National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Fort Donelson National Battlefield

Natural Resource Report NPS/FODO/NRR—2013/621

ON THE COVER

Clockwise from top left: Lower River Battery overlooking Cumberland River, American Robin (*Turdus migratorius*) eggs inside cannon, musket demonstration, and resident Bald Eagle (*Haliaeetus leucocephalus*) pair

Photographs courtesy of National Park Service

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Natural Resource Report NPS/FODO/NRR—2013/621

Gary Sundin, Luke Worsham, Nathan P. Nibbelink, Michael T. Mengak, Gary Grossman
Warnell School of Forestry and Natural Resources
University of Georgia
180 E. Green St.
Athens, GA 30602

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Executive Summary

This report provides a comprehensive assessment of the state of natural resources at Fort Donelson National Battlefield (FODO). It also addresses sets of stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Cumberland Piedmont Inventory and Monitoring (I&M) Network (CUPN), and on attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air quality, water quality, vegetation, animal communities, and landscape dynamics.

Data used in the assessment included I&M reports and bio-inventories, spatial information, park-commissioned reports, publicly-available data, and personal communication with FODO, CUPN, and NatureServe staff. No new field data was collected for this report. When available, published criteria were used to derive a condition assessment based on available data, and when appropriate, we identify opportunities for improved data collection to allow for stronger assessment in the future.

Fort Donelson National Battlefield is located on the banks of the Cumberland River, commemorating the site of a decisive Civil War battle during February 1862. This conflict resulted in Federal control of the Tennessee and Cumberland Rivers, both of which were important supply lines that proved important in later victories at Shiloh, Vicksburg, and Chattanooga. In addition to the main site at Fort Donelson, the park unit also incorporates the recently acquired Fort Heiman located on the west bank of the Tennessee River. Although located in the town of Dover, TN, the park unit is mostly forested, and also includes Fort Donelson National Cemetery, wherein several hundred Union soldiers and other veterans are interred.

FODO contains a moderately diverse plant and vertebrate biota. A total of 1275 distinct taxonomic classes are included on the list of vascular plants at FODO. Recent inventory efforts reported 175 species of birds from the park. No federal threatened or endangered species were reported. Nine reported bird species were endangered or deemed in need of management at the state level. A recent mammal inventory reported 30 mammals, including the federally listed gray bat (*Myotis grisescens*). Recent work reported 11 fish species and no threatened or endangered species were included. A herpetofauna inventory reported 37 species of reptiles and amphibians, with no threatened or endangered species. Several broad classes of potential threats and stressors to natural resources are applicable to FODO and are addressed in this report. They include:

Decreased air quality – Ozone concentrations appear low, but regional models indicate plants at FODO may be susceptible to foliar injury.

Decreased water quality – Current water quality at FODO also appears good, though low dissolved oxygen concentrations at the Indian Creek embayment and Hickman Spring could potentially affect aquatic populations.

Exotic plant species – The presence and proliferation of exotic plants can cause loss of native plant diversity and can negatively alter habitat for animal communities. At FODO, exotic species are predominant throughout the park and represent a threat to natural vegetation communities.

Exotic/range-expanding vertebrate animal species – The presence and proliferation of exotic animal species, species outside of their native range, and parasitic species can cause loss of native animal and plant diversity. Exotic or range expanding species of fishes, birds, and mammals have been reported from FODO. Species of particular risk reported from the park include the Brown-headed Cowbird (*Molothrus ater*) and the feral or free-ranging domestic cat (*Felis catus*).

Animal disease – Several threats or potential threats to park vertebrate populations are recognized and discussed in the report. These diseases could have impacts at the population level. Diseases of concern in the region include Ranavirus and Chytrid fungal infections of amphibians, and white-nose syndrome in bats.

Insect pests – Insect pests can cause loss of native plant diversity and negatively impact ecosystems and wildlife habitat. Dogwood anthracnose (*Discula destructiva*) has been documented in the park, and southern pine beetle (*Dendroctonus frontalis*) is also a risk.

Altered fire regimes – The oak – hickory forests at FODO typically had frequent understory burns after European settlement, though today, regular burning is suppressed. Loss of fire in an ecosystem can result in the build-up of fuels, cause loss of plant and animal biodiversity, and alter successional patterns.

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

Thirteen ecological attributes were assessed for this report. Of these, nine (69%) were ranked good and four (31%) were ranked as fair. No attributes received a poor condition rating. Nine attributes (69%) were judged to have good data quality and four (31%) were ranked as fair. Assessment method was highly variable among assessed attributes, and therefore condition rankings are not necessarily directly comparable. As additional information becomes available, the relative impact of each of these stressors on park natural resources will allow park management to be directed more effectively.

Chapter 1 NRCA Background Information

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

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

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

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

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

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

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

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

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]

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

and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

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

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

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

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

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

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

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

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

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Originally established as a National Cemetery in 1867, Fort Donelson National Military Park was designated in 1928 and transferred from the US War Department to the National Park Service in 1933. In 1960, legislation was amended to include additional lands and change the designation to Fort Donelson National Battlefield and Cemetery. According to the enabling legislation, Fort Donelson is established "with a view of preserving and marking such field for historical and professional military study."

Today, the main park features include the two river batteries along the Cumberland River, outer earthworks, the Surrender House (Dover Hotel), and the National Cemetery.
In 2004, Congress authorized the expansion of the park to acquire Fort Heiman in Calloway County, KY, across the Tennessee River. Fort Henry, originally located close to Fort Heiman along the Tennessee River, was inundated in 1944 upon creation of Kentucky Lake. As a result, the legislation also mandated that Fort Donelson and the US Forest Service "facilitate cooperatively protecting and interpreting the remaining vestige of Fort Henry and other remaining Civil War resources," which remain in part at the Land Between the Lakes National Recreation Area (NRA).

2.1.2 Geographic Setting

Fort Donelson National Battlefield (FODO) is located along Lake Barkley (historic Cumberland River) in Stewart County in Dover, TN. The park unit covers 407 ha (1,006 acres) and abuts an additional 121 ha (300 acres) of associated property currently owned by the Civil War Trust (CWT). The National Cemetery is located along the eastern park boundary and covers roughly 6 ha (15 acres). Fort Donelson is located on Highway 79 about 50 km (30 miles) west of Clarksville, TN. Ft. Heiman is consists of 61 ha on the west bank of the historic Tennessee River, which has since been inundated to create Kentucky Lake.

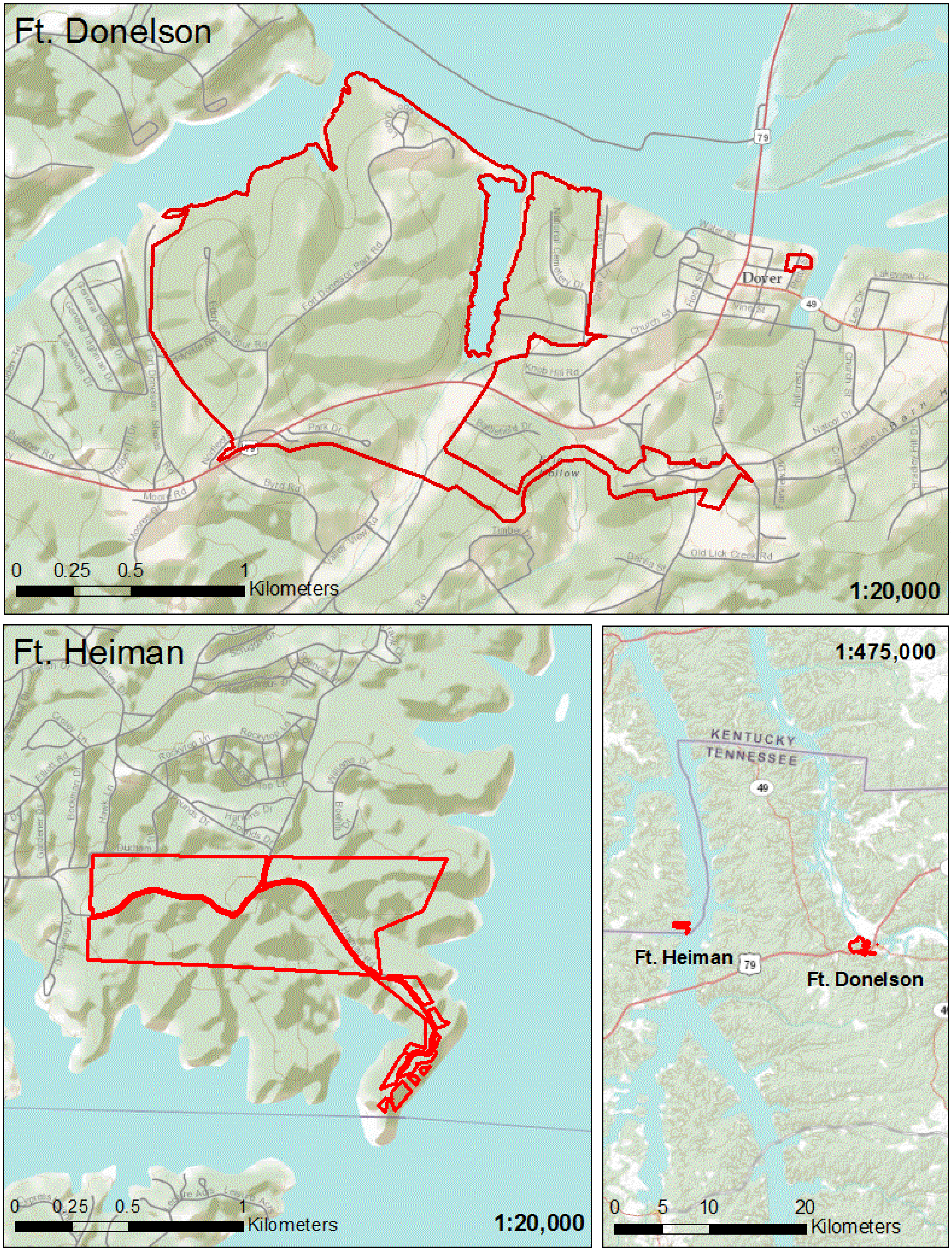

Figure 1. Fort Donelson National Battlefield (FODO) consists of two disparate tracts. The National Battlefield and Cemetery are located in the main section of the park unit adjacent to Dover, TN along the Cumberland River (Lake Barkley). The recently acquired Fort Heiman tract is located on the west bank of the Tennessee River (Kentucky Lake).

2.1.3 Park History

Fort Donelson was the site of a pivotal battle during the Civil War that lasted from February 14th–16th, 1862. It represented the first major victory for the American Union and secured their hold on major supply routes on the Tennessee and Cumberland Rivers. After defeating Confederate defenses along the Tennessee River at nearby Fort Henry and Fort Heiman on February 6, Flag Officer Andrew H. Foote's fleet of gunboats sailed onwards to Fort Donelson along the Cumberland River. Cannons from the riverbank water batteries at Fort Donelson successfully repelled Foote's gunboat fleet, however. On land, Brigadier General Ulysses S. Grant and his troops had succeeded in encircling the fort to cut off its supplies. Confederates in the fort were forced to fight their way out, and on February 15th, they attacked Grant's line and were successful in breaching the Union defenses. However, in a decision that still remains inexplicable, Confederate commanders ordered troops back into the fort. As a result, Grant counterattacked and closed his lines, and eventually secured his capture of Fort Donelson with his famous response to General Bruckner's request for terms of surrender: "No terms except and unconditional and immediate surrender can be accepted." This was the first of a string of victories for Grant, followed by successful battles at Shiloh, Vicksburg, and Chattanooga, and eventually leading to his promotion to commander of the Union army in 1864. In 1869, Grant was elected the 18th US President.

2.1.4 Soils and Geology

A geologic resources inventory (GRI) scoping summary was initiated for Fort Donelson in 2009 by the NPS Geologic Resources Division. Scoping and digital geologic GIS data layers have been completed. A GRI geologic report is still pending. The GRI geologic report identifies and provides a description of key geologic resource management issues, a discussion of geologic features and processes important to park ecosystems and management, a map unit properties table that identifies characteristics of geologic map units, a brief geologic history of the park area; and an overview of the digital geologic map data.

The scoping summary reported three main geologic units at FODO: alluvial deposits, St. Louis Limestone, and Warsaw Limestone. The Fort Heiman unit is classified into loess, alluvium, continental deposits, and various Cretaceous rocks of fluvial origin (Figure 2). Predominant soil types at Fort Donelson include Bodine gravelly silt loams (97 ha), Lax silt (clay) loams (25 ha), and Sengtown gravelly silt loams (22 ha), all of which are limestone-derived (Thornberry-Ehrlich 2009).

Because much of the landscape at FODO occurs on sloping land, erosion is a potential issue that can damage earthworks. Fortunately, the large amount of forested area acts as a preventative measure.

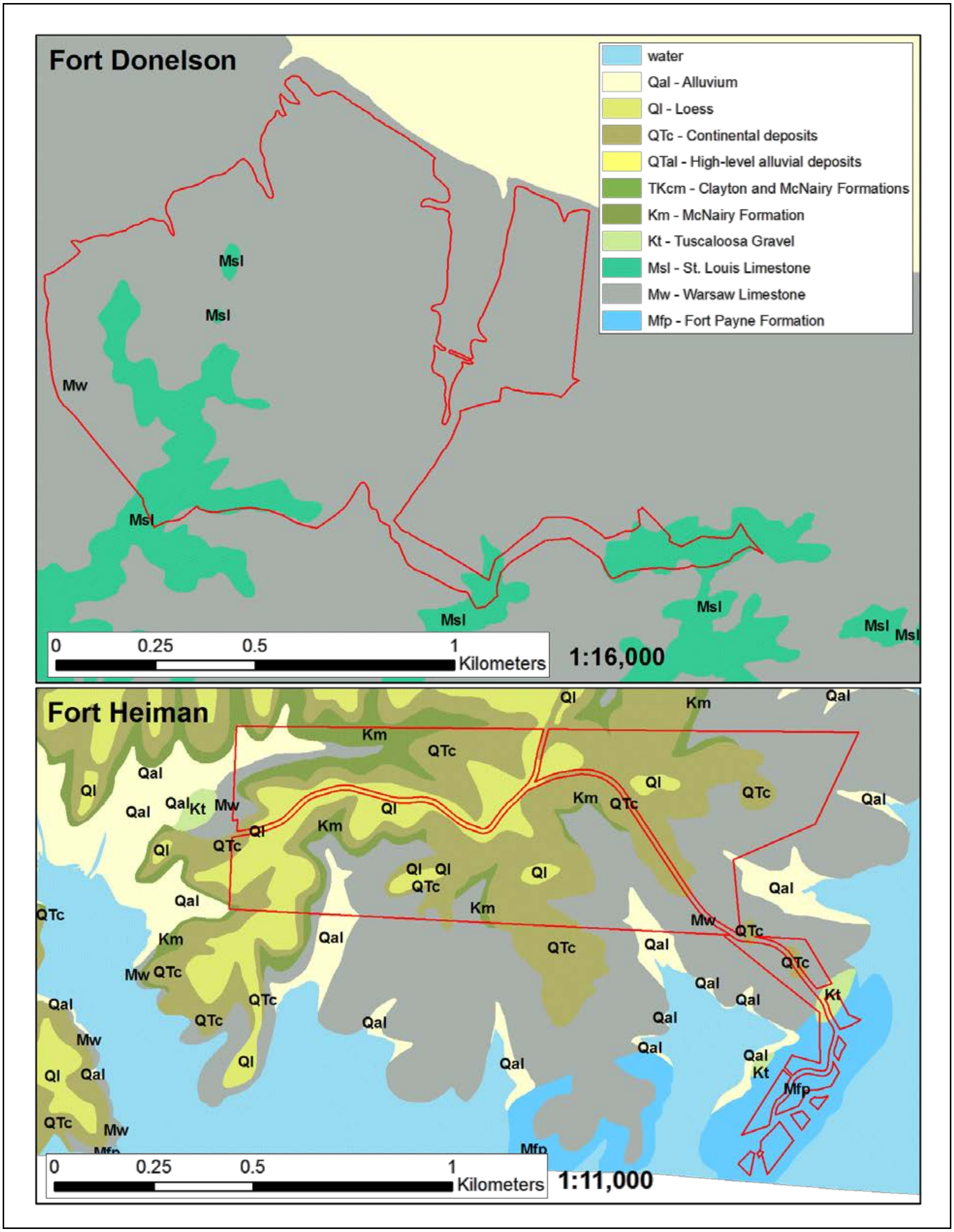

Figure 2. Geology at Fort Donelson and Fort Heiman reveal that sites are composed of alluvium, loess, and limestone formations (Thornberry-Ehrlich 2009).

2.1.5 Hydrology

Fort Donelson National Battlefield lies within the Lower Cumberland cataloging unit (HUC 05130205). The Cumberland River (Lake Barkley) abuts the northern boundary of the park unit, and represents a key feature in the interpretation of the battle setting. Fort Heiman falls within the Kentucky Lake cataloging unit across the Tennessee River (Kentucky Lake) from Fort Donelson. Both the Cumberland and Tennessee Rivers were large free-flowing waterbodies at the time of the battle that have since been dammed into reservoirs, dramatically changing their hydrologic role in the region. The shoreline of the Cumberland River has been stabilized with riprap, and the majority of its floodplain area occurs on the bank opposite of Fort Donelson (Thornberry-Ehrlich 2009).

