally threaten wildlife, significantly depress biodiversity, and damage crops, ornamental plants, and electrical equipment (Porter and Savignano 1990, Wojnik et al. 2001, Hawaii Ant Group 2007).

Finally, many wildlife populations have been negatively impacted by predation from feral dogs and cats (USDI and NPS 2000, Watson 2005). Their effect on the natural biota of the park is a concern to park staff.

3.7.10. Management Actions

3.7.10.1. Exotic/Invasive Species:

Exotic vegetation was described by Chief Ranger J. Cahill as a primary concern for Horseshoe Bend. Two species specifically were mentioned: Chinese privet is mechanically removed on a five-year cycle, mostly within 9.1 m (30 ft) from the river. Each year 0.2 hectare (0.5 acre) of parkland infested with Chinese privet is treated to remove it, and an additional 1.2 hectares (3 acres) is treated with mechanical or chemical means to reduce growth of targeted invasive plants including Chinese privet, mimosa, Japanese honeysuckle, and kudzu. One to two areas of kudzu infestation are targeted for removal ever year as well. Cultural resource management at Horseshoe Bend includes removal of exotic plant species, as well, from certain areas along with erosion control and trail maintenance.

The National Park Service has created an Exotic Plant Management Team (EPMT) through its Exotic Plant Management Program. This program assists parks in preventing introductions of new species, reducing existing infestations, and restoring native plant communities and ecosystem functions. The

EPMT visits NPS partner parks on a rotational basis for several days at a time but, as of yet, Horseshoe Bend is not listed as a “host and partner park (NPS 2015a)

3.7.10.2. Longleaf Pine Restoration Efforts:

The park’s prescribed fire program was initiated in 2002 by previous Horseshoe Bend Superintendent Mr. Mark Lewis, who also authored the park’s first Fire Management Plan in 2003. A fire break was constructed along the entire park boundary in fiscal year 2004. Burning was planned to continue in winter annually, following the approved fire plan for the park on a five-year cycle. In fiscal year 2005, a burn plan was approved, but weather conditions delayed the first prescribed burn until 2006 (NPS 2006; and NPS 2015f).

The major goal of the program is to reduce fuels buildup while allowing for natural regeneration of longleaf pine along the ridgeline. A second goal is to manage southern pine beetle-damaged areas to establish early successional grassland or shrub scrub habitat. Longleaf pine forests require fire for long-term viability, but fires in the Horseshoe Bend area have been rare and management actions previously emphasized fire avoidance. In fact, throughout the history of the park until 2006, there was no record of a forest fire. Over the past 30 years, there has been a significant increase in flammable ground fuels (e.g. plant debris), see the Strategic Management Plan for Horseshoe Bend (NPS 2015g). Prior to the first prescribed burn at the park, concern was expressed by longleaf pine specialists at Auburn University that with excessive duff and forest litter that had accumulated over time, longleaf pine feeder roots tend to rise to the surface where they could sustain fire damage during prescribed burns. Therefore, the fire plan was slightly modified to reduce fuel loads while also removing duff layers surrounding longleaf pine stands.

In mid-April of 2006, 115 hectares (285 acres) in the northwest area of the park were successfully burned (Plate 2) with assistance of fire use modules from Cumberland Gap National Historical Park, Great Smoky Mountains National Park, an engine crew from Kings Mountain National Military Park, local Rural Fire Assistance cooperators, and Clemson University. The management goal for 2008 was to reduce the forest fuel load in Horseshoe Bend by 40% on at least one burn unit that was identified in the 2003 Fire Management Plan. The most recent fire fuel survey at Horseshoe Bend by the National Park Service was in summer 2011.

The College of Forestry at Auburn University is an active partner in the park’s longleaf pine restoration efforts. In 2009, Auburn University researchers purchased and planted 1,565 containerized longleaf pine seedlings scattered over 10 small gaps throughout Horseshoe Bend in three separate sites designated as Northeast (NE), Northwest (NW), and Southwest (SW; Figure 46). This planting is a pilot effort to assess the success of planting containerized longleaf in small regeneration gaps within a disturbed, previously fire-excluded landscape (NPS 2015d).

Plate 2. Left: Fire from a prescribed burn, moving through litter layers along the park. Right: Longleaf pine “grass stage” seedling, viable after the fuel reduction burn. NPS: photos by J. Cahill and A. Callis (Forest and Rangelands 2006).

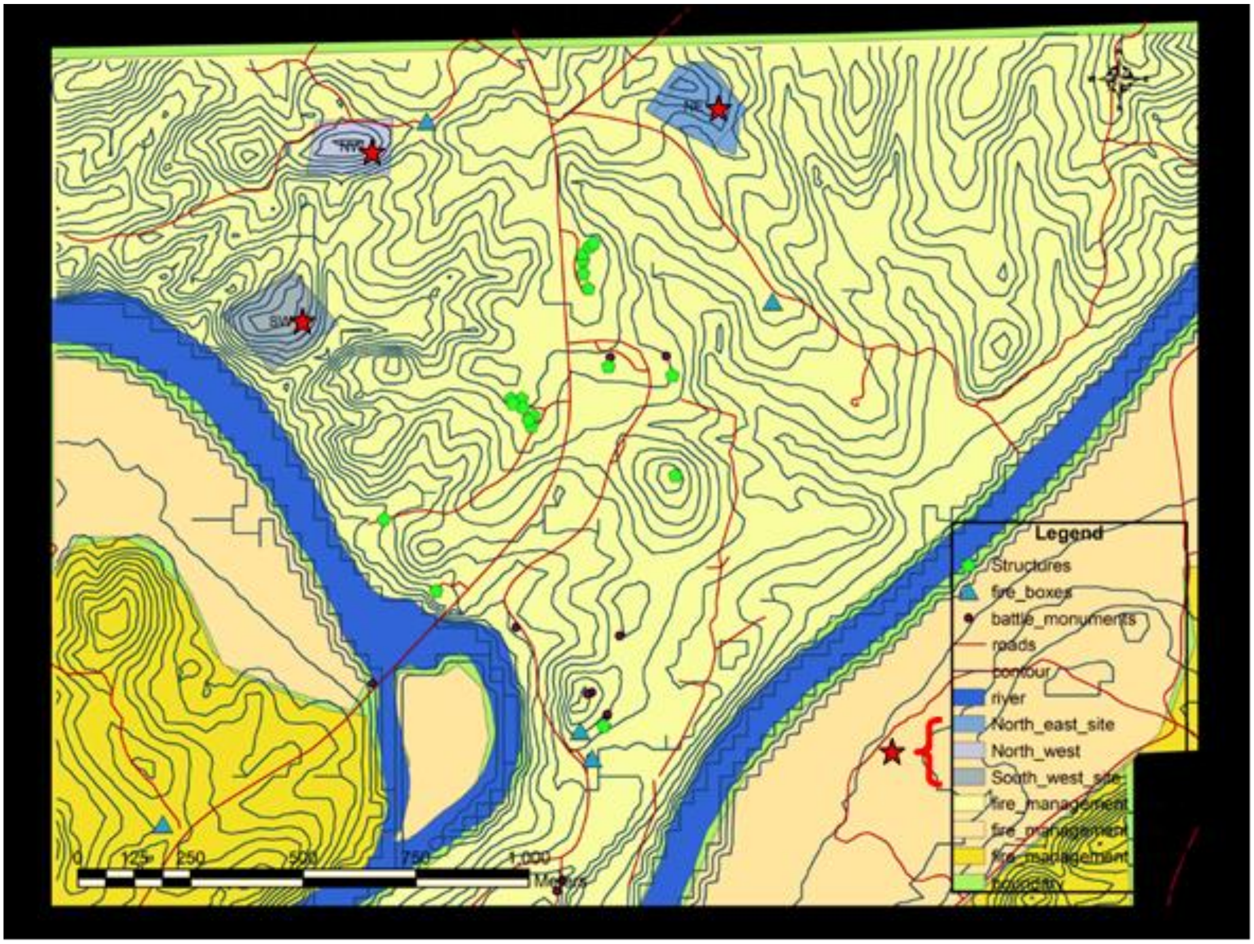

Figure 46. Map of the three longleaf pine restoration sites (shaded areas with red stars) at HOBE, also showing fire boxes (blue triangles). Provided by HOBE Superintendent Doyle Sapp.

3.8. Synopsis of Stressors to Horseshoe Bend Natural Resources

The present and potential stressors that are affecting or may affect Horseshoe Bend are summarized in Table 33. Despite the relatively remote and rural location of the park, degraded air quality is already a moderate to significant concern, encompassing ozone and particulate pollution, acidification from N and S chemical species, and reduced visibility. Surface water quality data are sparse and indicate fair conditions; groundwater quality data apparently are completely lacking. Potential pollution sources in the watershed include point source dischargers and nonpoint sources such as clear-cutting and agriculture. For example, agricultural impacts may have resulted in local extirpations of herpetofauna (Tuberville et al. 2005). The highly artificial flow regime that has been imposed on the middle Tallapoosa River by hydroelectric operations periodically would be expected to cause sudden, extreme stress and elimination of aquatic life. The dams have also fragmented the natural breeding and migration patterns of fish and mussels. Water demands could be exacerbated in the future depending on allocations to population centers such as Atlanta. Neighboring Lee County is recruiting retirees, resulting in increased population growth and higher value of rural lands being sold for development. If this continues, Horseshoe Bend staff expect increased highway traffic, waste product pollution, noise, and other urban sprawl issues (NPS 2008).

Other concerns are soil erosion, habitat loss and disruption near the park, and the impacts of exotic/invasive plants and animals, which have been evaluated as a major threat to the natural ecosystems of Horseshoe Bend (Chief Ranger Jim Cahill, pers. comm., 2009).

Table 33. Current and potential stressors that are affecting or may affect HOBE (ND ≡ no data to make judgment; NP ≡ not a problem;-- ≡ not applicable; EP ≡ existing problem; PP ≡ potential or pending problem).

Stressor	Surface Waters	Ground-water	Airshed	Forest	Human Health
Acidification	EP	ND	PP	PP	PP
Algal blooms	PP	---	---	---	NP
Toxic algae	ND	---	---	---	NP
Encroaching development (clear-cutting. etc.)	ND (PP)	ND (PP)	ND (PP)	ND (PP)	NP
Erosion (including dust)	EP	---	---	ND (PP)	NP
Excessive nutrients	EP	ND	PP	---	NP
Exotic invasive species*	EP	---	---	EP	ND (PP)**
Fecal bacteria, other microbial pathogens	ND (PP)	ND	ND	ND	PP
Habitat disruption	EP	ND	---	EP	---
Hypoxia	EP	---	---	---	---
Light pollution	ND (PP)	---	---	---	---
Metals contamination	ND (PP)	ND (PP)	ND (PP)	---	ND (PP)
Noise pollution	ND (PP)	---	---	ND (PP)	ND (PP)
Other toxic substances	EP	ND (PP)	EP	ND (PP)	PP
Ozone pollution	---	---	EP	EP	EP
Particulate matter pollution	EP	ND	EP	---	EP
Sedimentation	EP	ND	EP	---	---
Trash/refuse pollution	ND (PP)	ND (PP)	ND (PP)	ND (PP)	---
Visibility (air pollution)	---	---	EP	PP	EP
Water demand	PP	PP	---	---	PP

* Suspected for aquatic resources; known for terrestrial resources.

** Includes consideration of West Nile virus, carried by mosquitoes and known to be in the area.

4. Indicators to Assess Natural Resource Conditions

4.1. Management Directives and Planning Guidance

The NPS mission is to "preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations" (NPS 2013c). About 15 years ago the NPS (1999) developed an action plan, the Natural Resources Challenge, for preserving the natural resources of the national parks (see Carter 2007), and the agency has been engaged in many efforts to carry out that plan.

Horseshoe Bend was listed on the National Register of Historic Places in 1976. Thus, the entire area was to be "managed with preservation and interpretation of cultural values as the central focus." The park does not have a General Management Plan Environmental Assessment, but it does have a five-year Strategic Plan (2008-2012; NPS 2008). According to the present Strategic Plan for Horseshoe Bend, the overarching charge for the National Park Service is to preserve "outstanding representations of America's natural, cultural, and recreational resources of national significance..." and make them available to visitors. The Strategic Plan was written to fulfill requirements of Section 104 of the National Parks Omnibus Management Act of 1998, consistent with the Government Performance and Results Act of 1993.

A Resource Stewardship Strategy (RSS) has not yet been developed for Horseshoe Bend. Once available, the RSS should help to protect the park's natural resources. The present Strategic Plan for Horseshoe Bend (NPS 2008) identified long-term goals and five key factors affecting accomplishment of those goals. Four of the five key factors - *water resources* (severe hydrologic fluctuations imposed by the Alabama Power Company on the Tallapoosa River in the park), *climate* (major storms causing natural disasters), *area population increases*, and the *local economic situation* - significantly affect the natural resource conditions of the park, and all four are factors that are Not Possible for the NPS to Control (NPC). Thus, various indicators developed and described in this chapter to evaluate Natural Resource Conditions in Horseshoe Bend over time are related to factors that are NPC.

The National Park Service has done considerable work to identify natural resources and indicators that are important from the perspective of the NPS I&M Program: Three general properties were identified that broadly affect the integrity of ecosystems and natural resources in SECN parks: (a) parks are generally surrounded by altered landscapes; (b) the ecosystems of the Network are driven to a large extent by natural disturbance process such as hurricanes, flooding, and fire; and (c) the SECN region is increasingly subject to human development, resulting in diverse anthropogenic effects on park resources (DeVivo et al. 2008).

The NPS I&M Program was created as part of the National Park Service's efforts to improve park management through greater reliance on scientific knowledge. The Network developed a suite of conceptual models to support and guide development of a monitoring program for the parks, using General Ecosystem Model as a template for specific models of the six dominant ecosystem types found in SECN parks. Horseshoe Bend has three of these - Upland Forests, Bottomland Hardwoods, and Streams. Each model includes a set of system drivers, local drivers, and park resources.

Importantly as well, the Network identified 25 Vital Signs, most of which are being/planned to be monitored as part of the I&M Program (Table 34). The ecosystem-centered Vital Signs span all categories of the Ecological Monitoring Framework: Air & Climate, Geology & Soils, Water, Biological Integrity, Human Use, and Ecosystem Patterns and Processes. Most - Air Quality, Climate, Geology & Soils, Water, and Biological Integrity (Biological Resources) have been discussed in Chapters 2 and 3 of this Report. The Inventory also covers Ecosystem Patterns (land use/land cover) and various aspects of Human Use. Many of the Measures were on our preliminary list of potential indicators for Horseshoe Bend. For many of these parameters, however, information for Horseshoe Bend is not yet available, underscoring the importance of the I&M Program to establish present natural resource conditions in the park and track them over time to assess park ecosystem health.

Table 34. Vital signs identified by the SECN for its inland parks including HOBE (✚ ≡ Vital Sign for which the SECN will develop protocols and implement monitoring; ● ≡ Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency; ◈ ≡ monitoring deferred). Modified from DeVivo et al. (2008).

Ecological Monitoring Framework Categories					
Level 1	**Level 2**	**Level 3**	**Network Vital Sign**	**Measures**	**Status**
Air & Climate	Air Quality	Ozone	Air Quality	Atmospheric ozone concentration, damage to sensitive vegetation	●
		Wet and Dry Deposition	Wet and Dry Deposition	Wet and dry sulfate and nitrate deposition	●
		Visibility and Particulate Matter	Visibility and Particulate Matter	IMPROVE suite for visibility and fine particulates, particle size analyses: pm 10, pm 2.5, haze index	●
		Air Contaminants	Air Contaminants	Concentration of mercury, semi-volatile organic compounds, acidic components of contaminants	●
	Weather & Climate	Weather and Climate	Weather and Climate	Air temperature, precipitation, relative humidity, tides, location and magnitude of extreme weather events	●
Geology and Soils	Geomorphology	Coastal/Oceano-graphic Features and Processes	Coastal Shoreline Change	Shoreline position	
			Salt Marsh Elevation	Sediment elevation, salinity	
		Stream/River Channel Characteristics	Stream/ River Channel Characteristics	Percent cover of coarse woody debris, detritus, distribution and extent of geomorphic features (runs, riffles, pools); grain size distribution; distribution, extent, and rate of change of erosion features	✚
Water	Hydrology	Groundwater Dynamics	Groundwater Dynamics	Water table levels for freshwater and saltwater	●
		Surface Water Dynamics	Surface Water Dynamics	Discharge, magnitude and duration of flooding events	●
	Water Quality	Water Chemistry	Marine Water Quality	pH, temperature, dissolved oxygen, turbidity, salinity, concentrations of chlorophyll a, TDN, TIN, TDP, TIP, metals, and volatile organic compounds	

Table 34 (continued). Vital signs identified by the SECN for its inland parks including HOBE (✚ ≡ Vital Sign for which the SECN will develop protocols and implement monitoring; ● ≡ Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency; ◈ ≡ monitoring deferred). Modified from DeVivo et al. (2008).

Ecological Monitoring Framework Categories					
Level 1	**Level 2**	**Level 3**	**Network Vital Sign**	**Measures**	**Status**
Water (continued)	Water Quality (continued)	Water Chemistry (continued)	Riverine Water Quality	pH, temperature, dissolved oxygen, specific conductance, turbidity, trace ions, nutrient concentrations	✚
Biological Integrity	Invasive Species	Invasive/Exotic Plants	Invasive/ Exotic Plants	Occurrence of invasive plant species	✚
	Focal Species or Communities	Marine Invertebrates	Marine Invertebrates	Occurrence of selected marine Invertebrate species	
		Fishes	Fish Communities	Fish community diversity, relative abundance, Index of Biotic Integrity, percentage of non-native species, number of crevice spawner species	◈
		Amphibians and Reptiles	Amphibians	Species occurrence, diversity, percent area occupied, disease incidence	✚
		Birds	Breeding Forest Birds	Species occurrence, diversity, relative abundance	✚
		Mammals	Small Mammals	Species occurrence, diversity, percent area occupied, relative abundance	◈
	Focal species or communities cont.	Vegetation Complex	Plant Communities	Plant species occurrence, diversity; percent cover by herbaceous, shrub and overstory; rooting by feral hogs and armadillos; occurrence of disease, occurrence of insect outbreaks, occurrence of non-native species; NVCS class	✚

Table 34 (continued). Vital signs identified by the SECN for its inland parks including HOBE (✚ ≡ Vital Sign for which the SECN will develop protocols and implement monitoring; ● ≡ Vital Sign that is monitored by a network park, another NPS program, or another federal or state agency; ◈ ≡ monitoring deferred). Modified from DeVivo et al. (2008).

Ecological Monitoring Framework Categories					
Level 1	**Level 2**	**Level 3**	**Network Vital Sign**	**Measures**	**Status**
Bioligical Integrity (continued)	At risk Biota	T&E Species and communities	Shorebirds	Number and location of piping plover, red knot, Wilson's plover, American oystercatcher	
		T&E Species and communities	T&E Species	Abundance, distribution, and recruitment of rare species such as sea beach amaranth, beach mouse, sea turtles, red-cockaded woodpeckers	●
Human Use	Consumptive Use	Consumptive Use	Fisheries Take	Species occurrence, weight, size based on compilation of existing data from State and other sources	
	Visitor & Recreation Use	Visitor Usage	Visitor Use	Monthly and annual visitor attendance compiled from existing Park and other sources	●
Landscapes	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Burn area and extent, down woody debris, duff depth	✚
	Landscape Dynamics	Landscape Dynamics	Land Cover and Use	Extent and distribution of land cover and use types, fragmentation, extent and distribution of management actions (compiled from park records)	✚

4.2. Study Scoping and Design

Program Manager Joe. DeVivo organized an initial workshop for this project in Atlanta, wherein we received guidance about the background and foundation of NPS National Resource Condition Assessments. We also received counsel about the best NPS specialists to contact about various aspects of the project, available NPS data, and NPS websites with important information. This meeting addressed all project objectives, especially (ii) - Determine the subset of NPS-identified and PI-identified data and information sources that are most pertinent and useful for developing indicators and performance measures) and (vi) - Conduct a series of workshops to assist in project completion.

In recognition of the fact that park staff have, by far, the most advanced and detailed, comprehensive understanding about the natural resources of Horseshoe Bend, we then visited Horseshoe Bend and spent several hours with park staff. They graciously took us on an informative tour of the park's natural resources. We also discussed each category of natural resources with them, and learned their knowledgeable views about issues for each category that would need to be considered in inventory and assessment efforts. Their input was truly essential to enable us to select an optimal set of natural resource indicators that would be the most useful to the park staff both short-term and long-term. We additionally were given their guidance on which indicators should be emphasized as major priorities for the park. We all were in accord that the indicator framework needed for Horseshoe Bend should follow an *ecosystem* approach as in DeVivo et al. (2008).

An extensive, continued effort over the entire span of the project was then conducted to obtain all manner of natural resource information pertinent to the park - historic information, reports, books, peer-reviewed publications, management plans, GIS data, etc. All of this information was carefully considered in writing the final synthesis of the inventory and status of Horseshoe Bend natural resources. The findings were presented within an ecosystem framework (Figure 47), considering Horseshoe Bend as the ecosystem. Following a hierarchical framework patterned after Unnasch et al.'s (2009) *Ecological Integrity Assessment Framework*, we first considered the overall goal(s) of the park staff for the desirable status, i.e., the ecological integrity, of each category of natural resources in Horseshoe Bend. *Ecological integrity* is defined here as the ability of an ecological system to support and maintain a community of organisms with species composition, diversity, and functional organization comparable to those of the natural/historic habitats in the park. We then conducted a macroscale inventory of landscape pattern (land cover/ land use) surrounding the park; the "human biological factor," i.e. human population demographics in the area surrounding Horseshoe Bend and visitor statistics within the park; air quality (airshed level), water quality (within the park insofar as possible, but considering pollution sources near the park), the soundscape, and the lightscape; and stressors on the natural resources *within* the park. This included a concerted effort to gather and organize existing databases for multiple GIS data layers describing Horseshoe Bend natural resources. Next, we inventoried what is known about the present composition and condition of the vegetation, habitat structure, and including the natural communities, SoC, exotic/invasive species, and species of special interest for park managers. For each category of natural resources, we then identified a suite of indicators and measures for tracking natural resource health in Horseshoe Bend. These indicators were carefully selected to be scientifically sound while also providing the most “user-friendly,” straightforward, and easily accomplished method for evaluation that we could find.

Our intentions in meeting the latter requirement were two-fold: First, to provide, insofar as possible, a suite of indicators and the methods to assess them that park staff and the National Park Service in general will find clear, simple and rapid, and relatively inexpensive to conduct; and second, in this world where information must be conveyed in sound bites and one-page bullets, to provide an indicator system with powerful messages that are easy/fast to explain to policymakers who often have dramatic influence over our nation’s increasingly precious national parks.

As noted by the South Florida Ecosystem Restoration Task Force (2011) from its “System-wide Indicators for Everglades Restoration - 2010 Report,” any method of communicating complex scientific and findings to non-scientists [for Horseshoe Bend, the general citizenry, visitors to the park, and politicians who strongly influence critically needed funding for the park] must (1) be developed with consideration for the specific audience, (2) be transparent as to how the science was used to generate the summary findings, (3) be easy to follow the simplified results back through the analyses and data to see a clear and unambiguous connection to the information used to roll up the results, (4) maintain the credibility of the scientific results without minimizing or distorting the science, and (5) should not be, or appear to be, simply a judgment call (Norton 1988, Dale and Beyeler 2001, Niemi and McDonald 2004, Dennison et al. 2007) [T]he system must be effective in quickly and accurately getting-the-point-across to the audience in order for the information to be used effectively (Rowan 1991, 1992; Dunwoody 1992; Weigold 2004; Thomas et al. 2006; Dennison et al. 2007). For further information, see http://issuu.com/evergladesrestoration/docs/2014_indicator_report?e=8031892/12097978, last accessed in May 2015.

Thus, here we use a “stoplight report card system” approach (e.g. Doren et al. 2009, NPS 2009) of *good* (green), *fair* (yellow), and *poor* (red) to summarize our evaluation of present natural resource conditions at Horseshoe Bend (Figure 48). This system has been used with great success to assess natural resource conditions systems such as Chesapeake Bay and its watershed (Williams et al. 2007), and the Florida Everglades ecosystem (Ferriter et al. 2007, Doren et al.2008, 2009).

Importantly, we were instructed by the National Park Service to design indicators that were quantifiable insofar as possible, and supported by peer-reviewed science literature. We therefore carefully clarify, with supporting scientific basis, any suggested indicators for which quantitative information for the park was not available. Because this stipulation, while logical, greatly restricted the suite of indicators that could be proposed, in Chapter 5 we also include discussion of data gaps that we view as especially important to fill so that certain much-needed indicators can be developed. Finally, to ensure that the data used to develop the indicators and assessment were of acceptable quality, we restricted our inventory and this analysis to reliable sources (e.g. NPS, peer-reviewed literature, quality assured/ quality controlled water quality data, etc.), and to data collected by those sources within the past decade.

This indicator framework and suite of indicators for Horseshoe Bend support the identified goals of the National Park Service to "develop service-wide products that improve management of biological resources in parks, and maintain a broad ecosystem-based framework for park management" (Unnasch et al. 2009).

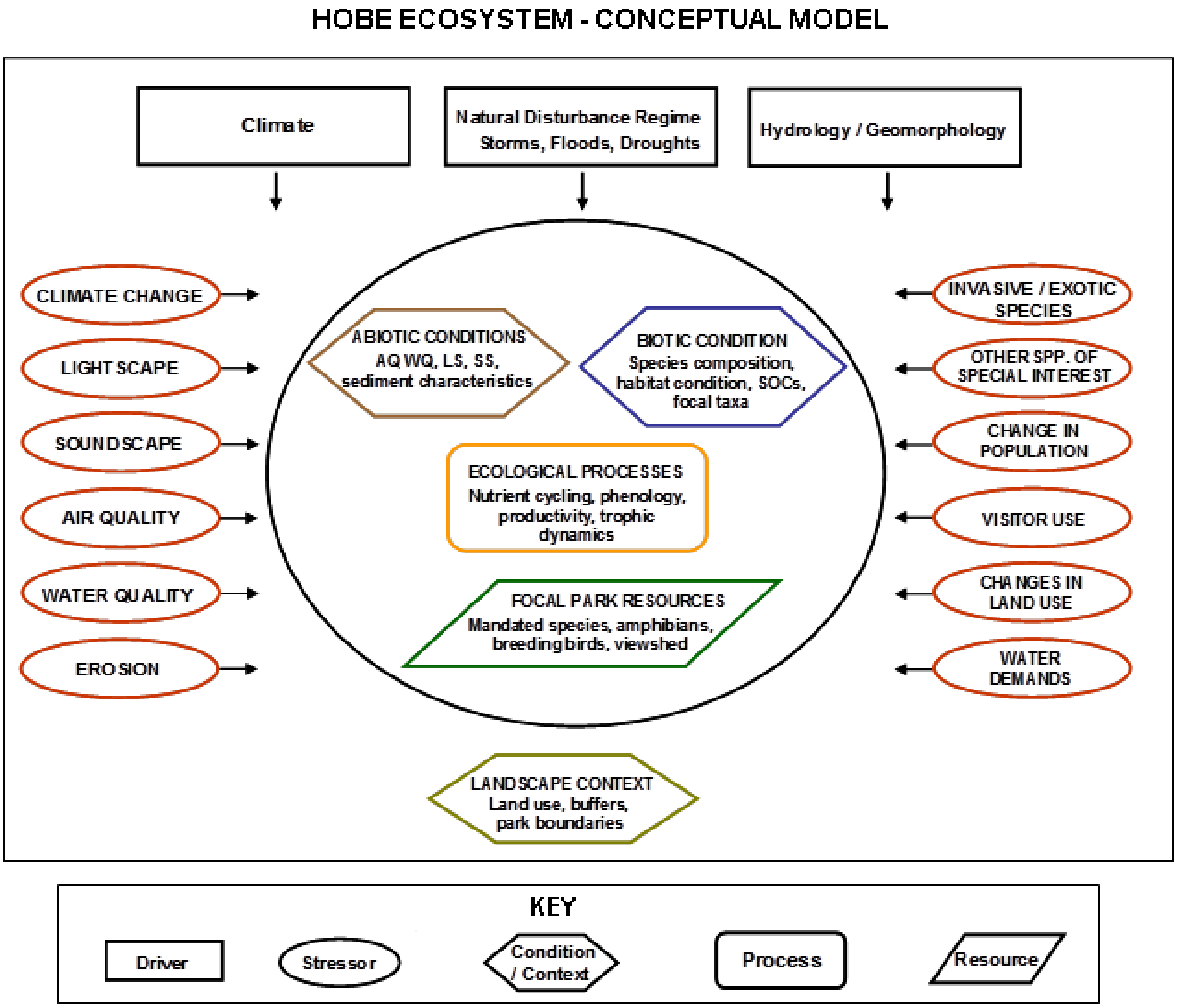

Figure 47. Conceptual model of the HOBE ecosystem, used as a general framework to select indicators of natural resource health for the park. Modified from DeVivo et al. (2008, Appendix: Conceptual Ecological Models; examples of stressors are shown).

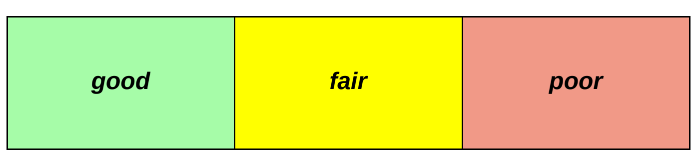

Figure 48. The color-coded "stoplight report card" system used to succinctly convey the status of HOBE natural resources. Adapted from Ferriter et al. (2007).