Not counting the Cumberland River, there are only four streams that flow through the park: Indian Creek, Erin Hollow, and two unnamed tributaries to Hickman Creek and Indian Creek. The north and west portions of the main park area are respectively bordered by the Cumberland River and Hickman Creek, neither of which are part of the park unit.

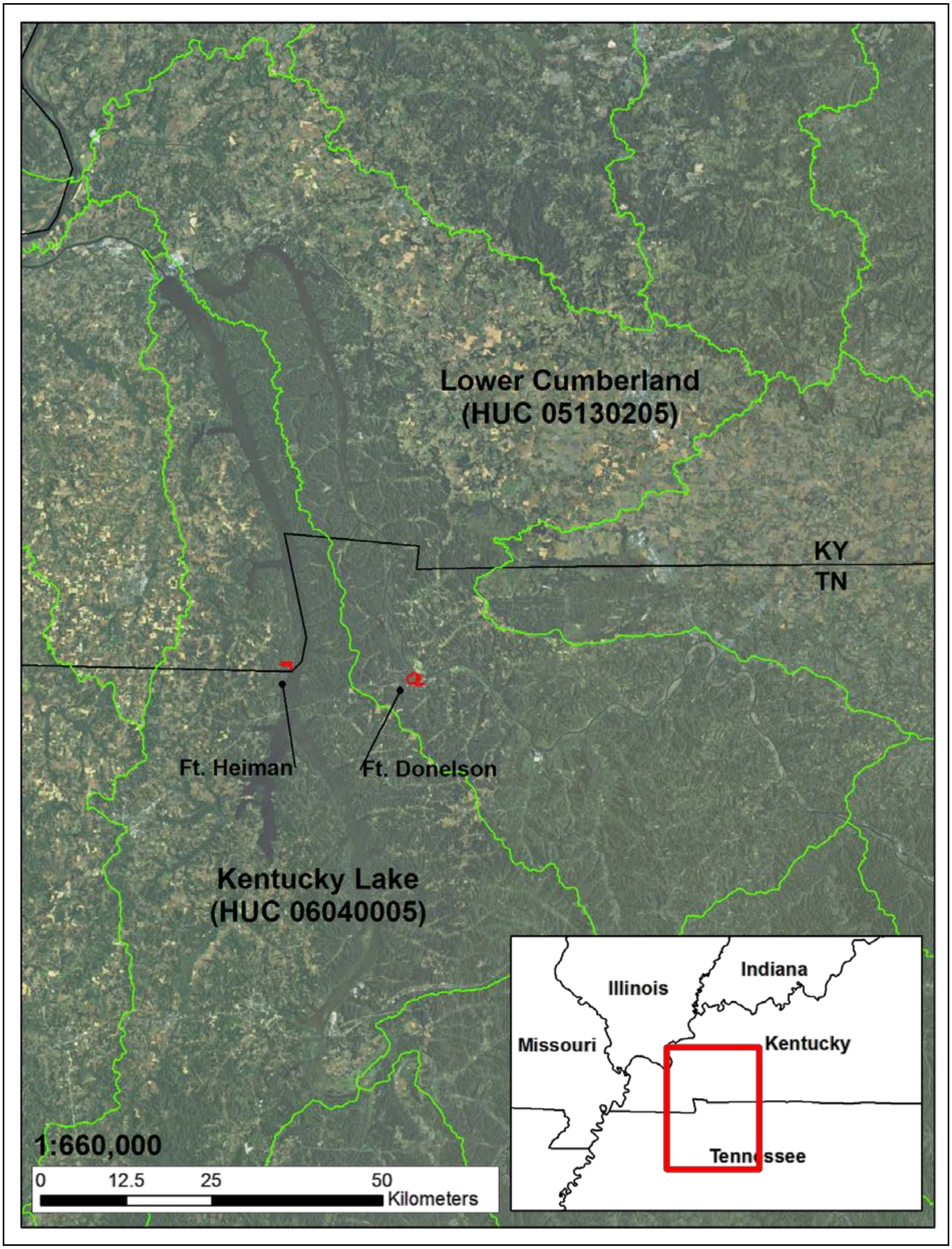

Figure 3. Fort Donelson and Fort Heiman respectively fall within the Lower Cumberland and Kentucky Lake cataloging units.

2.1.6 Visitation Statistics

Data for annual number of visitors at FODO is available starting in 1934. Visitation rose steadily after World War II, and rapidly jumped in time for the park centennial. Peaking in 1968-1969 with just over a million visitors each year, visitation dropped off immediately afterwards and declined steadily to a consistent pace of ~200,000 annual visitors, which has held for the past two decades (Figure 4). The overall average is 260,000 visitors per year.

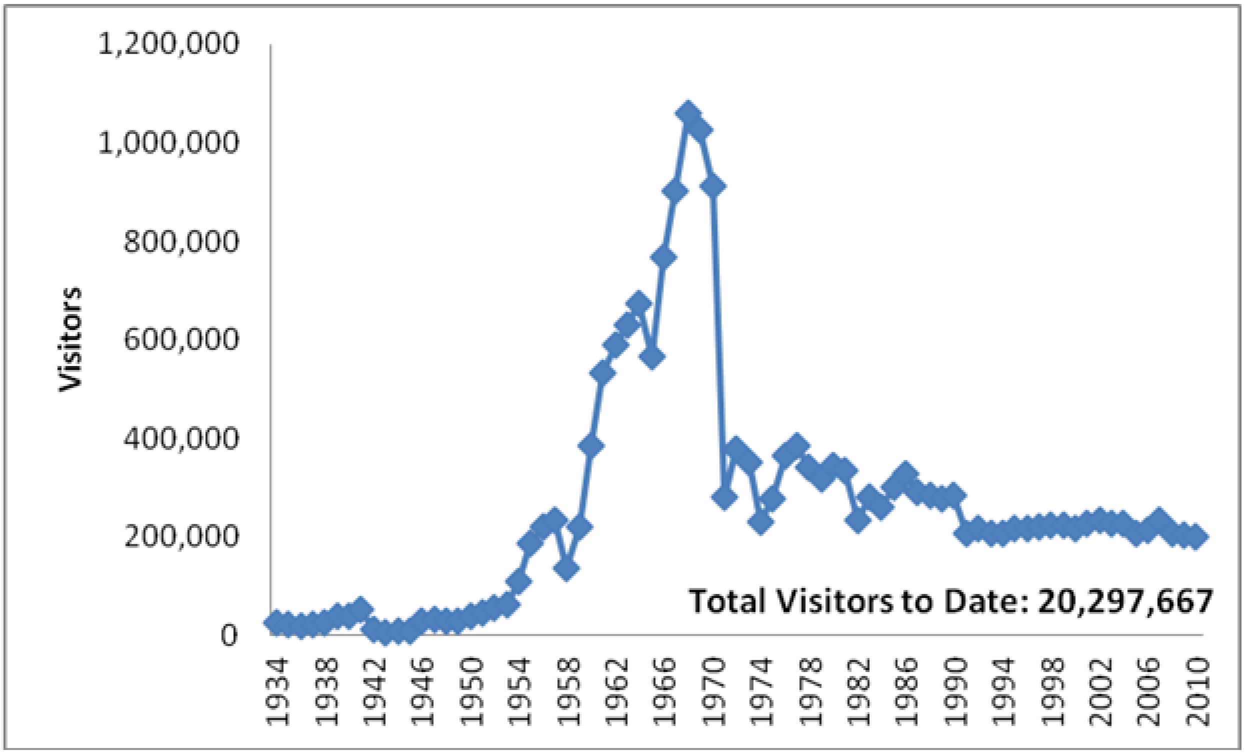

Figure 4. Visitor data for FODO from 1934 to 2009.

2.2 Natural Resources

2.2.1 Resource Descriptions

<u>Sensitive Plant Species</u>

A single federally threatened plant species, Price's potato-bean (*Apios priceana*), occurs at FODO and represents perhaps the most important conservation priority. Besides its federal listing, it is state-listed as imperiled or critically imperiled in four southern states: AL, MS, KY, and TN. Other important plant species include barbed rattlesnake root (*Prenanthes barbata*) and ginseng (*Panax quinquefolia*), both of which are state-listed in TN and KY. Ginseng is additionally considered a possible target of exploitation.

<u>Invasive Plants</u>

In a recent vegetation inventory at FODO by NatureServe (White 2004), the author reported that exotic plant species represent "probably the biggest single threat to the overall ecological health of the park at this point in time." The inventory also showed that roughly 16% of species in the park are non-native, and that a total of 26 are considered particularly aggressive or invasive. The most noxious invasives, whose removal might be the most beneficial, include privet (*Ligustrum* spp.), Japanese stiltgrass (*Microstegium vimineum*), multiflora rose (*Rosa multiflora*), jointgrass (*Arthraxon hispidus*), autumn olive (*Elaeagnus umbellata*), English ivy (*Hedera helix*), Johnsongrass (*Sorghum halepense*), and lespedeza (*Lespedeza* spp.).

Fishes

Although FODO is bounded by the Cumberland River, there is little fish habitat within the park. A single small stream, Indian Creek, is the only stream large enough to contain a significant fish assemblage. The observed assemblage in Indian Creek includes 11 species, lacks species of identified high conservation concern, and contains at least one non-native species (Zimmerman 2007). The observed assemblage is regionally-typical and is not indicative of major habitat degradation.

Birds

Fort Donelson has a relatively rich bird assemblage for its size and 175 species were reported from a recent inventory (Stedman and Stedman 2005). The species count is substantially increased because a number of water birds use areas adjacent to the park as overwintering or migratory stopover habitat. Several species of conservation concern occur in the park. A pair of Bald Eagles (*Haliaeetus leucocephalus*) has nested repeatedly in FODO.

Mammals

The mammals found in the park are indicative of a regionally typical fauna. A recent park inventory (Kennedy et al. 2007) found 30 species of mammals. One state and federal endangered species, the gray bat (*Myotis grisescens*), was reported from the park. Three non-native species were reported from the park, including feral or free ranging domestic animals. The observed mammal species richness in the park was not high relative to the list of mammals potentially occurring in the region. However, the species richness was consistent with expectations for a small and relatively protected area.

Reptiles and Amphibians

A recent inventory of FODO herpetofauna reported 37 species (Scott and Davenport 2005). No threatened or endangered species were reported, and no non-native species were reported. The park harbors a regionally typical fauna that includes around 70% of the species expected, and is consistent with expectation for a small and relatively well-protected area.

Insect Pests

Fort Donelson experiences relatively little impact from insect pests. However, gypsy moth (*Lymantria dispar*) may represent a threat in the near future, and the US Forest Service conducts annual trapping within the park unit. So far, no captures have been made. Although the gypsy moth invasion originated in the New England area, it continues to spread south and west. The invasion front has reached as far as northern Kentucky, though traps have caught gypsy moth as far south as Chickamauga and Chattanooga National Battlefield in southeastern TN in 2009. The closest confirmed capture to FODO was at Nolin River Lake in KY, approximately 170 km to the northeast. Spot infestations have brought the pest close to the park, including nearby Humphreys County, TN, which recently completed an eradication program.

Water Quality

In 2003, water quality sampling began at FODO as part of the CUPN I&M program (Meiman 2009). Quarterly biennial sampling is conducted at five locations at Fort Donelson within or along the park boundary. Since monitoring began, no water quality issues have emerged at FODO.

2.2.2 Ecological Units

In general, analysis of natural resources at FODO is considered for the entire park unit because of its small size. Also, because Fort Heiman along the west bank of the Tennessee River is such a recent addition to FODO as a whole, animal and plant inventories and general monitoring conducted by the CUPN for natural resources did not include this tract. As a result, virtually no knowledge of these issues is available for incorporation into this report.

2.2.3 Resource Issues Overview

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

Fire Management

The fire management plan (FMP) at FODO (NPS 2003) outlines that all wildland fires, regardless of ignition source (i.e. natural or anthropogenic) will be suppressed. Mechanical fuel reductions will be undertaken to minimize fuel buildup, control exotic vegetation, and to maintain historic vistas. The FMP and its environmental assessment (Gorder and Whitney 2003) acknowledge that fire has historically played a large role in southern forests and that the adoption of a prescribed burning program at FODO could afford numerous potential benefits. These benefits include invasive plant reduction, soil enrichment, increased habitat for fire-adapted plant species, and reduced fuel load. However, the preferred management plan, which did not include prescribed burning, was adopted because of the small management area of the park and its proximity to private residences. This plan includes the creation of fuel break buffers and removal of hazard fuels along the park perimeter, all of which would total approximately 1 ha.

Landscape Change

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

The NPS created a series of landscape dynamics data products called NPScape, the goal of which was to create an organized protocol for landscape scale assessment for all park units in the US. To achieve that goal, NPScape divided the landscape analysis into five main categories: (1)

landcover, (2) roads, (3) population and housing, (4) pattern, and (5) conservation status. Each of these categories has an associated set of data sources and data products that provide the foundation for further analysis. For each section, the NPScape interpretative guide provides a literature review, including lists of thresholds that can serve as metric guidelines (NPS 2012).

Air Quality

The potential for creation of ozone is particularly a threat near industrialized areas, where nitrogen oxides (NOx) in the presence of volatile organic compounds (VOCs) can result in the creation of ground-level ozone. This ozone can be particularly harmful to human health, as well as cause foliar injury in natural and agricultural vegetation. A 2007 assessment of ozone injury risk to plants in NPS units resulted in a high risk classification risk at FODO (Kohut 2007); ozone monitoring and foliar injury assessments are conducted on a six-year rotating basis among CUPN park units (Jernigan et al. 2010).

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Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

During November 2010, an initial scoping meeting was held to discuss natural resource issues at FODO (See Appendix A for list of attendees). The purpose of this meeting was to provide an introduction to the scope of the NRCA report and identify potential sources of data. Using the list of vital signs outlined by the CUPN as a starting point, additional points of interest and important natural resource issues at the park unit were added as focal points to the assessment. Other discussion was devoted to how the report could maximize its utility at the park unit level.

3.2 Study Design

3.2.1 Indicator Framework

The ranking framework used for this natural resource condition assessment draws from the NPS ecological monitoring framework (EMF, Fancy et al. 2009, Table 1). Using an Environmental Protection Agency (EPA) ecological condition framework (Young and Sanzone 2002) as a model, the NPS framework divides monitoring into six general categories: air and climate, geology and soils, water, biological integrity, human use, and landscape pattern and processes. Each of these general categories, referred to as level-one, are further subdivided into level-two and level-three categories, with each park vital sign most closely associated with this fine-scale level-three division. Biological integrity, a level-one category for example, is divided into 4 level-two categories: invasive species, infestations and disease, focal species or communities, and at-risk biota. Invasive species, in turn, includes 2 level-three categories: invasive/exotic plants and invasive/exotic animals. As the categories move from level-one to level-three, the resolution of the data involved also increases.

Table 1. NPS Ecological Monitoring Framework used to organize and identify natural resource areas of interest at FODO (Fancy et al. 2009). Blue highlights indicate areas of interest identified at FODO during initial scoping meeting using CUPN vital signs as guidance.

Ecological Monitoring Framework—FODO			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Air and Climate	Air Quality	Ozone	Atmospheric ozone concentration; damage to sensitive vegetation
		Wet and Dry Deposition	
		Visibility and Particulate Matter	
		Air Contaminants	
	Weather and Climate	Weather and Climate	
Geology and Soils	Geomorphology	Windblown Features and Processes	
		Glacial Features and Processes	
		Hillslope Features and Processes	
		Coastal/Oceanographic Features and Processes	
		Marine Features and Processes	
		Stream/River Channel Characteristics	
		Lake Features and Processes	
	Subsurface Geologic Processes	Geothermal Features and Processes	
		Cave/Karst Features and Processes	
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	
		Surface Water Dynamics	Flow
		Marine Hydrology	
	Water Quality	Water Chemistry	Temperature, specific conductivity, pH, DO, ANC
		Nutrient Dynamics	
		Toxics	
		Microorganisms	Fecal coliform, Escherichia coli
		Aquatic Macroinvertebrates and Algae	

Table 1. continued.

Ecological Monitoring Framework—FODO			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Biological Integrity	Invasive Species	Invasive/Exotic Plants	New invasions (early-warning emphasis); occurrence, distribution models
		Invasive/Exotic Animals	
	Infestations and Disease	Insect Pests	New invasions (early-warning emphasis) of forest insect pests; occurrence, distribution models
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	
		Riparian Communities	
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	
		Desert Communities	
		Grassland/Herbaceous Communities	
		Shrubland Communities	
		Forest/Woodland Communities	Biotic integrity, Rare vegetation communities, threat from exotics
		Marine Invertebrates	
		Freshwater Invertebrates	
		Terrestrial Invertebrates	
		Fishes	Species richness, species of concern, biotic integrity
		Amphibians and Reptiles	Species richness, species of concern, comparable assemblages, observed vs. expected richness
		Birds	Species richness, species of concern, relative abundance, biotic integrity
		Mammals	Species richness, species of concern, comparable assemblages, observed vs. expected richness
		Vegetation Complex (use sparingly)	
		Terrestrial Complex (use sparingly)	
	At-risk Biota	Rare Plants	Price's potato bean, Michigan lily

Table 1. continued.