4.3. Climate Change

Issue: Climate change is rapidly advancing in the Southeast, manifested through warming temperatures, altered patterns and amounts of precipitation (droughts, floods), and the storm frequency. These changes will dramatically impact Horseshoe Bend natural resources.

Baron et al. (2008) described climate change as already redefining U.S. national parks, and advised park managers to begin to include climate change considerations into all activities and plans. Not surprisingly, species richness, extirpations, and introductions in national parks in other nations, as well as the U.S., have been found to be strongly related to climate, more so than to any other factor (Rivard et al. (2000). To increase the resilience of the natural biota to the many changes resulting from climate change, Baron et al. (2008) recommended reducing habitat fragmentation and loss, invasive species, and pollution; protecting important ecosystem and physical features; restoring damaged systems and natural processes; and reducing the risks of catastrophic loss through establishing refugia, relocating valued species, replicating populations and habitats, and attempting to maintain representative examples of beneficial species populations. The extent to which these goals can be done for Horseshoe Bend is unclear, especially for the wetland/aquatic ecosystems of the park because of the extreme hydrologic fluctuation that has caused dramatic adverse alterations.

The IPCC 2007 has projected that temperature in the Southeast will increase 2.2 to 5.0^{o}C (4 to 9^{o}F) by 2080 (Karl et al. 2009). Since 1970, average annual temperatures in this region have increased by ~1.1^{o}C (~2^{o}F), and winters in particular are warming: The average number of freezing days has declined by four to seven days per year (Karl et al. 2009). Most areas are also becoming wetter, especially in the autumn; in contrast, during the spring and summer seasons, areas affected by moderate to severe droughts have increased (Karl et al. 2009). It is uncertain whether precipitation will increase or decrease, but models suggest that there will be heavier downpours interspersed with increased droughts between storm events. Thus, both the risk of flooding and the risk of drought are expected to increase. Coastal areas are expected to sustain stronger hurricanes, accelerated sea level rise, and larger storm surges (Karl et al. 2009). The IPCC also has projected that flow seasonality will increase in rain-dominated regions such as the U.S. Southeast, resulting in higher flows during the peak flow season and lower flows during low flow seasons and/or longer dry periods (Kundzewicz et al. 2007). Future floods and droughts likely will not occur at historic rates because climate change is expected to be a major force controlling the frequency and timing of flow seasonality (Brekke et al. 2009). Projections about smaller-scale, regional and subregional impacts have high uncertainty, such that accurate assessment of climate change effects on flow and water supply will require long-term monitoring (Knowles et al. 2006, Brekke et al. 2009).

The historic and present climatic conditions at Horseshoe Bend, and the significance of changes in these conditions, were described in Chapter 3 of this Report in terms of five parameters that are recommended here as indicators: air temperature, precipitation, moisture (the PDSI and the number of dry months), phenology, and extreme weather events. In fulfilling the “easy and straightforward” criterion, the data for temperature, precipitation, and PDSI are easily plotted online from the NOAA NWS. Other climate information may require assistance from knowledgeable state and federal personnel. Evaluation considers trends in the six indicators over the past decade (Table 46):

- Summer Average (Mean) Air Temperature: *poor* = increasing;
- Summer Average (Mean) Precipitation: *poor* = decreasing;
- Moisture: *poor* = increasing dryness (lower PDSI, more dry months);
- Annual GDD: *poor* = increasing; and
- Number of Major Storms: *poor* = increasing.

As mentioned, an important feature of the selected indicators is that they are easy to assess. Detailed climatic data for these indicators are easily available from NOAA (see Chapter 3).

However, we initially encountered difficulty in (1) determining the date when the 1200 GDD threshold is reached, and (2) using the PDSI data to rank the severity of drought over seven "moisture classes" ranging from excessively wet to severely dry (Chapter 3, Table 4). Therefore, with assistance from the Department of Statistics at NCSU, we wrote two straightforward, user-friendly programs for the National Park Service, which automate the computations (Appendix 3). Both programs use data that are routinely supplied to end users by the SERCC.

The first program uses GDD data to calculate the date where the 1200 GDD threshold is reached. The computation involves finding the calendar date when the 1200 GDD threshold is reached for each year in the dataset, by summing the monthly values until the sum is greater than 1200 and then calculating the slope of the line between that month and the month preceding to determine the exact date on which 1200 would occur. Typically, the value 1200 is achieved between April and May, but occasionally it occurs between March and April, or between May and June, depending on the temperature. The second program uses the PDSI data to rank the severity of drought over the seven moisture classes. The computation involves calculating the proportion of the number of monthly observations in each drought class for every nine-year period.

The "keystone" indicator of climate change is temperature, as it strongly influences all four other indicators. Therefore, an overall score of 0 to only 1 *poor* evaluation among the five indicators is *good*, unless the *poor* score is for temperature wherein the overall score is *fair*. The four possible evaluation scenarios are shown in Table 35.

For Horseshoe Bend, rapidly rising average summer temperatures over the past decade have been accompanied by a striking decrease in average summer precipitation during the same period, as well as a strong increase in the proportion of months that have been abnormally dry and excessively dry, and a striking decrease in PDSI values. The annual GDD has decreased from the 1930s - 2012, but appears to have increased in the past decade, and the approximate date when 1200 GDD was reached for each year since 1930 has also increased by several days. The number of storms has increased each decade since the 1980s. All of these conditions are undesirable. Thus, all five indicators for Climate Change Condition are *poor*, leading to an overall average evaluation of *poor* (Table 36). These indicators are all *NPC* for the National Park Service. The Network has worked to develop a Climate Science Strategy in an attempt to prepare for and mitigate the adverse impacts of global warming on all of the national parks in the region (DeVivo et al. 2011).

Table 35. Overall scores for climate change, based on the six selected indicators.

Indicators, Evaluations	Status	Overall Score
Scenario 1		
Summer average air temperature Good	↔ or ⬇	*good*
Other indicators	≤ 1 *poor*, < 2 *fair*, > 3 *good*	
Scenario 2		
Summer average air temperature ($TEMP_{SUM}$) *poor*	⬆ *poor*	*fair*
Other indicators	≤ 1 *poor*, > 4 *good* or *fair*	
Scenario 3	≥ 3 indicators *poor*	*poor*

Table 36. Evaluation of Climate Change Condition in HOBE, based on five Climate Indicators.

Climate Change Indicators	Trend at HOBE	Rating
Summer Average Air Temperature (T_{SUM})	↑	*poor*
Summer Average Precipitation (Ppt)	↓	*poor*
Moisture - PDSI, # of Dry Months$_{Dry}$	↓ , ↑	*poor*
Phenology (GDD_{ANNUAL})	↓	*poor*
Number of Major Storms ($STORMS_{MAJOR}$)	↑	*poor*
Evaluation (each indicator = 1 point). *good* = 0 *poor* or only 1 *poor* (not T) *fair* = 1 (T) or 2 indicators (not T) *poor* *poor* = 3-5 *poor*		OVERALL-*poor*

4.4. Watershed/Landscape Dynamics

4.4.1. Human Population in the Surrounding Area

Issue: Population size and rate of growth have been strongly linked to adverse ecosystem impacts. Horseshoe Bend is threatened by a relatively high surrounding poverty level, and its rural setting is also threatened by rapid population growth in adjacent Lee County.

Human-related land transformation is the primary driving force in the loss of biological diversity worldwide (Vitousek et al. 1997). The size, density, and rate of growth of the human population in a given area have been strongly linked to rapidly escalating environmental disruption (Ehrlich and Holdren 1971) and exotic plant species diversity and abundance (McKinney 2001). As noted by Meyer and Turner (1992), "population remains one of the few candidate driving forces that is readily measured and for which statistical associations have been found with ecosystem decline." The human population size, growth, and density surrounding national parks are unquestionably major influences on the park ecosystems. Thus, Rivard et al. (2000) found that species richness, extirpations, and alterations within other national parks were all strongly related to characteristics of the lands surrounding the parks. In addition, species invasions and introductions were more frequent in parks that were subject to the most human influence.

Although the science literature is replete with reports about environmental degradation linked to increasing human population density (HPD), information is mostly lacking about the quantitative level of HPD that acts as a threshold triggering significant damage to the adjacent natural ecosystem. Luck (2007) summarized the issue as follows: "…clear and predictable links between human population dynamics and environmental change remain elusive largely because of the complexity of the human enterprise and its many and varied impacts on nature" (Figure 49). Viewed from a quantitative standpoint, impacts of high HPD can extend many kilometers beyond city boundaries (Myers 1994, Repetto 1994), but the effects can vary from minor to major in areas of lower HPD, largely depending on the main land use (Luck 2007, and references therein).

Context is also important: For example, a marked increase in HPD near a wilderness reserve would be expected to have quite different impacts than if the increase occurred near a city park. This difference is especially true of the rate of change: Non-native species introductions (McKinney 2001) and species extinctions (Balmford 1996) have occurred faster in more rapidly growing areas with lower human population than in highly populated areas. Socioeconomics can also be an important influence on the degree of environmental impact, which has been shown to be higher per capita in economically depressed areas for reasons ranging from limited economic means to protect natural resources, to environmental injustice (Blaikie and Brookfield 1987, Durning 1989, Allen and Hoekstra 1991).

Regardless of these complexities, we felt it important to represent HPD and human population growth (HPG) as indicators of natural resource health in Horseshoe Bend, to account for the fact that human population impacts on adjacent natural resources are not fully captured by related indicators such as land use (Figure 49). In addition, it generally can be stated with confidence that HPG results in increasing land changes and exotic species introductions; and that land protected for conservation is often greatly reduced near human population centers (Luck 2007).

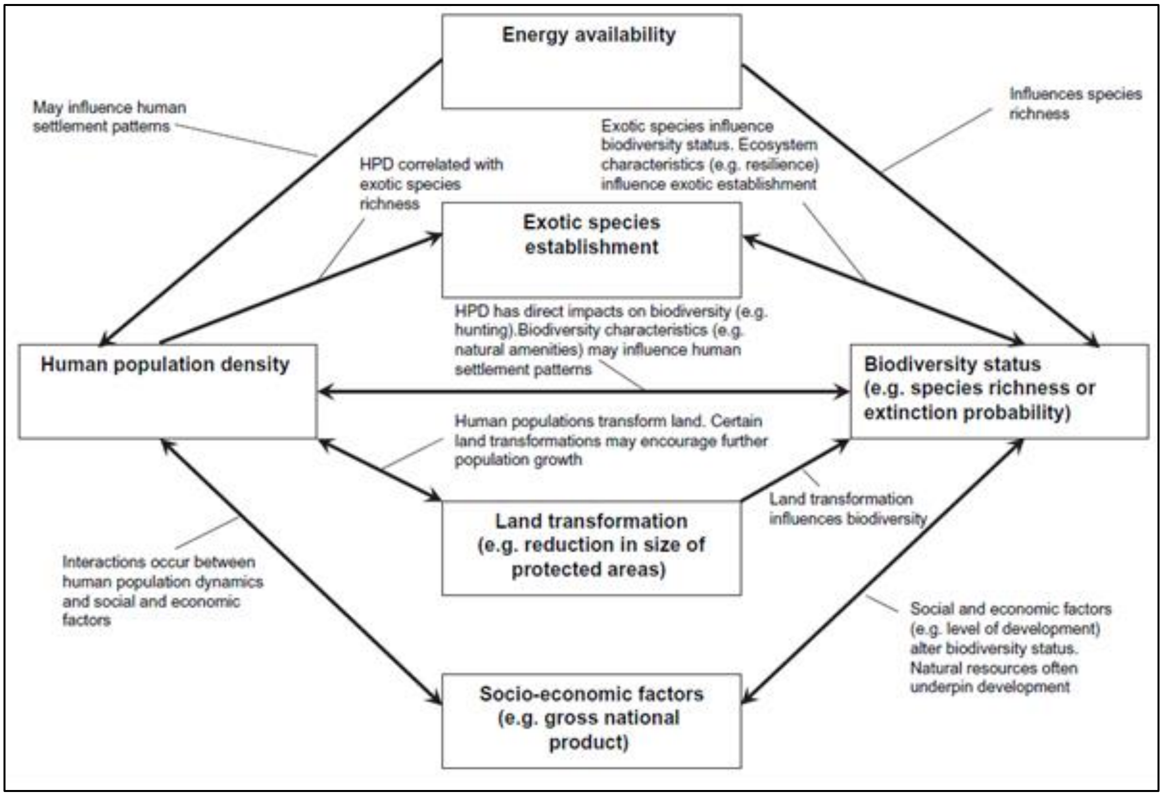

Figure 49. A schematic of possible relationships between human population density and biodiversity, especially focusing on the negative impacts of human population growth. The evidence for each of these relationships varies in the literature. The diagram includes biodiversity feedback loops, but not interconnections between energy availability, exotic species establishment, land transformation and socio-economic factors. From Luck (2007), with permission.

Our evaluation system for human population indicators in Horseshoe Bend considered the following information:

- Tallapoosa County has a small human population, only ~41,600 as of 2012. The population density (HPD) of Tallapoosa County is also low, only 22.4 people per km^2 (58 people/mile^2). By comparison, the national average HPD in the past decade (2001-2010) was ~31.4 people per km^2 (~81.3 people per mile^2).
- Over the past ~decade (2000-2010), the population of the county increased by only 0.34%, and the population *declined by ~1.1%* in 2012-2013. By comparison, the national average over the ~same decadal period was a 9.71% increase in HPG, or about 1% increase per year.
- Tallapoosa County is economically depressed; median household income is only about two-thirds of the national average; unemployment is high; and 17.1% of the population (based on data from 2007-2011) is below the poverty level, versus a national average of 13.8%.
- In contrast to the profile of Tallapoosa County, less than 64 km (40 miles) away is the Au-OpMA, the 11th fastest growing metropolitan area in the nation, with *2.6% increase* in population from July 2011-July 2012 (from 143,580 people to 147,257 people, respectively; most recent available data; Figure 50). In 2010 the population density of Lee County, which includes the Au-

OpMA, was 91 people per km^2 (236 people per $mile^2$). In 2009, U.S. News and World Report ranked Auburn in its top ten list of Best Places to Live in the U.S., enhancing the popularity of the Au-OpMA (U. S. News and World Reports 2009).

- The State of Alabama had a population of 4,822,023 as of 2012, up ~1% from 2011. The total surface area of the state if 135,765 km^2 (52,419 $miles^2$); thus, the average statewide population density in 2011 was 35.5 people per km^2 (92 people per $mile^2$).
- As an historic "reference" condition, about 500 years ago the HPD of the area was 0.9 people per km^2 (2.3 people per $mile^2$; area of the Southeast Region from Burkett et al. 2001; number of Native Americans there from Fagan 1995, Smith 2000).
- Analysis of 24 present-day wilderness areas revealed that all had population densities of $\leq$ 5 people per km^2 (12.8 people per $mile^2$; Mittermeier et al. 2003). It would be expected that present-day conditions, even in areas considered somewhat "remote," would have substantially higher HPD than did the southeastern U.S. about 500 years ago.
- Considering this information collectively, for HPG we centered the middle evaluation category, *fair*, around the ~+1% per year national average (0.8 to 1.2% increase per year).

For HPD we set the *good* category cutoff at $\leq$ 5 people per km^2 (~13 people per $mile^2$), comparable to present-day conditions near the above-mentioned wilderness areas. *Fair* was set to the high end of the range of the average for Alabama excluding population centers, based on Figure 50 - upper panel (20 people per km^2, or 50 people per $mile^2$). The evaluation of the five selected human population indicators in relation to Horseshoe Bend is shown in Table 37. One of the five indicators yielded a *good* evaluation, one was *fair*, and three were *poor*; thus, the overall evaluation of Surrounding Human Population Impact Condition affecting Horseshoe Bend is POOR.

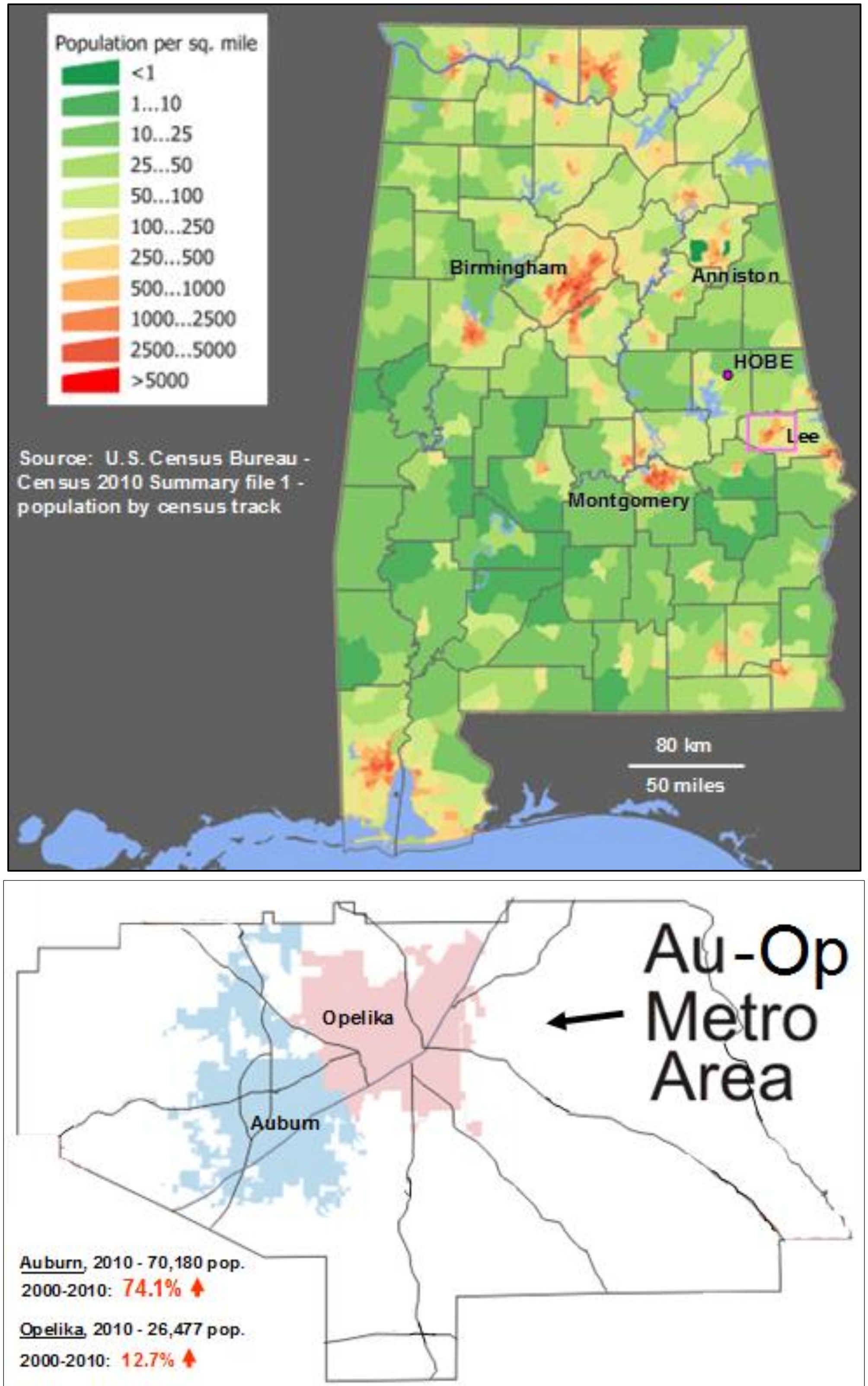

Figure 50. Map showing the population density of the State of Alabama as of 2010 (upper panel: Au-OpMA in pink box, and a magnified view of the Au-OpMA in 2004 (lower panel; Wikipedia Commons 2006). Note that the population of Auburn in particular is rapidly “sprawling” north toward HOBE.

Table 37a. Five Population Condition Indicators, and the Present status of Surrounding Population Condition in impacting or potentially impacting the park. Note that for this indicator, *good* ≡ minimal adverse impact, whereas *poor* ≡ maximal adverse impact.

Population Impact Indicators	Condition at HOBE	Rating
Human Population Growth within a 5-km (3.1-mile) radius ($HPG_{5\text{-km}}$)	↓ -1.1% per yr for Tallapoosa County	*good*
Human Population Growth within an 80-km (50-mile) radius ($HPG_{80\text{-km}}$)	↑ +2.6%/yr (Au-OpMA, Lee County), comparable to growth in the Atlanta, Ga. metropolitan area	*poor*
Human Population Density within a 5-km radius ($HPD_{5\text{-km}}$)	Tallapoosa County: 22.4 people/km^2 (58 people/mile^2)	*fair*
Human Population Density within an 80-km radius ($HPD_{80\text{-km}}$)	Lee County: 91 people/km^2 (236 people/mile^2); this high density is ~48 km (~30 miles) from HOBE	*poor*
Poverty surrounding the park (POV)	Tallapoosa County: 17.1% of population is below poverty level	*poor*

Table 37b. Paramerters used to rate the Five Population Condition Indicators in HOBE.

Indicator	*good*	*fair*	*poor*
$HPG_{5\text{-km}}$	< 0.8%/yr	> 0.8 to 1.2%/yr	> 1.2%/yr
$HPG_{80\text{-km}}$	same	same	same
$HPD_{5\text{-km}}$	< 5 people/km^2 (13/mile2)	> 5 to 20/km^2 (13 to 50/mile^2)	> 20 per km^2 (> 50/mile2)
$HPD_{80\text{-km}}$	same	same	same
POV	< 5% of the population	5-10%	>10%

Table 37c. Overall evaluation for the Five Population Condition Indicators in HOBE.

Evaluation (decadal basis - 5 indicators)	Rating
good: $HPG_{5\text{-km}}$, $HPD_{5\text{-km}}$ both *good*, < 2 others *good*, < 1 *fair*, 0 *poor*	OVERALL-*poor*
fair: > 2 *fair*, < 1 *poor*	
poor: > 2 *poor*	

4.4.2. Visitors - Human Population Within the Park

Issue: Although the National Park Service mission is partly centered on excellence in service for park visitors, visitors have been shown to negatively impact another key portion of the agency's mission, to protect natural and cultural resources.

Visitors' impacts are identified by the National Park Service as among the Top Ten Issues for National Parks (National Geographic 2015; Buckley 2003, Taylor and Knight 2003, Park et al. 2008). The two central portions of the National Park Service mission statement are in conflict especially when visitor pressure is high.

Although ~1 million travelers on Highway 49 pass through the park, on average, each year, the actual number of visitors is about 10% of that number, or 100,000. Of these, ~70,000 visitors were reported to use the Tour Road, Nature Trail, and park grounds. Additional statistics were not available to gain further insights about use of the Nature Trail, for example. Park staff have not expressed concerns about parking, however. Our evaluation of Visitation Condition is based on three indicators:

- Visitor Number (annual total, March-October season total, and trend over time);
- Visitor Number per Area (season from March-October, 245 days); and
- Visitor Pressure on Trails (growing season total).

The annual Visitor Number per Area was estimated by dividing the number of visitors by the total park area. This approach tacitly assumes that visitors use all areas of the park equally, but is unrealistic because many visitors concentrate in certain areas such as trails. Therefore, the approach underestimates Visitor Pressure in the highly used areas, but enables a straightforward calculation of Visitor Pressure for the park. The growing season total was estimated based on the fact that according to NPS statistics, ~75% of visitors come to the park in March - October (NPS 2015h). The final indicator, Visitor Pressure on Trails, would be more realistic than Visitor Number per Area (because people do concentrate in trail areas) except for the fact that the Tour Road and park grounds were combined with the Nature Trail in the available park statistics. A similar approach was followed as for Visitor Number per Area, using trail length rather than area. For these calculations, we conservatively assumed that one-third of the 70,000 visitors per year use the Nature Trail. Evaluation of overall Visitation Condition in Horseshoe Bend is outlined in Table 38. It should be noted that this Visitation Condition is intended to serve as a “place holder” until park staff can develop a RSS, including a targeted recreational carrying capacity for Horseshoe Bend. This target could be developed, for example, following Cole and Thomas (2010). It would also be helpful for park staff to collect data on trail damage and trash left in the park to strengthen the Visitation Condition index.

Table 38a. Visitation Condition in HOBE, based on three Visitation Indicators.

Visitation Indicators	Visitation Condition in HOBE	Rating
Trend in Number of Visitors/Yr (VIS)	HOBE had 58,668 visitors in 2012 (NPS statistics), comparable to/or lower than in previous years.	*good*
Visitor Pressure Per Unit Area (VP-A_{SEAS})	Total park area is 826 hectares (2,040 acres). HOBE has an average of 91 visitors/hectare/peak season (March-October), or 0.4 visitor/hectare/day (37 visitors/acre/peak season, or 0.15 visitor/acre/day).	*good*
Visitor Pressure on Trails (VP-T_{SEAS})	HOBE has ~4.8 km (3 miles) of Nature Trail and Battlefield Hiking Trail. Growing season basis (214 days): HOBE has 3,645 visitors/km/peak season, or ~15 visitors/km of trail/day (5,833 visitors/mile of trail/peak season, or ~24 visitors/mile of trail/day)	*poor*

Table 38b. Overall evaluation of Visitation Condition in HOBE, based on three Visitation Indicators.

good	fair	poor	Rating
VIS trend ↓ or --	VP-A_{SEAS} < 10 visitors/hectare/day	VP-T_{SEAS} < 5 visitors/km of trail/day	**OVERALL-fair**
VIS trend ↓	VP-A_{SEAS} > 10 to 25	VP-T_{SEAS} > 5 to < 15	
VIS trend -- or ↑	VP-A_{SEAS} > 25	VP-T_{SEAS} > 15	
> 2 indicators *good*, 0 *poor*	> 2 indicators *fair* or *good*, 1 *poor*	> 2 indicators *poor*	

4.4.3. Land Use/Land Cover

Issue: Watershed land use /land cover has been shown to strongly affect the habitat quality and integrity of terrestrial and aquatic communities. Horseshoe Bend is in an area that likely will be increasingly be targeted for development due to sprawl from the Au-OpMA.

Changes in the composition and configuration of different land cover types within and adjacent to national parks has been shown to greatly affect biological and physical processes within those parks, such as habitat availability, animal movements, potential for invasion by non-native plants, water quality, and in-stream habitat for fish and other aquatic life (NPS 2012). Information about changes and trends in landscape-scale indicators in and around parks can help park managers anticipate, plan for, and manages associated effects to park resources.

4.4.3.1. Agriculture and Urbanization:

Changes in land use/land cover over time, especially loss of "green" or natural categories through increase in two land use/land cover categories - urbanization and agriculture - are increasingly used as broad-scale predictors of watershed conditions and ecosystem health (King et al. 2005, Rothenberger et al. 2009). Nonpoint source pollution - especially from urban/ suburban areas, croplands (including silviculture), and industrialized animal production - has been identified as the greatest threat to water quality in the U.S. (U.S. EPA 1994b). Major changes resulting from conversion of natural lands to agricultural use include soil erosion, chemical contamination of those lands and receiving waters, and increased water demands. Chemical contaminants - pesticides, fertilizers, heavy metals from animal feeds, etc. - cause diverse acute and chronic impacts on water quality and quantity, soil quality, air quality, pollination by beneficial fauna, seed dispersal, biodiversity, and habitat loss (Pickett et al. 2001, and references therein). Confined swine and poultry operations of industrialized agriculture, found mostly upstream from Horseshoe Bend in the upper Tallapoosa River watershed and in sub-watersheds of several streams in the middle watershed (CH2MHill 2005), produce extremely high quantities of manure, which are applied to small land areas that cannot accommodate the massive wastes (Burkholder et al. 2007, and references therein).

Although agricultural land use has been clearly related to environmental degradation, thresholds in the percent land use linked to significant change in ecosystem health are seldom reported, likely because adverse impacts occur at very low levels of natural land conversion to agriculture. Thus, Hagen et al. (2010) documented major impacts on streams at a level of "light" (percentage undefined) agricultural land use in cropland. Industrialized swine production agriculture can cause extreme impacts to sub-watershed airsheds, soils, surface waters, and groundwaters from only one operation (Mallin 2000, Burkholder et al. 2007, and references therein). As another example, Cuffney et al. (2005) assessed invertebrates and algae in-stream sites across a gradient of agricultural land use. The data suggested a threshold response with precipitous declines in biological metrics at low levels of agricultural intensity.

Entire ecosystems, including all components from soil, air, and water to biota, have been "drastically modified" (wording from Pickett et al. 2001) by watershed urbanization, in comparison to ecosystems in watersheds dominated by natural land cover or cropland cultivation (Paul and Meyer 2001). In the U.S. and other industrialized nations, conversion of land to urban/suburban development is growing more rapidly than the populations in urban areas, leading to increased urban sprawl and fragmentation of remaining green spaces (Makse et al. 1995). Urbanization severely degrades aquatic communities and terrestrial ecosystems (Garie and McIntosh 1986, Pickett et al. 2001, and references therein, Center for Watershed Protection 2003). More specifically germane to Horseshoe Bend, in a study now more than 30 years old of 21 watersheds in the Atlanta area, Benke et al. (1981) found a negative relationship between benthic macroinvertebrate species richness and the degree of watershed urbanization. Increased urbanization promotes an increase in avian biomass but a reduction in species richness, and selection for omnivorous, granivorous, and cavity-nesting species (Chace and Walsh 2004). Analogous findings have been reported for a wide array of aquatic and terrestrial biota.

4.4.3.2. Impervious Cover:

The percentage of impervious cover (IC) in particular - roads, parking lots, building roofs, etc. - has been a reliable "barometer" for ecosystem health in urbanizing areas. IC blocks water and associated pollutants from being able to percolate through soil, resulting in rapid transport of much higher volumes and pollutant loads directly to receiving surface waters. As a typical example, the total volume of pollutant-laden runoff from a 0.4-hectare (1-acre) parking lot was ~16-fold more than the runoff from an undeveloped meadow (Schueler 1994, U.S. EPA 2001). IC thresholds have been developed for ecological damage, especially focusing on stream ecosystems. In fact, the term "urban stream syndrome" has been used to describe the state of ecological degradation common for "city streams" worldwide (Meyer et al. 2005). Key features are low species diversity, dominance of pollution-tolerant taxa, poor water quality, and degraded physical habitat (Schueler et al. 2009, and references therein). Schueler et al. (2009) developed an empirical impervious cover model (ICM; Figure 51) that is improved over Schueler (1994), which is much more often cited; Schueler (1994) set a threshold of 10% as the initial IC at which adverse impacts on stream biota occur, but it turns out that that threshold was too high to protect sensitive aquatic life from urbanization impacts, explained as follows.

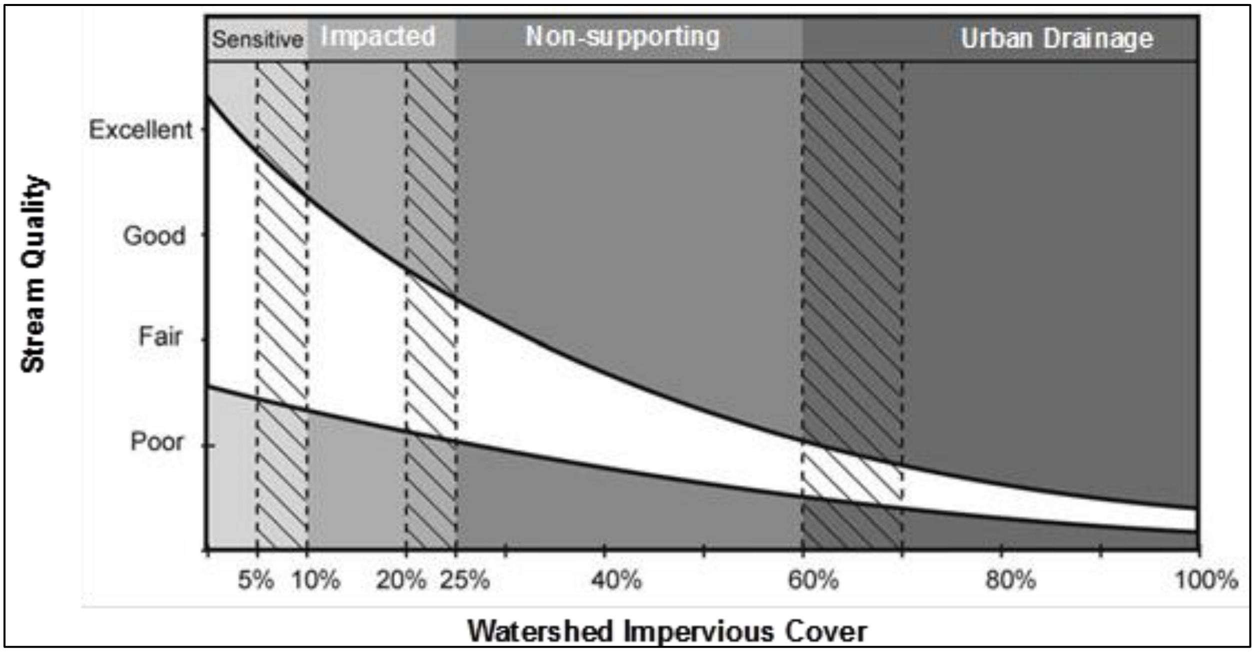

Figure 51. A widely used Impervious Cover Model (ICM) of stream quality and macroinvertebrate community response to urban development as the percentage of impervious cover in a given watershed or sub-watershed. Modified from Schueler et al. (2009).

Schuler et al (2009) based his refined empirical ICM on data for many streams which indicated that detectable stream degradation generally occurs - sometimes described as "greatly depressed ecosystem health" - when the IC of a given watershed is ~7 to 10% (overall range 2-15%; e.g. Booth and Reinelt 1993; Booth and Jackson 1994; Shaver et al. 1994, 1995; Booth and Jackson 1997, Mallin et al. 2000; Wang 2011). The IC thresholds in these ICMs depended on the specific biological indicator, the ecoregion, and the history of watershed land use: Lower IC thresholds were found for streams in watersheds that had extensive forests or natural vegetation cover prior to urban development. Higher IC thresholds characterized streams in watersheds that had extensive prior disturbance (e.g., croplands) prior to urbanization (Harding et al. 1998, Ourso and Frenzel 2003, Cuffney et al. 2005) because the macroinvertebrate communities had already lost sensitive species to stressors from the pre-urban agricultural land use (Coles et al. 2012).

An underlying, widely accepted assumption in efforts to determine the first threshold for decline of stream biota in response to urbanization is that the "biological communities are resistant to change at low levels of urban development. Then, as levels of urban development increase, a period of rapid degradation occurs in the community condition, ending in a period of exhaustion when no further change occurs" (Coles et al. 2012; Figure 52). However, a detailed recent analysis conducted by the USGS, involving multiple study regions across the nation, found evidence of neither a resistance threshold nor an exhaustion threshold. Instead, beneficial macroinvertebrate communities declined in response to very low levels of urbanization; for example, in the Atlanta and Boston study regions, stream macroinvertebrates showed a linear rather than threshold response to urbanization (Figure 53; also documented elsewhere, e.g. Moore and Palmer 2005). The authors concluded that stream macroinvertebrate communities are much more sensitive to urbanization than previously thought (Coles et al. 2012). In fact, at 10% IC, the macroinvertebrate community composition had already decreased by ~25%. The lack of an exhaustion threshold was also considered important, because it indicates that stream rehabilitation efforts have a high probability of improving biological condition (Coles et al. 2012). In other words, the data from this study indicate that, if given a chance, many streams can recover from "urban syndrome."

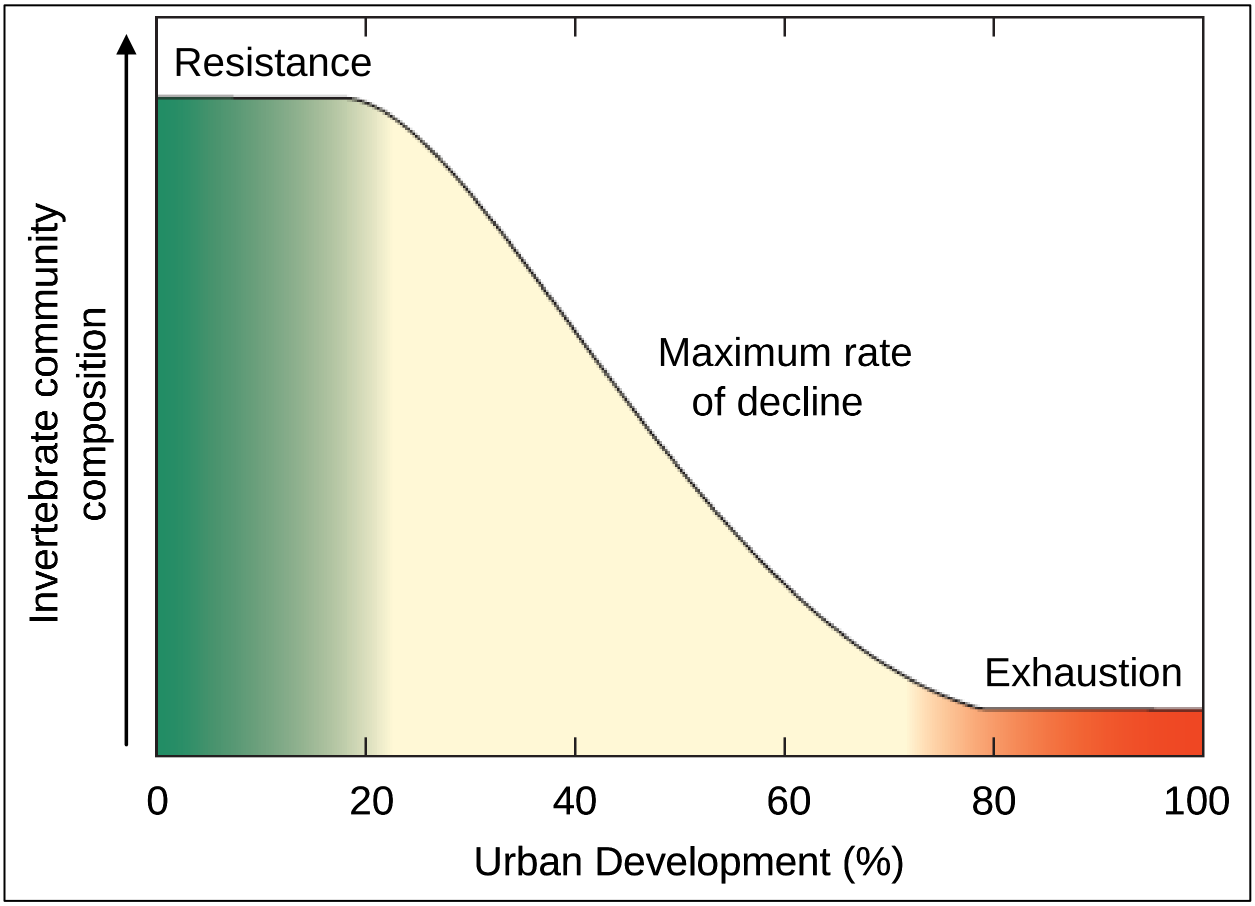

Figure 52. Previous widely accepted conceptual model of the response of stream biota to urban development - now questioned. Modified from Coles et al. (2012).

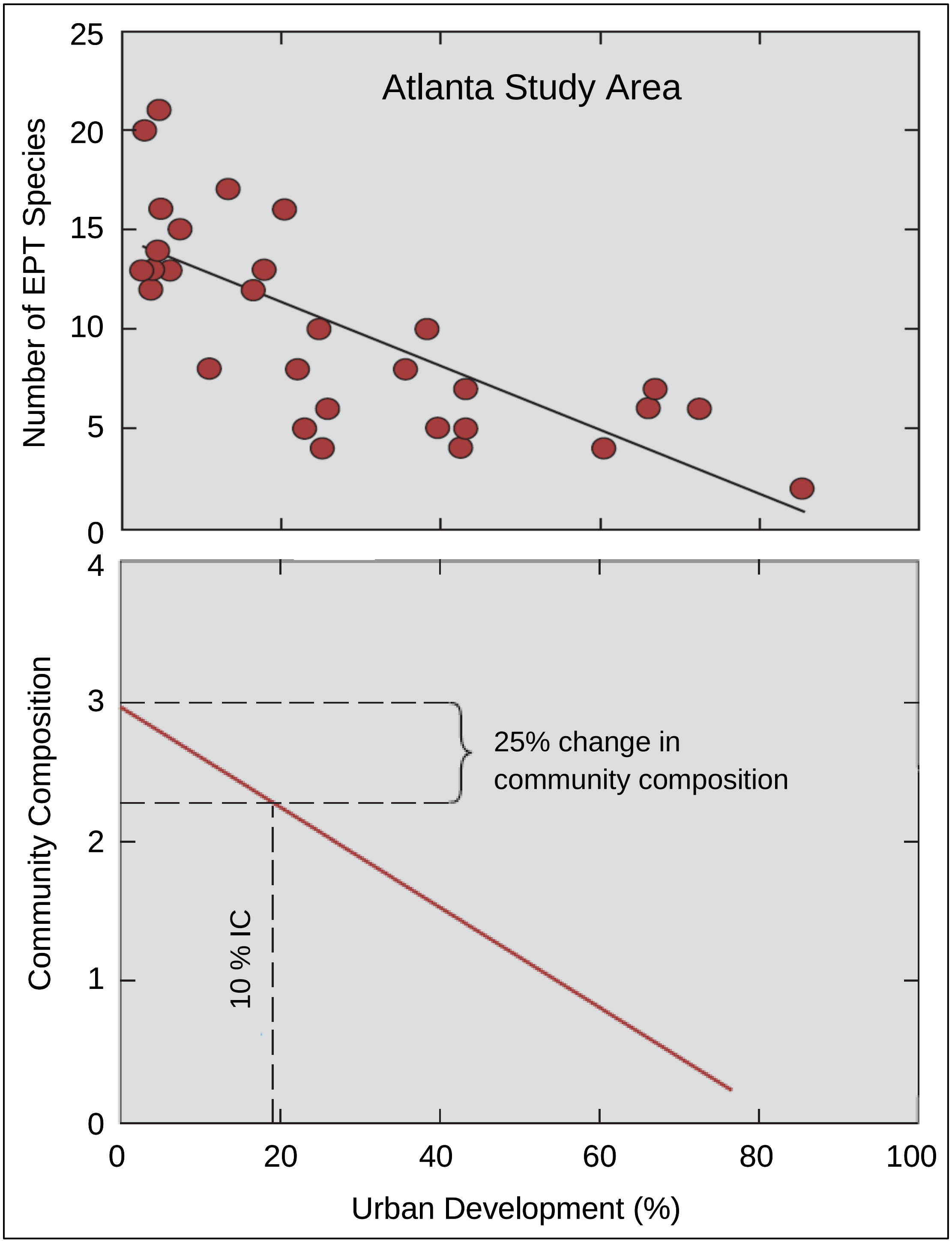

Figure 53. Left: Response of EPT species (Ephemeroptera - mayflies, Plecoptera - stoneflies, and Trichoptera - caddisflies) to urbanization in the Atlanta area (IC ≡ impervious cover). Many of these species are sensitive to contaminants, changes in-stream flow, and other stressors caused by urbanization, and have been lost from streams in the Atlanta area. Right panel: Generalized schematic from the USGS (Coles et al. 2012). Right: Similar response of invertebrate communities to urban development in the Boston area: Note that at 10% impervious cover (= less than 20% urban development), the community composition had declined by ~25%. Modified from Coles et al. (2012).

This background information is included here because IC thresholds to protect ecosystem health have mostly been based on the ICM approach, using a first threshold of ~10% IC as *good*, and a second threshold of ~20-25% as *fair*. The approach recently was re-evaluated as insufficiently protective, both the formerly accepted 10% IC primary threshold and the 20-25% IC secondary threshold (Coles et al. 2012). Regarding the latter, 20-25% IC would protect only highly tolerant biota from stress, disease and death due to urbanization impacts (Weaver and Garman 1994). Stream biological metrics were described as consistently shifting to *poor* condition at ~20-25% watershed IC (Collier and Clements 2011, Wang et al. 2011, Cole et al. 2012).

4.4.3.3. Indicators for Land Use/Land Cover Influence:

Horseshoe Bend at present is little influenced by agriculture other than silviculture, which is included in the land use/land cover category, "forest." Land use/land cover has changed by only a few percentage points in the past five years, as shown in Section 2.3 of this Report (mainly reflecting small shifts in loss of grassland to silviculture-as-"forest" - CH2MHill 2005, p.5-6). Unfortunately, a concerted hunt for the proportion of "forest" that is actually silviculture in the Middle Tallapoosa River watershed was unsuccessful in finding that information, so it was not possible to assess the percentage of silviculture versus natural forest. There also has been very little development near Horseshoe Bend to cause urban impacts but, as explained in Section 4.4.1 of this Report, that situation likely will change in the coming decade because of rapidly developing Lee County. As mentioned, the expected continued sprawl north/northwest from the Au-OpMA has been identified as a concern of park staff (NPS 2008).

For the above reasons, the following indicators and ratings were developed without consideration of agriculture/silviculture except indirectly through the tacit assumption that loss of agricultural/silvicultural lands will occur through urban/suburban development. It is recommended that the indicators should be tracked at 10-year intervals (or five-year intervals, if park staff consider that more desirable). The indicators describe conditions that are often economically difficult or impossible to reverse. Therefore, the *good* rankings are conservatively defined toward the goal of maximizing protection of the park.

Impervious Cover (IC) - Viewed from a resource protection standpoint, as explained above, it is not scientifically supported to evaluate a ~25% loss in-stream macroinvertebrate community composition with 10% IC in a given watershed as *good*. Figure 51, a widely accepted ICM, suggests that at 10% IC, streams develop "detectable" to "greatly depressed" ecosystem health. Although the lower end of range of percentage IC at which ecosystem health is seriously impacted is broad (~2-15%), it also seems reasonable to err on the side of caution to afford more protection for the nation's national parks. Other studies have shown that wetlands exhibit signs of adverse impacts when watershed IC exceeds 2-4%, or about one house for every 3.2 to 4.0 hectares (8 to 10 acres) of watershed area (Hicks and Larson 1997, Reinelt and Horner 1991). The recent USGS analysis (Cole et al. 2012) - and the central conclusion that stream macroinvertebrate communities, commonly considered a major "barometer" of stream ecosystem health, are much more sensitive to urbanization that previously thought - also factored heavily in our considerations about the levels of %IC to be assigned to *good*, *fair*, and *poor* rankings. These rankings reflect the present status of what is known in the science literature about stream macroinvertebrate community response to urbanization.

Change in Green Space - The Greenspace Indicator (%GRN) tracks the change in the percentage of greenspace land over time, both within a 5-km (~3-mile) radius of the park, and in the middle Tallapoosa River watershed. The change is generally as loss, which is surely the situation for Horseshoe Bend, although cities such as Atlanta are developing programs to restore some greenspace area. It has been demonstrated that only a 12% loss of forest cover in a watershed results in detectable adverse impacts on the macroinvertebrate communities of streams draining the area (Klein 1979). Conversion of a forest to homes on 0.10-hectare (0.25-acre) lots can increase the frequency and severity of flooding by 100-fold (basis - Soil Conservation Service 1986; Zielinski 2002; Community and Environmental Defense Services 2007). When the land is converted to IC rather than open space, impacts are sustained at lower percentages of impervious surface (explained above).

The evaluation format used to assess the Land Use/Land Cover Condition surrounding Horseshoe Bend is shown in Table 39. Based on these indicators and this evaluation format, the present overall condition of Land Use/ Land Cover surrounding the park is *good*.

Table 39a. Land Use/ Land Cover Condition surrounding the park, based on evaluation using two indicators.

Land Use/ Land Cover Indicators	Watershed Surrounding HOBE	Rating
Impervious Cover (% $IC_{5\text{-km}}$, 5-km radius surrounding park, decadal basis)	The only population center upstream and near to HOBE, New Site, has 764 people. IC in the 5-km radius surrounding the park is negligible, < 1% of the Land use/land cover	*good*
Total greenspace loss (% GRN_{WAT}, (past 5-10 yr): middle Tallapoosa sub-watershed	The entire middle Tallapoosa River watershed had only 5% developed (urban/suburban) land as of 2006. In the 5 yr between 2001 and 2006, there was a gain of only 0.1% in developed land use/land cover.	*good*

Table 39b. 5-10 year overall evaluation for Land Use/ Land Cover Condition surrounding the park, based on evaluation using two indicators.

good:	fair:	poor:	Rating
IC ≤ 5%, and < 1% GRN Loss	IC > 5 to < 10%, and ≥ 1 to < 5% GRN loss	IC ≥ 10%, and ≥ 5% GRN loss	OVERALL- good

4.5. Air Quality

Issue: Air pollution is an ongoing, serious problem from urbanized areas mostly west, north/ northwest, and south of Horseshoe Bend, and is expected to be adversely impact the park's natural resources. Animals are exposed to air pollutants by inhaling gases or small particles, ingesting particles suspended in food or water, or absorbing gases through the skin (soft-bodied invertebrates, amphibians with thin, moist skin etc.; U.S. EPA 2008). Ozone, SO_2, and NO_x mostly affect the respiratory system, and animals to with higher respiratory rates (e.g., many birds) are likely to be more adversely affected by gaseous pollutant injury. Metals such as mercury in air pollution can affect the circulatory, respiratory, gastrointestinal, and central nervous systems. Often organs such as the kidney, liver, and brain are targeted, and entire populations can be adversely affected with damage extending through subsequent generations.

The many impacts of acid deposition on terrestrial and freshwater ecosystems is the subject of an exhaustive literature (Tomlinson and Tomlinson 1990, Charles and Christie 1991, Brimblecombe et al. 2007, and references therein). In terrestrial ecosystems species such as pines are especially sensitive to the elevated nitrate enrichment that results in the soils, and their growth and survival are depressed (Aber 1992). Leaves affected by acid deposition are damaged, especially the chlorophyll pigment that is vital to photosynthesis. Like many other pollutants, acid deposition depresses terrestrial biodiversity as sensitive species are eliminated and more acid-tolerant species can survive. Acidification effects in freshwater streams depend on the surrounding geology and soils, which determine the capacity of the water to neutralize acids. Streams most susceptible to acidification occur in watersheds with granite or gneiss bedrock typical of some soils at Horseshoe Bend, where thin soils have insufficient base cations freely available to neutralize incoming H^+ ions. The effects of decreasing pH on aquatic invertebrates and fish have been summarized in National Acid Precipitation Assessment Program (NAPAP) reports (e.g. NAPAP 2005) and similar documents from Scandinavia where acidification impacts have been extreme: In early stages of acidification, acid-sensitive species are replaced by acid-tolerant ones. As the pH continues to decline, toxic metals become more bioavailable, and more species are lost until even the microbial consortium of decomposers is adversely affected. The worst problems with acid deposition result from acid spates, wherein a “slug” or high amount of acid moves into a stream in the early phases of a storm. Larval stages of amphibians and fish are eliminated by acid spates over a short period (hours to a few days).

Considering the entire Southeast region, the NPS Air Resources Division (ARD) evaluates 10-year trends in air quality for parks with on-site or nearby monitoring. Maps in the most recently available progress report show trends in ozone, deposition, and visibility that can be used to discern regional trends (NPS 2007). For the period 1996 – 2005, ozone concentrations and nitrogen and sulfur deposition in the Southeast appear to be decreasing, while visibility is relatively unchanged.

More specific to Horseshoe Bend, as related in Chapter 2 of this Report, the National Park Service (2011) has developed guidance for assessing the air quality conditions within its parks, focusing on five key indicators among the myriad of air pollutants potentially affecting the middle Tallapoosa River basin. These indicators include Ozone (with two sub-indicators: human health, and Horseshoe Bend flora), N deposition, S deposition, visibility, and acidification (with five sub-indicators: Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and overall Summary Risk). For ozone the National Park Service included consideration of vegetation sensitivity as well as human health because science has shown that some plant species are more sensitive to ozone than humans. Thus, use of an ozone standard for humans would not be sufficiently protective of those species.

The National Park Service has developed management targets or “thresholds” for these five indicators as presented in Section 3.2. of this Report and summarized in Table 40. The information and supporting science are given in several agency reports, especially National Park

Service (2011) and Sullivan et al. (2011) where the conditions in Horseshoe Bend are also described. All five of the NPS-selected Air Quality Indicators are NPC, not possible for park staff or the Network to control. Following the NPS guidance and stoplight system, one of the five indicators, Ozone, is Moderate Concern (*fair* rating in the Stop Light approach); the other four indicators are of significant concern (*poor* rating in the Stop Light approach). Therefore, the present overall Air Quality Condition at Horseshoe Bend is evaluated as *poor*.

Table 40a. Evaluation of overall Air Quality Condition in HOBE, based on the AQI (Air Quality Index of the U.S. EPA.

Air Quality Indicators	Air Quality Measurements Near HOBE	Rating
Air Quality Index (AQI) for Alexander City, Ala. (U.S. EPA)	As of 2012-2013*: Ozone "Good" 87.1-94.3% of days; CO, NO_2, SO_2, and PM_{10} "Good" 100% of days; and $PM_{2.5}$ "Good" 81.8-92.6% of days. Overall AQI - *good* 98.9% of days, MODERATE 1.1% of days.	*good*

Table 40b. Evaluation of 2005-2009 Air Quality Condition in HOBE, based on the AQI (Air Quality Index of the U.S. EPA, and seven NPS indicators (ozone concentration that protects human health, ozone concentration that protects plant health [2 indicators], N deposition, S deposition, Visibility, and Acidification).

Air Quality Indicators	Air Quality Measurements Near HOBE	Rating
Ozone: Human health (Ozone)	61-75 ppb for the 8-hr averaging time, 4th maximal value	*fair*
Ozone: Flora (W126)	7-13 ppm-hr	*fair*
Ozone: Flora (SUM06)	8-15 ppm-hr	*fair*
Nitrogen Deposition (N-DEP)	> 3 kg/ha/yr	*poor*
Sulfur Deposition (S-DEP)	> 3 kg/ha/yr	*poor*
Visability (VIS)	> 8 dv	*poor*
Acidification (ACID)	HOBE ranked as follows: *Pollutant exposure - very high (rank > 23) *Ecosystem sensitivity - low (rank, 9) *Park Protection - low (rank, 9) *Overall risk - low (2.4).	*good*

Table 40c. Paramerters used to rate NPS Air Quality Condition in HOBE.

NPS INDICATOR (2005-2009)	*good* (LOW)	*fair* (MODERATE)	*poor* (HIGH)
Ozone - human health	≤ 60 ppb	61-75 ppb	≥ 76
Ozone - Plants (W126, SUM06)	< 7 ppm-hr, < 8 ppm-hr	7-13 ppm-hr, 8-15 ppm-hr	> 12 ppm-hr, > 15 ppm-hr
N-DEP	< 1 kg/hectare/yr	1-3 kg/hectare/yr	> 3 kg/hectare/yr
S-DEP	< 1 kg/hectare/yr	1-3 kg/hectare/yr	> 3 kg/hectare/yr
VIS (deciviews, dv)	< 2 dv	2-8 dv	> 8 dv
ACID: Overall evaluation is the Summary Risk Index			
Pollutant Exposure	rank < 13	≥ 13 to 23	> 23 to 35
Ecosystem Sensitivity	rank < 15	≥ 15 to 20	> 20 to 35
Park Protection	rank < 15	≥ 15 to < 23	≥ 23 to 35
Summary Risk Index (different scale)	rank ≤ 2.5	≥ 2.5 to 3.4	> 3.4 to 5

Table 40d. Overall evaluation of NPS Air Quality Condition in HOBE.

good (LOW)	fair (MODERATE)	poor (HIGH)	Rating
AQI Good (0-50 for ≥ 90% of days); NPS indicators: ≥ 5 of 7 Good, ≤ 2 Fair (Moderate Concern), 0 *poor* (Significant Concern)	AQI Good or Fair (Moderate), ≤ 100, for ≥ 90% of days; NPS indicators: ≥ 3 Fair, ≤ 3 *poor*	AQI Unhealthy to hazardous (101-500) for ≥ 10% of days; NPS indicators: ≥ 4 *poor*	***Overall - fair***

4.6. Soundscape

Issue: Noise pollution can adversely affect the physiology, behavior, and survival of fauna communities. Horseshoe Bend is still within a predominantly rural area and noise pollution generally is minor. As stated, human-related environmental noise is minor and the park usually is very quiet (Superintendent Doyle Sapp, pers. comm., April 2013). Three Soundscape Indicators were developed as follows:

- Proximity to a population center (POP_{SOUND}): *good* - nearest population center with ≥ 50,000 people is > 97 km (> 60 miles) distant; *fair* - nearest population center with ≥ 50,000 people is 16 to ≤ 97 km (10 to ≤ 60 miles) distant; *poor* - nearest population center with ≥ 50,000 people is < 16 km (10 miles) distant.
- Proximity to a major road (state or interstate highway), railroad; and/or to several county roads with heavy traffic (here, collectively considered as 1 source); and/or major airport, or to a speedway, concert amphitheater as major forms of travel ($SOURCE_{SOUND}$): *good* - no major sound source nearby (≤ 16 km [10 mile] radius); *fair* - 1 major sound source nearby that directly

affects much of the park; *poor* - ≥ 1 major sound source nearby that directly affects much of the park.

- Available data or park staff observations (DATA/OBS$_{SOUND}$): *good* - outside noise levels ≤ 24 dB(A) during daytime periods when human travel is generally heaviest ("rush hours"), and/or park staff describe the park as very quiet; *fair* - outside noise levels 24 to 40 dB(A), and/or park staff describe the park as sometimes noticeably noisy ; *poor* - outside noise levels > 40 dB(A), and/or park staff describe the park as commonly having noticeable or substantial noise pollution.

In the overall evaluation, the DATA/OBS$_{SOUND}$ indicator is weighted more heavily than the other two indicators (Table 41). However, the other two indicators can be used to evaluate the soundscape if data and/or reliable observations are not available.

Table 41a. The three Soundscape Indicators, and present Soundscape Condition in HOBE.

Soundscape Indicators	Soundscape Condition in HOBE	Rating
Proximity to population center (POP$_{SOUND}$)	HOBE is ~64 km (40 miles) from the Au-OpMA (rapidly growing population center; population 147,257 as of 2012).	*fair*
Proximity to a major mode of travel (SOURCE$_{SOUND}$)	State Highway 49 passes through the park, but its traffic is usually light so it is considered a minor mode of travel.	*good*
Data or observations (DATA/OBS$_{SOUND}$)	Data not available (n.a.); park staff describe HOBE as usually very quiet.	*good*
Indicators:		

Table 41b. Paramerters used to rate Soundscape Condition in HOBE.