Ecological Monitoring Framework—FODO			
Level 1 Category	**Level 2 Category**	**Level 3 Category**	**Specific Resource / Area of Interest**
Human Use	Point Source Human Effects	Point Source Human Effects	
	Non-point Source Human Effects	Non-point Source Human Effects	
	Consumptive Use	Consumptive Use	
	Visitor and Recreation Use	Visitor Use	
	Cultural Landscapes	Cultural Landscapes	
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	
	Landscape Dynamics	Land Cover and Use	NPScape areas of interest: conservation status, population/housing, landcover, roads, and pattern
	Extreme Disturbance Events	Extreme Disturbance Events	
	Soundscape	Soundscape	
	Viewscape	Viewscape/Dark Night Sky	
	Nutrient Dynamics	Nutrient Dynamics	
	Energy Flow	Primary Production	

Table 2. Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Fort Donelson National Battlefield. “—“ indicates no data period associated with source

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	Portable Ozone Monitoring System (POMS) in FODO	Hourly measurements of ozone concentration within FODO	2005, 2009
		NPS ARD 5-year interpolated estimates	Estimates of ozone concentration at FODO	5-year means between 1999-2009
	Foliar injury risk predictions (3-metric index)	NPS report for the Cumberland Piedmont Monitoring Network (NPS ARD 2004)	Kriged predictions extracted from US-wide ozone models	1995-1999
		Foliar injury field assessment (Jernigan et al. 2010)	On-the-ground foliar injury assessment at FODO	2009
	Sensitive plant species	NPS ARD list of sensitive plant species (Porter 2003)	Sensitive plant species list	2003
Water Chemistry	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), ANC (mean)	I&M Data Collection	Raw water quality monitoring data from five FODO sampling stations	2003-2010
		Meiman (2009)	FODO water quality serial report	2003-2008
Microorganisms	*E. coli* (mean colonies/100mL), fecal	*Same sources as above*	*Same sources as above*	*Same sources as above*
Invasive/Exotic Plants	Presence, relative predominance, and invasibility of exotics	White (2005) vegetation communities report	Description of major vegetation communities mapped at FODO, as well as areas of concern for exotics	2002-2003
		Morse et al. (2004) I-ranks	Generalized invasibility ranks (I-Ranks) for exotic species	--
Vegetation Communities	Diversity and status of vegetation communities	White (2005) vegetation communities report	Description of major vegetation communities mapped at FODO, as well as areas of concern for exotics	2002-2003
		Center for Remote Sensing and Mapping	Image classification map of vegetation at	2002

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
		Science (CRMS) vegetation maps (Jordan and Madden (2008)	FODO	
		Wetland report (Roberts and Morgan 2006)	Inventory and description of wetlands at FODO	2004
Rare Plants	Extent and protection status	NatureServe (2011) database	Rare plant status and description, extent, and list of stressors	--
		White (2005) vegetation communities report	Rare species occurrences in plots data	2002-2003
Forest Pests and Pathogens	Southern pine beetle, gypsy moth, Sudden oak death, oak wilt	White (2005) vegetation communities report	Plot descriptions of infestations	2002-2003
		US Forest Service gypsy moth trapping program (Puckett 2008)	Gypsy moth trapping data	2002-2011
Fish Communities	Species richness, Index of Biotic Integrity	Zimmerman (2007) Fish inventory report of four National Parks	Sample data for three seasonal samples of Indian Creek including relative abundance and species; from narrative of the report	2005-2006
Bird Communities	Bird community index (BCI), conservation value, richness	Stedman and Stedman (2005) Bird inventory report	Narrative report and database of data from standardized breeding season point counts, walking transects, raptor counts, and general observations	2003-2005
Mammal Communities	Comparisons of reported vs. expected, comparisons with results of similar studies	Kennedy et al. (2007) Mammal inventory report for FODO	Narrative report with tabular data summarizing results for all trap types	2004-2007
		Hopkins and Kennedy (2004) Report of mammal sampling from Milan Army Ammunition Plant	Published research including species lists, used for comparison with FODO	1999-2001
		Thomas (2012) Mammal inventory report for MACA	Summary of effort and species observed, used for comparison with FODO	2003-2004
		Britzke (2007) Mammal inventory report for BISO	Narrative report with tabular summary data, used for comparison with FODO	
Reptile and Amphibian	Comparisons of reported vs.	Scott and Davenport (2005) Herpetofauna inventory report for FODO	Narrative report with associated data	2004-2005

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Communities	expected; amphibian breeding effort; mitigation wetland function	Scott (1991) Report on sampling at Barnett Woods Natural Area	Published research including effort and species lists, used for comparison	1982-1985
		Niemeller et al. (2011) Report of sampling at seven small protected areas in central TN	Published research including effort and species lists, used for comparison	1990-2010
Landscape Dynamics	NPScape main categories: landcover, roads, population and housing, pattern, and conservation status	NPScape dataset	Suite of GIS layers and associated data for each of the main categories, as well as resulting spatial analysis data products	Varies
		National Landcover Dataset (NLCD) 2006 landcover/imperviousness classifications	Supplementary landcover information	2006
		GAP landcover dataset	Supplementary landcover information	1999-2001
Dark Night Sky	Bortle Dark-Sky Scale, Limiting Magnitude Average, Magnitudes per Square Arc-Second, Candela per m^2	Dark Sky Monitoring	Series of dark sky surveys collected at points throughout FODO	2012

3.2.2 General Approach and Methods

Condition and Trend Status Ranking Methodology

Data collected as part of the NPS I&M program typically is intended to assess the condition of the vital sign at level 3, and therefore we summarize at this level using the ranking status tables at the end of each natural resource section. These tables represent a subset of the EMF tables and show finest-scale division of the level 1 category to which the ranked attribute belongs. Individual attributes are assigned two individual rankings: condition and trend.

We used this hierarchical framework to choose assessment attributes and to organize the presentation of results. We developed a list of ecological attributes suitable for condition assessment using 1) level-three category attributes from the adapted EPA framework described above, 2) the inventory and monitoring goals for the Cumberland Piedmont Network (CUPN, Leibfreid et al. 2005), and 3) input from NPS staff. We assessed the condition of each attribute using standard methods and reference criteria. When appropriate, we performed statistical comparisons using $a = 0.05$. We represented the condition of each attribute as a colored circle where color indicated condition (dark green = excellent, etc.) (Table 4). Condition rankings are comparable only within an attribute; consequently, identical rankings for different attributes may represent slightly different levels of impairment or resource integrity. We used published metrics and established reference thresholds (e.g. Index of Biotic Integrity, National Ambient Air Quality Standards) to assign rankings whenever possible. But when no quantitative metric was found, we used non-quantitative information from the scientific literature and expert opinion. Whenever possible, we also assigned a trend to each condition ranking based on time series data or data sources from multiple time periods. We represented condition trends with a directional arrow within the condition circle. Arrow orientation indicated improving condition (arrow points up), stable condition (arrow points right), or deteriorating condition (down).

Data Quality

We assigned a data quality ranking to each attribute as an assessment tool for ranking reliability and to identify data gaps. This ranking is divided into three pass-fail categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al.'s (2008) NRCA report for Fort Pulaski National Monument (Table 3). The first category, thematic, refers to the adequacy of the data used to make the assessment, such as whether a certain water quality parameter is measured directly or inferred from a secondary variable. The spatial category assesses whether the data are spatially explicit, and inside the park unit. As in the ozone example, ozone concentration may be available from direct measurements (meeting the thematic requirement), but the monitoring station may not be inside the park boundary, therefore conditions at the park unit are inferred or interpolated. In such cases, the spatial requirement is not met. The third data quality category, temporal, is fulfilled if the data are five years old or less. To give an overall rank to the data quality, the number of requirements met are summed and translated into a good (3), fair (2), or poor (1) ranking and reported alongside the overall condition assessment (Table 4). Data that fulfill none of the three ranking categories are not used to assess vital sign conditions.

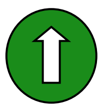
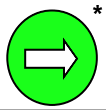
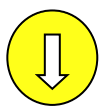
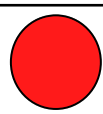
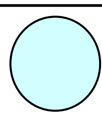
Because monitoring is relatively new for many aspects of natural resources in park units, several categories are missing criteria for data quality. However, as continued monitoring adds to the available data for future condition assessments, it is likely that these data quality rankings will improve. In addition, implementation and refinement of monitoring protocols for the various natural resource categories is still underway. Data collection methods will likely also change as monitoring needs are fine-tuned to specific metrics and aspects of vital signs at each park unit.

Table 3. Data quality ranking criteria.

Data Category	Criteria
Thematic	Are data adequate? Is data reliable for attribute?
Spatial	Are data spatially explicit?
Temporal	Are data 5 years old or less at time of writing?

3.2.3 Reporting Areas
Fort Donelson National Battlefield is located directly adjacent to the small town of Dover, TN, and with the exception of the National Cemetery and Battlefield areas, the park unit itself is mostly forested. Because FODO is such a small park unit, it is treated as a single reporting area. The park unit recently acquired Fort Heiman, located on the western side of the Tennessee River and disparate from the main battlefield. Four vegetation monitoring plots were established in 2011 at Fort Heiman, with four additional plots planned for 2012. However, because monitoring at Fort Heiman has just recently been initiated, this section of the overall park unit is not represented in our report.

Table 4. Example condition assessments. Attribute condition is as follows: dark green = excellent, light green = good, yellow = fair, red = poor, blue = no condition assigned. Condition trend is indicated by the arrow within the circle. Pointing up = improving condition, pointing right = stable condition, pointing down = declining/deteriorating condition, no arrow = no trend assigned. Checkmarks indicate whether data were appropriately thematic, spatial, or temporal for assessments, as described in the text. Colored bar indicates data quality score. Green = 3 of 3 possible checks, yellow = 2 of 3 possible checks, red = 1 of 3 possible checks. An “*” is used to caution the disparity of when condition receives a rank of good or higher and the data quality simultaneously receives a rank of poor of lower.

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

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Zimmerman, J. C. 2007. Seasonal variations in fish assemblages of small warmwater streams in four southeastern National Parks. Master of Science Thesis, University of Tennessee, Knoxville.

Chapter 4 Natural Resource Conditions

4.1 Air Quality

4.1.1 Ozone

Relevance and Context

As one of the recognized vital signs of the CUPN, air quality is a major consideration at FODO. Air quality is federally protected from degradation by the Clean Air Act (CAA) through a series of National Ambient Air Quality Standards (NAAQS), which are guidelines for certain airborne pollutants. Although there are six airborne pollutants for which NAAQS exist, a potential air quality issue at FODO is ozone and its associated potential for foliar injury. The CAA classifies park units into two air quality classes which determine the level of focus on air quality as a natural resource. Throughout the US, there are 49 park units classified as Class I, meaning they are large, high-priority areas that are held accountable for stringent air quality standards. The EPA's Regional Haze Rule also applies to Class I areas, which requires parks to carryout measures to reduce pollution that results in visibility impairment (EPA 2012). Most park units, including FODO, fall into Class II classification, which allows higher levels of pollutants before they are considered an issue. These more lenient standards are mainly intended to allow for some development. An even more lenient Class-III designation exists, though no park units are currently classified with this category (NPS 2012a).

Ozone is an atmospheric constituent produced from reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs). In humans, exposure to high concentrations of ozone may contribute to respiratory problems, inhibit lung capacity, and result in overall impairment of the immune system. High ozone concentrations are harmful to plants, and may inhibit natural plant communities as well as agricultural production (NPS 2012b).

Methods

The NAAQS set by the EPA include two thresholds for primary and secondary pollutant limits. For ozone, the NAAQS lowered primary and secondary standard concentrations on May 27, 2008 from 0.080 parts per million (ppm) to 0.075 ppm. As a result, a violation is incurred when the 3-year averages of the 4th highest daily maximum 8-hour average ozone concentration (4th Hi Max 8-hr) exceeds 0.075 ppm (Ray 2010).

Data

There are two Portable Ozone Monitoring Station (POMS) that rotates among park units in the CUPN on a six year basis. The most recent year of monitoring at FODO was 2009 (Figure 6), which from late May through mid-July (Jernigan et al. 2010). Data was also collected for three weeks during late summer 2005. Subsequent monitoring by the POMS will include the entire April – October ozone season (J. Jernigan pers. comm.).

Figure 5. The POMS at FODO collected ozone concentration measurements next to the visitors center in 2009. [Source: Jernigan et al. 2010]

NPS ARD and POMS

Of the two years of collection at the POMS in FODO, maximum 8-hr averages for 2005 and 2009 were respectively 0.061 ppm and 0.049. Respective 4th Hi max 8-hr ozone values were 0.058 ppm and 0.044 ppm. In addition, the NPS Air Resources Division (ARD) estimated 4th Hi Max 8-hr metrics based on national interpolation datasets over five-year periods. They were: 0.083 ppm (1999-2003), 0.077 ppm (2001-2005), 0.075 ppm (2003-2007), and 0.075 ppm (2005-2009). While these NPS ARD estimates appear to show a steady decrease in ozone concentrations since 1999, the latest estimate greatly exceeds both years of on-the-ground monitoring by the POMS at FODO. This may be partly due to the shorter monitoring period by the POMS.

Trigg County

Data is also available over the period 2006 to 2011 from a nearby monitor in Trigg County, KY, approximately 50 km to the north. Records for 4th Hi 8-hr Max metrics are relatively high over the period, whereas the 3-yr mean for 2008 (2006 – 2008) exceeds the EPA NAAQS. Means over the period 2009 – 2011 were barely under the NAAQS (Figure 7).

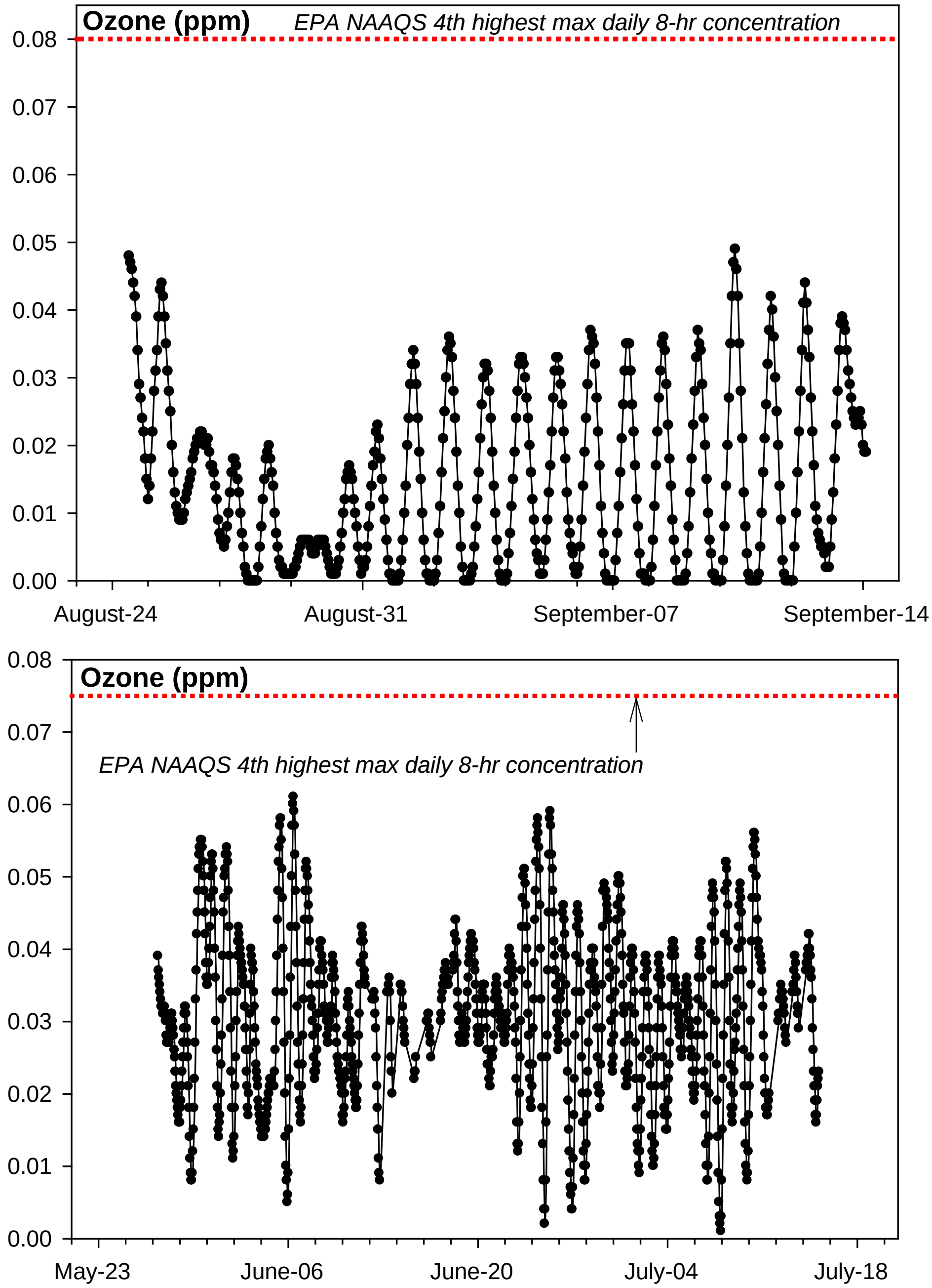

Figure 6. A Portable Ozone Monitoring Station (POMS) collected ozone concentration data at FODO during the summer of 2005 (top) and 2009 (bottom).

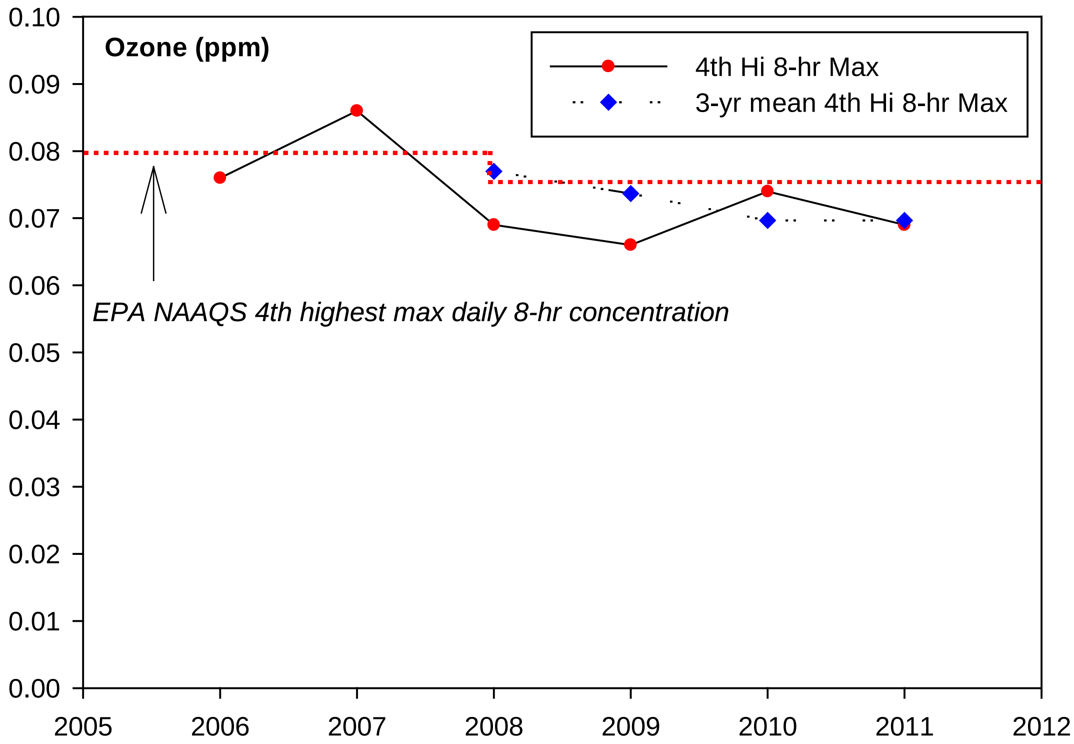

Figure 7. Ozone concentrations from Trigg County, KY were available over the period 2006 to 2011.

Condition and Trend

The consistency of low ozone concentrations observed at the POMS in 2005 and 2009 is encouraging. Estimates for the 4th Hi 8-hr Max at FODO by NPS ARD are higher than concentrations at the POMS, which is likely due to the short on-site monitoring period. Data from monitoring in Trigg County, KY corroborates the NPS ARD estimates, reporting elevated 4th Hi 8-hr Max metrics, and a 3-yr mean that exceeded the NAAQS in 2008, though not since then. All of this suggests that ozone concentrations at FODO may present somewhat of a concern and have implications for human health and vegetation at the park. For these reasons, the condition status for ozone at FODO receives a fair ranking. Linear regression reveals neither a significant increasing nor decreasing trend in annual measurements at Trigg County, and thus a stable trend is assigned (Table 5).

Due to budget constraints within the CUPN, monitoring at FODO with the POMS is limited to a six-year rotation. This sampling schedule may miss certain patterns that cause ozone fluctuations on a multi-year cycle, and thus more frequent sampling at the park would be ideal, especially given the high concentrations already observed (J. Jernigan pers. comm.).

Table 5. The condition status ranking for ozone concentration at FODO was fair with a stable trend. The data quality for this attribute was also good.

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

4.1.2 Foliar Injury

Relevance and Context
Ozone concentrations have been linked with deleterious growth and physiological effects in sensitive plant species (Ollinger et al. 1997, Lefohn and Runeckles 1987). In an assessment of overall foliar injury risk at nationwide park units, Kohut (2007) assigned FODO a high rating based on a model that accounts for vegetation type, ozone exposure rates, and environmental conditions.

Methods
The NPS ARD also developed foliar injury metric prediction maps to predict potential harm to vegetation across park units. The metrics assigned to FODO are not measurements, but are actually kriged predictions extracted from ozone models for the entire US. These metrics are available as yearly predictions from 1995-1999 from the 2004 foliar injury assessment report for the CUPN (Table 6).

Sum06
In order to describe potential foliar injury in park units, three biological indices with injury thresholds based on ozone concentrations were selected and applied to a representative group of ozone-susceptible plant species (NPS 2004a). The first metric, Sum06, is an index representing the cumulative sum of ozone concentrations ≥ 0.060 ppm between 8 AM and 8 PM over a moving 3-month period. The collection period usually occurs during the summer, when ozone concentrations are highest. The NPS ARD classifies 8 cumulative ppm-hours as the threshold for foliar injury, with the potential for growth reduction starting at 10 cumulative ppm-hrs (NPS 2004). At FODO, Sum06 prediction values averaged 17 cumulative ppm-hrs during the five-year prediction period, which is well past the threshold for foliar injury.

W126
The second index, W126, is a twofold description which includes the sum of hourly concentrations during the peak ozone season from April through October, and also considers the number of hours where the concentration was ≥ 0.010 ppm for the same period (LeFohn et al. 1997). For the hourly sum, this index weights the values using a sigmoidal function according to the equation:

$$W_i = \frac{1}{1 + M * e^{-(A*C_i)}} \qquad \text{(Eq. 1)}$$

where W_i is the weighing factor for concentration C_i in ppm, and M and A are constants representing 4403 and 126 ppm, respectively. The constant A represents the ozone concentration of maximum weighting, and lends itself to the naming of the index. By using this index, higher ozone concentrations are weighted disproportionately greater since they present more of a threat for foliar injury (LeFohn & Runeckles 1987). For W126, highly-sensitive species are affected beginning at 5.9 cumulative ppm-hrs, and moderately sensitive at 23.8 ppm-hrs. Predictions at FODO for this metric averaged 43.2 for 1995-1999, which places it between the threshold affecting moderately and marginally sensitive species (Table 5).

N100

The final index is an N-value that corresponds to the number of hours that exceed 0.060, 0.080, and 0.100 ppm. Although these thresholds are relatively arbitrary, ozone concentrations above 0.080 and 0.100 ppm are typically associated with risk for foliar injury (NPS 2004). Like the W126 metric, this one is also separated into three categories for N100 based on plant sensitivity: highly sensitive—6 cumulative hrs, moderate—51 cumulative hrs, and marginally—135 cumulative hrs. The average predicted N100 index during the five-year period was 19 cumulative hrs, which falls into the region affecting highly sensitive species only (Table 6).

In 2009, an on-the-ground foliar injury assessment was conducted at three sites in FODO, wherein 263 plants of 10 species were inspected for ozone damage (Figure 8, Jernigan et al. 2010). Only a single tulip-poplar (*Liriodendron tulipifera*) leaf was confirmed for ozone injury. Researchers expressed limitations with the assessment, however, indicating that none of the plants represented ideal specimens for foliar injury inspection, but instead the inspected areas were often shaded and possibly somewhat protected from ozone exposure (J. Jernigan pers. comm.).

Figure 8. Foliar injury assessment site adjacent to River Batteries. [Source: Jernigan et al. 2010]

It is also possible to predict the potential severity of foliar injury risk in the park unit based on the species composition in the park. The NPS and the US Fish and Wildlife Service (USFWS) developed a list of ozone sensitive plant species, defined as species that "exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar symptoms…have been documented." In addition, a subset of bioindicator species was developed, defined as a subset of sensitive species that best serve as indicators of ozone injury, due to easy identification of both the species and injury symptoms (Porter 2003). From that overall list, 24 sensitive and bioindicator species are recognized at FODO (Table 7).

Table 6. Set of foliar injury indices for FODO (NPS 2004a).

FODO Ozone Foliar Injury Indices					
	Sum06	W126	N60	N80	N100
	--ppm-hr--			--hrs--	
1995	12	39.3	710	106	9
1996	16	31.4	556	60	4
1997	16	32.6	581	83	8
1998	15	48.9	884	153	17
1999	25	63.7	1145	249	32
1995-1999 Mean	**17**	**43.2**	**775**	**130**	**14**

Sum06 (ppm-hr): 8-10 (low risk), 11-15 (mid risk), 16+ (high risk)
W126 (ppm-hr): 5.9-23.7 (low), 23.8-66.5 (mid), 66.6+ (high)
N100 (hr): 6-50 (low), 51-134 (mid), 135+ (high)

Table 7. Twenty-four species at FODO were identified as bioindicators of ozone based on ease of identification of both species and injury symptoms (Porter 2003). Species were crosswalked with NPSpecies for FODO (Jernigan et al. 2011).

Species		Family
Ailanthus altissima	Tree-of-heaven	Simaroubaceae
Apios americana	Groundnut	Fabaceae
Apocynum cannabinum	Indianhemp	Apocynaceae
Artemisia ludoviciana	Silver wormwood	Asteraceae
Asclepias incarnata	Swamp milkweed	Apocynaceae
Asclepias syriaca	Common milkweed	Apocynaceae
Cercis canadensis	Redbud	Fabaceae
Clematis virginiana	Woodbine	Ranunculaceae
Corylus americana	American hazelnut	Betulaceae
Eupatorium rugosum	Tulip-poplar	Asteraceae
Fraxinus americana	White ash	Oleaceae
Fraxinus pennsylvanica	Green ash	Oleaceae
Gaylussacia baccata	Black huckleberry	Ericaceae
Liquidambar styraciflua	Sweetgum	Hamamelidaceae
Liriodendron tulipifera	Tulip-poplar	Magnoliaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Pinus taeda	Loblolly pine	Pinaceae
Pinus virginiana	Virginia pine	Pinaceae
Platanus occidentalis	Sycamore	Platanaceae
Prunus serotina	Black cherry	Rosaceae
Rhus copallinum	Winged sumac	Anacardiaceae
Robinia pseudoacacia	Black locust	Fabaceae
Rubus cuneifolius	Sand blackberry	Rosaceae
Rudbeckia laciniata	Cutleaf coneflower	Asteraceae
Sambucus canadensis	American elder	Adoxaceae
Sassafras albidum	Sassafras	Lauraceae
Solidago altissima	Canada goldenrod	Asteraceae
Verbesina occidentalis	Yellow crownbeard	Asteraceae

Soil Moisture

In addition to these exposure indices, soil moisture conditions play a large role in mitigating or exacerbating the potential for foliar injury. During periods of higher soil moisture, injury risk is reduced as leaf stomates close, thus reducing ozone uptake (Kohut 2007). Often, foliar injury is reduced by weather conditions, because environmental conditions that facilitate the production of ozone such as a clear sky, high temperatures, and high UV levels also tend to reduce atmospheric gas exchange in plants, thus minimizing ozone uptake. The Palmer Z index (Palmer 1965) is essentially a short-term measure of drought and wetness. It attempts to describe soil moisture and its departure from long-term averages for a given month and location by assigning a number in the range -4.0 to +4.0 based on temperature, precipitation, and available soil water content, with -0.9 to +0.9 representing the typical range for soil moisture (NPS 2004; Wager, 2003). This method was used to calculate drought indices for the same time periods used to calculate both the Sum06 and W126 metrics (Table 8 and Table 9) from 1995-1999.

The 2004 foliar injury report for the CUPN points out that soil moisture levels appear to be inversely related to ozone concentrations. In 1999, for instance, when the highest Sum06 and W126 metrics were estimated for FODO, the highest number of drought months were observed, which would mitigate ozone exposure in vegetation. However, because months over the period 1995-1999 were generally wet, and metrics were all in the range to indicate foliar injury, it is likely that years with a predominance of wet months during the ozone season facilitated its uptake.

Table 8. Palmer Z indices for Sum06 at FODO (NPS ARD 2004).

Sum06	Month 1	Month 2	Month 3
1995	0.33	-2.06	-0.95
1996	0.49	3.03	-0.02
1997	-1.50	0.61	1.74
1998	3.31	-0.93	-2.50
1999	-1.23	-2.01	-1.97

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

Table 9. Palmer Z indices for W126 at FODO (NPS ARD 2004).

W126	A	M	J	J	A	S	O
1995	-0.25	2.39	0.98	0.14	0.59	0.96	2.81
1996	0.80	0.31	0.49	3.03	-0.02	4.20	1.09
1997	-0.80	1.51	4.61	-1.50	0.61	1.74	0.43
1998	3.42	0.15	5.86	3.31	-0.93	-2.50	-0.88
1999	-1.35	-0.35	1.61	-1.23	-2.01	-1.97	-0.87

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

Condition and Trend

Overall, the recent field survey at FODO provides the most up-to-date information on the potential for foliar injury. Despite the high risk rating for FODO by Kohut (2007) and the elevated injury metric estimates during the period 1995-1999, overall danger of injury at FODO appears low. Of 263 specimens inspected at the park unit, only a single leaf was confirmed for injury. In addition, drought maps showed normal moisture levels at FODO during the time of the assessment. The field assessment also coincided with the use of a POMS at the park unit, which also recorded very low ozone concentrations during the monitoring season (see section *Ozone*).

As a result of this recent assessment, foliar injury at FODO is assigned a good condition status ranking (Table 10). As currently planned, assessments will continue on a six-year rotation to coincide with POMS monitoring.

Table 10. The condition status for foliar injury at FODO was good, with no trend assigned. The data quality for this attribute was also good.

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

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4.2 Water Quality

4.2.1 Data

Quarterly water quality monitoring began at FODO in 2003 at five sampling stations: Indian Creek near Graves Battery (GBIC), the Indian Creek embayment (EMIC), the Hickman Creek embayment (EMHC), Hickman Spring (HSHS), and the Cumberland River (Lake Barkley, FDLB, Figure 9). Sampling is conducted every other year, with a summary report issued by CUPN during off years. Field measurements collected include temperature, specific conductance, pH, dissolved oxygen, and *Escherichia coli* concentration (Meiman 2009).

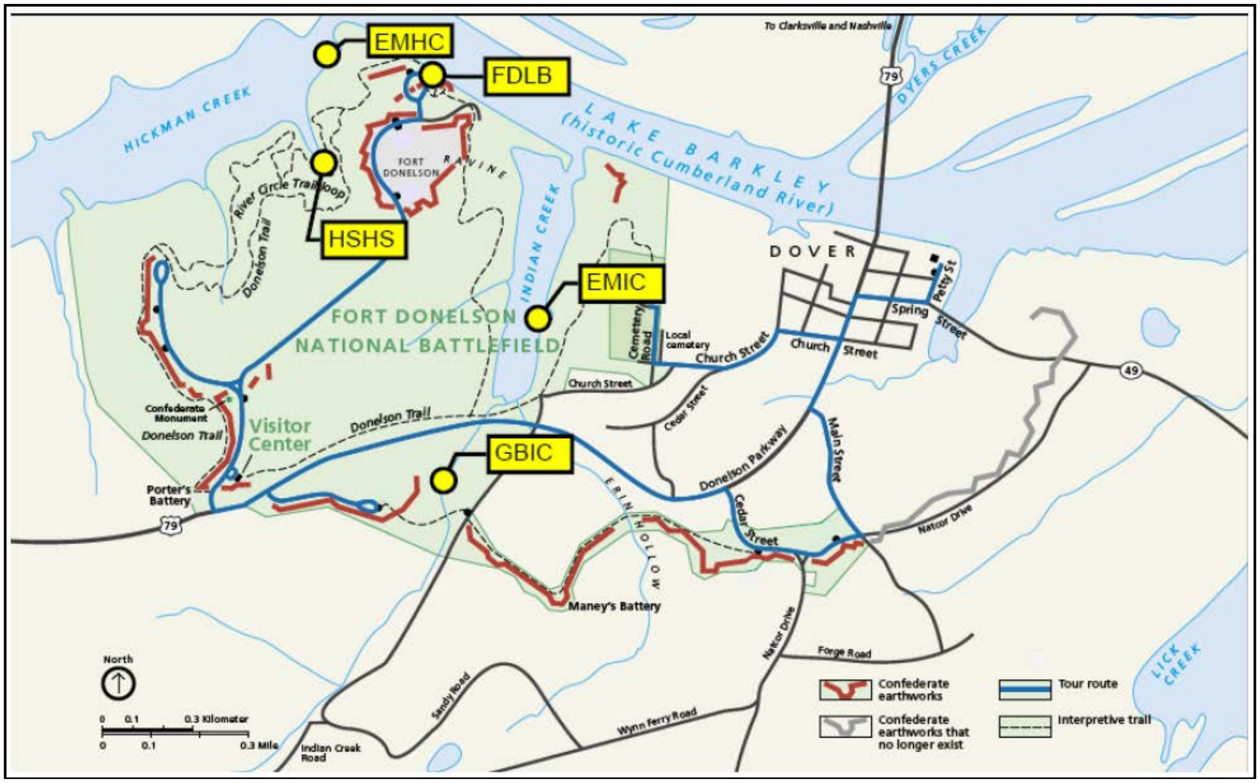

Figure 9. Location of five water quality sampling stations at FODO. [Source: Meiman 2009]

Although there are five sampling locations, only two, Indian Creek (GBIC) and Hickman Spring (HSHS), are located within the park boundary. Both of these stations flow into embayment bodies that connect to the Cumberland River. The other three stations are located within these large embayment bodies and the Cumberland River, respectively. Tennessee classifies waters into one or several use categories that dictate water quality criteria. Of the sampling stations at FODO, only the Cumberland River had official use classifications: 1) Fish and Aquatic Life (FAQ), 2) Industrial Water Supply (IWS), 3) Irrigation (IRR), 4) Livestock Watering and Wildlife (LWW), and 5) Recreation (REC). Streams without specific use classifications receive, by default, these same use classifications as the Cumberland River with the exception of IWS. Both embayment tributaries are also classified as exceptional state waters due to their location within FODO.