Soundscape Indicators	Definition
POP$_{SOUND}$	*good* - closest population center has ≤ 50,000 people and is > 80 km (> 50 miles) distant.
	fair - closest population center has ≥ 50,000 to 100,000 people and is ≥ 16 to 80 km (10 to 50 miles) distant.
	poor - closest population center has > 100,000 people and is < 16 km (< 10 miles) distant.
SOURCE$_{SOUND}$	*good* - nearest major road or railroad is > 8 km (5 miles) distant; no major airport, flyway influence, etc.
	fair - 1 major road and/or railroad is nearby, or one railroad, or a major airport/airplane flyway.
	poor - ≥ 1 major road and/or railroad and/or major airport nearby.
DATA/ OBS$_{SOUND}$	*good* - outside noise ≤ 24 dB(A) during daytime when related (noise-generating) human activity is greatest; or, observations by park staff as overall very quiet
	fair - outside noise > 24 to 55 dB(A) during daytime periods with greatest related human activity.
	poor - outside noise > 55 dB(A) during daytime periods with greatest related human activity.

Table 41c. Overall Soundscape Condition in HOBE.

Indicator Evaluation	Description of Soundscape Condition in HOBE	Overall Rating
good	DATA/OBS$_{SOUND}$ + 1 other indicator *good*; 3rd indicator *good* or *fair*; or no data but the other 2 indicators *good*	good
fair	All three indicators *fair*; or no data but both other indicators *fair*	
poor	DATA/OBS$_{SOUND}$ *poor*; or no data but one or both other indicators *poor*	

4.7. Lightscape

Issue: Light pollution in urbanized or developing areas can adversely affect the physiology, behavior, and survival of naturally occurring, beneficial fauna.

The Lightscape Condition for Horseshoe Bend is similar to its Soundscape Condition: Both are NPC, but fortunately both noise and light pollution are described by park staff as negligible. Thus, Superintendent Doyle Sapp (pers. comm., April 2013) stated that Horseshoe Bend night time habitat is equivalent to the Truly Dark Skies of the BDSS. The Lightscape Indictor for Horseshoe Bend uses this scale to assess artificial light pollution, as follows:

- *good* - Class 1 (excellent, truly dark skies) to Class 2 (typical, truly dark skies)
- *fair* - Class 3 (rural sky - ground objects are vaguely apparent); Class 4 (rural/suburban transition - sky is noticeably brighter than the terrain, but ground objects are still fairly obscure)
- POOR - $\geq$ Class 5 (suburban sky - ground objects are partly lit).

These rankings are based on potential impacts of sufficient light to reveal "ground objects," meaning that sufficient light would be available to alter predator-prey interactions at least in some areas of the park. The night sky for Horseshoe Bend is Class 2, as noted above (Truly Dark Skies - the ground is mostly dark; only objects projecting into the sky may be discernible). Thus, the overall evaluation of the Lightscape Condition in the park is *good* (Table 42).

Table 42a. Evaluation of the Lightscape Condition at HOBE, using the Bortle Dark-Sky Scale.

Lightscape Indicator	Lightscape Condition at HOBE	Rating
Bortle Dark-Sky Scale (LITE$_{ARTIF}$)	The park at present is still in a predominantly rural setting, and the lightscape is described as Class 2, Truly Dark Skies.	*good*

Table 42b. Paramerters used to rate Lightscape Indicators in HOBE.

Rating	Definition
good	Classes 1 to 2 (excellent, truly dark skies; or typical, truly dark skies).
fair	Classes 3 to 4 (rural sky - ground objects vaguely apparent; or rural/suburban transition - sky noticeably brighter than the terrain, ground objects still fairly obscure.
POOR	≥ Class 5 (suburban sky - ground objects partly lit, to inner city sky.

4.8. Soil and Streambank Erosion

Issue: The soils in the Horseshoe Bend area are moderately to highly erodible, increasing the potential for damage along streambanks as well as park roads, trails, and other highly used areas, although presently there is minimal streambank erosion along the Tallapoosa River in the park. The high acid deposition sustained by the park could decrease the soil pH to conditions that impede the metabolism of beneficial microbial consortia while also enhancing solubility of porewater toxic metals (Bååth 1989).

There have been no studies of soils, soil erosion, or streambank erosion in Horseshoe Bend, but its soils logically would be expected to be similar to those in the general region. Therefore, we developed a simple index of Soil Condition for the park as follows:

Soil erodibility of the soil types in Horseshoe Bend (#1, $Soil_{EROD}$), which has been assessed in the published literature, based on the soil erodibility factor, K (Olson and Wischmeier 1963, Daniels 1987, and USDA Soil Conservation Service maps):

- *good* - ≤ 10% of the soil types are characterized as eroded to severely eroded
- *fair* - > 10% to 20% of the soil types are eroded to severely eroded, including one abundant soil
- *poor* - > 20% of the major soil types are eroded to severely eroded, including ≥ 2 abundant soils

Visual evidence of soil erosion in the park (#2, $Soil_{VIS}$):

- *good* - little or no soil erosion evident in the park
- *fair* - a few areas along roadways and trails show signs of erosion
- *poor* - severe erosion clearly is common along roadways and trails

Visual evidence of streambank erosion in the park (#3, $Bank_{EROD}$):

- *good* - little or no streambank erosion is notable in the park
- *fair* - there are occasional signs of streambank erosion after major rain events in a few reaches
- *poor* - severe erosion clearly is common along the park's major stream segments

Soil acidification potential based on air quality in areas such as Horseshoe Bend with poor buffering capacity of the mostly clay soils, due to the absence of limestone parent materials (#4, $Soil_{ACID}$):

- *good* - low
- *fair* - moderate
- *poor* - high

Soil Indicators 1 and 4 are based on information already provided to the park; indicators 2 and 3 are based on surveys that can be conducted within ~two hours. Assessment of these indicators can be conducted at intervals deemed appropriate by park staff (e.g., two-year or five-year) using a consistent, quantitative approach such as walking three 100-m segments along the Tallapoosa River and the smaller streams in the park (e.g. see Gordon et al. 2004), and including photographic documentation. It should also be noted that the National Park Service is developing a visual technique using a consistent approach with photography over time to document streambank erosion in SECN parks, which will strengthen the $Bank_{EROD}$ indicator (SECN Coordinator Mr. Joe DeVivo, pers. comm., April 2013).

To assess the overall Soil and Streambank Erosion Condition in the park, we suggest this evaluation system:

- *good*: $\geq$ 3 of the four indicators are *good*, and $\leq$ 1 indicator is *fair*.
- *fair*: $\geq$ 2 indicators are *fair*, and $\leq$ 1 indicator is *poor*.
- *Poor* $\geq$ 2 indicators are *poor*.

As noted in this Report, more than half (12 of 20) of the soil types found in Horseshoe Bend are characterized as moderately eroded. In addition, nearly a third of the soil types are occasionally to frequently flooded, including indicating two of the three most abundant soil types (see Section 3.5.2 of this Report). Both features typify the three most abundant soils in Horseshoe Bend (ToA, PrDZ, and PrEZ). The soil acidification potential is high, based on the air quality as described in Section 3.2.3. Thus, two of the four indicators are *good* but the other two are *poor*, leading to an overall evaluation of Soil and Streambank Condition in Horseshoe Bend as *poor* (Table 43).

Table 43a. Evaluation of present Soil Condition in HOBE, based on four Soil and Streambank Erosion Indicators - erodibility; visible evidence of erosion along trails and roadways; visible evidence of streambank erosion; and soil acidification potential.

Soil/Streambank Erosion Indicators	Soil Condition in HOBE	Rating
Erodability of soil types ($Soil_{EROD}$)	12 of 20 soil types in the park are moderately eroded including two of the three most abundant soils. About 20% of the soil types are occasionally to frequently flooded, including one of the three most abundant soils	*poor*
Visual evidence of soil erosion ($Soil_{VIS}$)	There is little visual evidence of soil erosion in the park.	*good*
Visual evidence of streambank erosion ($Bank_{EROD}$)	There is little visual evidence of streambank erosion in the park.	*good*
Soil acidification potential ($Soil_{ACID}$)	Moderate in HOBE, based on air quality information considered together with the ~poor buffering capacity of the mostly clay soils.	*fair*

Table 43b. Paramerters used to rate Soil Condition Indicators in HOBE.

Soil/Streambank Erosion Indicators	Rating	Definitions
$Soil_{EROD}$	*good:*	< 10% of the soil types are eroded to severely eroded.
	fair:	> 10% to 20% of the soil types are eroded to severely eroded, including one abundant soil
	poor:	> 20% of the major soil types are eroded to severely eroded, including > 2 abundant soils
$Soil_{VIS}$	*good:*	little or no streambank erosion in the park.
	fair:	a few areas along roadways and trails show signs of erosion
	poor:	erosion is obvious and common along roadways and trails
$Bank_{EROD}$	*good:*	little or no streambank erosion is evident in the park
	fair:	occasional signs of streambank erosion after major rain events
	poor:	severe erosion is evident and common along major stream segments in the park
$Soil_{ACID}$	*good:*	low (basis: NPS air quality analysis)
	fair:	moderate
	poor:	high

Table 43c. Overall evaluation of present Soil Condition in HOBE, based on four Soil and Streambank Erosion Indicators - erodibility; visible evidence of erosion along trails and roadways; visible evidence of streambank erosion; and soil acidification potential.

Evaluation of Soil/Streambank Erosion Indicators	Rating
good: > 2 indicators are *good*, < 2 indicators are *fair*, and there is no *poor* evaluation	OVERALL-*fair*
fair: > 2 indicators are *fair* or *good*, and < 2 indicators are *poor*	
poor: > 3 indicators are *poor*	

4.9. Surface Water Hydrology

Issue: Extreme, artificial manipulation of discharge to the Tallapoosa River in the park has adversely impacted the wetland and aquatic communities of HOBE since the upstream Harris Dam was installed in 1982, and has been linked to the loss of sensitive species.

Tracking surface water hydrologic changes over time is important for the natural resources in the park, considering that as development around the park increases, the surrounding metropolitan land cover will in turn increase flash flooding potential. This problem may be exacerbated by the escalating trend in global warming (Richter et al. 1997 Groundwater supply information unfortunately is not available for Horseshoe Bend (see Section 3.6.2.1 of this Report)., Kundzewicz et al. 2007, Brekke et al. 2009).

The availability of IHA software (see Section 3.6.1.1 of this Report) makes it possible to use the hydrologic data provided by the USGS to rapidly assess hydrologic changes affecting other Horseshoe Bend natural resources over time. As mentioned, IHA calculates EFCs and IHA.

Unfortunately, 20 years of daily data are recommended for estimating many of the parameters for analysis (the Nature Conservancy 2007). Over time, park staff can apply the IHA to conduct a Range of Variability analysis (Richter 1997, Mathews and Richter 2007) to quickly identify thresholds in biological response within an adaptive framework. Once Horseshoe Bend has a RSS, park staff will have developed a plan with strategies for managing the park's natural (and cultural) resources. That plan will include hydrologic indicators and targets. For example, in the RSS for the Chattahoochee River National Recreation Area, minimum flows of water in the Chattahoochee River were selected as a key indicator of hydrologic conditions. Five management targets were identified based on relevance to state standards and recommended flows for rafting, canoeing, and trout fishing and fishery condition (Nestler et al. 1986, Gregory et al. 2012).

Until the RSS and hydrologic targets have been developed for Horseshoe Bend, we suggest the following interim approach to evaluating the Hydrologic Condition of the park, namely, focus on the extremes in stage fluctuation because of upstream reservoir (Harris Lake) management by the Alabama Power Company. Water release from the reservoir is controlled entirely for electrical purposes, with no consideration for aquatic communities downstream. These communities sustain adverse impacts from highly abnormal, extreme river fluctuations. Commonly these fluctuations are more than 1 m per day, up to 1.8 m (5 feet), and often there are two such "high water" events per day.

Altered flow regime is commonly identified as the single most serious threat to the ecological sustainability of rivers and associated floodplain wetlands (e.g. Naiman et al. 1995, Sparks 1995, Lundquist 1998, Ward et al. 1999; and see the excellent review by Poff et al. 1997). Karr (1999, p.225) described a fundamental disconnect in present-day policy and management that have sanctioned extreme hydrologic alterations such as the flow regime sustained by the middle Tallapoosa River including the Horseshoe Bend segment:

Society, oblivious either to human health risks or to the ecological risks of radically altering rivers, has chronically undervalued rivers' biological components. We have behaved as if we could repair or replace any lost or broken parts of regional water resource systems, much as we replace toasters, cars, jobs, and even hearts or livers. This disregard has only worsened the lack of coherence in water law and in regulations regarding water use. The result in the U.S.A. is a body of federal, state, and local law that fails to make the connections between water quality and quantity, surface water and groundwater, headwater streams and large rivers, and the living and non-living components of aquatic ecosystems.

The extreme hydrologic regime imposed on the Tallapoosa River results in reduced and artificially, "rapidly repeated" seasonality because the natural flow conditions are literally lost, leading in turn to depressed reproduction and recruitment of various aquatic species and, eventually, to their loss from the system (Karr and Dudley 1981). Low flows become more extreme; indeed, as previously noted (see Section 3.6 of this Report, since installation of the Harris Dam in 1982, downstream river segments (including Horseshoe Bend) have sustained flows as low as zero, and as high as 453 cms (16,000 cfs). The hydrologic connectivity between the river channel, floodplain, and groundwater largely structures spatial and temporal features of floodplain habitats (Ward and Stanford 1995, Ward et al. 1999). Flow regulation by dams commonly results in reduced connectivity and altered succession in river floodplains, and reduced biodiversity (Ward and Stanford 1995). Sudden flooding followed by greatly reduced flow, a pattern sometimes repeated twice daily in the middle Tallapoosa River, washes out species and eliminates sensitive species (Poff et al. 1997, and references therein). The altered flow regime also can favor proliferation of exotic/ invasive species (Bunn and Arthington 2002, and references therein).

The Hydrologic Indicators for Horseshoe Bend were developed based on the historic, pre-dam flows of the Tallapoosa River at the Wadley, Ala., USGS gaging station which is 22 km (13.7 miles) downstream from the Harris Dam. As explained previously (see Section 3.6 of this Report), this station has historic information available for 58 years prior to installation of the Harris Dam. Despite the fact that it is ~30 km (19 miles) upstream from Horseshoe Bend, the present-day flow patterns are similar for the Wadley station versus the USGS gaging station that is much closer to Horseshoe Bend (New Site, Ala.), and historic pre-dam information is not available for the New Site station. The Wadley USGS station dataset clearly shows that the present-day flow regime is extreme and highly artificial (example shown in Figure 54)

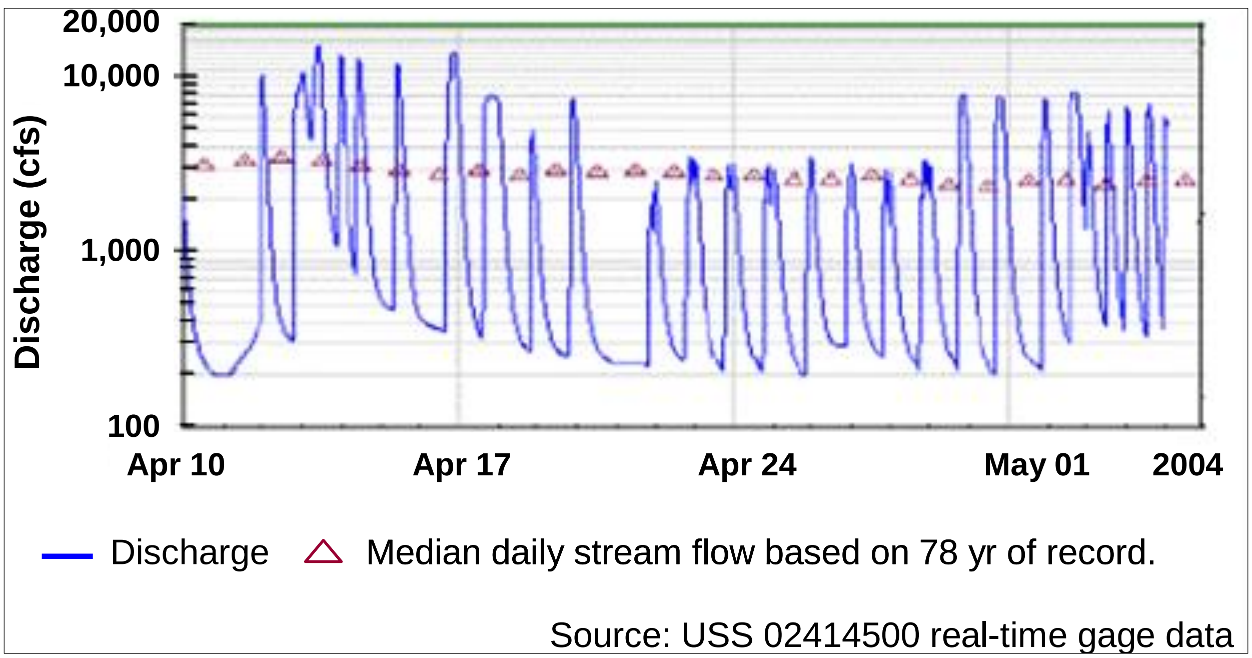

Figure 54. The extreme “hydro-peaking” effects from regulation of discharge at the Harris Lake outflow, downstream at the Wadley USGS gaging station. About 75% of the 78-years median discharge was prior to installation of the dam (58 years of historic conditions, 1923-1981). The relatively stable historic flow of the middle Tallapoosa River in this semi-log plot contrasts starkly with the extreme values imposed daily, sometimes twice daily, since the dam was installed (here, represented by the depicted period in 2004). From CH2MHill (2005, Exhibit 5-5).

We suggest two Hydrologic Indicators in the interim until a RSS for Horseshoe Bend is available that identifies Hydrologic Indicators specific to park waters (Table 44). These recommended interim indicators represent discharge magnitude and “flashiness” as follows:

$Hydro_{MAG}$ - At a given time interval, the amount of water moving past a fixed location (here, the Wadley USGS gaging station) per unit time (Poff et al. 1997). Absent appreciable precipitation:

- *good* – $\leq$ 1.5-fold change in discharge (in cfs) under non-storm conditions (defined as $\geq$ 5 days after a $\leq$ 1.25-cm [0.5-inch] storm at or upstream from Wadley, with no additional storms in the interim)
- *fair* – > 1.5 to $\leq$ 3-fold change in discharge between storm events
- *poor* – > 3-fold change in discharge between storm events

$Hydro_{FLASH}$ - The rate of change or "flashiness," that is, how quickly flow changes from one magnitude to another (Poff et al. 1997):

- *good* – discharge varies by $\leq$ 1.5 over a given 24-hr period during non-storm conditions, defined as above.
- *fair* – discharge varies by > 1.5 to $\leq$ 3-fold over a given 24-hr period during non-storm conditions.
- *poor* – discharge varies by > 3-fold over a given daily period during non-storm conditions.

These Hydrologic Indicators can be assessed multiple times between storm events over each season.

Table 44a. Present Hydrologic Condition in HOBE, evaluated using the $Hydro_{MAG}$ and $Hydro_{FLASH}$ Indicators.

Hydrologic Condition Indicator	**Upstream from HOBE (Wadley Station), Representing Conditions in the Park**	**Rating**
$Hydro_{MAG}$ - discharge at the Wadley USGS gaging station (in cfs) for $\geq$ 3 days during non-storm conditions	The Tallapoosa River at Wadley commonly sustains > 5-fold change in discharge for $\geq$ 3 days during non-storm conditions	*poor*
$Hydro_{FLASH}$ - discharge at the Wadley USGS gaging station (in cfs) within a 24-hr period during non-storm conditions	The Tallapoosa River at Wadley commonly sustains high variation in discharge, ranging from ~5- to 50- fold, over each 24-hr period during non-storm conditions.	*poor*

Table 44b. Evaluation of Present Hydrologic Condition, non-storm conditions, in HOBE, evaluated using the $Hydro_{MAG}$ and $Hydro_{FLASH}$ Indicators.

Evaluation (non-storm conditions)	**Rating**
Good - HydroMAG (over > 3 days) and HydroFLASH (over 24 hr.) each vary < 1.5-fold	*Overall-poor*
Fair - HydroMAG (over > 3 days) and HydroFLASH (over 24 hr.) each vary > 1.5-fold to < 3-fold	
Poor - HydroMAG (over > 3 days) and HydroFLASH (over 24 hr.) each vary > 3-fold	

4.10. Surface Water Quality

Issue: Water pollution is an ongoing problem for the biota of the Tallapoosa River segment in the park, caused by upstream land disturbance, silviculture, agriculture, and other development.

Sparse information is available about groundwater quality in or near the park, insufficient for use in developing indicators (see Section 3.6.2 of this Report). Therefore, this section focuses on surface water hydrology. There is a wealth of peer-reviewed literature in support of widely accepted parameters indicating the status of surface water quality in freshwaters, and state standards and/or federal recommendations for use in interpreting acceptable levels of these parameters (Hynes 1970, Whitton 1975, Wetzel 2001, U.S. EPA 2000, 2003; GA DNR 2011). These parameters - pH, Dissolved Oxygen (DO), turbidity, nutrients (especially TP and inorganic N as nitrate and/or ammonium), suspended algal biomass as chlorophyll *a* concentration (chl*a*, corrected for pheopigments from freshly dead and/or decomposing algae), and various toxic chemical environmental contaminants (CECs). We selected the suite of indicators and the evaluation procedure shown in Table 45 to assess Surface Water Quality Condition in the park, using the information contained in Table 26 of this Report. A *good* evaluation was based on protecting, at least, most sensitive aquatic life and sensitive life history stages in park waters.

Table 45a. The present Surface Water Quality Condition in HOBE, based on seven Water Quality Indicators (see Table 24 for references).

Surface Water Quality Indicators	NPS Management Target(s)	HOBE	Rating
pH	GA Std: 6.0 - 8.5	100% compliance (337 of 337 samples)	*good*
Dissolved Oxygen (DO, mg/L)	GA Std: Average 5.0 mg/L; minimum 4.0 mg/L	100% compliance (237 of 237)	*good*
Biochemical Oxygen Demand (BOD_5, mg/L)	Mallin et al. (2006) recommendation: $\leq$ 3 mg/L	100% met recommendation (19 of 19)	*good*
Turbidity (NTU)	U.S. EPA recommendation: 5.7 NTU	44% met recommendation (11 of 25)	*poor*
Total Phosphorus (TP, µg/L)	U.S. EPA recommendation: 30 µg/L	100% met recommendation (19 of 19)	*good*
Nitrate + Nitrite (NO_x^-N, µg/L)	U.S. EPA recommendation: 177 µg/L	84% met recommendation (16 of 19)	*fair*
Suspended microalgal chlorophyll *a* (Chla; corrected for pheopigments; µg/L)	U.S. EPA recommendation: < 4 µg/L	84% met recommendation (16 of 19)	*fair*

Table 45b. Paramerters used to rate Surface Water Quality Condition Indicators in HOBE.

Rating	pH	DO	BOD5	Turbidity	TP, NOx	Chl*a*
good	> 90%	> 90%	> 90%	> 90%	> 90%	> 90%
fair	> 75 to < 90%	> 80 to < 90%	> 80 to < 90%	> 75 to < 90%	> 75 to < 90%	> 75 to < 90%
poor	< 75%	< 80%	< 80%	< 75%	< 75%	< 75%

Table 45c. Overall evaluation of Surface Water Quality Condition in HOBE, based on seven Water Quality Indicators (see Table 24 for references).

good	*fair*	*poor*	Overall Rating
5-7 parameters *good* 0-2 parameters *fair* 0 parameters *poor*	< 2 groups *poor*	> 3 groups *poor*	OVERALL- *fair*

4.11. Biological Resources

Issue: Horseshoe Bend lies within a region that was once among the highest in biodiversity nationwide and included many endemic species. Watershed development has led to species extinctions at a rate unrivaled across the U.S. mainland. Various species are now threatened, endangered, or locally extirpated. Major habitat fragmentation imposed by dams upstream and downstream from the park has also adversely affected faunal diversity, species distributions, and fisheries, while at the same time the Tallapoosa River has become an important transportation corridor for exotic/ invasive species. Exotic/ invasive taxa are a primary concern of park staff, along with several SSMCs.

This suite of indicators was especially challenging because there is no quantitative information available about species of interest among the biological resources of Horseshoe Bend, a situation common to various other parks in the SECN. The information available for all-important plant communities at the base of Horseshoe Bend terrestrial and wetland/aquatic food webs is restricted to species lists - that is, numbers of species. Based on analyses of SECN parks for which recent, vouchered species lists were available for vascular plants, the NPS Certified Species List for Horseshoe Bend (NPS 2013b) should be updated and vouchered, as has been planned by the Network. This analysis is based on the only information available for Horseshoe Bend, which is the present NPS Certified Species List.

Unfortunately, population abundance data are lacking for all species of interest in the park, from SoCs to exotic/ invasive taxa to SSMCs. That information is needed to calculate reliable basic diversity indices such as Shannon Weaver (Shannon-Wiener; Shannon and Weaver 1949, MacArthur and MacArthur 1961, Peet 1974). Other indices that rely solely on species numbers were considered, but have major limitations: For example, classic incidence-based indices such as the Jaccard and Sørensen Index (J&SI) estimate similarity between two communities, focusing on richness and composition. The efficacy of the J&SI in providing a realistic measure of species diversity is in debate because the presence/absence data used are neither quantitative nor abundance-based; typically a significant under-sampling bias is involved; and there is no accounting for rare species or unseen shared species (Gotelli and Colwell 2001, Chao et al. 2006). Because of these significant limitations, the J&SI often has been found to yield variable results *for the same dataset* (Koleff et al. 2003). The following Biota Indicators were developed within the major constraints imposed by the lack of abundance data for species in the park. The suite of available indicators should be modified as more information becomes available, especially abundance data for selected species.

4.11.1. Vascular Plant Flora, Compromised by Exotic/ Invasive Species

Indicators for this large, important group were developed considering terrestrial and wetland habitats separately. For each of the two general habitats, the indicators were based on the proportion of exotic taxa and total number of exotic taxa as outlined in Table 58, and on the proportion of invasive taxa. Thus, we considered vascular plant communities within the context of alteration by exotic/invasive plant species.

Exotic/ invasive plants represent ~9% of the terrestrial plant taxa in this park, and less than 5% of the wetland flora (Table 46). While these percentages are small in comparison to various other SECN parks, Horseshoe Bend is infested with four Category #1 and two Category #2 terrestrial invasive plants, and its wetlands contain two Category #1 and 1 Category #2 invasive species. Based on the indicators and evaluation format shown in Table 46, the overall Vascular Plant Flora Condition in the park is *fair*.

Table 46a. Evaluation of present Vascular Flora Condition in the park, based on two Terrestrial and two Wetland Indicators.

Vascular Flora Indicators	Vascular Flora Condition in HOBE	Rating
Proportion of exotic terrestrial taxa to total ($TERR_{EX}$)	216 terrestrial vascular plant taxa in the park, including 19 exotic/ invasive taxa (9%).	*fair*
Number of highly invasive taxa ($TERR_{CAT}$)	4 Category #1 species + 2 Category #2 species.	*poor*
Proportion of exotic wetland/ aquatic taxa (WET_{EX})	215 wetland/aquatic vascular plant taxa including 10 exotic/ invasive (4.7%).	*Good*
Number of highly invasive wetland/aquatic taxa (WET_{CAT})	2 Category #1 species + 1 Category #2.species.	*fair*

Table 46b. Paramerters used to rate Vascular Flora Indicator Condition Indicators in HOBE.

Vascular Flora Indicators	Rating	Definition
$TERR_{EX}$	*good*	< 5% of the terrestrial taxa are exotic/invasive
	fair	≥ 5-15% are exotic/invasive
	poor	> 15% are exotic/invasive
$TERR_{CAT}$	*good*	no Category #1-#4 taxa
	fair	≤ 2 Category #1 taxa + some Category #2-#4 taxa
	poor	3 or more Category #1 taxa + 1 or more Category #2-#4 taxa
WET_{EX}	*good*	< 5% of the wetland taxa are exotic/invasive
	fair	≥ 5-15% are exotic/invasive
	poor	> 15% are exotic/invasive
WET_{CAT}	*good*	no Category #1-#4 taxa
	fair	≤ 2 Category #1 taxa + ≥ 1 Category #2-#4 taxa
	poor	3 or more Category #1 taxa + 1 or more Category #2-#4 taxa

Table 46c. Overall evaluation of Vascular Flora Indicator Condition Ratings for HOBE.

Rating	Overall Evaluation of Indicator Ratings	Overall Rating
good	≥ 3 indicators *good*, ≤ 1 indicator *fair*, 0 *poor*	OVERALL-*fair*
fair	≥ 2 indicators *fair*, ≤ 1 indicator *poor*	
poor	≥ 2 indicators *poor*	

4.11.2. Fish

In the southern U.S., a pattern has been reported wherein vulnerable fish species at risk of becoming threatened or endangered are increasingly more extirpation-prone (Warren et al. 2000). As mentioned (see Section 3.7.4), comparison of previous versus present NPS Certified Species Lists suggests that species known to have declined in the Middle Tallapoosa River basin (speckled chub, bullhead minnow, madtom catfish, redhorse sucker), as well as at least four species known to have been endemic to the region (lipstick darter, Tallapoosa darter - *Etheostoma tallapoosae*, Tallapoosa shiner, mottled sculpin), are no longer found in the Middle Tallapoosa River, including the segment within Horseshoe Bend - although three of these species were once listed as occurring in Horseshoe Bend. The Alabama Natural Heritage Program lists 14 fish species as SoCs within Tallapoosa County; the NPS Certified Species List for Horseshoe Bend lists only one species, the blacktail redhorse (*Moxostoma poecilurum*), which is not mentioned in the Alabama Natural Heritage Program list (Auburn University 2015).