Figure 10. Water quality monitoring began at FODO in 2003. Samples are collected four times per year, every other year.

Table 11. Water quality criteria for TN use classifications (TDEC 2008).

Parameter	**Use Classification***				
	FAQ	IWS	IRR	LWW	REC
Acid Neutralizing Capacity (mg/L)	--	--	--	--	--
Dissolved Oxygen (mg/L)	≥ 5.0	--	--	--	--
Temperature (˚C)	30.5	30.5	--	--	30.5
Specific Conductance (µS/cm)	--	--	--	--	--
Escherichia coli (colonies/100mL)	2,880†	--	--	--	487/941§
pH (SU)	6.0/6.5–9.0‡	6.0–9.0	6.0-9.0	6.0–9.0	6.0-9.0

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

†For single samples

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

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

4.2.2 Parameters

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is measured *in situ* using a sensor that adjusts for temperature and is calibrated for atmospheric pressure at each site. The significance of this observation derives from its sensitivity to natural or anthropogenic alterations to the stream, as sensitive aquatic plants are one of the main sources of oxygen, along with aeration and mixing of atmospheric O_2. Concentrations of DO are also important to the survival of essentially all aquatic species (Palmer et al. 1997). Several sources of runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (EPA, 1997).

Dissolved oxygen measurements (mg/L) at FODO showed that all stations at FODO dropped below the 5.0 mg/L fish and aquatic life criterion at some point during the warmer summer months, while the Hickman Spring (HSHS) embayment station fell below this threshold more often—roughly one-third of the time (Figure 11).

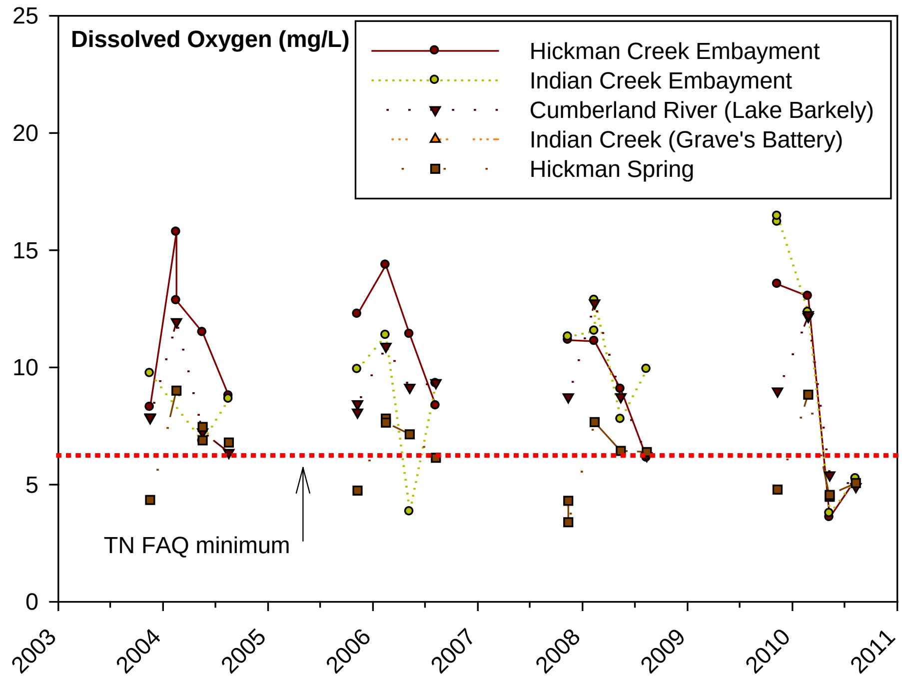

Figure 11. Dissolved oxygen measurements at FODO for four monitoring periods since 2003.

<u>Temperature</u>
Tennessee specifies a limit of 30.5˚C for fish and aquatic life, industrial water supply, and recreation waters. Summer samples exceeded the TN limit at both embayment stations on a single date in 2010, and twice in 2008 and 2010 on the Cumberland River. Sampling station means ranged from 16 – 18 ˚C.

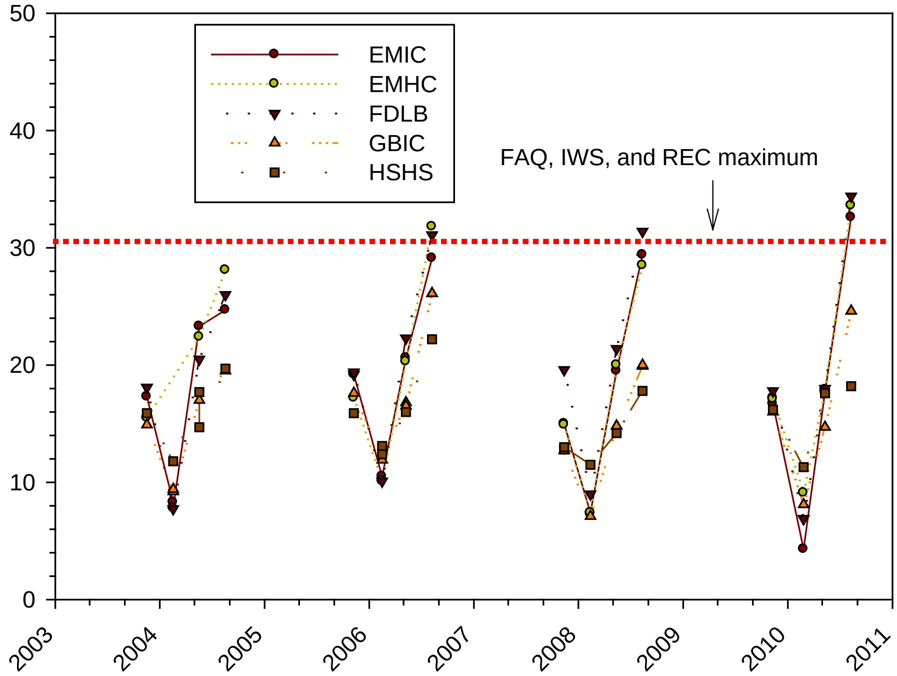

Figure 12. Temperature at FODO for four monitoring periods since 2003.

Microorganisms

Coliform bacteria are a group of bacteria that live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated viruses and pathogens. Total coliform counts themselves, however, do not necessarily represent a health risk. Fecal coliform are a subset of total coliform bacteria that exist only in warm-blooded organisms, and may often originate in streams via wildlife feces. Fecal coliform was measured at FODO during the first sampling period, but ultimately deemed unreliable as an indicator of bacterial contamination. For the second and subsequent sampling periods, *Escherichia coli*, part of the fecal group of bacteria, was collected instead.

In Tennessee, waters classified as fish and aquatic life are limited to 2,880 colonies per 100 mL, whereas lakes and reservoirs classified as recreational waters are limited to 487 colonies per 100mL for a single sample. This latter limit applies to both embayment stations and the Cumberland River. A single elevated measurement was observed on the Cumberland River in 2010 (Figure 13). At the Indian Creek embayment, including two samples that exceeded device detection limits, samples exceeded the state limit on three separate occasions during the last two sampling periods (TDEC 2008). Meiman (2009) indicates that one of the 2008 spikes was the result of post-rainfall sampling.

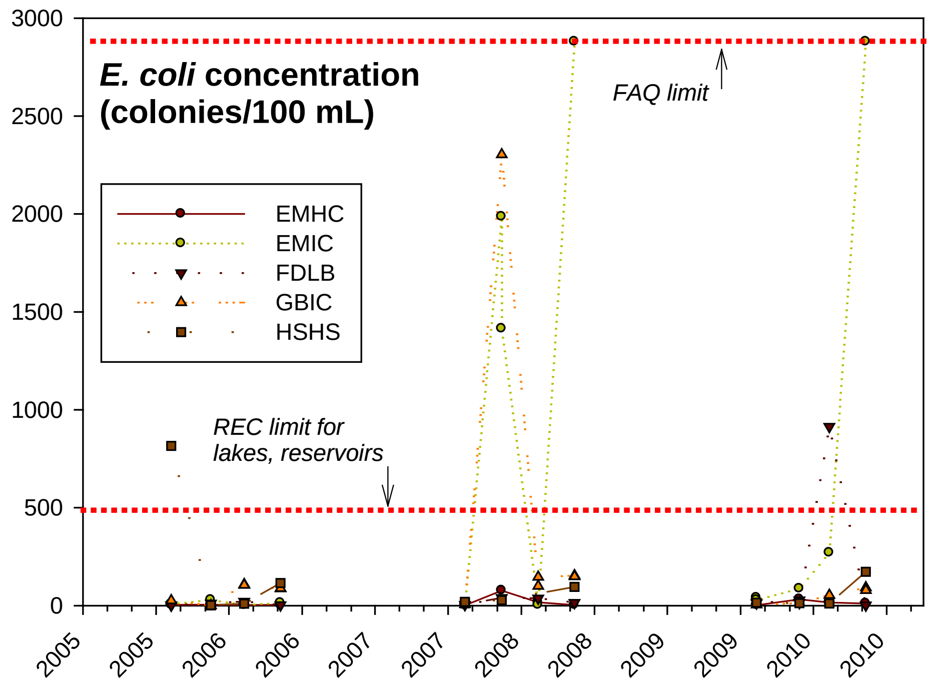

Figure 13. *E. coli* concentrations at FODO for four monitoring periods since 2003. Elevated samples reaching the FAQ limit at EMIC were beyond the device detection limit and are displayed at the FAQ limit.

<u>pH</u>

Measurement of pH is an important water quality attribute, because it affects almost all biological processes in aquatic systems. Low pH is toxic to many aquatic species and also may increase the mobility and uptake of toxicants (EPA 1997). Tennessee requires pH measurements between 6 and 9 standard units for all uses at FODO, with the exception of freshwater and aquatic life, which has a higher minimum of 6.5 in lakes, reservoirs, large rivers, and wetlands (TDEC 2008). With the exception of a sample on the Cumberland River in 2009, all samples were within state standards (Figure 14).

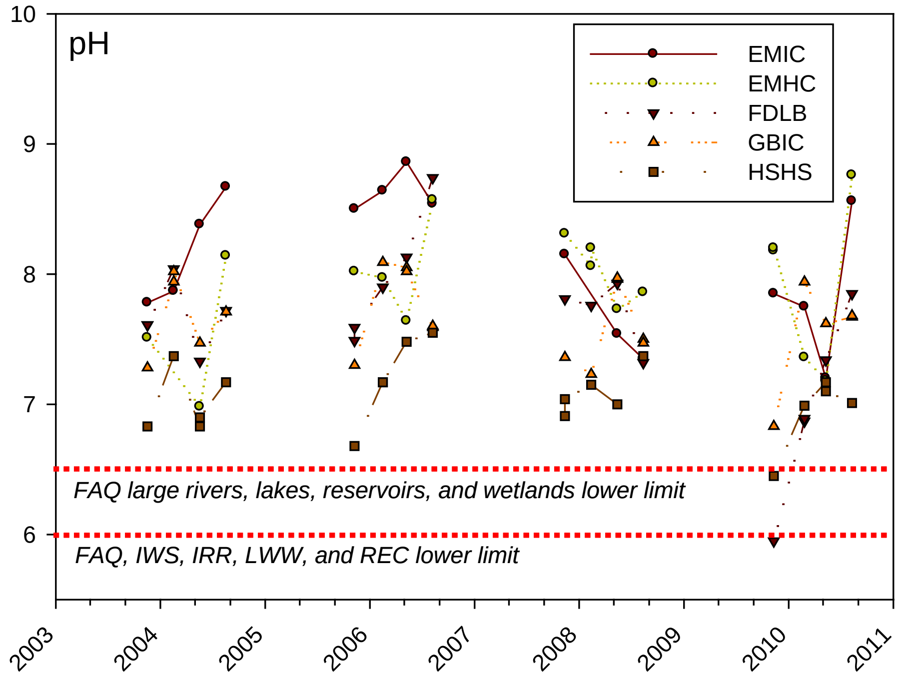

Figure 14. pH at FODO for four monitoring periods since 2003.

Specific conductance

Specific conductance gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Conductance is measured as the reciprocal of resistance and expressed in micro-Siemens/cm (µS/cm). Although no state standard exists for this parameter, the EPA (1997) sampling methods manual identifies an ideal range of 150 to 500 µS/cm for "inland fresh waters…supporting good mixed fisheries," and furthermore suggests that "conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates."

Samples at FODO fell within the EPA recommended range. Meiman (2009) points out that markedly low samples during February 2008 were due to a recent rainfall that resulted in diluted dissolved solids.

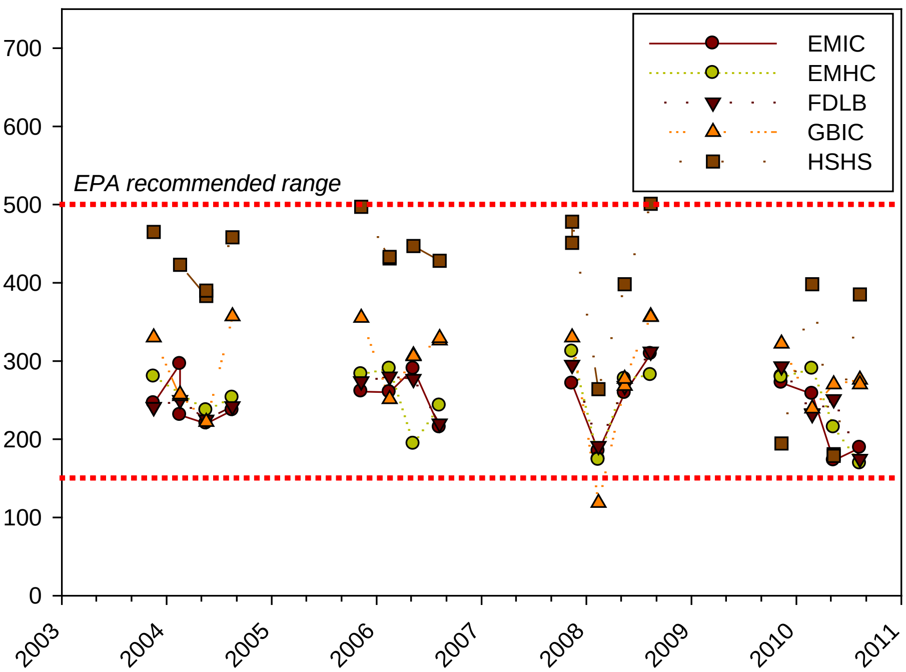

Figure 15. Specific conductance measurements at FODO for four monitoring periods since 2003.

4.2.3. Condition and Trend

During the first round of water quality monitoring at FODO, several additional laboratory measurements were taken other than just the core ones presented here. Most of these samples were cations that showed low concentrations and poor reproducibility. As a result, Meiman (2005) recommended discontinued monitoring of these analytes.

Meiman (2009), based on three monitoring periods of observations, suggested that overall water quality at FODO is in good condition, though he noted that DO measurements fell below state standards during each year of monitoring, which was also true for the latest round of monitoring. Samples falling below the state standard were mostly at Hickman Spring, though all stations showed low concentrations during the final two observations. Meiman (2009) considers the low concentrations at Hickman Spring to be the result of natural conditions. Concentrations of *E. coli* were also elevated at the Indian Creek embayment during the last two sampling periods, which Meiman (2009) attributes to rainfall events.

We agree with the assessment of Meiman (2009) that the general water quality status at FODO is good (Table 12). No trends are apparent in the data, and continued monitoring by CUPN will ensure the detection of any emerging water quality issues.

Table 12. The condition status for water quality at FODO is good, with no trend assigned. The data quality for this attribute is also good.

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

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4.3 Exotic Plants

4.3.1 Relevance and Context

Exotic species can impact functioning of native ecosystems at small to very large scales (Vitousek et al. 1997). In the case of exotic plants, these impacts may result from any number of factors resulting from invasion, including altered nutrient cycling, allelopathy, or changes in hydrology or fire regime (Levine et al. 2003).

4.3.2 Data and Methods

White (2005), who completed the most recent vascular plant inventory at FODO in 2002-2003, describes exotic species at FODO as "probably the biggest single threat to the overall ecological health of the park at this point in time." Of the 665 species confirmed at the park at the time of the survey, White (2005) reported that 16% (109 species) were exotic. Exotics were recorded in at least one-third of the vegetation plots at FODO. Of the 109 species, 27 are considered aggressively invasive according to the TN and KY Exotic Pest Plants Councils (Table 13). These particular species have the ability to outcompete and replace native species, and as a result represent the greatest management concern. Many of the remaining non-native species, White (2005) points out, are escaped plantings from past introductions.

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics to native species and ecosystems, called the I-rank. The overall I-rank consists of 20 questions that cover four main subranks: ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty. To offer a further quantitative assessment of the aggressively invasive species present at FODO, each I-rank has been recalculated excluding consideration of current distribution and abundance, which considers the overall distribution of the species at large rather than just within the park unit. These rankings are shown in Table 14 and are expressed on a scale of zero to three, with three representing the greatest threat to park resources. Following this approach, five of the 16 species resulted in an I-Rank in the highest category (>2.00): cheatgrass (*Bromus tectorum*), Japanese honeysuckle (*Lonicera japonica*), bicolor lespedeza (*Lespedeza bicolor*), autumn olive (*Elaeagnus umbellata*), and Japanese knotweed (*Polygonum cuspidatum*). Thirteen species were categorized between one and two, and three species were ranked below one at a minimal risk. The other six species did not have I-Ranks available. White (2005) also specifies nine species whose removal would be the most beneficial to ecological processes at the park: Chinese privet (*Ligustrum sinense*), autumn olive (*Elaeagnus umbellata*), Japanese stiltgrass (*Microstegium vimineum*), English ivy (*Hedera helix*), Johnsongrass (*Sorghum halepense*), jointgrass (*Arthraxon hispidus*), bicolor lespedeza (*Lespedeza bicolor*), sericea lespedeza (*Lespedeza cuneata*), and multiflora rose (*Rosa multiflora*). It is important to note that these I-ranks represent the average invasibility for a species over its range; abundance and threat at FODO may dictate management prioritization differently than using the I-ranks alone. Cheatgrass, for example, may not necessarily represent a prime target for control at FODO, as it represents less of a threat in the eastern US. Sweet autumn clematis, though not given an I-rank, also represents an emerging threat at FODO and may necessitate additional management attention (R. White pers. comm.)

Table 13. I-Ranks shown for 27 species of especially aggressive exotics observed in NatureServe plots at FODO.

Species	Common Name	Family	I-Rank*	State Exotic Pest Plant Council Ranking TN	State Exotic Pest Plant Council Ranking KY	Habitat
Bromus tectorum	Cheatgrass	Poaceae	2.50	Severe Threat	--	Old field
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae	2.33	Severe Threat	Severe Threat	Forest interior
Lespedeza bicolor[†]	Bicolor lespedeza	Fabaceae	2.17	Severe Threat	Significant Threat	Old field
Elaeagnus umbellata[†]	Autumn olive	Elaeagnaceae	2.17	Severe Threat	Severe Threat	Forest interior
Polygonum cuspidatum	Japanese knotweed	Polygonaceae	2.17	Severe Threat	Severe Threat	Riparian
Lespedeza cuneata[†]	Sericea lespedeza	Fabaceae	2.00	Severe Threat	Severe Threat	Old field
Microstegium vimineum[†]	Japanese stiltgrass	Poaceae	2.00	Severe Threat	Severe Threat	Floodplain
Hedera helix[†]	English ivy	Araliaceae	2.00	Lesser Threat	Significant Threat	Forest gaps/ edges
Sorghum halepense[†]	Johnsongrass	Poaceae	1.83	Severe Threat	Severe Threat	Old field
Albizia julibrissin	Mimosa	Fabaceae	1.67	Severe Threat	Significant Threat	Forest gaps/ edges
Carduus nutans	Musk thistle	Asteraceae	1.67	Significant Threat	Severe Threat	Old field
Ligustrum sinense[†]	Chinese privet	Oleaceae	1.67	Severe Threat	Severe Threat	Forest interior, floodplain
Euonymus fortunei	Climbing euonymus	Celastraceae	1.67	Lesser Threat	Severe Threat	Forest interior
Verbascum thapsus	Common mullein	Scrophulariaceae	1.50	Significant Threat	--	Old field
Arthraxon hispidus[†]	Jointgrass	Poaceae	1.50	Significant Threat	--	Floodplain
Paulownia tomentosa	Princesstree	Bignoniaceae	1.33	Severe Threat	Severe Threat	Forest gaps/ edges
Rosa multiflora[†]	Multiflora rose	Rosaceae	1.17	Severe Threat	Severe Threat	Floodplain
Euonymus alatus	Burning bush	Celastraceae	1.17	Lesser Threat	Severe Threat	Forest interior
Bromus commutatus	Hairy brome	Poaceae	1.00	--	--	Old field
Vinca minor	Common periwinkle	Apocynaceae	1.00	Significant Threat	Significant Threat	Forest interior
Daucus carota	Queen Anne's Lace	Apiaceae	0.33	Alert	Significant Threat	Old field
Coronilla varia	Crown vetch	Fabaceae	Not Ranked	Alert	Severe Threat	Old field
Bromus japonicus	Japanese brome	Poaceae	Not Ranked	Alert	--	Old field
Eleusine indica	Goose grass	Poaceae	Not Ranked	--	Significant Threat	Old field
Setaria faberi	Giant foxtail	Poaceae	Not Ranked	Significant Threat	Significant Threat	Old field
Setaria viridis	Green bristles grass	Poaceae	Not Ranked	Significant Threat	Significant Threat	Old field
Clematis terniflora	Sweet autumn clematis	Ranunculaceae	Not Ranked	Lesser Threat	--	Forest gaps/ edges

* I-Rank is calculated as a mean of ecological impact, trend in distribution and abundance, and general management difficulty, each of which is assigned a value of 1 to 3 (Morse et al., 2003). Each category is assigned a number based on its categorical rating, the average of which is the overall I-Rank: low (0-0.99), medium (1-1.99), or high (2+). Ranks do not reflect overall abundance within the park unit.

†Species identified by White (2005) whose removal would be the most beneficial to ecological processes at the park

4.3.3 Condition and Trend

Overall, it is clear that exotics pose a threat to native vegetation communities at FODO. White (2005) provides three main recommendations regarding exotics: 1) forested wetland areas are in greatest need of protection from invasives, 2) natural communities with high species diversity represent ideal candidates for protection from exotic invasion, and 3) old field areas would also benefit from reintroduction of native grasses and forbs. The four natural communities identified by White (2005) include the Central Interior Beech – White Oak Forest (CEGL7881), White Oak – Mixed Oak Dry – Mesic Alkaline Forest (CEGL2070), Central Interior Upland Cherrybark Oak Forest (CEGL3871), and Sycamore – Silver Maple Calcareous Floodplain Forest (CEGL7334), shown in Figure 16. White (2005) mentions that the most globally rare community type is the Cherrybark Oak Forest, though it is particularly common at FODO. Overall, he suggests that these communities take priority for preservation and protection from exotics, except in cases where sensitive species may be present in exotic-dominated vegetation types.

Because of the high number of exotics at FODO included on the TN and KY Exotic Pest Plant Council lists, in addition to the high number of plots with exotics present, the condition status for exotic plants at FODO is ranked fair, with insufficient information to qualify a trend (Table 14).

Table 14. The condition status for exotic plants at FODO is fair, with no trend assigned. The data quality is good.

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

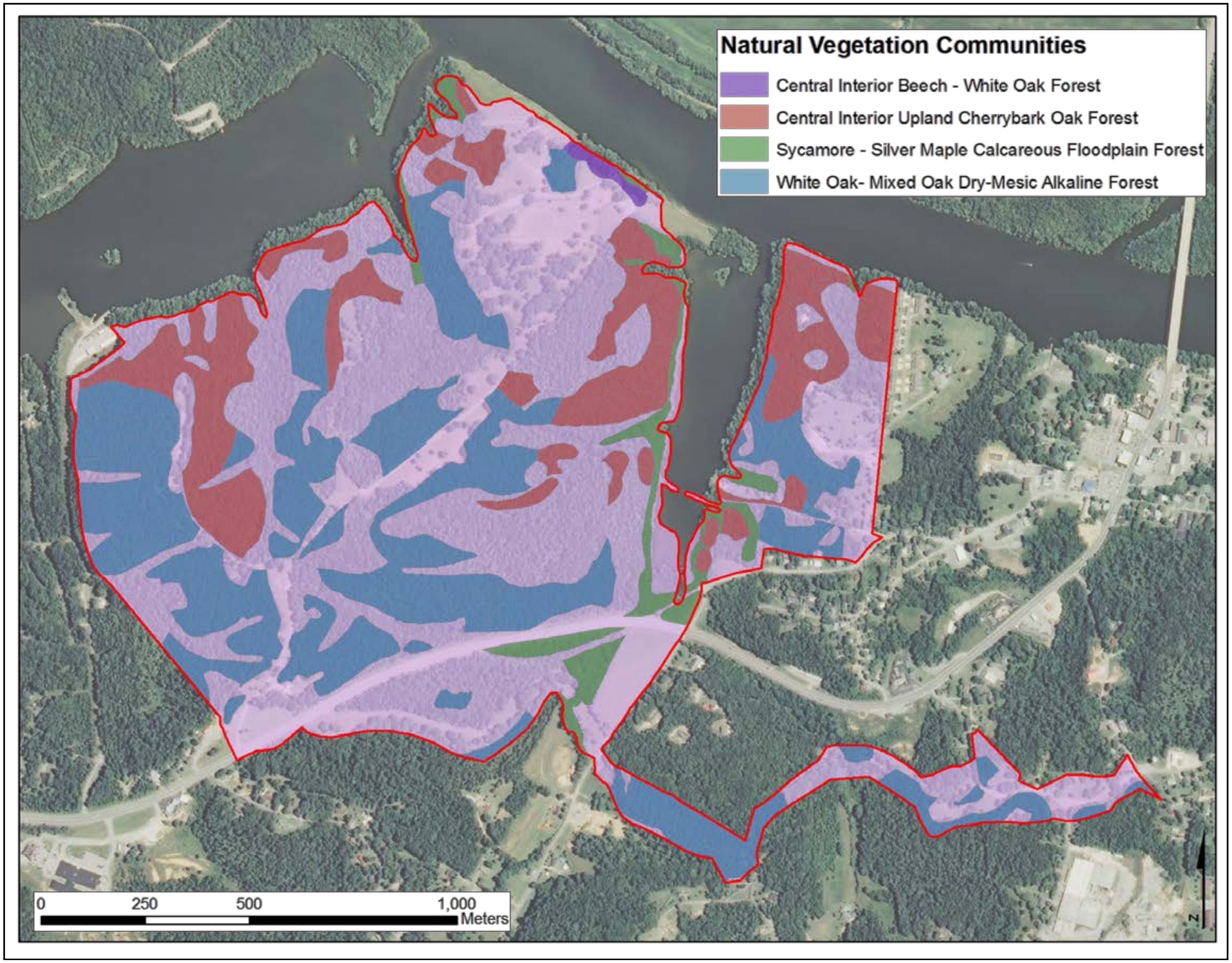

Figure 16. There are four “natural” communities at FODO as defined by White (2005), which comprise 97 ha, or roughly half of the Fort Donelson unit.

4.3.4 Literature Cited

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4.4 Vegetation Communities

4.4.1 Resource Knowledge

<u>Wetland Communities</u>
Wetlands contain a unique vegetation composition, and in turn provide habitat for a distinctive set of animal species. At FODO, Roberts and Morgan (2006) identified 2 small wetland areas totaling approximately 81 m^2—one in the northwest section along the battlefield trail and one in the southeast corner near French’s Battery. Based on the Cowardin et al. (1979) system, Roberts and Morgan (2006) classified one wetland as seasonally flooded, palustrine, and scrub-shrub with persistent vegetation (PSS1C), and the other as an emergent, palustrine, and temporarily flooded wetland with persistent vegetation (PEM1A). Roberts and Morgan (2006) indicated both wetlands were likely the result of human activity. The wetland near French’s battery appeared to be in an excavated depression, while the other formed behind Civil War earthworks that partially blocked drainage flow. According to Roberts and Morgan (2006), this latter wetland also has a hydroperiod long enough to support amphibian reproduction.

<u>Forest Communities</u>

Classification and Accuracy
NatureServe collaborated with the Center for Remote Sensing and Mapping Science (CRMS) at the University of Georgia to map the vegetation communities at FODO, in accordance with the national standards outlined by the Federal Geographic Data Committee (Figure 17, FGDC 2008). Using leaf-on aerial color infrared photos taken in fall 2002 by US Forest Service Air Photographics, the CRMS classified 13 vegetation associations at FODO that included 284 delineated polygons (Figure 18). Of the community types, four were considered natural vegetation types (Figure 16) and nine successional or exotic-dominated communities (Jordan and Madden 2008).

NatureServe performed an accuracy assessment of the vegetation map created by the CRMS using 112 assessment plot points (Figure 19), which resulted in an overall accuracy of 46% when considering only the dominant vegetation types, and 64% when matching dominant, secondary, or tertiary classifications (Summer and Nordman 2009). As a result, three class combinations were recommended to boost the accuracy:

a. Cultivated meadows (CEGL004048) and Successional Broom-sedge Vegetation (CEGL004044)
b. White Oak – Mixed Oak Dry-Mesic Alkaline Forest (CEGL002070) and Central Interior Upland Cherrybark Oak Forest (CEGL003871)
c. Successional Sweetgum Floodplain Forest (CEGL007330) and Sycamore-Silver Maple Calcareous Floodplain Forest (CEGL007334)

Using this combination, confusion between classes was minimized and overall accuracy was boosted to 80% for all three classification levels.

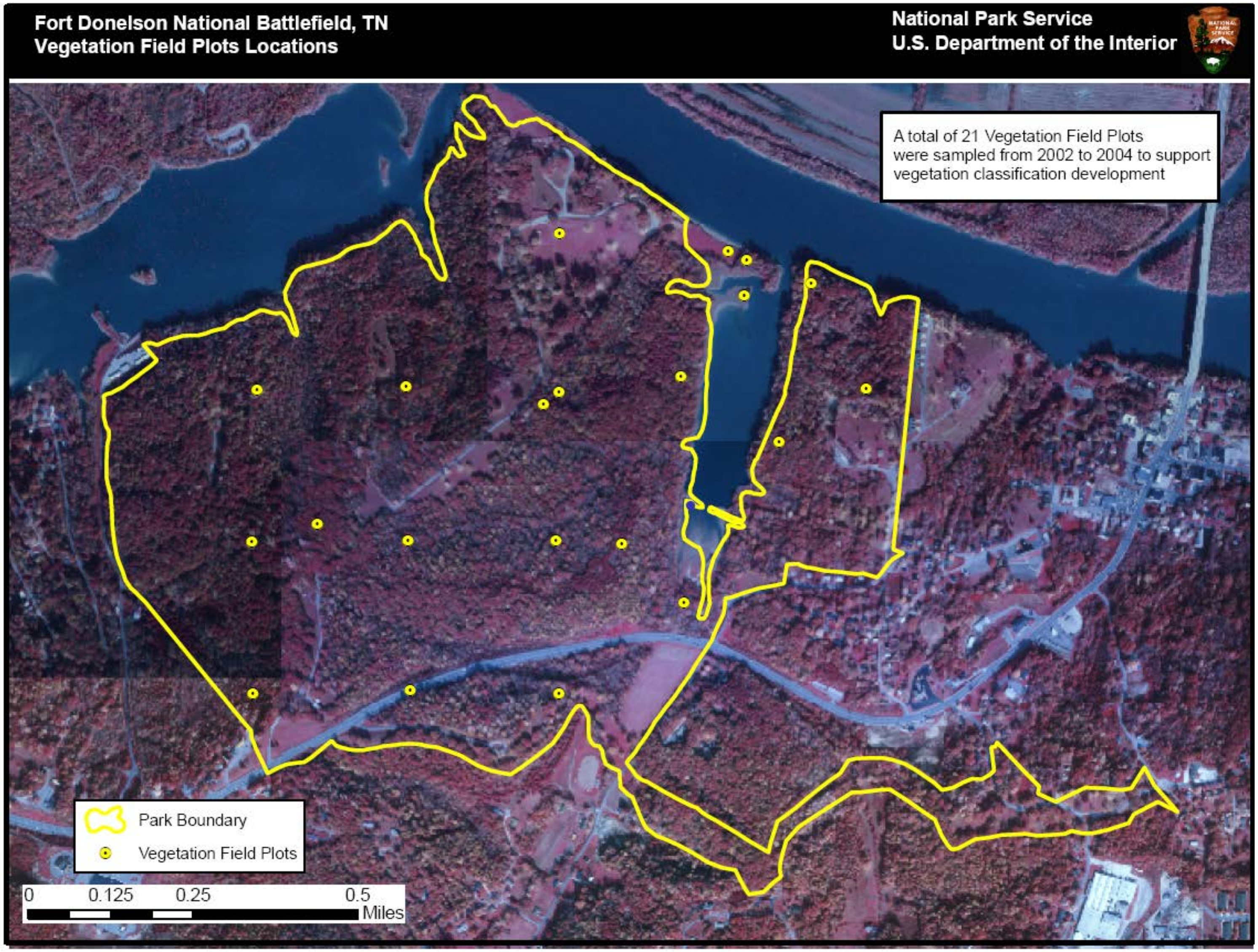

Figure 17. During field work from 2002-2004, a total of 21 vegetation classification plots were established and inventoried by NatureServe (White 2005).