The total Tallapoosa River drainage previously was described to contain 114-120 native fish species, yet only ~20% of that number (25 native species) are listed as presently still occurring in Horseshoe Bend. The present number of species is low, even if it is assumed that the historic number of fish species in the middle Tallapoosa River was only half of the historic total, ~60 species. Based on this information, we developed two Fish Indicators and evaluated the Fish Condition in the park as *poor* (Table 47). We recommend that fish species in the park should be assessed at five-year intervals or more frequently.

Table 47. Fish Condition in HOBE, based on two Fish Indicators.

Fish Indicator	HOBE	Rating
Fish Species Richness ($FISH_{SPP}$) *good* - > 50 native species *fair* - 40-50 native species *poor* - < 40 native species	25 native fish species and one exotic/invasive taxon have been reported to occur in the park; declines in species richness have been linked to the extreme, artificial hydrologic regime.	***poor***
Number of SoCs ($FISH_{SoC}$) *good* - ≥ 10 species *fair* - 6-9 species *poor* - < 6 species	1 SoC is listed as still occurring in HOBE	***poor***

4.11.3. Herpetofauna

Although the recent surveys of herpetofauna in the park have yielded interesting and helpful information, abundance data for the species found are not yet available so that classic species diversity indices such as the Shannon Weaver cannot be developed (Peet 1974; Magurran 1988, 2004). Therefore, as first and second indicators of Herpetofauna Condition, we suggest that trends in detection of vocal anurans and the data from visual encounter surveys should be tracked over time, beginning with the 2011 baseline data. The overall Herpetofauna Condition for Horseshoe Bend is *good.* It should be noted, however, that there is no information on the historic species richness of herpetofauna in the park. An assumption used in developing these indicators was that the highest species richness for the parks in the Southeast that were assessed by Tuberville et al. (2005) represents a *good* Herpetofauna Condition. Considering the known high diversity of herpetofauna in this region together with the high habitat degradation/loss and other negative impacts from watershed development, herpetofauna diversity may have been substantially higher.

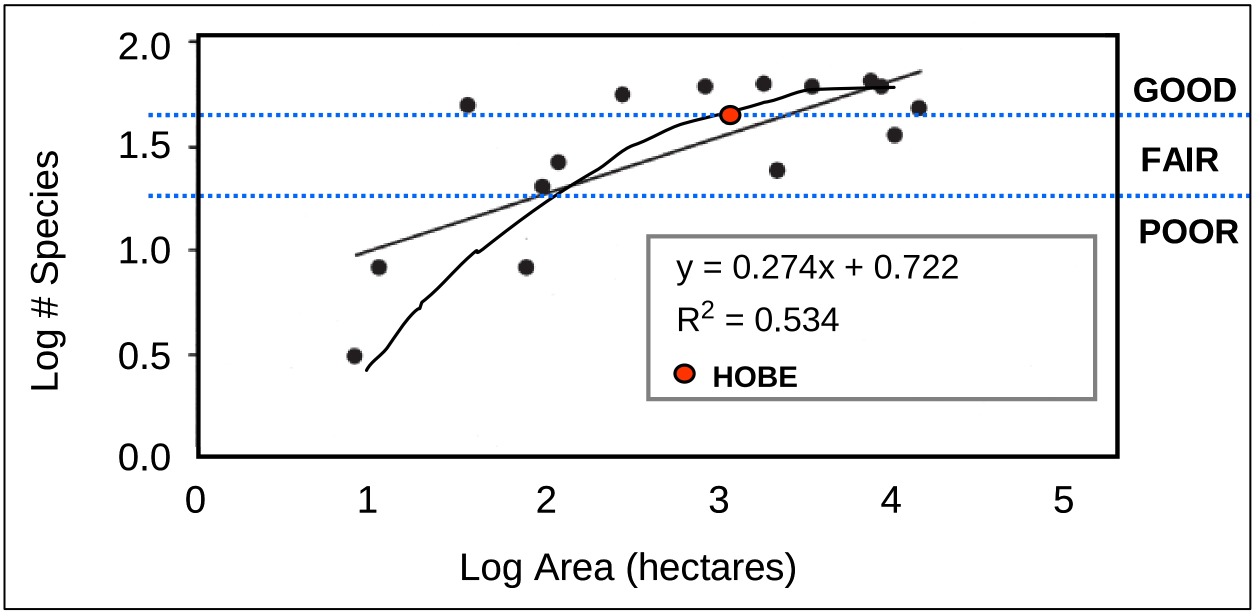

Figure 55. Relationship between land area (in hectares) and species richness, excluding exotic introduced) species, among 16 parks within the Southeast Coast Network of the NPS, including HOBE. Modified from Tuberville et al. (2005) to show apparent breaks in the data.

Table 48a. Herpetofauna Condition in HOBE, based on three indicators.

Herpetofauna Indicators	HOBE	Rating
Vocal Anuran Amphibians (V-Anurans) detected with ARD (consistent procedure, same timing/sites) *good* - ≥ 13 vocal anurans detected *fair* - ≥ 10-12 detected (up to 25% fewer) *poor* - < 10 detected	March through May 2011 - 13 vocal anuran amphibian species detected at the 30 established sites.	*good*
# of Species from VES, using consistent procedure, same timing/sites ($HERP_{VES}$) *good* - ≥ 15 amphibian & reptile taxa *fair* - 11-14 taxa (up to 25% fewer) *poor* - < 11 taxa	August 2011 - 15 amphibian and reptile taxa detected (same 30 sites).	*good*

Table 48b. Overall evaluation of Herpetofauna Condition in HOBE.

Evaluation of Herpetofauna Indicators	Rating
good: $HERP_{SPP}$ *good*, < 2 other indicators *good*, < 1 other indicator *fair* *fair*: $HERP_{SPP}$ *fair*; < 2 other indicators *fair*, < 1 other indicator *poor* *poor*: < 2 indicators *poor*	OVERALL-*good*

4.11.4. Birds

Horseshoe Bend is listed as having 208 bird species, slightly more than the number of species given for an SECN park (Kennesaw Mountain National Battlefield Park - 202 species) that is a globally Important Bird Area and has been described as having high bird fauna diversity based on species richness. Unfortunately, abundance data are lacking for bird species in Horseshoe Bend, preventing calculation of Shannon Weaver or other widely accepted diversity indices for bird diversity. Therefore, at present we have based indicators for Bird Fauna Condition in this park on the North American Breeding Bird Survey (BBS), and on the baseline survey conducted by Byrne et al. (2011b).

The BBS was developed by the U.S. Fish and Wildlife Service in response to the need for a continental monitoring program following the widespread use of DDT (dichloro-diphenyl-trichloro-ethane) and other chlorinated hydrocarbon pesticides, and anecdotal reports about related increased mortality of songbirds (Robbins et al. 1986). The program presently represents a cooperative effort between the U.S. (USGS), Environment Canada - Canadian Wildlife Service, and the Comisión Nacionale para el Conocimiento Uso de la Biodiversidad (CONARIO). The BBS presently includes ~3,400 randomly located permanent survey routes established along secondary roads. Each route is 39.4 km (24.5 miles) long and consists of 50 stops spaced at 0.8-km (0.5-mile) intervals. The routes are surveyed once each year during the peak of the breeding season. Volunteers experienced in identifying birds by sight and sound record all birds detected within 0.4 km (0.25 mile) of each stop during a 3-minute observation period (Robbins et al. 1986, Peterson et al. 1995). As a limitation, the annual surveys yield what might be more accurately described as a relative abundance index because they do not produce a complete counting of the breeding bird populations. In addition, differences in experience among volunteers can sometimes cause inconsistencies in the results. Nevertheless, these annual surveys have proven valuable in assessments of bird population trends (Link and Sauer 1998, Sauer et al. 2003).

BBS summaries of the data by year allow a rapid, user-friendly analysis of trends in the number of individuals and the number of species detected over time at a station of interest (USGS 2001b). The data are also presented by individual species. For BBS Route 02209 (Wedowee, Ala.), the number of species and the number of individuals appear to have remained comparable, given the scatter in the data, over the past ~13 years (Table 49).

Table 49. Breeding Bird Survey results for BBS Route 02209- Wedowee, Ala., the route closest to HOBE, ~20 km (12.5 miles) northeast of the park.

Parameter	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of Species	65	67	----	63	60	53	54	49	56	60	51	58	61
Number of Individuals	614	579	----	588	577	467	474	502	492	511	564	712	767
4 yr average	**63 species, 584 individuals**					**53 species, 483 individuals**				**57 species, 638 individuals**			

Three other indicators suggested here for Bird Fauna Condition in Horseshoe Bend were developed from the baseline survey conducted in 2009 by Byrne et al. (2011b). They include the observed number of species ($BIRD_{OBS\ SPP}$), total bird abundance ($BIRD_{ABUND}$, number of individuals), and $BIRD_{DIST}$ (the six most widely distributed birds in the park; Table 50). The fifth and final indicator, $BIRD_{SoC}$, is based on the three bird SoCs that were reported for the park in the NPS Certified Species List (2013a; Table 61).

Finally, the status of the NPS Certified Species List (2013a) for bird fauna in Horseshoe Bend merits mention. This valuable list should be verified at least on a decadal basis. Otherwise, there will be no way to track the total number of species that actually can be found in Horseshoe Bend at some time during an annual cycle, or the percentage of neotropical migrants, or other important information. At present, the total number reported on the list is 208 native species. We did not suggest the total number of species on the NPS Certified Species List, tracked over time, as an indicator in consideration of the fact that extensive survey of the park over an annual cycle would require a major, personnel- and time-intensive effort, but it is important nevertheless.

Table 50a. Bird Fauna Condition in HOBE, based on evaluation using five indicators.

Bird Fauna Indicators	HOBE	Rating
Breeding Birds ($BIRD_{BBS}$, annual, routinely conducted by volunteers for the USGS) *good* - ≥ 65 native spp. *fair* - 55-64 spp. *poor* - < 55 spp.	North American BBS in the park area: 2000-2003 - 63 spp., 584 individuals 2004-2007 - 53 spp., 483 individuals 2008-2012 - 57 spp., 638 individuals The lowest # of species annually over the 2000-2012 period was 49 spp. in 2007.	*good*
$BIRD_{OBS\ SPP}$ (assessed at 10-yr intervals, same timing/sites as in 2009) *good* - ≥ 50 native spp. *fair* - 41-49 native spp. *poor* - < 41 native spp.	April-May 2009 - 53 native species detected at 30 established sites.	*good*
$BIRD_{ABUND}$ (# individuals, same assessment) *good* - ≥ 800 individuals in total *fair* - 700-799 individuals *poor* - < 700 individuals	April-May 2009 - 845 individuals detected at 30 established sites.	*good*
$BIRD_{DIST}$ (most widely distributed, same): *good* - same 7 spp. *fair* - 5-6 of the seven spp. *poor* - ≤ 4 of the seven spp.	April-May 2009 - most widely, distributed taxa: northern cardinal, northern parula, red-bellied woodpecker, red-eyed vireo, tufted titmouse, Carolina wren, and American crow.	*good*
$BIRD_{SoC}$ (assessed at 10-yr intervals in "best" locations) *good* - all 3 SoCs observed *fair* - 2 of 3 SoCs observed *poor* - ≤ 1 SoC observed	As of 2013 (NPS Certified Species List) - 3 SoCs: the American kestrel, solitary vireo, and yellow warbler.	*good*

Table 50b. Overall Evaluation of Bird Fauna Condition in HOBE.

Evaluation of Bird Fauna Indicators	Rating
good: $BIRD_{BBS}$ or $BIRD_{OBS\ SPP}$ *good*, ≥ 2 other indicators *good*, ≤ 1 other indicator *fair*, no indicator *poor*	**OVERALL-** *good*
fair: $BIRD_{SPP}$ or $BIRD_{OBS\ SPP}$ *fair*; ≤ 2 other indicators *fair*, ≤ 1 other indicator *poor*	
poor: ≥ 2 indicators *poor*	

4.11.5. Mammals

Lacking other helpful information, we based the present form of the mammalian species indicator on the proportion of exotic/invasive mammalian taxa relative to the total number of mammalian taxa inhabiting Horseshoe Bend (Table 51). Webster (2010) described depauperate mammalian species for this park, consisting of 22 documented native taxa. His final list included 11 other species that are widely distributed in the Southeast and probably inhabit Horseshoe Bend, but these 11 species were not documented there. We recommend that mammalian species should be re-assessed on a five- to 10-year basis, and that population-level studies should be conducted on mammalian SSMCs, to strengthen and improve the Mammalian Indicator in the future.

Table 51. The present Mammalian Fauna Condition in HOBE, based on evaluation using three indicators.

Mammalian Fauna Indicators	HOBE	Rating
Proportion of exotic/invasive species (MAM_{INV} - assess every 10 yr) *good* - < 5%, none common *fair* - 5-10% *poor* - > 10%	NPS Certified Species List (2013) - at least ~16% (5 of 32) of the mammalian species in the park are exotic/invasive, or recent invasive taxa	*poor*

4.11.6. Species of Special Management Concern (SSMCs)

In addition to the SOCs addressed above in other sections, we developed indicators for the following four SSMCs:

- Longleaf pine natural regrowth and reduced accumulation of materials that act as natural fuels, through use of prescribed fires (LLEAF);
- Poaching and other over-hunting of wild turkeys ($TURK_{POACH}$);
- Impacts of coyotes that have invaded the park in the past ~decade (COY_{INV}); and
- Stress to deer from over-population or over-harvest ($DEER_{ST}$).

Because quantitative information is not available for any of these species, or for related issues such as poaching or disease, the indicators requested by park staff must be qualitative (*Table 52*). Nevertheless, we hope that these straightforward indicators can be used to help leverage support for rigorous assessment of the SSMC populations.

It should be noted that we have elected not to develop specific indicators for exotic/ invasive species, for two reasons: First, we have already factored exotic/ invasive species into the indicators for Vascular Flora and Mammals in this park. The exception was the coyote, in deference to a special request from park staff. Second, as Ferriter et al. (2007, p.9-15) wrote,

> The indicator[s] for invasive exotics is not similar in nature or context to other indicators because nonindigenous [species] in themselves do not make good indicators of ecological function, process, or structure….

Based on their extensive experience combating exotic/invasive species in the Florida Everglades, Ferriter et al. (2007) suggested use of the following parameters to evaluate and report the status of invasive species: the number of different exotic/ invasive species present; the number, abundance, and frequency of new exotic/ invasive species in the ecosystem; the number and abundance of extant exotic/ invasive species found in new locations; the location and density of invasive exotic species, especially in relation to native communities; the rate of invasive species spread; and the effectiveness of control actions or programs for exotic/invasive species, generally measured as a decrease in the spatial extent of a (plant) species. Very little of any of these types of information is available for Horseshoe Bend other than the total number of exotic/ invasive taxa. For example, park staff have expressed a desire to manage southern pine beetle-damaged areas so as to replace them by establishing early successional grassland or shrub scrub habitat.

However, quantitative information is not available as to whether/how much effort has been expended to achieve this long-term goal, or measures of progress. An indicator for this effort should be developed when this information becomes available.

Overall, the Everglades National Park illustration is apt: Despite major restoration efforts and billions of dollars expended over the past decade, that important ecosystem was recently described to be in urgent need of work to establish the distributions and biological data for various exotic/invasive species (Ferriter et al. 2007). As for the Everglades and many other national parks across the U.S., as well as the Southeast, Horseshoe Bend is in urgent need of such work as well.

Table 52a. Present condition of Species of Special Management Concern (SSMCs) in HOBE, based on four indicators.

SSMC Indicators	HOBE	Rating
Re-establishment of longleaf pine habitat (LLEAF) *good* - prescribed burns at 5-yr intervals. *fair* - prescribed burns at 6- to 7-yr intervals. *poor* - prescribed burns at > 7-yr intervals.	Prescribed burns were conducted in 2006 and 2011, and are continuing to be scheduled at 5-yr intervals in an attempt to allow natural regrowth of longleaf pines.	*good*
Poaching of wild turkeys ($TURK_{POACH}$) *good* - no signs of incidents *fair* - signs of incidents mainly in 1 area *poor* - incidents increasingly reported or signs noted, more widespread in the park	Signs/incidents of poaching of wild turkeys, in one area of the park, are a concern to park staff.	*fair*
Recent invasive species (COY_{INV}) *good* - none recently detected *fair* - 1-2 newly invasive spp. detected *poor* - > 2 newly invasive spp. detected	Coyotes recently (past ~decade), increasingly noted ; their potential impacts are a concern for park staff.	*fair*
Deer over-population stress ($DEER_{ST}$) *good* - non-recently detected *fair* - occasional signs mainly in 1 area *poor* - common signs widespread in park	Thin animals suggestive of insufficient food have been noted in various areas of the park. Staff have expressed concern about potential over-population and disease.	*poor*

Table 52b. Evaluation of overall condition of Species of Special Management Concern in HOBE.

Evaluation of Condition of Species of Management Concern	Rating
good: > 3 indicators *good*, < 1 *fair*, 0 *poor* *fair*: > 3 *good* or *fair*, < 1 *poor* *poor*: > 2 *poor*	OVERALL-*fair*

5. Discussion

5.1. Summary of Natural Resource Conditions in Horseshoe Bend

This in-depth analysis of the natural resources of Horseshoe Bend considered available information for all natural resource categories ranging from climate to SSMCs (Tables 53 and 54). A total of 59 indicators were used to evaluate the 16 categories of natural resources for which sufficient information was available to allow some level of assessment. The overall condition of five categories was rated as *good*; 6 were evaluated to be in *fair* condition and five were in *poor* condition.

The above overall Report Card of Natural Resource Conditions in Horseshoe Bend is evenly distributed with *good*, *fair*, and *poor* evaluations, rating an overall "C." Importantly, of these 16 categories of natural resources, most are not possible for the National Park Service to control. Only a few categories, within the park biota, can be even partly controlled by park staff. For example, park staff cannot control the introductions of more exotic/ invasive taxa that have dramatically altered the natural communities, because these undesirable taxa can be carried into the park by human visitors, birds, wind, water, etc. As another NPC example, the category Human Population Surrounding the Park would have rated an overall *fair* except for two factors, namely, the level of poverty in Tallapoosa County, and the looming threat of Lee County population growth and expansion.

This Report Card can function as a valuable resource for Horseshoe Bend staff and the Network by enabling rapid communication to concerned citizens, policymakers in local, state, and federal governments, industries etc. about the pressing need to improve protection of the natural (and cultural) resources in this valuable park. It is our hope that the many people who depend on Horseshoe Bend for recreation and insights about the early history of our nation - and who expect to continue to enjoy its natural and cultural resources - will respond to this Report Card by contributing more stewardship toward the goal of improving the status and the protection of the natural resource conditions in this national park.

Table 53. Overall Report Card of Natural Resource Conditions in HOBE

Natural Resource Category	Indicator(s)	Rating
Climate	5	***poor***
Human Population Surrounding the Park	5	***poor***
Visitation - Human Population in the Park	3	***fair***
Land Use/Land Cover	2	***good***
Air Quality	8	***fair***
Soundscape	3	***good***
Lightscape	1	***good***
Soil and Streambank Erosion	4	***fair***
Surface Water Hydrology	2	***poor***
Surface Water Quality	7	***fair***
Vascular Flora	4	***fair***
Fish	2	***poor***
Herpetofauna	2	***good***
Birds	5	***good***
Mammals	1	***poor***
Species of Special Management Concern	4	***fair***

Table 54. Summary of Natural Resource Conditions in HOBE, including 16 separate categories that were evaluated using the 59 listed indicators.

Category	Indicators	Present Status in HOBE	Condition	Overall
CLIMATE	T_{SUM} - mean summer air temperature	*Mean summer air temperature - increasing trend.	*poor*	***poor***
	GDD_{ANN} – phenology;PDSI - moisture	*Phenology (GDD_{ANNUAL}) increasing; *PDSI decreasing	*poor* *poor*	
	PPT_{SUM} – mean summer precipitation	*Mean summer precipitation – decreasing trend	*poor*	
	Dry - # of dry months/yr	*Dry - increasing; MSt - increasing:	*poor*	
	MSt - # of major storms	HOBE climate is warming; annual # of growing degree days is increasing; more dry months/yr, more major storms	*poor*	
HUMAN POPULATION SURROUNDING PARK	$HPG_{5\text{-km}}$ - human population growth (5-km radius around park)	*Population growth declined in past decade in Tallapoosa Co.	*good*	***poor***
	$HPG_{80\text{-km}}$ - human population growth (80-km radius)	*High population growth (+2.6%/yr) in adjacent Lee Co.	*poor*	
	$HPD_{5\text{-km}}$ - human population density (5-km radius)	*Moderate population density (5-km radius- 22.4 people/km^2)	*fair*	
	$HPD_{80\text{-km}}$ - human population density (80-km radius)	*High population density (80-km radius- 91 people/km^2)	*poor*	
	POV - poverty surrounding park	*Tallapoosa Co. - 17.1% of population is below poverty level	*poor*	
VISITATION - HUMAN POPULATION IN PARK	VIS - # visitors/yr (trend)	*~100,000 visitors (2012), comparable or lower than previous years.	*good*	***fair***
	$VP\text{-}A_{GR\text{-}SEAS}$ - visitor pressure/park area (growing season)	*Average of 91 visitors/hectare/growing seasons, or 0.4 visitor/hectare/day (0.2 visitor/acre/day).	*good*	
	$VP\text{-}T_{GR\text{-}SEAS}$ - visitor pressure on trails (growing season)	*Avg. of 17 visitors/km of trail/day (27 visitors/mile of trail/day).	*poor*	

Table 54 (continued). Summary of Natural Resource Conditions in HOBE, including 16 separate categories that were evaluated using the 59 listed indicators.

Category	Indicators	Present Status in HOBE	Condition	Overall
LAND USE/LAND COVER	$\%IC_{5\text{-}km}$ - % imperv. cover (5-km radius)	*Negligible IC, < 1% land use/land cover within a 5-km radius of the park.	*good*	***good***
	$\%GRN_{WAT}$ - greenspace (middle Tallapoosa sub-watershed)	*Entire sub-watershed had only 5% developed land as of 2006 (most recent available data). In 2001-2006, there was a gain of only 0.1% in developed lands.	*good*	
AIR QUALITY	AQI - Air Quality Index (U.S. EPA)	*2012-2013: Overall AQI Good 98.9% of days, Moderate 1.1%.	*good*	***fair***
	O_3 - Ozone concentration (humans); W126, SUM06 (plants)	*2005-2009: Ozone 61-75 ppb (8-hr avg. time, 4th maximum value); W126, 7-13 ppm-hr.; SUM06 8-15 ppm-hr.	*fair*	
	N-DEP - nitrogen deposition	*2005-2009: N-DEP > 3 kg/ha/yr.	*poor*	
	S-DEP - sulfur deposition	*2005-2009: S-DEP > 3 kg/ha/yr.	*poor*	
	VIS - visibility	*2005-2009: VIS > 8 dv.	*poor*	
	ACID - acidification	*Pollutant exposure very high, ecosystem sensitivity low, Park Protection low; overall, low risk from acidic pollution.	*good*	
SOUNDSCAPE	POP_{SOUND} - proximity to pop. center	*HOBE is ~64 km from the Au-OpMA (rapidly growing).	*fair*	***good***
	$SOURCE_{SOUND}$ - proximity to major source (road, RR, etc.)	*State Hwy 49 passes through park, but its traffic is usually light so it is considered a minor mode of travel.	*good*	
	$DATA/OBS_{SOUND}$ - noise pollution data available for the park	*Data n.a.; parks staff describe HOBE as usually very quiet.	*good*	

Table 54 (continued). Summary of Natural Resource Conditions in HOBE, including 16 separate categories that were evaluated using the 59 listed indicators.

Category	Indicators	Present Status in HOBE	Condition	Overall
LIGHTSCAPE	Bortle Dark-Sky Scale - classes: 1-2 (truly dark skies) 3-4 (rural skies) ≥ 5 (suburban sky, ground objects partly lit) to 9 (inner city sky)	HOBE is still in a predominantly rural setting; lightscape is described by park staff as Class 2, Truly Dark Skies.	*good*	**GOOD**
SOIL & STREAMBANK EROSION	$Soil_{EROD}$ - erodability of all soil types	*12 of 20 soil types moderately eroded, including two of the three most abundant soil types; ~20% of the soil types are occasionally to frequently flooded, including one of the three most abundant soils.	*poor*	***fair***
	$Soil_{VIS}$ - visual evidence of soil erosion	*Little evidence of soil erosion in HOBE.	*good*	
	$Bank_{EROD}$ - visual evidence of stream-bank erosion	*Little visual evidence of streambank erosion in the park.	*good*	
	$Soil_{ACID}$ - soil acidification potential	*Moderate soil acidification potential, based on air quality data + poor buffering capacity of the mostly clay soils.	*poor*	
SURFACE WATER HYDROLOGY	$Hydro_{MAG}$ - magnitude of discharge at the Wadley gaging station for ≥ 3 days (non-storms conditions; cfs)	*Tallapoosa River at Wadley commonly sustains > 5-fold change in discharge for ≥ 3 days during non-storm conditions.	*poor*	***poor***
	$Hydro_{FLASH}$ - discharge at the Wadley gaging station within a 24-hr period (non-storm conditions; cfs)	*Tallapoosa River at Wadley commonly sustains high variation in discharge, ranging from ~5- to 50-fold, over each 24-hr period during non-storm conditions.	*poor*	

Table 54 (continued). Summary of Natural Resource Conditions in HOBE, including 16 separate categories that were evaluated using the 59 listed indicators.

Category	Indicators	Present Status in HOBE	Condition	Overall
SURFACE WATER QUALITY	pH - 6.0 to 8.5	*pH - 100% compliance (337 samples)	*good*	***fair***
	DO - $\geq$ 4 mg/L; Avg - 5.0 mg/L	*DO - 100% compliance (237 samples)	*good*	
	BOD_5 - $\leq$ 3 mg/L	*BOD_5 - 100% met recommendation (19 samples)	*good*	
	Turbidity - < 5.7 NTU	*Turbidity - 44% met recommendation (11 of 25 samples)	*poor*	
	TP - $\leq$ 30 µg/L	*TP - 100% met recommendation (19 samples)	*good*	
	NO_x^-N - $\leq$ 177 µg/L	*NO_x^-N - 84% met recommendation (16 of 19 samples)	*fair*	
	Chl*a* - < 4 µg/L	*Chl*a* - 84% met recommendation (16 of 19 samples)	*fair*	
VASCULAR FLORA	$TERR_{EX}$ - # Exotics/Total	*9% (19 spp. of 216 total) of the total terrestrial taxa are exotic/invasive.	*fair*	***fair***
	$TERR_{CAT}$ - # highly invasive taxa	*4 CATEGORY #1 species + 2 CATEGORY #2 species present in the terrestrial vascular flora.	*poor*	
	WET_{EX} - # Exotics/Total	*19% (42 spp.) of the total wetland taxa are exotic/invasive.	*good*	
	WET_{CAT} - # highly invasive taxa	*15% (3 spp.) of CATEGORY #1 taxa are wetland and occur in the park, + 2 CATEGORY #1 Alert taxa + 9 CATEGORY #2-#4 species. All 5 CATEGORY #1/CATEGORY #1 Alert taxa are common in the park.	*fair*	
FISH	$FISH_{SPP}$ - fish species number	*25 native fish species and one exotic/invasive species reported in the park; declines in species richness have been linked to the extreme, artificial hydrologic regime.	*poor*	***poor***
	$FISH_{SoC}$ - number of fish SoCs	*Only 1 SoC still listed as occurring in HOBE.	*poor*	

Table 54 (continued). Summary of Natural Resource Conditions in HOBE, including 16 separate categories that were evaluated using the 59 listed indicators.

Category	Indicators	Present Status in HOBE	Condition	Overall
HERPETOFAUNA	$HERP_{SPP}$ - total # of species	*2004: 66 native species of herpetofauna, leading the SECN parks.	*good*	***good***
	V-Anurans - # spp. detected	*Mar-May 2011: 13 vocal anuran native spp. detected.	*good*	
	$HERP_{VES}$ - # spp. detected	*Aug 2011: 15 amphibian and reptile taxa detected with VES.	*good*	
BIRDS	$BIRD_{BBS}$ - # native spp./yr	*68-71 spp. in 2000-2004, 2005-2008, and 2009-2012; lowest # was 65 spp. in 2007.	*good*	***good***
	$BIRD_{OBS\ SPP}$ - # native spp.	*Apr-May 2009: 53 native spp. (30 sites in park).	*good*	
	$BIRD_{ABUND}$ - # individuals	*845 individuals.	*good*	
	$BIRD_{DIST}$ - 6 most widely distributed spp.	*N. cardinal, northern parula, red-bellied woodpecker, red-eyed vireo, tufted titmouse, Carolina wren, and American crow.	*good*	
	$BIRD_{SoC}$ - SoCs observed	*As of 2013, American kestrel, solitary vireo, yellow warbler.	*good*	
MAMMALS	MAM_{INV} - #exotic spp./total #	*At least 16% of the mammalian spp. in the park (5 of 32) are exotic/invasive taxa, including recent invasives.	*poor*	***poor***
SSMCs	LLEAF - re-establishment of longleaf pine via prescribed burns	*Prescribed burns in 2006, 2011; targeted at 5-yr intervals.	*good*	***fair***
	$TURK_{POACH}$ - signs/incidents of turkey poaching in the park	*Signs/incidents of poaching wild turkeys in 1 area of park.	*fair*	
	COY_{INV} - recent invasive spp.	*Coyotes recently and increasingly noted (past ~decade).	*fair*	
	$DEER_{ST}$ - deer over-population stress	*Thin animals (suggestive of insufficient food for deer) commonly noted in various areas of park.	*poor*	

5.2. Remaining Major Knowledge Gaps and Next Steps

Major knowledge gaps prevented or seriously restricted evaluation of the present condition of several natural resource categories. These gaps, and efforts needed to fill them, include:

- *Streambank Erosion* - A study should be conducted to develop a channel stability index for the Tallapoosa River in the park following the approach used by Heeren et al. (2012). The CSI is a type of rapid geomorphic assessment (RGA) that provides a quick, straightforward method for characterizing stream reaches in terms of stability (Simon and Downs 1995). The CSI would be applicable to Horseshoe Bend because this index was originally designed for areas that are highly sensitive to erosion. Required measurements include bank height, bank face length, river stage at baseflow, degree of constriction, and average diameter of streambed sediment, following guidance on a 2-page sheet. Metrics include representative river stage (water surface height, measured in the thalweg of the stream, avoiding local scour pools), river channel width at the cross-section and one fourth of a meander length upstream, measured at the bankfull height; and degree of constriction (relative decrease in channel width from upstream to downstream). Scores from several metrics are summed to create an aggregate score, with a higher score indicating greater instability: ≤ 10 ≡ stable, 10-20.
- *Surface Water Hydrology* - The RSS in development for Horseshoe Bend is expected to identify additional hydrologic targets, such as an indicator for tracking undesirable high water conditions over time, and an indicator to assess changes in flows of the springs in the park.
- *Groundwater Supply* - A monitoring well is needed near Horseshoe Bend within the Piedmont aquifer that underlies the park, to provide the data needed to assess aquifer drawdown over time.
- *Surface Water Quality* - Data for the parameters selected as indicators should be collected at least monthly to enable reliable assessment of water quality conditions over time, from one station on each stream in the park. In addition, data are needed for fecal coliform bacteria and chlorophyll *a* (suspended algal biomass in the Tallapoosa River within Horseshoe Bend).
- *Stream Sediment Quality* - Information is needed to enable assessment of the quality of stream sediments in Horseshoe Bend, focusing on toxic substances such as mercury and polychlorinated biphenyls (PCBs), to address an identified concern of park staff.
- *Groundwater Quality* - Information is lacking on groundwater quality in or near the park. Monthly sampling at least every other year is needed to characterize the pH and track concentrations of contaminants such as nitrate+nitrite, sulfide, and metals (e.g. iron, aluminum, manganese), following the approach of Donahue (1998).
- *Stream Macroinvertebrate Communities* - Stream macroinvertebrates are commonly used to evaluate habitat conditions, but data for these biota are lacking in or near the park. Stream macroinvertebrates should be added as an important biological component, and should be sampled at five-year intervals to assess stream biological condition following well-established protocols (Barbour et al. 1999, Bowles et al. 2008).
- *Ecological Studies to Advance Beyond Species Lists and Presence/Absence Information* - Focused work to characterize key vascular plant communities and key species of interest are needed, including quantitative abundance data and maps. The species-level studies should

emphasize the dominant terrestrial and wetland vascular plants in each of the general habitat types found in the park; the common Category #1 and Category #1 Alert invasive vascular plants of most concern to park staff; and any other exotic/invasive fauna of major concern to park staff.

- *Population Studies* - SSMCs, including wild turkeys, coyotes, and white-tailed deer, should be assessed for food availability, hunting/ poaching pressure, disease, and effects on the park ecosystem.
- *Updated Biota Surveys* - It would be very helpful to conduct rigorous efforts on a decadal basis to track the natural resource conditions of the flora and fauna in Horseshoe Bend. Up-to-date, vouchered species lists of vascular flora in terrestrial and wetland habitats are needed. The most recent survey of mammals in Horseshoe Bend is already a decade old, and should be updated in order to track the condition of this important natural resource category over time.
- *Analysis Over Time of the Cumulative and Synergistic Effects of Pressures from Climatic, Land Use, and Exotic/Invasive Species Changes* - The rate of climate warming in this century is projected to be from 2.5- to 5.8-fold higher than the rate measured during the 1900s (Hansen et al. 2014, and references therein). Temperatures are expected to increase by 2.58^{o}C to 4.58^{o}C. Watershed development is expected to accelerate; for example, an average 255% increase in housing density is projected by 2100 in lands surrounding national parks throughout the nation. The Au-OpMA, near the park, is rapidly growing. Exotic/invasive species generally are favored by disturbances such as these (Ferriter et al. 2007). The cumulative, synergistic effects of such changes are predicted to dramatically impact ecosystem function and biodiversity in national parks (Hansen et al. 2014). In fact, it has been estimated that ~30% of the parklands may lose their present biomes by as early as 2030 (Hansen et al. 2014).

We have recommended various additional efforts by the SECN which, together with the present and planned I&M Program works, will greatly strengthen understanding about how each of these pressures affects Horseshoe Bend natural resources. The resulting databases will make it possible for the Network to consider climatic, land use, and exotic/invasive species changes more realistically — through integrative rather than separate analyses of cumulative/synergistic impacts over time. Ultimately, that approach offers the best hope of restoring and protecting the natural resources of Horseshoe Bend.

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Appendix 1. GIS Data Used for Assessing Conditions

Table A1-1. GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
hobe_administrative.shp	*Current NPS Administrative Boundary for Horseshoe Bend National Military Park*	Boundary	Vector polygon shapefile representing the NPS administrative boundary for HOBE. This boundary was originally part of a larger NPS regional dataset and is intended for use at the regional level. This boundary is also found in the state_regional_gis directory and it may need to be updated as the NPS national administrative boundary dataset is updated.	NPS	1:10,000,000	Yes
COUNTY.shp	*1990 County and Equivalent Area*	Counties	This dataset contains 1990 County and Equivalent Areas by State equivalent code (FIPS) located in the state of Alabama.	U.S. Census Bureau	1:5,000,000	Yes - text file only
hobe_cities.shp	*Cities of the United States*	Cities	This map layer includes cities in the United States, Puerto Rico and the U.S. Virgin Islands. These cities were collected from the 1970 National Atlas of the United States. Where applicable, U.S. Census Bureau codes for named populated places were associated with each name to allow additional information to be attached. The Geographic Names Information System (GNIS) was also used as a source for additional information. This is a revised version of the December 2003 map layer. The original dataset was clipped to the county boundaries that contain HOBE.	National Atlas of the United States	1:2,000,000	Yes
hobe_urban_areas.shp	*Urban Areas of the United States*	Cities	This data set includes a selection of urban areas in the United States derived from the urban areas layer of the Digital Chart of the World (DCW). This is a revised version of the 1998 data set. The original dataset was clipped to the county boundaries that contain HOBE.	USGS	1:2,000,000	Yes
dem_mtr (directory)	*7.5 Minute Digital Elevation Model*	Elevation	Digital Elevation Model (DEM) is the terminology adopted by the USGS to describe terrain elevation data sets in a digital raster form. The7.5-minute DEM (30- by 30-m data spacing, cast on a Universal Transverse Mercator (UTM) projection) provides coverage in 7.5- by 7.5-minute blocks. The directory also contains a park mosaic.	USGS	30 meter	Yes - text file only
hobe_dem.img	*National Elevation Dataset (DEM)*	Elevation	The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. NED has been clipped to HOBE surrounding extent.	USGS	30M	Yes

Table A1-1 (continued). GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
al_plss_utm.shp	*Public Land Survey System of the United States*	Land Survey	This data set portrays the Public Land Surveys of the United States, including areas of private survey, Donation Land Claims, and Land Grants and Civil Colonies. This is a revised version of the May, 2002 data set. The national dataset has been clipped to the state of Alabama.	USGS	1:2,000,000	Yes
pipetran (dlg - directory)	*Large-scale Digital Line Graph - Pipelines*	Transportation	Vector polyline shapefiles representing pipeline DLGs in 7.5 minute blocks for the extent of HOBE.	USGS	1:24,000	Yes - text file only
hobe_railroad.shp	*Railroads of the United States*	Transportation	This map layer includes railroads in the conterminous United States and Alaska. This is a replacement for the December 1998 map layer. The original dataset was clipped to the county boundaries that contain HOBE.	National Atlas of the United States	1:2,000,000	Yes
railroad (dlg - directory)	*Large-scale Digital Line Graph - Railroads*	Transportation	Vector polyline shapefiles representing railroad DLGs in 7.5 minute blocks for the extent of HOBE.	USGS	1:24,000	Yes - text file only
roads.shp	*Bureau of Transportation Statistics U.S. Road Networks*	Transportation	This data set portrays a Bureau of Transportation Statistics overview of the road networks for all fifty States, the District of Columbia, and Puerto Rico. An extent containing HOBE was extracted from the original dataset.	BTS	1:100,000	Yes
ftp_roads	*Large-scale Digital Line Graph - Roads*	Transportation	Vector polyline shapefiles representing road DLGs in 7.5 minute blocks for the extent of HOBE.	USGS	1:24,000	Yes - text file only
roads.shp	*HOBE Roads*	Transportation	The following file represents roads and fire roads located in the Horseshoe Bend National Military Park (HOBE). The University of Tennessee at Chattanooga Environmental Research and Mapping Facility created these linear vector files using handheld and backpack GPS units, aerial photographs, preexisting road files, historical documents, and satellite imagery. Features classified as roads represent paved or improved surfaces, and "fire roads" represent gated solid roadways used for fire and law enforcement access. An identical file can be found in the utc_project directory described below.	UTC ERMF	unknown	Yes

Table A1-1 (continued). GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
hobe_aquifer.shp	*Principal Aquifers of the 48 Conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands*	Geology	This data set contains the shallowest principal aquifers of the conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands, portrayed as polygons. The data set was developed as part of the effort to produce the maps published at 1:2,500,000 in the printed series "Groundwater Atlas of the United States". This is a replacement for the July 1998 data set called Principal Aquifers of the 48 Conterminous United States. The original dataset was clipped to the county boundaries that contain HOBE.	USGS	1:2,500,000	Yes
ssurgo (directory)	*Soil Survey Geographic (SSURGO) database for Tallapoosa County, Alabama*	Soils	This dataset is a SSURGO digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The data is divided into spatial files in poly, line, and point formats and descriptive attribute files in text and database tabular formats.	U.S. Department of Agriculture, Natural Resources Conservation Service	1:12,000	Yes
ssurgo_nps (directory)	*National Park Service - Soil Survey Geographic (SSURGO) database for Horseshoe Bend National Military Park, Alabama*	Soils	This data set is a digital soil survey and generally is the most detailed lever of soil geographic data. Specifically, the data set is identical to the one listed above except that it has undergone some additional processing by NPS personnel such as clipping the set to the park extent and adding the musym names to the attribute table.	NPS - GRD - SIMP	1:24,000	Yes
SREL_Inv (directory)	*Herpetofaunal Species Locations*	Species	This directory contains the locations of herpetofauna found in Horseshoe Bend National Battlefield Park (HOBE) during a study performed by Tuberville, Willson, Dorcas, and Gibbons in conjunction with the Savannah River Ecology Laboratory (SREL) between May 2001 and October 2003. Please refer to: "Herpetofaunal Species Richness of Southeastern National Parks." Southeastern Naturalist 4.3 (2005): 537-569 for more detailed information about the study. The data is divided into one spatial file and one tabular file in order to provide all of the features found during the study as some of the sampling locations were not defined spatially.	SREL/SECN	1:24,000	Yes

Table A1-1 (continued). GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
alhuc12_draft.shp	*The 8, 10, and 12 hydrologic unit boundaries for Alabama*	Watershed	This dataset is a complete digital hydrologic unit boundary layer to the Sub-watershed (12-digit) 6th level for the State of Alabama. This data set consists of georeferenced digital data and associated attributes created in accordance with the "FGDC Proposal, Version 1.0 - Federal Standards For Delineation of Hydrologic Unit Boundaries 3/01/02" (http://www.ftw.nrcs.usda.gov/huc_data.html). Polygons are attributed with hydrologic unit codes for 4th level subbasins, 5th level watersheds, 6th level sub-watersheds, name, size, downstream hydrologic unit, type of watershed, non-contributing areas and flow modification. Arcs are attributed with the highest hydrologic unit code for each watershed, linesource and a metadata reference file. The home directory of this shapefile also contains huc 2,4,6,8, and 10 level data but the metadata pertains cheifly to the huc 12 layer.	Alabama Natural Resources Conservation Service State Office	1:24,000	Yes
wqgis (directory)	*Horseshoe Bend National Military Park-Small-Scale Base GIS Data*	WQ GIS	The data are comprised of small-scale base GIS data layers, including roads, hydrography, political boundaries, trails and other layers as available and appropriate, compiled for the purpose of displaying the locations of point-based hydrologic features (water quality monitoring stations, stream gages, industrial discharges, drinking intakes, and water impoundments) proximate to national park units. The data are intended to be used as a set to ensure spatial alignment. The accompanying Microsoft Excel file,sources.xls, lists the data sources for each data layer.	NPS - WRD	varies: 1:100,000 or larger	Yes
drg_nad83 (directory)	*Digital Raster Graphics (DRGs)*	DRGs	This directory contains non-collared digital raster graphics (DRGs), which are scanned images of U.S. Geological Survey (USGS) topographic maps that cover the extent of HOBE in .tif format. The images inside the map neatline are georeferenced to the surface of the Earth. The directory also contains a mosaic that joins all of the quads that contain or immediately surround the park.	USGS?	1:24,000?	No

Table A1-1 (continued). GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
hobe_forest_cover.img	*Forest Cover Types*	Land Cover	This data set portrays general forest cover types for the United States. Data were derived from Advanced Very High Resolution Radiometer (AVHRR) composite images recorded during the 1991 growing season, with the exception of Puerto Rico, for which Landsat Thematic Mapper (TM) data were used. A total of 25 classes of forest cover types were interpreted from the AVHRR and TM imagery, aided by field observations and refined with ancillary data from digital elevation models. The original dataset has been clipped to an unknown extent that covers HOBE and the surrounding areas by an unknown source.	USDA Forest Service/USGS	1:7,500,000	Yes
hobe_2004_partial (directory)	*2004 IKONOS Imagery*	Images	This base directory contains a jpeg overview image and the po_228818_0000000 directory that contains the main 2004 IKONOS imagery files. The po_228818_0000000 directory contains 2004 IKONOS imagery in GeoTIFF format that covers a portion (eastern half approximately) of HOBE. The imagery is projected in both UTM 16N, WGS 84 (original projection) and NAD 83 (nad_83 folder). The directory contains the standard four bands as well as a false color (comp_fc) and natural color (comp_nc) composite. Please refer to the individual metadata files for specific process information.	GeoEye	1 meter	Yes - text file only
LT_2006	*2006 Landsat Imagery*	Images	This directory contains 2006 Landsat 5 Thematic Mapper Imagery in GeoTIFF format that covers the extent of HOBE. Specifically, the directory contains the seven multispectral bands and three composites that were made by SECN personnel (please see COMP_PROC_STEP for composite details). There is a somewhat limited text metadata file as well as a technical specification sheet that states all of the background imaging data and processes.	USGS	30 meter	Yes - text file only
hobe_landsat.img	*WEBMAP.LANDSAT_L277 (Landsat Orthoimagery Mosaic)*	Images	The Landsat Mosaic orthoimagery database contains Landsat Thematic Mapper imagery for the conterminous United States. The more than 700 Landsat scenes have been resampled to a 1-arc-second (approximately 30-meter) sample interval in a geographic coordinate system using the North American Horizontal Datum of 1983. The original image was clipped to include the area containing and surrounding the park area.	USGS	30 meters	Yes

Table A1-1 (continued). GIS data used in development of Natural Resource Condition Assessment for Horseshoe Bend National Military Park, Alabama. For all data, the projection is UTM Zone 16N and the datum is NAD 83. [Res.=resolution]

File_name	Layer_name	Category	Description	Source	Scale/Res	Metadata
hobe_92nlcd.img	*Alabama Land Cover Dataset*	Images	The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The original image was clipped to include the area containing and surrounding the park.	USGS	30 meters	Yes
hobe_01_nlcd.img	*National Land Cover Database Zone 58 Land Cover Layer*	Images	This dataset (NLCD 2001) is an update of the 1992 NLCD described above. The extent covers the extent of HOBE and the surrounding areas.	USGS	30 meter	Yes
utc_project (directory)	*University of Tennessee at Chattanooga Environmental Research and Mapping Facility (UTC ERMF) HOBE Project Files*	Park Data	This directory contains a number of files that were produced as a part of a park inventory and mapping project conducted by the University of Tennessee at Chattanooga Environmental Research and Mapping Facility (UTC ERMF) at the request of the NPS. The files are found in both decimal degrees and UTM and include boundaries, streams, roads, trails, utilities, infrastructure points, fire management areas and a natural color IKONOS image among others. The directory seems to contain some useful base data and it appears to be well documented.	UTC ERMF	Varies	Yes

Table A1-2. Data used in the Natural Resource Condition Assessment for HOBE.

Data Layer_name	Source Agency	Year	Notes
Current NPS Admininistrative Boundary for Horseshoe Bend National Military Park	NPS		Vector polygon shapefile representing the NPS administrative boundary for HOBE. This boundary was originally part of a larger NPS regional dataset and is intended for use at the regional level. This boundary is also found in the state_regional_gis directory and it may need to be updated as the NPS national administrative boundary dataset is updated.
1990 County and Equivalent Area	U.S. Census Bureau	1990	This dataset contains 1990 County and Equivalent Areas by State equivalent code (FIPS) located in the state of Alabama.
Cities of the United States	National Atlas of the United States	revised from Dec. 2003 (2010)	This map layer includes cities in the United States, Puerto Rico and the U.S. Virgin Islands. These cities were collected from the 1970 National Atlas of the United States. Where applicable, U.S. Census Bureau codes for named populated places were associated with each name to allow additional information to be attached. The Geographic Names Information System (GNIS) was also used as a source for additional information. This is a revised version of the December 2003 map layer. The original dataset was clipped to the county boundaries that contain HOBE.
Urban Areas of the United States	USGS	revised from 1998 (2010)	This data set includes a selection of urban areas in the United States derived from the urban areas layer of the Digital Chart of the World (DCW). This is a revised version of the 1998 data set. The original dataset was clipped to the county boundaries that contain HOBE.
7.5 Minute Digital Elevation Model	USGS		Digital Elevation Model (DEM) is the terminology adopted by the USGS todescribe terrain elevation data sets in a digital raster form. The7.5-minute DEM (30- by 30-m data spacing, cast on a Universal Transverse Mercator (UTM) projection) provides coverage in 7.5- by 7.5-minute blocks. The directory also contains a park mosaic.
National Elevation Dataset (DEM)	USGS		The U.S. Geological Survey has developed a National Elevation Dataset (NED). The NED is a seamless mosaic of best-available elevation data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. NED has been clipped to HOBE surrounding extent.
Large-scale Digital Line Graph (DLG)	USGS		Vector polyline shapefiles representing hydrographic DLGs in 7.5 minute blocks for the extent of HOBE. There is also a shapefile that has all of the individual quads merged together in order to form a continuous hydro coverage of the park.
Streams and Waterbodies of the United States	USGS		This dataset portrays the polygon water features of the United States, Puerto Rico and the U.S. Virgin Islands. The file was produced by joining the individual State hydrography layers from the 1:2,000,000-scale Digital Line Graph (DLG) data produced by the USGS. This data set was formerly distributed as Hydrography Features of the United States. This is a revised version of the November 1999 data set. The original dataset was clipped to the county boundaries that contain HOBE.
Streams and Waterbodies of the United States	USGS		This dataset portrays the line water features of the United States, Puerto Rico and the U.S. Virgin Islands. The file was produced by joining the individual State hydrography layers from the 1:2,000,000-scale Digital Line Graph (DLG) data produced by the USGS. This data set was formerly distributed as Hydrography Features of the United States. This is a revised version of the November 1999 data set. The original dataset was clipped to the county boundaries that contain HOBE.

Table A1-2 (continued). Data used in the Natural Resource Condition Assessment for HOBE.

Data Layer_name	Source Agency	Year	Notes
Realtime USGS Streamflow Stations	USGS		This dataset portrays the approximately 5,000 of the 6,900 U.S. Geological Survey sampling stations that are equipped with telemetry to transmit data on streamflow, temperature, and other parameters back to a data base for real-time viewing via the World Wide Web. A map of the realtime stations is produced every day. The original dataset was clipped to the county boundaries that contain HOBE.
Tallapoosa River	UTC ERMF	fall 2003 - summer 2004	This vector polygon depicts the Tallapoosa river in Horseshoe Bend National Millitary Park (HOBE). The file was created as part of an University of Tennessee at Chattnooga Environmental Research and Mapping Facility (UTC ERMF) park inventory and mapping project, started in the fall of 2003 and ending in the summer of 2004. An identical file can be found in the utc_project directory described below.
Large-scale Digital Line Graph (DLG)	USGS		Vector polyline shapefiles representing hypsographic DLGs in 7.5 minute blocks for the extent of HOBE.
National Wetlands Inventory	USFWS		NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. These data are individual NWI quads in polygon and polyline shapefile format that cover the extent of HOBE.
Public Land Survey System of the United States	USGS	revised from May 2002 (2014)	This data set portrays the Public Land Surveys of the United States, including areas of private survey, Donation Land Claims, and Land Grants and Civil Colonies. This is a revised version of the May, 2002 data set. The national dataset has been clipped to the state of Alabama.
Large-scale Digital Line Graph - Pipelines	USGS		Vector polyline shapefiles representing pipeline DLGs in 7.5 minute blocks for the extent of HOBE.
Railroads of the United States	National Atlas of the United States	replacement for Dec. 1998 map layer (2010)	This map layer includes railroads in the conterminous United States and Alaska. This is a replacement for the December 1998 map layer. The original dataset was clipped to the county boundaries that contain HOBE.
Large-scale Digital Line Graph - Railroads	USGS		Vector polyline shapefiles representing railroad DLGs in 7.5 minute blocks for the extent of HOBE.
Bureau of Transportation Statistics U.S. Road Networks	BTS		This data set portrays a Bureau of Transportation Statistics overview of the road networks for all fifty States, the District of Columbia, and Puerto Rico. An extent containing HOBE was extracted from the original dataset.
Large-scale Digital Line Graph - Roads	USGS		Vector polyline shapefiles representing road DLGs in 7.5 minute blocks for the extent of HOBE
HOBE Roads	UTC ERMF		The following file represents roads and fire roads located in the Horseshoe Bend National Military Park (HOBE). The University of Tennessee at Chattanooga Environmental Research and Mapping Facility created these linear vector files using handheld and backpack GPS units, aerial photographs, preexisting road files, historical documents, and satellite imagery. Features classified as roads represent paved or improved surfaces, and "fire roads" represent gated soild roadways used for fire and law enforcement access. An identical file can be found in the utc_project directory described below.

Table A1-2 (continued). Data used in the Natural Resource Condition Assessment for HOBE.

Data Layer_name	Source Agency	Year	Notes
Principal Aquifers of the 48 Conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands	USGS	replacement for July 1998 map layer (2010)	This data set contains the shallowest principal aquifers of the conterminous United States, Hawaii, Puerto Rico, and the U.S. Virgin Islands, portrayed as polygons. The data set was developed as part of the effort to produce the maps published at 1:2,500,000 in the printed series "Ground Water Atlas of the United States". This is a replacement for the July 1998 data set called Principal Aquifers of the 48 Conterminous United States. The original dataset was clipped to the county boundaries that contain HOBE.
Soil Survey Geographic (SSURGO) database for Tallapoosa County, Alabama	U.S. Department of Agriculture, Natural Resources Conservation Service		This dataset is a SSURGO digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The data is divided into spatial files in poly, line, and point formats and descriptive attribute files in text and database tabular formats.
National Park Service - Soil Survey Geographic (SSURGO) database for Horseshoe Bend National Military Park, Alabama	NPS - GRD -SIMP		This data set is a digital soil survey and generally is the most detailed lever of soil geographic data. Specifically, the data set is identical to the one listed above except that it has undergone some additional processing by NPS personnel such as clipping the set to the park extent and adding the musym names to the attribute table.
Herpetofaunal Species Locations	SREL/SECN	May 2001 - October 2003	This directory contains the locations of herpetofauna found in Horseshoe Bend National Battlefield Park (HOBE) during a study performed by Tuberville, Willson, Dorcas, and Gibbons in conjunction with the Savannah River Ecology Laboratory (SREL) between May 2001 and October 2003. Please refer to: "Herpetofaunal Species Richness of Southeastern National Parks." Southeastern Naturalist 4.3 (2005): 537-569 for more detailed information about the study. The data is divided into one spatial file and one tabular file in order to provide all of the features found during the study as some of the sampling locations were not defined spatially.
The 8, 10, and 12 hydrologic unit boundaries for Alabama	Alabama Natural Resources Conservation Service State Office	Mar-02	This dataset is a complete digital hydrologic unit boundary layer to the Subwatershed (12-digit) 6th level for the State of Alabama. This data set consists of geo-referenced digital data and associated attributes created in accordance with the "FGDC Proposal, Version 1.0 - Federal Standards For Delineation of Hydrologic Unit Boundaries 3/01/02" Polygons are attributed with hydrologic unit codes for 4th level sub-basins, 5th level watersheds, 6th level subwatersheds, name, size, downstream hydrologic unit, type of watershed, non-contributing areas and flow modification. Arcs are attributed with the highest hydrologic unit code for each watershed, linesource and a metadata reference file. The home directory of this shapefile also contains huc 2,4,6,8, and 10 level data but the metadata pertains cheifly to the huc 12 layer.
Horseshoe Bend National Military Park-Small Scale Base GIS Data	NPS - WRD		The data are comprised of small-scale base GIS data layers, including roads, hydrography, political boundaries,trails and other layers as available and appropriate, compiled for the purpose of displaying the locations of point-based hydrologic features (water quality monitoring stations, stream gages, industrial discharges, drinking intakes, and water impoundments) proximate to national park units. The data are intended to be used as a set to ensure spatial alignment. The accompanying Microsoft Excel file,sources.xls, lists the data sources for each data layer.
Digital Raster Graphics (DRGs)	USGS?		This directoy contains non-collared digital raster graphics (DRGs), which are scanned images of U.S. Geological Survey (USGS) topographic maps, that cover the extent of HOBE in .tif format. The images inside the map neatline are georeferenced to the surface of the Earth. The directory also contains a mosaic that joins all of the quads that contain or immediately surround the park.

Table A1-2 (continued). Data used in the Natural Resource Condition Assessment for HOBE.

Data Layer_name	Source Agency	Year	Notes
Forest Cover Types	USDA Forest Service/ USGS		This data set portrays general forest cover types for the United States. Data were derived from Advanced Very High Resolution Radiometer (AVHRR) composite images recorded during the 1991 growing season, with the exception of Puerto Rico, for which Landsat Thematic Mapper (TM) data were used. A total of 25 classes of forest cover types were interpreted from the AVHRR and TM imagery, aided by field observations and refined with ancillary data from digital elevation models. The original dataset has been clipped to an unknown extent that covers HOBE and the surrounding areas by an unknown source.
2004 IKONOS Imagery	GeoEye	2004	This base directory contains a jpeg overview image and the po_228818_0000000 directory that contains the main 2004 IKONOS imagery files. The po_228818_0000000 directory contains 2004 IKONOS imagery in GeoTIFF format that covers a portion (eastern half approximately) of HOBE. The imagery is projected in both UTM 16N, WGS 84 (original projection) and NAD 83 (nad_83 folder). The directory contains the standard 4 bands as well as a false color (comp_fc) and natural color (comp_nc) composite. Please refer to the individual metadata files for specific process information.
2006 Landsat Imagery	USGS	2006, 2011	This directory contains 2006 and 2011 Landsat 5 Thematic Mapper Imagery in GeoTIFF format that covers the extent of HOBE. Specifically, the directory contains the 7 multispectral bands and three composites that were made by SECN personnel (please see COMP_PROC_STEP for composite details). There is a somewhat limited text metadata file as well as a technical specification sheet that states all of the background imaging data and processes.
WEBMAP.LANDSAT_L277 (Landsat Orthoimagery Mosaic)	USGS		The Landsat Mosaic orthoimagery database contains Landsat Thematic Mapper imagery for the conterminous United States. The more than 700 Landsat scenes have been resampled to a 1-arc-second (approximately 30-meter) sample interval in a geographic coordinate system using the North American Horizontal Datum of 1983. The orignal image was clipped to include the area containing and surrounding the park area.
Alabama Land Cover Dataset	USGS	~1992	The National Land Cover Dataset was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The orignal image was clipped to include the area containing and surrounding the park.
National Land Cover Database Zone 58 Land Cover Layer	USGS	2001	This dataset (NLCD 2001) is an update of the 1992 NLCD described above. The extent covers the extent of HOBE and the surrounding areas.
University of Tennessee at Chattanooga Environmental Research and Mapping Facility (UTC ERMF) HOBE Project Files	UTC ERMF		This directory contains a number of files that were produced as a part of a park inventory and mapping project conducted by the University of Tennessee at Chattanooga Environmental Research and Mapping Facility (UTC ERMF) at the request of the NPS. The files are found in both decimal degrees and UTM and include boundaries, streams, roads, trails, utilities, infrastructure points, fire management areas and a natural color IKONOS image among others. The directory seems to contain some useful base data and it appears to be well documented.