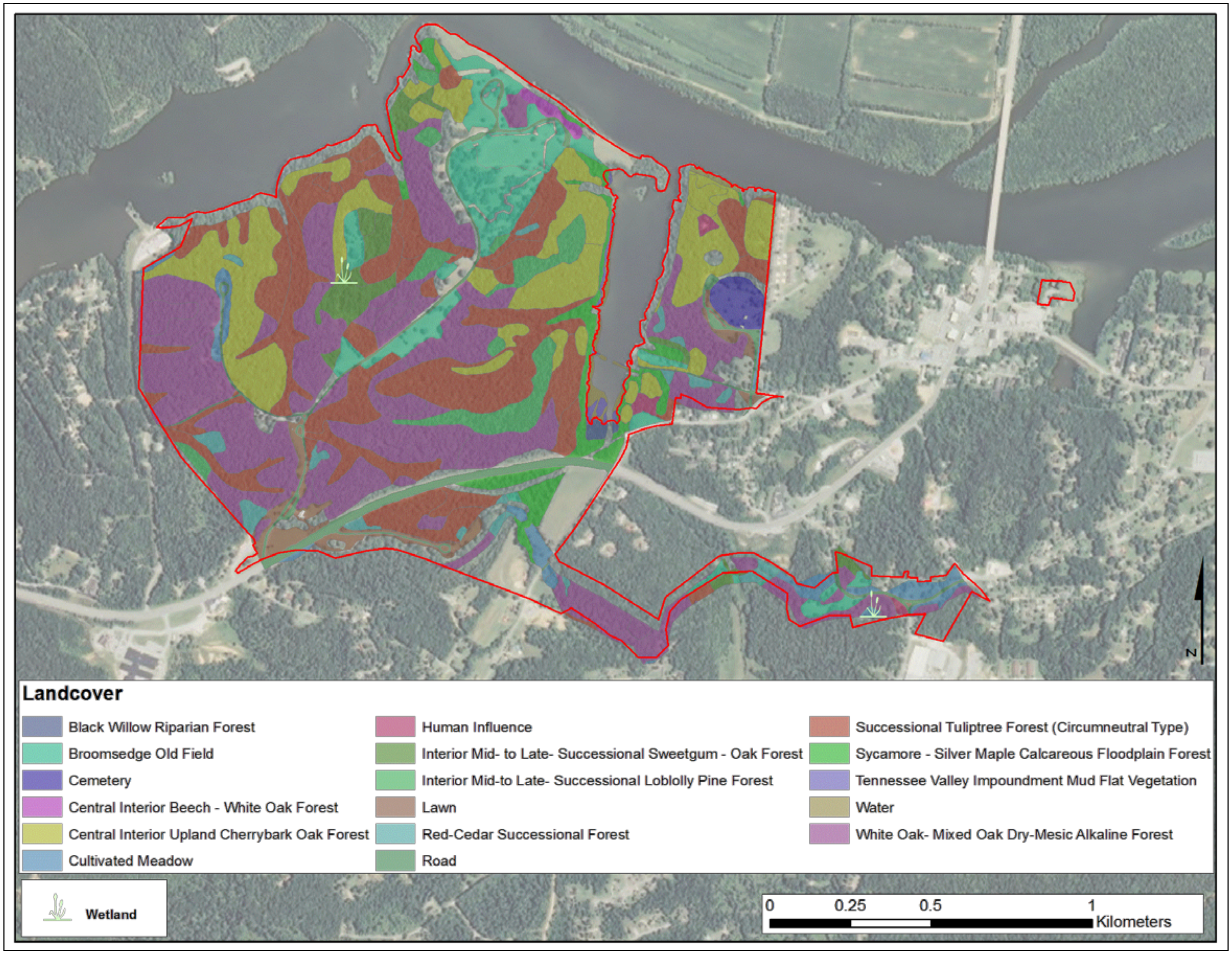

Figure 18. Vegetation classification for FODO created by the Center for Remote Sensing and Mapping Science (CRMS) at UGA. Also shown are wetland sites delineated by Roberts and Morgan (2006).

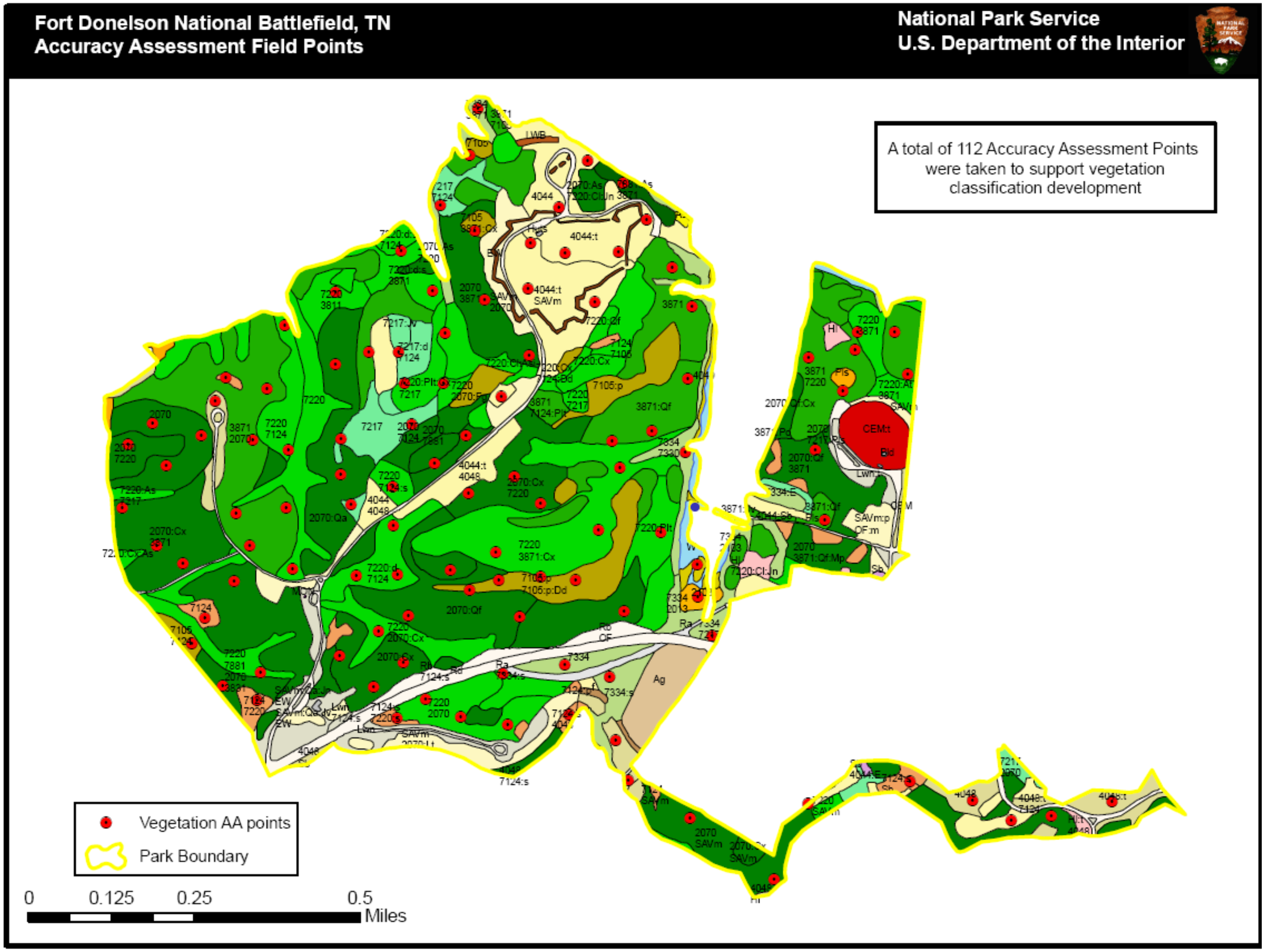

Figure 19. Summer and Nordman (2009) performed an accuracy assessment on the original vegetation classification map by CRMS at UGA.

Significant Communities

Although no particularly rare vegetation associations were mapped at FODO by the CRMS classification, White (2005) mentions that the Cherrybark Oak / Eastern Hophornbeam Forest, a fairly common vegetation type throughout the park unit comprising 31 ha, is relatively uncommon throughout its range.

4.4.2 Condition and Trend

Overall, the vegetation at FODO is typical of what may be found in the general region. As mentioned earlier, the floodplain forested areas are in the greatest need of protection from invasive plant species, in part due to the high diversity present in these community types. Due to the overall intactness of forest communities throughout the park unit, this attribute receives a condition status ranking of good (Table 15)

Table 15. The condition status for vegetation communities at FODO is good, with no trend assigned. The data quality for this attribute is also good.

Attribute	Condition & Trend	Data Quality: Thematic	Spatial	Temporal
Vegetation Communities	● (good)	✓	✓	✓
		3 of 3: Good		

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4.5 Rare Plants

4.5.1 Resource Knowledge

<u>Price's Potato Bean</u>

Several rare plant species are present throughout FODO (Table 16), though the most significant of these is Price's potato-bean (*Apios priceana*), which in addition to having a state rank of imperiled (S2), is federally-listed as threatened (Figure 20). This species depends on slightly disturbed areas for habitat, and is currently threatened by habitat loss and alteration. It prefers mesic areas and may be found along river and stream banks (Shea 1993). Remaining populations of this species are considered to number only four in Tennessee. At FODO, the most recent survey for Price's potato bean was conducted in 2010 by the TN Natural Heritage Program. The survey documented 16 stems and an overall stable population at a single location at a forest edge along the boundary of the park unit. Chinese yam (*Dioscorea oppositifolia*), however, appeared to be an escalating concern at the site (A. Bishop pers. comm.). In Trigg County, KY, which borders FODO to the north, specific identified threats to the species include trampling, mowing, succession, and competition from crown vetch. Plants can grow in open forest to woodland habitats, or even along roadsides and right-of-ways (NatureServe 2011). As a result, populations at FODO would likely benefit from forest thinning and prescribed burning to maintain open canopy and eliminate competition, especially near their current location.

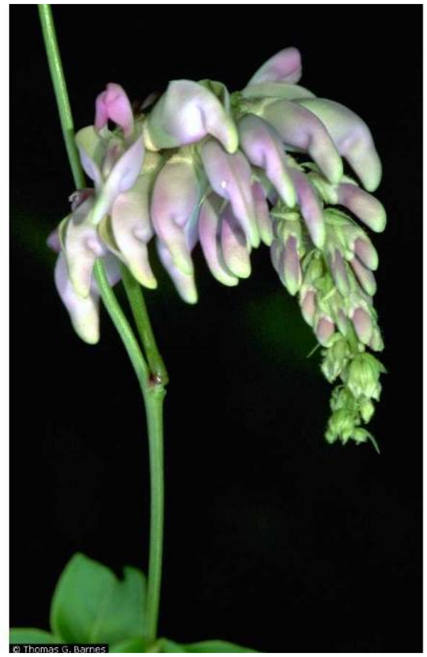

Figure 20. Price's potato bean, a federally threatened species found at FODO. [Source: Thomas G. Barnes, USDA-NRCS PLANTS Database]

<u>Purple Milkweed</u>

The only species with the highest state conservation ranking of critically imperiled (S1), purple milkweed (*Asclepias purpurascens)* does not have the same strict habitat requirements as Price's potato bean (Figure 21). This species may occur in open fields, forest edges, or thickets, and also adapts to either wet or dry conditions. The state rank has much to do with its limited distribution throughout its southern range—globally, it is ranked as G5? (Secure/ Uncertain). As a result, populations of this species at FODO do not necessarily weigh highly in terms of its

Figure 21. Purple milkweed is state-listed as critically-imperiled (S1). [Source: Thomas G. Barnes, USDA-NRCS PLANTS Database]

overall survival, but may instead be most valuable as a source of genetic diversity (R. White pers. comm.). The range of this species is considerable—from the eastern US to the prairie states (NatureServe 2012). Any occurrence of this species at FODO would likely persist with limited management attention.

Barbed Rattlesnake-root

Barbed rattlesnake-root (*Prenanthes barbata*) occurs throughout the south, where it is assigned state conservation ranks of imperiled (S2) or critically imperiled (S1) rangewide except in Oklahoma. In the eastern part of its range, which includes Tennessee, its main habitat includes open areas, barrens, and right-of-ways. One of the main threats to this species in Tennessee is herbicide application on roadsides and in right-of-ways. Declines of this species are expected to increase over time due to habitat alteration (NatureServe 2012).

Southern Nodding Trillium

Southern nodding trillium (*Trillium rugelii*) is state-listed as endangered and ranked as imperiled (S2). This species was located in a single NatureServe survey plot at FODO during the inventory in 2002 (White 2005). Southern nodding trillium grows in mesic forest areas, and is threatened throughout its range mainly by trampling, collecting, silvicultural disturbance, and general habitat loss. At FODO, any populations located close to trails could be threatened by trampling or collecting. Forest exotics such as honeysuckle and English ivy could also threaten this species (NatureServe 2012).

Table 16. Sensitive plant species present at FODO.

Species		**State Rank**	**Additional Comments**
Price's Potato-bean	*Apios priceana*	S2; E	Federally-listed as Threatened; declining throughout range
Purple Milkweed	*Asclepias purpurascens*	S1; S	--
Goldenseal	*Hydrastis canadensis*	S3; S	Declining throughout range
Michigan Lily	*Lilium michiganense*	S3; T	--
American Ginseng	*Panax quinquefolius*	S3; S	G3; TN Special Concern due to exploitation; declining throughout range
Giant Solomon's-seal	*Polygonatum biflorum var. commutatum*	S2	--
Barbed Rattlesnake-root	*Prenanthes barbata*	S2; S	G3
Northern White Cedar*	*Thuja occidentalis*	S3; S	TN Special Concern
Southern Nodding Trillium	*Trillium rugelii*	S2; E	G3

*Species likely planted (R. White, pers. comm.)

4.5.2 Condition and Trend

Overall, much additional survey work is needed to inventory and monitor the status of these rare plants at FODO. Of the species listed in Table 16, only the southern nodding trillium was identified in vegetation monitoring plots during the most recent plant inventory by White (2005), whereas Price’s potato bean is monitored by the TN Natural Heritage Program. The remaining species were confirmed in the park by previous botanical efforts (NPSpecies 2010), but their status may have changed since they were last observed, necessitating targeted monitoring. Although threats to rare species are generally minimized at FODO due to protection within the

park unit, certain species such as American ginseng, southern nodding trillium, and goldenseal are still vulnerable to exploitation.
While it is likely that rare species at FODO will continue to be protected from development, their future is still uncertain, mainly due to the lack of a targeted management plan. Price's potato bean in particular may be lost from the park unit because of its growth in highly disturbed areas. As a result, the status for all rare plants receives a condition ranking of fair. A stable trend is assigned based on the TN Natural Heritage Program assessment of the population at FODO, though the persistence of this species at FODO appears especially precarious (Table 17).

Data quality for this attribute receives three checks, mainly due to the recent surveys conducted by the TN Natural Heritage Program (Table 17). Work for the most recent floral inventory by White (2005) took place in 2002-2004, eight years ago at the time of this writing, though most sensitive species have not been documented since prior surveys as early as 1986. Changes in the status or presence altogether of these populations are therefore highly likely, necessitating periodic updates via field observations.

Table 17. The condition status for rare plants at FODO is fair with a stable trend. The data quality for this attribute is good.

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

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4.6 Forest Pests and Pathogens

4.6.1 Resource Knowledge

Southern Pine Beetle

Because such a large portion of FODO is forested, this park unit is susceptible to infestation by forest pests that can defoliate and kill stands. One of the main forest insect pests in the southeast is the native southern pine beetle (*Dendroctonus frontalis*), which causes tree mortality at a rate higher than any other forest pest. Typical stand infestations may last 3-4 years (Fettig et al. 2007). Southern pine beetle outbreaks have been linked in part to areas experiencing altered fire regimes, modified species composition, and nonnative introduction (Strom et al. 2002, Fettig et al. 2007). Although White (2005) reported no evidence of southern pine beetle during the vegetation inventory and community assessment, some of the successional loblolly community present at FODO may be susceptible to infestation. This community type only occupies a small area (8 ha) of the park.

Gypsy Moth

Another potential forest insect pest in the southeastern US is gypsy moth (*Lymantria dispar*), which was introduced from Europe to the east coast of the US in the late 19th century, and has subsequently been shown to affect tree health through infestation and defoliation (Schultz and Baldwin 1982, Elkinton and Liebhold 1990).

The Forest Health and Monitoring division of the US Forest Service has annual reports for gypsy moth traps on federal lands throughout the southeast during the period 2002 – 2011. At FODO, eight traps were monitored from 2002 to 2008, three traps during 2009 to 2010, and 11 traps in 2011. No gypsy moth captures were recorded for any year at any trap. The closest confirmed capture to FODO was at Nolin River Lake in KY, approximately 170 km to the northeast. Gypsy moth likely represents a future threat to forests at FODO, but is not currently affecting the park or the nearby surrounding region.

Dogwood Anthracnose

Dogwood anthracnose (*Discula destructiva*) is a fungal disease that infects flowering dogwood (*Cornus florida*). Originally detected in the northeast, the disease has spread to the south and has been reported in some western states, where it infects Pacific dogwood (*Cornus nuttallii*). Contributing factors include cold and wet spring and fall weather, and over time the disease may kill the tree. Symptoms include necrotic leaf blotches and retained dead leaves in the fall. Eventually symptoms may spread to the twigs and main trunk, where cankers and split bark may result. Watering individual trees during periods of drought may help prevent infection, as well as avoiding mechanical injuries which can leave the tree more susceptible. Fungicides may also be effective after infection (Mielke and Daughtrey 2012).