Appendix 2. Lists of the Biota Reported from Horseshoe Bend

Table A2-1 The 228 terrestrial vascular plant taxa (227 species + 1 variety) reported to occur in HOBE. Note that exotic/invasive taxa are indicated in bold[1]. This list is modified from the NPS Certified Species List (2013a) using taxonomic information from the USDA Plants Database Database (http://plants.usda.gov/java/). Exotic/invasive taxa are from information for Tallapoosa County at http://www.eddmaps.org/tools/countyplants.cfm?id=us_al_01123, and from EDDMapS (2013) at http://www.eddmaps.org/. All of these websites were last accessed in May 2015. SoCs are indicated in blue*.

Scientific Name	Common Name(s)
Acer barbatum [a]	Southern sugar maple
Achillea millefolium	Bloodwort, carpenter's weed, common yarrow
Aesculus pavia	Red buckeye
Agrimonia pubescens	Groovebur, roadside agrimony, soft agrimony
Albizia julibrissin[1]	**Mimosa, mimosa tree, powderpuff tree**[1]
Allium canadense	Canada garlic, meadow garlic, meadow onion
Ambrosia artemisiifolia	Annual ragweed, common ragweed, low ragweed
Amphicarpaea bracteata	American hogpeanut, hogpeanut
Antennaria plantaginifolia	Plantainleaf pussytoes, woman's tobacco
Apocynum cannabinum [b]	Indianhemp
Aristolochia serpentaria [b]	Virginia snakeroot
Asclepias quadrifolia	Fourleaf milkweed
Asclepias tuberosa	Butterfly milkweed, butterflyweed
Asimina parviflora	Smallflower pawpaw
Asplenium platyneuron	Ebony spleenwort
Aster pilosus	White heath aster, white oldfield aster
Aureolaria flava	Smooth yellow false foxglove
Aureolaria virginica	Downy yellow false foxglove
Botrychium biternatum	Sparselobe grapefern
Botrychium virginianum	Rattlesnake fern
Callicarpa americana	American beautyberry
Carya alba	Mockernut hickory
Carya carolinae-septentrionalis	Southern shagbark hickory
Cassia fasciculata	Partridge pea, showy partridgepea, sleepingplant
*Castanea pumila**	Allegeny chinkapin, allegheny chinkapin, chinkapin*
Catalpa speciosa	Northern catalpa
Ceanothus americanus	Jersey tea, jerseytea, new jersey tea
Celtis occidentalis	Common hackberry, hackberry, western hackberry
Centrosema virginianum	Butterflypea, spurred butterfly pea
Cerastium glomeratum[1]	**Sticky chickweed**[1]
Cercis canadensis	Eastern redbud, Redbud
Chamaecrista nictitans ssp. *nictitans* var. *nictitans* [c]	Sensitive partridge pea

Scientific Name	Common Name(s)
Cheilanthes lanosa	Hairy lipfern
Chimaphila maculata	Striped prince's pine, striped prince's-pine
Cimicifuga racemosa	Black bugbane
Cirsium discolor	Field thistle
Clitoria mariana [b]	Atlantic pigeonwings
Cnidoscolus stimulosus	Finger rot
Collinsonia serotina	Blue Ridge horsebalm
Commelina erecta	Erect dayflower, whitemouth dayflower
Conyza canadensis var. *canadensis* [d]	Canadian horseweed
Coreopsis auriculata	Lobed tickseed
Coreopsis major	Greater tickseed
Cornus florida	Flowering dogwood
Coronilla varia	Crownvetch, purple crownvetch, purple crownvetch
Crataegus uniflora	Dwarf hawthorn, oneflower hawthorn
Cynodon dactylon[1]	**Bermudagrass, chiendent pied-de-poule, common bermudagrass**[1]
Daucus carota[1]	**Bird's nest, Queen Anne's lace, wild carrot**[1]
Daucus pusillus	American wild carrot, rattlesnake carrot, rattlesnake weed
Desmodium lineatum	Sand ticktrefoil
Desmodium nudiflorum	Barestem tickclover, bare-stemmed tick-treefoil, nakedflower ticktrefoil
Desmodium tenuifolium	Slimleaf ticktrefoil
Dichanthelium boscii	Bosc's panicgrass
Dichanthelium commutatum	Variable panicgrass
Dioscorea oppositifolia[1]	**Chinese yam**[1]
Duchesnea indica[1]	**India mockstrawberry, Indian strawberry**[1]
Elephantopus tomentosus	Devil's grandmother, hairy elephantfoot
Eleusine indica[1]	**Goosegrass, crowsfoot grass, goose grass**[1]
Epifagus virginiana	Beechdrops
Eragrostis capillaris	Lace grass, lacegrass
Erigeron annuus	Annual fleabane, eastern daisy fleabane
Erigeron strigosus	Daisy fleabane, prairie fleabane, rough fleabane
Euonymus americana	Strawberry bush, strawberrybush
Eupatorium glaucescens	Waxy thoroughwort
Eupatorium rugosum	Richweed, snakeroot, white snakeroot
Euphorbia corollata	Flowering spurge, floweringspurge euphorbia
Fagus grandifolia	American beech
Fragaria virginiana	Virginia strawberry, thickleaved wild strawberry, wild strawberry
Galax urceolata	Beetleweed
Gamochaeta purpurea	Spoonleaf purple everlasting, spoon-leaf purple everlasting
Geranium maculatum	Spotted crane's-bill, spotted geranium, wild crane's-bill
Glechoma hederacea [e1]	**Ground ivy**[1]
Gnaphalium obtusifolium	Rabbit-tobacco

Scientific Name	Common Name(s)
Goodyera pubescens	Downy rattlesnake plantain, downy rattlesnake plantain
Halesia carolina	Carolina silverbell, silverbell
Helianthus tuberosus	Jerusalem artichoke, girasole, Jerusalem sunflower
Helenium amarum[1]	**Sneezeweed, bitter sneezeweed, yellowdicks**[1]
Hepatica nobilis var. *acuta* [f]	Sharplobe hepatica
Hepatica nobilis var. *obtusa* [g]	Roundloabe hepatica
Hexastylis arifolia	Littlebrownjug
Hieracium gronovii	Gronovis hawkweed, queendevil
Hieracium venosum	Rattlesnakeweed
Houstonia longifolia	Longleaf bluet, longleaf summer bluet, longleaf summer bluet
Houstonia purpurea	Purple bluets, Venus' pride
Hydrangea arborescens	Smooth hydrangea, wild hydrangea
Hydrangea quercifolia	Oakleaf hydrangea
Hypericum frondosum	Cedarglade St. Johnswort
Hypericum gentianoides	Orangegrass, pinweed st. johnswort
Impatiens capensis	Jewelweed, spotted touch-me-not
Iris cristata	Crested iris, dwarf crested iris
Iris verna	Dwarf violet iris
Juglans cinerea	Butternut
Juglans nigra	Black walnut
Juniperus virginiana	Eastern redcedar, eastern red cedar, red cedar juniper
Kalmia latifolia	Mountain laurel
Lamium amplexicaule[1]	**Henbit, common henbit, giraffehead**[1]
Lechea racemulosa	Illinois pinweed
Lepidium virginicum	Peppergrass, poorman pepperweed, poorman's pepper
Lespedeza cuneata[1]	**Chinese lespedeza, sericea lespedeza**[1]
Lespedeza procumbens	Trailing lespedeza
Lespedeza repens	Creeping lespedeza
Liatris squarrosa	Scaly blazing star, scaly gayfeather
Luzula multiflora	Common woodrush, common woodrush
Lycopodium digitatum	Fan clubmoss
Lysimachia quadrifolia [b]	Whorled yellow loosestrife
Magnolia acuminata	Cucumbertree, cucumbertree
Maianthemum racemosum ssp. *racemosum* [h]	Feathery false lily of the valley
Malus angustifolia	Southern crabapple
Manfreda virginica	False aloe
Matelea carolinensis [b]	Carolina milkvine
Melia azedarach[1]	**Chinaberry, Chinaberry tree, Chinaberrytree**[1]
Melica mutica	Oniongrass, twoflower melic, twoflower melicgrass
Menispermum canadense [b]	Common moonseed
Mimosa microphylla	Littleleaf sensitive-briar, sensitive brier

Scientific Name	Common Name(s)
Monarda bradburiana	Eastern beebalm, wildbergamot beebalm
Monarda punctata	Spotted beebalm
Monotropa hypopithys [b,i]	Pinesap
Morella cerifera	Wax myrtle, waxmyrtle
Nothoscordum bivalve	Crowpoison
Nuttallanthus canadensis	Canada toadflax, oldfield toadflax, oldfield toadflax
Oenothera biennis	Common evening primrose, common eveningprimrose, common evening primrose
Oenothera speciosa	Pinkladies, Showy evening primrose, showy eveningprimrose
***Opuntia ficus-indica*[1]**	**Indian fig, Indian fig, tuna cactus[1]**
Orbexilum pedunculatum var. *psoralioides* [j]	Sampson's snakeroot
Ostrya virginiana	Eastern hophornbeam, hophornbeam
*Oxalis grandis**	Great yellow woodsorrel*
Oxalis stricta	Common yellow oxalis, erect woodsorrel, sheep sorrel
Oxalis violacea	Purple woodsorrel, violet woodsorrel, violet woodsorrel
Packera anonyma	Small's ragwort
Parthenocissus quinquefolia	American ivy, fiveleaved ivy, Virginia creeper
***Paspalum notatum* var. *saurae*[1]**	**Bahiagrass[1]**
Passiflora incarnata	Purple passionflower
Passiflora lutea [b]	Yellow passionflower
Penstemon canescens	Eastern gray beardtongue
Phegopteris hexagonoptera	Broad beech fern, broad beechfern
Philadelphus inodorus	Scentless mock orange
Phlox amoena	Hairy phlox
Phlox divaricata	Wild blue phlox
Phoradendron leucarpum	Oak mistletoe
Physalis pubescens [b]	Husk tomato
Piptochaetium avenaceum	Blackseed needlegrass, blackseed speargrass
Pityopsis graminifolia [b]	Narrowleaf silkgrass
Pityopsis graminifolia var. *graminifolia* [k]	Narrowleaf silkgrass
***Plantago aristata*[1]**	**Bottlebrush Indianwheat, largebracted plantain[1]**
***Plantago lanceolata*[1]**	**Narrowleaf plantain, buckhorn (English) plantain, lanceleaf Indianwheat[1]**
Plantago virginica	Paleseed Indianwheat, Virginia plantain
Pleopeltis polypodioides ssp. *polypodioides* [l]	Resurrection fern
Podophyllum peltatum	May apple, mayapple
Polygala curtissii	Curtiss' milkwort
Polygala grandiflora	Showy milkwort
Polygonatum biflorum	Smooth Solomon's seal, King Solomon's seal, Solomon's seal
Polystichum acrostichoides	Christmas fern
Porteranthus	Indian physic

Scientific Name	Common Name(s)
Potentilla canadensis	Dwarf cinquefoil
Potentilla simplex	Common cinquefoil, oldfield cinquefoil, oldfield fivefingers
Prunus americana	American plum
Prunus angustifolia	Chickasaw plum
Prunus mexicana[1]	**Mexican plum**[1]
Prunus serotina	Black cherry, black chokecherry
Prunus umbellata	Flatwood plum, hog plum
Pteridium aquilinum	Bracken, bracken fern, brackenfern
Pueraria montana* var. *lobata[1]	**Kudzu, kudzu vine**[1]
Pycnanthemum incanum	Hoary mountainmint
Pyrrhopappus carolinianus	Carolina desert chicory, Carolina desert chicory, Carolina false dandelion
Quercus alba	White oak
Quercus austrina	Bastard white oak
Quercus falcata	Southern red oak
Quercus marilandica	Blackjack oak
Quercus rubra	Northern red oak
Quercus stellata	Post oak
Quercus velutina	Black oak
Rhus copallina	Dwarf sumac, shining sumac
Rhus glabra	Smooth sumac
Rhus hirta	Staghorn sumac
Rubus cuneifolius [b]	Sand blackberry
Rubus trivialis [b]	Southern dewberry
Rudbeckia hirta	Blackeyed Susan
Ruellia caroliniensis	Carolina wild petunia
Amelanchier arborea [b]	Common serviceberry
Salvia lyrata	Lyreleaf sage
Salvia urticifolia	Nettleleaf sage
Sanguinaria canadensis	Bloodroot
Sanicula canadensis	Canada sanicle, Canadian blacksnakeroot
Sanicula smallii	Small's blacksnakeroot
Sassafras albidum	Sassafras
Scrophularia marilandica	Carpenter's square, maryland figwort
Selaginella apoda	Meadow spike-moss, meadow spike-moss
Silene stellata	Whorled catchfly, widowsfrill
Silene virginica	Fire pink, firepink
Silphium asteriscus	Starry rosinweed
Silphium asteriscus var. *laevicaule* [m]	Starry rosinweed
Silphium compositum	Kidneyleaf rosinweed
Sisyrinchium fuscatum	Coastalplain blue-eyed grass
Smallanthus uvedalius	Hairy leafcup

Scientific Name	Common Name(s)
Solanum carolinense	Apple of Sodom, bull nettle, Carolina horsenettle
Solidago caesia	Wreath goldenrod
Solidago nemoralis	Dyersweed goldenrod, gray goldenrod
Specularia perfoliata	Clasping Venus' looking-glass
Spigelia marilandica	Indianpink, woodland pinkroot
Spiranthes cernua	Nodding ladiestresses, nodding ladies'-tresses, white nodding ladies'-tresses
Sporobolus indicus* var. *indicus [n1]	**Smut grass**[1]
Stylosanthes biflora	Endbeak pencilflower, sidebeak pencilflower
Symphyotrichum divaricatum	Southern annual saltmarsh aster
Taraxacum officinale[1]	**Blowball, common dandelion, dandelion**[1]
Tephrosia virginiana	Virginia tephrosia
Thalictrum thalictroides [o]	Rue anemone
Thelypteris noveboracensis	New York fern
Tilia americana var. *heterophylla* [p]	American basswood
Tillandsia usneoides	Spanish moss
Tipularia discolor	Crippled cranefly
Toxicodendron pubescens	Atlantic poison oak, poison oak
Tradescantia radicans	Poison ivy
Tradescantia virginiana	Virginia spiderwort
Tridens flavus	Purpletop, purpletop tridens
Trifolium campestre[1]	**Field (Big-hop) clover, field clover, large hop clover**[1]
Trifolium repens[1]	**Dutch clover, ladino clover, white clover**[1]
Trillium catesbaei	Bashful wakerobin
Trillium cuneatum	Little sweet Betsy
Trillium underwoodii	Longbract wakerobin
Uvularia perfoliata	Perfoliate bellwort
Vaccinium arboreum	Farkleberry, tree sparkleberry, tree-huckelberry
Vaccinium pallidum	Blue Ridge blueberry, Blueridge blueberry
Vaccinium stamineum	Deerberry
Verbascum Thapsus[1]	**Common mullein, big taper, flannel mullein**[1]
Viburnum rufidulum [b]	Rusty blackhaw
Viola pedata	Birdfoot violet
Viola tripartita[q]	Threepart violet
Yucca filamentosa	Adam’s needle

[a] *Acer barbatum* is given as *Acer saccharinum* var. *floridanum* (synonym) in the NPS Certified Species List.

[b] Newly reported for Horseshoe Bend by Heath et al. (2014a,b).[c] *Chamaecrista nictitans* ssp. *nictitans* var. *nictitans* is given as *Cassia nictitans* (synonym) in the NPS Certified Species List.

[d] *Conyza canadensis* var. *canadensis* is given as *Erigeron canadensis* (synonym) in the NPS Certified Species List.

[e] *Glechoma hederacea* is misspelled as *Glecoma hederacea* in the NPS Certified Species List.

[f] *Hepatica nobilis* var*. acuta* is given as *Hepatica acutiloba* (synonym) in the NPS Certified Species List.

[g] *Hepatica nobilis* var. obtusa is given as *Hepatica americana* (synonym) in the NPS Certified Species List.

[h] *Maianthemum racemosum* ssp. racemosum is given as *Smilacina racemosa* (synonym) in the NPS Certified Species List.

[I] *Monotropa hypopithys* is given as *Hypopitys monotropa* (synonym) in Heath et al. (2014b).[j] *Orbexilum pedunculatum* var. psoralioides is given as *Psoralea psoralioides* (synonym) in the NPS Certified Species List.

[k] *Pityopsis graminifolia* var*. graminifolia* is given as *Heterotheca graminifolia* (synonym) in the NPS Certified Species List.

[l] *Pleopeltis polypodioides* ssp. *polypodioides* is given as *Polypodium polypodioides* (synonym) in the NPS Certified Species List.

[m] *Silphium asteriscus* var. *laevicaule* is given as *Silphium dentatum* (synonym) in the NPS Certified Species List.

[n] *Sporobolus indicus* var. *indicus* is given as *Sporobolus poiretii* (synonym) in the NPS Certified Species List.

[o] Described by Heath et al. (2014b) as newly reported for Horseshoe Bend; was included in the NPS Certified Species List as of (NPS 2013a).[p] *Tilia americana* var. *heterophylla* is given as *Tilia heterophylla* (synonym) in the NPS Certified Species List.

[q] *Viola tripartita* is given as *Viola tripartita* var. *glaberrima* (synonym) in the NPS Certified Species List.

[j] *Pleopeltis polypodioides* ssp. *polypodioides* is given as *Polypodium polypodioides* (synonym) in the NPS Certified Species List.

[k] *Silphium asteriscus* var. *laevicaule* is given as *Silphium dentatum* (synonym) in the NPS Certified Species List.

[l] *Sporobolus indicus* var. *indicus* is given as *Sporobolus poiretii* (synonym) in the NPS Certified Species List.

[m] *Tilia americana* var. *heterophylla* is given as *Tilia heterophylla* (synonym) in the NPS Certified Species List.

[n] *Viola tripartita* is given as *Viola tripartita* var. glaberrima (synonym) in the NPS Certified Species List.

Table A2-2. Wetland vascular plant taxa in HOBE, modified from the NPS Certified Species List (2013a) with some taxonomic changes according to the USDA Plants Database (http://plants.usda.gov/java/, last accessed in September 2013). Exotic/invasive species (in bold)[1] are taken from the same information used to compile exotic/invasive taxa in Table A2-1.

Scientific Name	Common Name(s)
Acalypha gracilens[a]	Slender threeseed mercury
Acer negundo	Ashleaf maple, box elder, boxelder
Acer rubrum	Red maple
Acer saccharinum[b]	Silver maple
Agalinis fasciculata	Beach false foxglove
Agrimonia parviflora	Harvestlice, manyflowered groovebur, southern agrimony, swamp agrimony
Alnus serrulata	Alder, brook-side alder, hazel alder
Amianthium muscitoxicum	Flypoison
Amorpha fruticosa	Desert false indigo, desert indigobush, dullleaf indigo
Andropogon virginicus	Broomsedge, broomsedge bluestem, yellow bluestem
Apios americana	Apios americana, groundnut, potatobean
Aralia spinosa	Angelicatree, devils walkingstick, devil's walkingstick
Arisaema dracontium	Green dragon, greendragon
Arisaema triphyllum	Indian jack in the pulpit, Jack in the pulpit, Jack in the pulpit
Aristolochia tomentosa	Common dutchmanspipe, woolly dutchman's pipe
Arundinaria gigantea	Giant cane
Aster lateriflorus	Calico aster
Athyrium filix-femina ssp. *asplenioides* [c]	Asplenium ladyfern
Betula nigra	River birch
Bignonia capreolata	Cross vine, crossvine
Boehmeria cylindrica	Smallspike false nettle, smallspike false nettle, smallspike falsenettle
Calycocarpum lyonii	Cupseed, sasparilla
Campsis radicans	Common trumpetcreeper, cow-itch, trumpet creeper
Carex festucacea	Fescue sedge
Carex granularis	Limestone meadow sedge, limestone meadow sedge
Carex intumescens	Greater bladder sedge
Carex leptalea	Bristlestalked sedge, bristly-stalk sedge, bristlystalked sedge
Carex lurida	Shallow sedge
Carex vulpinoidea	Common fox sedge, fox sedge
Carpinus caroliniana	American hornbeam, American hornbean
Carya cordiformis	Bitternut hickory
Carya glabra	Pignut hickory
Carya illinoinensis[1]	**Pecan**[1]
Catalpa bignonioides	Southern catalpa
Cephalanthus occidentalis	Buttonbush, common buttonbush
Chaerophyllum tainturieri	Chervil, hairyfruit chervil, hairyfruit chervil
Chasmanthium latifolium	Broadleaf uniola, Indian woodoats, Indian woodoats

Scientific Name	Common Name(s)
Chasmanthium sessiliflorum	Longleaf spikegrass, longleaf woodoats
Chionanthus virginicus	Fringetree, white fringetree
Cicuta maculata	Common water hemlock, poison parsnip, spotted cowbane
Cirsium horridulum var. *horridulum* [d]	Yellow thistle
Clematis glaucophylla	Whiteleaf leather flower
Clematis virginiana	Devil's darning needles, devil's-darning-needles, Virginia bower
Cocculus carolinus[1]	**Carolina coralbead, Carolina snailseed, redberry moonseed**[1]
Collinsonia canadensis	Richweed
Commelina virginica	Virginia dayflower
Conoclinium coelestinum	Blue mistflower
Cornus amomum	Silky dogwood
Cornus foemina	Stiff dogwood
Crataegus spathulata	Littlehip hawthorn
Cryptotaenia canadensis	Canadian honewort, honewort
Cuscuta compacta	Compact dodder
Cuscuta gronovii	Scaldweed
Cyclospermum leptophyllum	Marsh parsley
Cynanchum laeve	Climbing milkweed, honeyvine, honeyvine milkweed
Cyperus echinatus	Globe flatsedge+B101
Cyperus refractus	Reflexed flatsedge
Cyperus strigosus	Stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass
Decumaria barbara	Woodvamp
Dichondra carolinensis [a]	Carolina ponysfoot
Diodia teres	Poor Joe, poorjoe, rough buttonweed
Diodia virginiana	Virginia buttonweed
Dioscorea villosa	Wild yam
Diospyros virginiana	Common persimmon, eastern persimmon, Persimmon
Dulichium arundinaceum [a]	Three-way sedge
Eleocharis obtusa	Blunt spikerush, blunt spikesedge
Elephantopus carolinianus	Carolina elephantsfoot, leafy elephantfoot
Elymus virginicus	Virginia wild rye, Virginia wildrye
Erechtites hieraciifolia	American burnweed
Erigeron philadelphicus	Philadelphia daisy, Philadelphia fleabane
Eryngium prostratum	Creeping eryngo
Eryngium yuccifolium	Button eryngo, button snakeroot, Yuccaleaf eryngo
Eupatorium capillifolium	Dogfennel
Eupatorium serotinum	Late eupatorium, lateflowering thoroughwort
Eutrochium fistulosum[e]	Trumpetweed
Eutrochium purpureum[f]	Sweetscented joe pye weed
Fraxinus pennsylvanica	Green ash
Galium aparine	Stickywilly, bedstraw, catchweed bedstraw, cleavers

Scientific Name	Common Name(s)
Gaylussacia dumosa	Dwarf huckleberry
Gelsemium sempervirens	Carolina jessamine, evening trumpetflower
Geum canadense	White avens
Gleditsia triacanthos	Common honeylocust, Honey locust, honeylocust
Halesia diptera	Two-wing silverbell, two-wing silverbell
Hamamelis virginiana	American witchhazel, witchhazel, witchhazel
Helianthus angustifolius	Swamp sneezeweed, swamp sunflower
***Heliotropium indicum*[1]**	**India heliotrope, Indian heliotrope[1]**
Hibiscus moscheutos	Crimsoneyed rosemallow, swamp rosemallow
Houstonia caerulea	Azure bluet
Hydrocotyle verticillata	Whorled marsh pennywort, whorled marshpennywort, whorled pennyroyal
*Hymenocallis caroliniana**	Carolina spiderlily, shoals spiderlily*
Hypericum drummondii	Drummond St. Johnswort, nits and lice
Hypericum hypericoides	St. Andrews cross, St. Andrew's cross
Hypericum mutilum	Dwarf St. Johnswort
Hypericum punctatum	Spotted St. Johnswort
Hypoxis hirsuta	Common goldstar, eastern yellow star-grass
Ilex decidua	Possumhaw
Ilex opaca	American holly
Ilex vomitoria	Yaupon
***Ipomoea hederacea*[1]**	**Ivyleaf morningglory, entireleaf morningglory, ivyleaf morningglory[1]**
Ipomoea pandurata	Bigroot morningglory, bigroot morninglory, man of the earth
Itea virginica	Virginia sweetspire
Juncus coriaceus	Leathery rush
Juncus effusus	Common rush, lamp rush
Juncus validus	Roundhead rush
Justicia americana	American water-willow, common water-willow, spike justica
Krigia dandelion	Potato dwarfdandelion, tuber dandelion, tuber dwarfdandelion
Laportea canadensis	Canada lettuce, Canada woodnettle, Canadian woodnettle
***Ligustrum sinense*[1]**	**Chinese privet, common Chinese privet[1]**
Lilium michauxii	Carolina lily
Lindera benzoin [a]	Northern spicebush
Liquidambar styraciflua	Sweetgum
Liriodendron tulipifera	Tulip poplar, tuliptree, yellow poplar
Lobelia cardinalis	Cardinal flower, cardinalflower
Lobelia puberula	Downy lobelia
***Lonicera japonica*[1]**	**Japanese honeysuckle, Chinese honeysuckle[1]**
Lonicera sempervirens	Trumpet honeysuckle
Ludwigia palustris	Marsh primrose-willow, marsh seedbox
Lycopus virginicus	Virginia bugleweed, Virginia bugleweed, Virginia water horehound

Scientific Name	Common Name(s)
Lysimachia ciliata	Fringed loosestrife, fringed yellow-loosestrife
Magnolia grandiflora[1]	**Southern magnolia**[1]
Magnolia virginiana	Sweetbay
Malaxis unifolia	Green addersmouth orchid, green adder's-mouth orchid
Matelea gonocarpos	Angularfruit milkvine
Medeola virginiana	Indian cucumber
Melothria pendula	Drooping melonnette, Guadeloupe cucumber
Microstegium vimineum [a1]	**Japanese stiltgrass, Nepalese browntop**[1]
Mikania scandens	Climbing hempvine, climbing hempweed
Mimulus alatus	Sharpwing monkeyflower
Mimulus ringens	Allegheny monkeyflower, Allegheny monkeyflower, ringen monkeyflower
Mitchella repens	Partridgeberry
Morus rubra	Red mulberry
Nyssa sylvatica	Black gum, black tupelo, blackgum
Onoclea sensibilis	Sensitive fern
Ophioglossum petiolatum [a]	Longstem adderstongue
Osmunda cinnamomea	Cinnamon fern
Osmunda regalis	Royal fern
Oxydendrum arboreum	Sourwood
Packera glabella	Butterweed
Paspalum dilatatum[1]	**Dallas grass, dallis grass, dallisgrass**[1]
Pedicularis canadensis	Canadian lousewort, early lousewort+B41
Peltandra virginica	Green arrow arum, Virginia peltandra
Penstemon laevigatus	Eastern smooth beardtongue
Penthorum sedoides	Ditch stonecrop, ditc+B41h-stonecrop, Virginia penthorum
Physalis angulata	Cutleaf groundcherry, cutleaf groundcherry, lanceleaf groundcherry
Physostegia virginiana ssp. *virginiana* [g]	Obedient plant
Phytolacca americana	American pokeweed, common pokeweed, inkberry
Plantago rugelii	Blackseed plantain, blackseed plantain, Rugel's plantain
Platanthera clavellata	Green woodland orchid, small green wood orchid
Platanthera cristata	Crested yellow orchid
Platanthera flava var. *flava* [h]	Palegreen orchid
Platanus occidentalis	American sycamore, sycamore
Pluchea camphorata	Camphor pluchea, camphor weed
Poa sylvestris	Woodland bluegrass
Polygonum caespitosum* var. *longisetum[1]	**Oriental ladysthumb**[1]
Polygonum punctatum	Dotted smartweed
Polygonum virginianum	Jumpseed, Virginia smartweed
Polypremum procumbens	Juniper leaf
Pontederia cordata	Pickerelweed

Scientific Name	Common Name(s)
Populus deltoides	Common cottonwood, cottonwood, eastern cottonwood
Prunella vulgaris[1]	**Common selfheal, heal all, healall**[1]
Quercus laurifolia	Laurel oak
Quercus michauxii	Swamp chestnut oak
Quercus nigra	Water oak
Quercus phellos	Willow oak
Quercus prinus	Chestnut oak
Ranunculus hispidus	Bristly buttercup
Ranunculus recurvatus	Blisterwort, littleleaf buttercup
Rhexia mariana	Maryland meadowbeauty
Rhexia virginica	Common meadowbeauty, handsome Harry
Rhododendron canescens	Mountain azalea, Piedmont azalea
Rubus argutus [a]	Sawtooth blackberry
Rudbeckia fulgida	Orange coneflower
Rudbeckia laciniata	Cutleaf coneflower, green-head coneflower
Rumex acetosella[1]	**Red sorrel, sheep sorrel, common sheep sorrel, field sorrel**[1]
Rumex crispus[1]	**Curley dock, curly dock, narrowleaf dock**[1]
Sabatia angularis	Rosepink, squarestem rosegentian
Saccharum giganteum [a]	Sugarcane plumegrass
Sagittaria latifolia	Broadleaf arrowhead, common arrowhead, duck-potato
Salix nigra	Black willow
Sambucus canadensis	American elder
Saururus cernuus	Lizards tail, lizard's tail
Schoenoplectus purshianus	Weakstalk bulrush
Scirpus cyperinus	Bulrush, woolgrass
Scleria triglomerata [a]	Whip nutrush
Scutellaria integrifolia	Helmet flower
Scutellaria lateriflora	Blue skullcap, mad dog skullcap
Sicyos angulatus	Blue-eyedgrass, bur cucumber, burcucumber
Sisyrinchium mucronatum	Needletip blue-eyed grass, needletip blue-eyed-grass
Smilax bona-nox	Saw greenbrier
Smilax glauca	Cat greenbrier
Smilax rotundifolia	Bullbriar, common catbriar, common greenbrier
Smilax smallii	Lanceleaf greenbrier, small greenbrier
Solidago rugosa	Wrinkleleaf goldenrod
Sorghum halepense[1]	**Aleppo milletgrass, herbe de Cuba, Johnson grass**[1]
Sparganium americanum	American burreed, American burreed
Staphylea trifolia	American bladdernut, American bladdernut
Stenanthium gramineum	Eastern featherbells
Styrax americanus	American snowbell, snowbell
Symphyotrichum racemosum	Smooth white oldfield aster

Scientific Name	Common Name(s)
Symplocos tinctoria [a]	Common sweetleaf
Teucrium canadense	American germander, Canada germander, Candad germander
Thalictrum revolutum	Waxyleaf meadowrue, waxyleaf meadowrue
Tiarella cordifolia	Heartleaf foamflower
Toxicodendron radicans	Eastern poison ivy, poison ivy, poisonivy
Trachelospermum difforme [a,i]	Climbing dogbane
Tradescantia ohiensis	Bluejacket, Ohio spiderwort
Typha latifolia	Broadleaf cattail, cattail, common cattail
Ulmus alata	Winged elm
Ulmus americana	American elm
Ulmus rubra	Slippery elm
Uvularia sessilifolia	Sessileleaf bellwort, sessileleaf bellwort
Vaccinium elliottii	Elliott's blueberry
Valerianella radiata	Beaked cornsalad
***Verbena bonariensis*[1]**	**Tall vervain, pretty verbena, purpletop vervain[1]**
Verbesina alternifolia	Wingstem
Verbesina occidentalis	Yellow crownbeard
Verbesina virginica	Iceweed, Virginia crownbeard, white crownbeard
Vernonia gigantea ssp. *gigantea* [j]	Giant ironweed
Viburnum nudum [a]	Possumhaw
Vitis baileyana	Graybark grape
***Vitis rotundifolia*[1]**	**Muscadine, muscadine grape[1]**
Woodwardia areolata	Chainfern, netted chainfern
Xanthorhiza simplicissima	Yellowroot
Zephyranthes atamasca	Atamasco lily

[a] Newly reported for Horseshoe Bend by Heath et al. (2014).

[b] Described by Heath et al. (2014a) as newly reported for Horseshoe Bend; was included in the NPS Certified Species List as of NPS (2013a).

[c] *Athryium filix-femina* ssp. *asplenioides* is given as *Athyrium asplenioides* (synonym) in the NPS Certified Species List.

[d] *Cirsium horridulum* var. *horridulum* is given as *Carduus spinosissimus* (synonym) in the NPS Certified Species List.

[e] *Eutrochium fistulosum* is given as *Eupatorium fistulosum* (synonym) in the NPS Certified Species List.

[f] *Eutrochium purpureum* is given as *Eupatorium purpureum* (synonym) in the NPS Certified Species List.

[g] *Physostegia virginiana* ssp. *virginiana* is given as *Dracocephalum virginianum* (synonym) in the NPS Certified Species List.

[h] *Platanthera flava* var. *flava* is given as *Habenaria flava* (synonym) in the NPS Certified Species List.

[i] *Trachelospermum difforme* is given as *Thyrsanthella difformis* (synonym) in Heath et al. (2014b).[i] *Veronia gigantea* ssp. *gigantea* is given as *Veronia altissima* (synonym) in the NPS Certified Species List.

Table A2-3. Aquatic vascular plant taxa reported to occur in Horseshoe Bend National Military Park (HOBE), based on the NPS Certified Species List (2013a).

Scientific Name	Common Name
Brasenia schreberi	Schreber watershield, watershield
Podostemum ceratophyllum	Hornleaf riverweed, threadfoot
Polygonum coccineum	Longroot smartweed

Table A2-4. List of all exotic/ invasive (non-native) species of vascular plants in HOBE, highlighting inclusion (in bold) on the Top Ten Alabama Worst Invasive Plants list (see http://www.se-eppc.org/pubs/alabama.pdf). These websites were all last accessed in May 2015.

Group	Scientific Name	Common Name
Terrestrial Plants (23)	*Albizia julibrissin*	**Mimosa, mimosa tree, powderpuff tree**
	Cerastium glomeratum	Sticky chickweed
	Cynodon dactylon	Bermudagrass, chiendent pied-de-poule, common bermudagrass
	Daucus carota	Bird's nest, Queen Anne's lace, wild carrot
	Dioscorea oppositifolia	Chinese yam
	Duchesnea indica	India mockstrawberry, Indian strawberry
	Eleusine indica	Goosegrass, crowsfoot grass, goose grass
	Glechoma hederacea	Ground ivy
	Helenium amarum	Sneezeweed, bitter sneezeweed, yellowdicks
	Lamium amplexicaule	Henbit, common henbit, giraffehead
	Lespedeza cuneata	**Chinese lespedeza, sericea lespedeza**
	Melia azedarach	Chinaberry, Chinaberry tree, Chinaberrytree
	Opuntia ficus-indica	Indian fig, Indian fig, tuna cactus
	Paspalum notatum var. *saurae*	Bahiagrass
	Plantago aristata	Bottlebrush Indianwheat, largebracted plantain
	Plantago lanceolata	Narrowleaf plantain, buckhorn plantain, English plantain, lanceleaf Indianwheat
	Prunus mexicana	Mexican plum
	Pueraria montana **var.** ***lobata***	**Kudzu, kudzu vine**
	Sporobolus indicus var. *indicus*	Smut grass
	Taraxacum officinale	Blowball, common dandelion, dandelion
	Trifolium campestre	Field (Big-hop) clover, field clover, large hop clover
	Trifolium repens	Dutch clover, ladino clover, white clover
	Verbascum thapsus	Common mullein, big taper, flannel mullein
Wetland Plants (16)	*Carya illinoinensis*	Pecan
	Cocculus carolinus	Carolina coralbead, Carolina snailseed, redberry moonseed
	Heliotropium indicum	India heliotrope, Indian heliotrope
	Ipomoea hederacea	Ivyleaf morningglory, entireleaf morningglory, ivyleaf morningglory
	Ligustrum sinense	**Chinese privet, common Chinese privet**
	Lonicera japonica	Japanese honeysuckle, Chinese honeysuckle
	Magnolia grandiflora	Southern magnolia
	Microstegium vimineum	Japanese stiltgrass, Nepalese browntop
	Paspalum dilatatum	Dallas grass, dallis grass, dallisgrass

Group	Scientific Name	Common Name
	Polygonum caespitosum var. *longisetum*	Oriental ladysthumb
	Prunella vulgaris	Common selfheal, heal all, healall
	Rumex acetosella	Red sorrel, sheep sorrel, common sheep sorrel, field sorrel
	Rumex crispus	Curley dock, curly dock, narrowleaf dock
	Sorghum halepense	Aleppo milletgrass, herbe de Cuba, Johnson grass
	Verbena bonariensis	Tall vervain, pretty verbena, purpletop vervain
	Vitis rotundifolia	Muscadine, muscadine grape

Table A2-5. Fish species reported to occur in Horseshoe Bend National Military Park (HOBE), from the NPS Certified Species List (2013a). The exotic/invasive species is indicated in **bold** and the SoC is in blue*.

Scientific Name	Common Name
Ameiurus nebulosus	Brown bullhead
Campostoma anomalum	Central stoneroller
Chaenobryttus gulosus	Warmouth
Cottus carolinae	Banded sculpin
Cyprinella callistia	Alabama shiner
Cyprinus carpio	**Common carp**
Etheostoma stigmaeum	Speckled darter
Fundulus olivaceus	Blackspotted topminnow
Gambusia affinis	Western mosquitofish
Ichthyomyzon gagei	Southern brook lamprey
Ictalurus punctatus	Channel catfish
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Luxilus chrysocephalus	Striped shiner
Lythrurus bellus	Pretty shiner
Micropterus coosae	Redeye bass
Micropterus punctulatus	Spotted bass
Moxostoma erythrurum	Golden redhorse
*Moxostoma poecilurum**	Blacktail redhorse*
Notemigonus crysoleucas	Golden shiner
Notropis baileyi	Rough shiner
Noturus leptacanthus	Speckled madtom
Percina caprodes	Logperch
Pomoxis annularis	White crappie
Pylodictis olivaris	Flathead catfish
Semotilus atromaculatus	Creek chub

Table A2-6. Amphibian taxa reported to occur in HOBE, from the NPS Certified Species List (2013a). Exotic/invasive amphibian species were not reported. One SoC is indicated in blue*.

Scientific Name	Common Name(s)
Acris crepitans	Northern cricket frog
Acris gryllus	Southern cricket frog
Ambystoma maculatum	Spotted salamander
Ambystoma opacum	Marbled salamander
Ambystoma talpoideum	Mole salamander
Bufo americanus	American toad
Bufo fowleri	Fowler's toad
Desmognathus conanti	Spotted dusky salamander
Desmognathus fuscus	Dusky salamander
Eurycea cirrigera	Southern two-lined salamander
Eurycea guttolineata	Three-lined salamander
Gastrophryne carolinensis	Eastern narrowmouth toad, eastern narrow-mouthed toad
Gyrinophilus porphyriticus	Spring salamander
Hyla avivoca	Bird-voiced treefrog
Hyla chrysoscelis	Cope's gray treefrog
Hyla cinerea	Green treefrog
Hyla gratiosa	Barking treefrog
Hyla squirella	Squirrel treefrog
Hyla versicolor	Gray treefrog
Notophthalmus viridescens	Eastern newt
Plethodon glutinosus	Northern slimy salamander, slimy salamander
Pseudacris brachyphona	Mountain chorus frog
Pseudacris crucifer	Spring peeper
Pseudacris feriarum	Southeastern chorus frog, upland chorus frog
Pseudotriton montanus	Mud salamander
Pseudotriton ruber	Red salamander
Rana catesbeiana	Bullfrog
Rana clamitans	Green frog
Rana palustris	Pickerel frog
Rana sphenocephala	Southern leopard frog
*Rana sylvatica**	Wood frog*
Scaphiopus holbrookii	Eastern spadefoot

Table A2-7. Reptilian taxa reported to occur in HOBE, based on the NPS Certified Species List (2013a). Exotic/invasive species were not reported. Two SoCs are indicated in blue*.

Scientific Name	Common Name(s)
Agkistrodon contortrix	Copperhead
Agkistrodon contortrix contortrix	Southern copperhead
Agkistrodon contortrix mokasen	Northern copperhead
Agkistrodon piscivorus	Cottonmouth
Anolis carolinensis	Green anole
Apalone spinifera	Spiny softshell, spiny softshell turtle
Apalone spinifera aspera	Gulf coast spiny softshell
Carphophis amoenus	Eastern worm snake, eastern wormsnake
Carphophis amoenus helenae	Midwest worm snake
Chelydra serpentina	Snapping turtle
Cnemidophorus sexlineatus	Six-lined racerunner
Coluber constrictor	Racer
Crotalus horridus	Timber rattlesnake
Diadophis punctatus	Ringneck snake
Elaphe obsoleta	Rat snake, texas ratsnake
Elaphe obsoleta spiloides	Gray rat snake
Eumeces egregius	Mole skink
Eumeces fasciatus	Five-lined skink
Eumeces inexpectatus	Southeastern finelined skink
Eumeces laticeps	Broadhead skink
Kinosternon subrubrum	Eastwern mud turtle
*Lampropeltis getula**	Common kingsnake*
*Masticophis flagellum**	Coachwhip*
Nerodia erythrogaster	Plainbelly water snake
Nerodia sipedon	Northern water snake
Opheodrys aestivus	Rough green snake
Pseudemys concinna	River cooter
Regina septemvittata	Queen snake
Sceloporus undulatus	Fence/prairie/plateau lizard
Scincella lateralis	Ground skink
Sternotherus minor	Loggerhead musk turtle
Sternotherus odoratus	Common musk turtle
Storeria dekayi	Brown snake
Storeria occipitomaculata	Redbelly snake
Tantilla coronata	Southeastern crowned snake
Terrapene carolina	Eastern box turtle

Scientific Name	Common Name(s)
Thamnophis sirtalis	Common garter snake
Trachemys scripta	Slider
Virginia valeriae	Smooth earth snake

Table A2-8. Bird taxa reported from HOBE, based on the NPS Certified Species List (2013a). An asterisk (*) is used to designated taxa associated with wetland/aquatic habitats; SoCs are indicated in blue[1].

Scientific Name	Common Name(s)
Accipiter cooperii	Cooper's hawk
Actitis macularia *	Spotted sandpiper
Agelaius phoeniceus *	Red-winged blackbird
Aix sponsa *	Wood duck
Anthus rubescens	American pipit, buff-bellied pipit
Archilochus colubris	Ruby-throated hummingbird
Ardea alba *	Great egret
Ardea herodias *	Great blue heron
Baeolophus bicolor	Tufted titmouse
Bombycilla cedrorum	Cedar waxwing
Bubo virginianus	Great horned owl
Buteo jamaicensis	Red-tailed hawk
Buteo lineatus	Red-shouldered hawk
Buteo platypterus	Broad-winged hawk
Butorides virescens *	Green heron
Caprimulgus carolinensis	Chuck-will's-willow
Cardinalis cardinalis	Northern cardinal
Carduelis pinus	Pine siskin
Carduelis tristis	American goldfinch
Carpodacus mexicanus	**House finch**
Carpodacus purpureus	Purple finch
Cathartes aura	Turkey vulture
Catharus fuscescens	Veery
Catharus guttatus	Hermit thrush
Ceryle alcyon *	Belted kingfisher
Chaetura pelagica	Chimney swift
Circus cyaneus	Northern harrier
Coccothraustes vespertinus	Evening grosbeak
Coccyzus americanus	Yellow-billed cuckoo
Colaptes auratus	Northern flicker
Colinus virginianus	Northern bobwhite
Contopus virens	Eastern wood-pewee
Coragyps atratus	Black vulture

Scientific Name	Common Name(s)
Corvus brachyrhynchos	American crow
Corvus ossifragus *	Fish crow
Cyanocitta cristata	Blue jay
Dendroica coronata	Yellow-rumped warbler
Dendroica discolor	Prairie warbler
Dendroica dominica	Yellow-throated warbler
Dendroica fusca	Blackburnian warbler
Dendroica magnolia	Magnolia warbler
Dendroica palmarum	Palm warbler
Dendroica pensylvanica	Chestnut-sided warbler
Dendroica petechia[1]	Yellow warbler[1]
Dendroica pinus	Pine warbler
Dendroica virens	Black-throated green warbler
Dryocopus pileatus	Pileated woodpecker
Dumetella carolinensis	Gray catbird
Egretta caerulea *	Little blue heron
Empidonax minimus	Least flycatcher
Empidonax virescens	Acadian flycatcher
Euphagus carolinus	Rusty blackbird
Falco sparverius[1]	American kestrel[1]
Gavia immer *	Common loon
Geothlypis trichas	Common yellowthroat
Guiraca caerulea	Blue grosbeak
Helmitheros vermivorus	Worm-eating warbler
Hirundo rustica	Barn swallow
Hylocichla mustelina	Wood thrush
Icteria virens	Yellow-breasted chat
Icterus spurius	Orchard oriole
Junco hyemalis	Dark-eyed junco
Larus delawarensis *	Ring-billed gull
Limnothlypis swainsonii	Swainson's warbler+B30
Melanerpes carolinus	Red-bellied woodpecker
Melanerpes erythrocephalus	Red-headed woodpecker
Meleagris gallopavo	Wild turkey
Melospiza melodia	Song sparrow
Mimus polyglottos	Northern mockingbird
Mniotilta varia	Black-and-white warbler
Molothrus ater	Brown-headed cowbird
Myiarchus crinitus	Great crested flycatcher
Oporornis formosus	Kentucky warbler
Otus asio	Eastern screech-owl

Scientific Name	Common Name(s)
Parula americana	Northern parula
Passer domesticus	**House sparrow** [added]
Passerella iliaca	Fox sparrow
Passerina cyanea	Indigo bunting
Petrochelidon pyrrhonota	Cliff swallow
Pheucticus ludovicianus	Rose-breasted grosbeak
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Pipilo erythrophthalmus	Eastern towhee, Rufous-sided towhee
Piranga olivacea	Scarlet tanager
Piranga rubra	Summer tanager
Poecile carolinensis	Carolina chickadee
Polioptila caerulea	Blue-gray gnatcatcher
Progne subis	Purple martin
Protonotaria citrea	Prothonotary warbler
Quiscalus quiscula	Common grackle
Regulus calendula	Ruby-crowned kinglet
Regulus satrapa	Golden-crowned kinglet
Sayornis phoebe	Eastern phoebe
Seiurus aurocapillus	Ovenbird
Seiurus motacilla *	Louisiana waterthrush
Seiurus noveboracensis *	Northern waterthrush
Setophaga ruticilla	American redstart
Sialia sialis	Eastern bluebird
Sitta carolinensis	White-breasted nuthatch
Sitta pusilla	Brown-headed nuthatch
Sphyrapicus varius	Yellow-bellied sapsucker
Spizella passerina	Chipping sparrow
Spizella pusilla	Field sparrow
Stelgidopteryx serripennis	Northern rough-winged swallow
Strix varia	Barred owl
Sturnella magna	Eastern meadowlark
Sturnus vulgaris	**European starling**
Thryothorus ludovicianus	Carolina wren
Toxostoma rufum	Brown thrasher
Troglodytes aedon	House wren
Troglodytes troglodytes	Winter wren
Turdus migratorius	American robin
Tyrannus tyrannus	Eastern kingbird
Vermivora celata	Orange-crowned warbler
Vermivora ruficapilla	Nashville warbler

Scientific Name	Common Name(s)
Vireo flavifrons	Yellow-throated vireo
Vireo griseus	White-eyed vireo
Vireo olivaceus	Red-eyed vireo
Vireo solitarius[1]	Blue-headed vireo, solitary vireo[1]
Wilsonia citrine	Hooded warbler
Zenaida macroura	Mourning dove
Zonotrichia albicollis	White-throated sparrow

Table A2-9. Mammalian taxa reported from HOBE, based on the NPS Certified Species List (2013a).

Scientific Name	Common Name
Blarina brevicauda	Northern short-tailed shrew
Canis familiaris	**Feral dog**
Canis latrans	Coyote
Castor canadensis	American beaver
Cryptotis parva	Least shrew
Dasypus novemcinctus	Nine-banded armadillo
Didelphis virginiana	Virginia opossum
Felis catus	**Feral cat**
Lasiurus borealis	Eastern red bat
Lontra canadensis	North American river otter, northern river otter
Lynx rufus	Bobcat
Marmota monax	Woodchuck
Mephitis mephitis	Striped skunk
Microtus pinetorum	Woodland vole
Neotoma floridana	Eastern woodrat
Nycticeius humeralis	Evening bat
Ochrotomys nuttalli	Golden mouse
Odocoileus virginianus	White-tailed deer
Ondatra zibethicus	Muskrat, common muskrat
Oryzomys palustris	Marsh rice rat
Peromyscus gossypinus	Cotton mouse
Peromyscus leucopus	White-footed mouse
Procyon lotor	Common raccoon, northern raccoon
Reithrodontomys humulis	Eastern harvest mouse
Scalopus aquaticus	Eastern mole
Sciurus carolinensis	Eastern gray squirrel
Sigmodon hispidus	Hispid cotton rat
Sorex longirostris	Southeastern shrew
Sylvilagus floridanus	Eastern cottontail
Tamias striatus	Eastern chipmunk
Urocyon cinereoargenteus	Common gray fox
Vulpes vulpes	**Red fox**
Additional Species Listed by Webster (2010) as Probably Present	
Glaucomys volans	Southern flying squirrel
Mus musculus	House mouse
Mustela frenata	Long-tailed weasel

Scientific Name	Common Name
Neovison vison	American mink
Rattus norvegicus	Norway rat
Sylvilagus aquaticus	Swamp rabbit

Appendix 3. Conservation Ranking Systems Used in Assessing Natural Resource Conditions

Table A3-1. Global conservation ranking system abbreviations.

Global Rank	Definition
G1	Critically Imperiled - At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	Imperiled - At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
G3	Vulnerable - At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
G4	Apparently Secure - Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	Secure - Common; widespread and abundant.
GX	Presumed Extinct (species) - Not located despite intensive searches and virtually no likelihood of rediscovery. Eliminated (ecological communities) - Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.
GH	Of historical occurrence throughout its range. Possibly Extinct (species) - Missing; known from only historical occurrences but still some hope of rediscovery. Presumed Eliminated (historic, ecological communities) - Presumed eliminated throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration (e.g. the American chestnut forest).
GU	Unrankable - Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
GNR	Not ranked to date.
G#T#	Infraspecific Taxon (trinomial) - The status of infraspecific taxa (subspecies or varieties) is indicated by a "T-rank" following the global rank for the species. Rules for assigning T-ranks follow the same principles outlined above for global conservation status ranks. A T-rank cannot imply that the subspecies or variety is more abundant than the species as a whole (e.g. a G1T2 cannot occur). At this time, a T-rank is not used for ecological communities.

[1] A conservation status rank may not be applicable for some species, including long-distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems, for several [unspecified] reasons.

[2] A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the state.

Table A3-2. State conservation ranking system abbreviations.

State Rank	Definition
S1	Critically Imperiled - Critically imperiled in Alabama because of extreme rarity (5 or fewer occurrences of very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation from Alabama.
S2	Imperiled - Imperiled in the state because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from Alabama.
S3	Vulnerable - Rare or uncommon in Alabama (on the order of 21 to 100 occurrences).
S4	Apparently Secure - Apparently secure in Alabama, with many occurrences.
S5	Secure - Demonstrably secure in Alabama; common, widespread, and abundant in the state.
SX	Presumed Extirpated - Species or community is believed to be extirpated from Alabama. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
SH	Historical (Possibly Extirpated) - Species or community occurred historically in Alabama, and there is some possibility that it may be rediscovered. Its presence may not have been verified in the past 20-40 yr. A species or community could become SH without such a 20-40 yr delay if the only known occurrence in the state was destroyed or if it had been extensively and unsuccessfully sought. The SH rank is reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.
SNR	Unranked - State conservation status not yet assessed.
SNA	A conservation status rank is not applicable because the species is not a suitable target for conservation activities in the state.1
SU	Unrankable - Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
SE	An exotic species established in Alabama.

[1] A conservation status rank may not be applicable for some species, including long-distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems, for several [unspecified] reasons.

[2] A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the state.

Table A3-3. Variant ranks and rank modifiers as applied to Global and State conservation ranking system abbreviations.

Rank Variants & Modifiers	**Definition**
G#G#	Range Rank - A numeric range rank is used to indicate the range of uncertainty in the status of a species or community (e.g. an element may be given a G-rank of G2G3, indicating global status is somewhere between imperiled and vulnerable). Ranges cannot skip more than one rank (e.g. GU should not be used rather than G1G4). Also applies to state ranks (e.g. S2S3).
HYB	Hybrid
Q	Questionable taxonomy - Taxonomic distinctive-ness of this entity at the current level is questionable; resolution of this uncertainty may result in a change from a species to a subspecies or hybrid, or to the inclusion of this taxon within another taxon, with the resulting taxon having a lower conservation priority.
?	Inexact Numeric Rank - e.g. G2? .

[1] A conservation status rank may not be applicable for some species, including long-distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems, for several [unspecified] reasons.

[2] A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the state.

Table A3-4. Breeding status qualifiers as applied to State conservation ranking system abbreviations.

Breeding Status Qualifiers2	
B	Breeding - Conservation status refers to the breeding population of the species in the state. Regularly occurring, usually migratory and may be present only during the breeding season.
N	Non-breeding - Conservation status refers to the non-breeding population of the species in the state. Regularly occurring, usually migratory and may not breed in Alabama; this category includes migratory birds and bats in inland areas.
M	Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the nation or state/province.

[1] A conservation status rank may not be applicable for some species, including long-distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems, for several [unspecified] reasons.

[2] A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the state.

Appendix 4. Definitions of Federal and State Species Status (Alabama Natural Heritage Program 2012)

<u>Federal designations</u>

The U.S. Endangered Species Act (U.S. ESA), administered by the U.S. Fish and Wildlife Service for inland areas, is the major legislation providing federal legal protection to threatened and endangered species (http://endangered.fws.gov/). "Endangered" is defined as in danger of extinction within the foreseeable future throughout all or a significant portion of the species range. "Threatened" refers to a species that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

LE - Listed Endangered: A species in danger of extinction throughout all or a significant portion of its range.

LT - Listed Threatened: A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

PE - Proposed Endangered: A species proposed to be listed as endangered.

PT - Proposed Threatened: A species proposed to be listed as threatened.

PS - Partial Status: An infraspecific taxon or population has federal status but the entire species is in only a portion of the species range.

C - Candidate: A species under consideration for official listing for which there is sufficient information to support listing. The U.S. Fish and Wildlife Service encourages other agencies to give consideration to such taxa in environmental planning.

XN - Experimental Population, Non-essential: Experimental reintroduced population.

SC - Species of Concern: Species that has not been petitioned or been given Endangered, Threatened, or Candidate status, but has been identified as important to monitor.

UR - Under Review in the Candidate or Petition Process: A 90-day finding indicated that listing this species may be warranted, and a full status review has been initiated to determine if listing is warranted.

<u>State status code designations</u>

Alabama does not have a state law equivalent to the federal Endangered Species Act so species do not have regulatory protection as state endangered or threatened species. However, some species do receive regulatory protection through the *Alabama Regulations on Game Fish and Fur Bearing Animals* published annually. These are the primary regulations affording state protection for some species in Alabama, and are administered by the Alabama Department of Conservation and Natural Resources (ADCNR - Wildlife & Freshwater Fisheries Division - see http://www.outdooralabama.com/hunting/regulations/ or the Nongame Species Regulation - Section 220-2-.92, at http://www.outdooralabama.com/watchable-wildlife/regulations/nongame.cfm).

SP – State Protected: Species protected by Regulation 220-2-.92 (Nongame Species Regulation, pp. 69-71 in the 2010-2011 Regulations), 220-2-.98 (Invertebrate Species Regulation, pp. 65-66), 220-2-.26(4; Protection of Sturgeon, p. 40), 220-2-.94 (Prohibition of Taking or Possessing Paddlefish, p. 57), or 220-2-.97 (Alligator Protection Regulation, p. 72).

PSM – Partial Status Mussels: All mussel species not listed as a protected species under the Invertebrate Species Regulation are partially protected by other regulations of the Alabama Game, Fish, and Fur Bearing Animals Regulations. Regulation 220-2-.104 prohibits the commercial harvest of all but the 11 mussel species for which commercial harvest is legal.

RT – Regulated Turtle: Species for which the Turtle Catcher/Dealer/Farmer Regulation (Regulation 220-2-.142) imposes a limit on the number which can be possessed or size limits.

GANOS – Game Animal - No Open Season: Species designated a game animal by Regulation 220-2-.07, but for which there is no open season.

GA - Game Animal (Managed hunting regulations).

GB – Game Bird (Managed hunting regulations).

GBNOS – Game Bird - No Open Season: Species designated a game bird by Regulation 220-2-.04, but for which there is no open season.

GF - Game Fish (Managed Fishing Regulations):

GF-HP – Game Fish – Harvest Prohibited: Species designated a game fish by Regulation 220-2-.34, but harvest of the species in the state is prohibited.

CNGF - Commercial or Nongame Fish (Managed Fishing Regulations): Designated a commercial or nongame fish by Regulation 220-2-.45 of the Alabama Regulations on Game, Fish, and Fur Bearing Animals.

Appendix 5. "Shortcut" Programs in SAS to calculate GDD and PDSI

These two programs were written with assistance from the NCSU Statistics Department (Dr. Consuelo Arellano). Both programs use data requested and received from the Southeast Regional Climate Center (SERCC) located in Chapel Hill, NC (Mr. William Schmitz, Service Climatologist/Meteorologist).

The first program uses data called Growing Degree Days (GDD) and calculates the date where the 1200 GDD threshold is reached. The computation involves finding the calendar date when the 1200 GDD threshold is reached for each year in the dataset. This requires summing the monthly values until the sum is greater than 1200 and then calculating the slope of the line between that month and the month preceding to determine the exact date on which the 1200 would be achieved. Typically the value 1200 is achieved between April and May, but occasionally between March and April, or May and June, depending on temperature.

The second program uses Palmer Drought Severity Index data and ranks the severity of drought over seven classes ranging from severely dry to excessively wet. The computation involves calculating the proportion of the number of monthly observations in each drought class for every nine-year period.

In these programs for Chattahoochee National Recreation Area and the Network, the reference city has been set equal to Atlanta.

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National Park Service
U.S. Department of the Interior

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