Figure 22. Leaf blotches from Dogwood anthracnose. [Source: USFS]

During the vegetation inventory by White (2005), two of the plots showed evidence of dogwood anthracnose. One plot occurred in the Successional Tuliptree Forest Type on the east side of

Indian Creek, while the other occurred in the interior of the Cherrybark Oak Forest Type near the Donelson Trail.

4.6.2 Condition and Trend

Fortunately, none of the forest pests and pathogens mentioned in this section except dogwood anthracnose have been confirmed at FODO. Pine stands that could potentially host a southern pine beetle infestation are relatively few, and gypsy moth monitoring by the US Forest Service has resulted in no documented cases of the pest at FODO or within the vicinity. A recent incidence of oak mortality at the park implicates a fungal blight such as sudden oak death or oak wilt, though again, neither of these diseases has been confirmed. Dogwood anthracnose is also present in the park. Despite this, the condition status for forest pests and pathogens at FODO receives a condition status ranking of good. The data quality is also good, because it includes recent and in-park monitoring for gypsy moth, though specific tests to confirm the presence of sudden oak death or oak wilt would be beneficial.

Table 18. The condition status for forest pests and pathogens at FODO is good, with no trend assigned. The data quality is also good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Forest Pests & Pathogens	Good (green circle)	✓	✓	✓
		3 of 3: Good		

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4.7 Fish Assemblages

4.7.1 Relevance and Context

The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000), and contains multiple drainages with faunal assemblages noted for high species richness and endemism (Sheldon 1988). The Cumberland River is notable for its high number of endemic aquatic species. The watershed below Cumberland Falls (located in southeastern KY), in which FODO is located, contains a rich assemblage of native fishes, and the Tennessee River, into which the Cumberland flows, has one of the richest fish assemblages among North American drainages (Sheldon 1988). FODO is bordered by an impounded reach of the Cumberland River on the north, and an impoundment-influenced section of Hickman Creek on the north-west. However, the sphere of management influence that FODO exerts on these aquatic habitats is negligible. The park does not possess a significant amount of fish habitat within its boundaries. Streams within FODO include a small spring-fed stream, Indian Creek, and two small tributary branches (Figure 23). Much of the watershed of Indian Creek lies to the south and upstream of park boundaries (Figure 23).

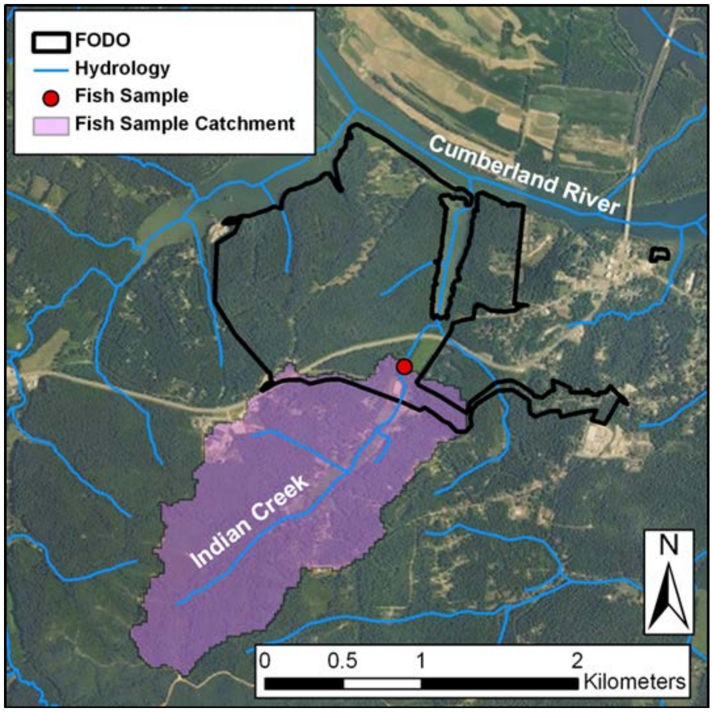

Figure 23. Streams, fish sampling location, and sample catchment area of a fish survey conducted at Fort Donelson National Battlefield 2005-2006 (Zimmerman 2007).

4.7.2 Resource Knowledge

A survey of park fishes was conducted by Zimmerman (2007) as part of a larger effort sampling four southeastern National Parks. Three seasonal samples were collected from a 100-meter reach of Indian Creek during the summer and fall of 2005 and the spring of 2006 (Zimmerman 2007). Fish were sampled with a single upstream pass with a backpack electroshocking unit (Zimmerman 2007). Zimmerman (2007) reported that Indian Creek was "intermittent" and subject to partial drying during the summer/fall depending on weather, although the stream was flowing during all the samples he collected. From three samples, Zimmerman (2007) reported 344 individuals of 11 species from five families from Indian Creek (Table 19). Eight or nine species were found during each seasonal sampling event. No state or federally listed threatened or endangered species were reported from FODO. A single species, the redbreast sunfish (*Lepomis auritus*), is not believed to be native to the Cumberland drainage (Warren et al. 2000), though it is native elsewhere in the Tennessee drainage. We considered it a non-native species in this report.

Table 19. Family, species, and season of occurrence of fish species sampled in FODO during a 2005-2006 survey (Zimmerman 2007).

Scientific Name	Common Name	Sum.	Aut.	Spr.
Family: Centrarchidae				
*Lepomis auritus**	redbreast sunfish	X	X	X
Lepomis cyanellus	green sunfish	X		X
Micropterus salmoides	largemouth bass		X	
Family: Cyprinidae				
Campostoma oligolepis	largescale stoneroller	X	X	X
Rhinichthys obtusus	western blacknose dace	X	X	X
Semotilus atromaculatus	creek chub	X	X	X
Family: Ictaluridae				
Ameiurus natalis	yellow bullhead	X		X
Family: Percidae				
Etheostoma caeruleum	rainbow darter	X	X	X
Etheostoma crossopterum	fringed darter	X	X	X
Etheostoma flavum	saffron darter		X	
Family: Poeciliidae				
Gambusia affinis	mosquitofish		X	

* Non-native to Cumberland drainage

4.7.3 Threats and Stressors
General threats to southern fishes include competition from invasive species, and habitat alteration resulting from human population increases, deforestation, and impoundment (Warren et al. 2000). Because FODO is located on an artificially impounded section of the Cumberland River, and because it is largely surrounded by urban development, fish assemblages in the park are undoubtedly affected. However, changes to the fish assemblage of Indian Creek over a historical time period are unknown. Water quality parameters for the stream fall within established bounds for good quality (see Water Quality section), although sedimentation, one of the most important factors affecting fish persistence (Warren et al. 2000) has not been assessed. Because much of the watershed of Indian Creek lies outside park boundaries, the greatest threat to fishes in the stream may result from development and inputs largely outside of park control.

4.7.4 Data
We used the data on numbers and species of fishes collected by Zimmerman (2007) for all analyses of FODO fish assemblages.

4.7.5 Methods
We used several methods to assess FODO fish assemblages. We summarized and reported species richness and relative abundance by season. We reported the Shannon-Weaver Index of Diversity (H') calculated for each seasonal sample by Zimmerman (2007). We also used an Index of biotic integrity (IBI, Karr 1981). Fish-based IBIs evaluate freshwater aquatic resources based upon relative density, diversity, and ecological attributes of sampled species (Karr 1981). Quality rankings are developed by analyzing assemblages from sites with known and independently-assessed levels of anthropogenic disturbance (Karr 1981). Generally, good

conditions are indicated when communities contain a wide diversity of trophic specialists, and relatively high proportions of specialists and sensitive species. We used the Kentucky Index of Biotic Integrity (KIBI) which was developed for use in Kentucky's wadeable and headwater streams, including the streams of the Cumberland River drainage (Compton et al. 2003). Although, the KIBI was developed and tested within Kentucky, FODO is nearby in an adjacent state and within a drainage for which the index has been tested. Therefore, we believe the KIBI was robust for use in this area. Perhaps more importantly, the KIBI is recommended for use in assessing samples with upstream catchments ranging between 5 - 777 km^2 (Compton et al. 2003). The catchment of the FODO Indian Creek sample (Figure 23) was 2.2 km^2. For calculating the IBI, we used the minimum recommended catchment area of 5 km^2. Therefore, our results may be conservative. The score ranges and narrative interpretation of the KIBI for the FODO region are given in Table 20.

Table 20. Ranges of values and narrative interpretations for possible scores of the Kentucky Index of Biotic Integrity (Pennyroyal Region) (Compton et al. 2003).

KIBI Score	Interpretation
≥67	Excellent
53-66	Good
35-52	Fair
17-34	Poor
0-16	Very Poor

4.7.6 Condition and Trend

Richness and species diversity were similar among the sampled seasons although total individuals captured varied by season (Table 21). The greatest number of individuals was captured in summer, and the fewest were captured in autumn (Table 21). The KIBI scores ranged from fair to good (Table 21). While the autumn 2005 sample, at 53, was within ±2 of the fair score interpretation (Table 20), as discussed above, these scores may be conservative due to the small size of the sample catchment. Generally, the few samples available from Indian Creek indicated a regionally-typical fauna, with at least one invasive species, that was similar to assemblages found in fair to good habitat in the lower Cumberland drainage in Kentucky.

Table 21. Summary of individuals, species richness, species diversity, KIBI score, and score interpretation for seasonal samples collected in Indian Creek in FODO 2005-2006 (Zimmerman 2007).

Measure	Sum. '05	Aut. '05	Spr. '06
Total Individuals	176	75	93
Species Richness	8	9	8
Species Diversity (H')	1.67	1.54	1.66
KIBI Score	61	53	50
KIBI Interpretation	Good	Good	Fair

We ranked the quality of FODO fish assemblages as good (Table 22). We emphasize that the available fish habitat within the park is limited to a single small stream, and that fish assemblages are a relatively minor component of FODO's natural resources. We also acknowledge several caveats to the interpretation of the IBI scores calculated using sampled fish assemblages in the park. Nonetheless, despite the limited nature of this resource, observations are consistent with a fish community in relatively good condition. We did not assign a trend to fish assemblage condition; a single baseline study is insufficient to establish a trend. The data used to make this assessment were fair. Samples were collected within the park using scientifically sound methods. Samples were collected with good seasonal coverage. Because samples were collected over five years ago, the data did not receive a temporal check.

Table 22. The FODO fish assemblage condition was good. No trend was assigned to fish assemblage condition. The data used to make the assessment were fair.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
Fish Assemblages	(green circle)	✓	✓	
		2 of 3: Fair		

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4.8 Bird Assemblages

4.8.1 Relevance and Context

Birds specialize in a variety of habitats and are relatively easy to monitor, making them valuable indicators of terrestrial ecosystem quality and function (Maurer 1993). Key species of eastern U.S. obligate forest birds have shown a steady decline in abundance for over 40 years, causing concern for managers (USGS 2009). Although FODO is a relatively small park, it is bordered on two sides by urban development and has potential to provide a habitat island for species that would not otherwise find suitable habitat in the area. The urban setting also increases the risk of predation by feral or free-ranging domestic pets. The interior low plateau physiographic region in which FODO is located supports a number of birds of conservation concern, several of which have been reported from the park.

4.8.2 Resource Knowledge

Stedman and Stedman (2005) conducted a comprehensive inventory of FODO birds during 2003-2005. Effort included breeding season point counts in all major park habitats, spring and fall walking transects, fall and early winter raptor surveys, night call-back surveys, and general surveys in likely habitat during all seasons (Stedman and Stedman 2005). Efforts began in the winter of 2003 so no breeding season point counts were conducted in 2003. Winter surveys were conducted in 2003, and not in 2005. These efforts found 175 species of birds in FODO. Stedman and Stedman (2005) reported that FODO had a “moderately large species list” for a park of its size, and that forest obligate species were relatively more abundant than early successional habitat species were.

Many reported species were water birds that occur in the park because of its location bordering a large body of water. Of the 175 species reported by Stedman and Stedman (2005), 29 were aquatic habitat obligates including ducks and geese, gulls and terns, and wading birds (Table 23). The Belted Kingfisher (*Ceryle alcyon*), Bald Eagle, and Osprey (*Pandion haliaetus*) are not included in Table 23, but are aquatic predators that nest in or near the park and are present because of the proximity of aquatic habitat. A pair of Bald Eagles has nested in the park for multiple years and is an attraction to park visitors. The Prothonotary Warbler (*Protonotaria citrea*) was found breeding in FODO (Stedman and Stedman 2005). This species of moderate conservation concern nests near water (Petit 1999) and confirmed breeding presence suggests the park provides suitable riparian habitat for this species (Stedman and Stedman 2005).

Table 23. Water bird species reported from FODO during a 2003-2005 bird inventory (Stedman and Stedman 2005). Bold font indicates species for which possible, probable, or confirmed breeding evidence was noted for the park.

Scientific Name	Common Name	Scientific Name	Common Name
Family Anatidae		**Family Ardeidae**	
Aix sponsa	**Wood Duck**	*Ardea alba*	Great Egret
Anas americana	American Wigeon	***Ardea herodias***	**Great Blue Heron**
Anas clypeata	Northern Shoveler	***Butorides virescens***	**Green Heron**
Anas crecca	Green-winged Teal	*Egretta caerulea*	Little Blue Heron
Anas platyrhynchos	Mallard	***Nyctanassa violacea***	**Yellow-crowned Night-Heron**
Anas rubripes	American lack Duck	***Nycticorax nycticorax***	**Black-crowned Night-Heron**
Anas strepara	Gadwall	**Family Laridae**	
Aythya collaris	Ring-necked Duck	*Chlidonias niger*	Black Tern
Branta canadensis	**Canada Goose**	*Hydroprogne caspia*	Caspian Tern
Bucephala albeola	Bufflehead	*Larus argentatus*	Herring Gull
Chen caerulescens	Snow Goose	*Larus delawarensis*	Ring-billed Gull
Lophodytes cucullatus	Hooded Merganser	*Larus philadelphia*	Bonaparte's Gull
Oxyura jamaicensis	Ruddy Duck	*Sterna forsteri*	Forster's Tern
Family Charadriidae		**Family Phalacrocoracidae**	
Charadrius semipalmatus	Semipalmated Plover	*Phalacrocorax auritus*	Double-crested Cormorant
Family Gaviidae		**Family Scolopacidae**	
Gavia immer	Common Loon	*Actitis macularius*	Spotted Sandpiper

The breeding season point counts were the most standardized sampling method used by Stedman and Stedman (2005), and resulted in 63 species. Fewer species (45) were reported in 2004 than in 2005 (62). Fewer individuals (271) were reported in 2004 than in 2005 (446). Many of the species not reported in 2004 were raptors and water birds. The observed assemblages varied between years, although several of the most abundant species, including Carolina Wren (*Thryothorus ludovicianus*), Red-eyed Vireo (*Vireo olivaceus*), and Tufted Titmouse (*Baeolophus bicolor*), were among the most common species in both years (Table 24). One notable difference between years was the difference in Brown-headed Cowbird (*Molothrus ater*) sightings. In 2004, a single individual of this species was reported; in 2005, 18 individuals were reported from seven locations. A single Chipping Sparrow (*Spizella passerina*) was reported in 2004, and 15 were observed in 2005. Eleven Northern Parula (*Parula americana*) were found in 2004, and four were observed in 2005. There were slight differences in sample timing and in weather between the 2004 and 2005 point counts (Stedman and Stedman 2005). However, none of these differences were obvious explanations for the differences in observed assemblages between years.

Table 24. Ten most common species of birds (by relative abundance) observed during 2004 and 2005 point counts at FODO (Stedman and Stedman 2005). Shown are season relative abundance, the number of plots (of 15 possible) where species was reported, and the total seasonal number of individuals reported.

Scientific Name	**Common Name**	**Relative Abundance**	**Plots Seen**	**Inds Seen**
	2004			
Thryothorus ludovicianus	Carolina Wren	0.070	12	19
Vireo olivaceus	Red-eyed Vireo	0.070	15	19
Empidonax virescens	Acadian Flycatcher	0.063	9	17
Polioptila caerulea	Blue-gray Gnatcatcher	0.059	12	16
Baeolophus bicolor	Tufted Titmouse	0.055	12	15
Poecile carolinensis	Carolina Chickadee	0.052	11	14
Cardinalis cardinalis	Northern Cardinal	0.044	10	12
Melanerpes carolinus	Red-bellied Woodpecker	0.044	10	12
Parula americana	Northern Parula	0.041	9	11
Hylocichla mustelina	Wood Thrush	0.041	7	11
	2005			
Cardinalis cardinalis	Northern Cardinal	0.085	12	38
Thryothorus ludovicianus	Carolina Wren	0.067	13	30
Vireo olivaceus	Red-eyed Vireo	0.056	13	25
Baeolophus bicolor	Tufted Titmouse	0.052	12	23
Piranga rubra	Summer Tanager	0.047	12	21
Molothrus ater	Brown-headed Cowbird	0.040	7	18
Poecile carolinensis	Carolina Chickadee	0.036	10	16
Hylocichla mustelina	Wood Thrush	0.036	11	16
Spizella passerina	Chipping Sparrow	0.034	6	15
Cyanocitta cristata	Blue Jay	0.031	7	14

The park contained a number of birds of conservation concern (Table 25). No federally threatened or endangered species were reported from the park. Nine species listed by the state as endangered or "deemed in need of management" were found in FODO (Table 25). Five birds received the highest conservation priority rank of "4", based on a ranking system that employs Partners in Flight (PIF) regional conservation scores to indicate species that "are declining rapidly, have a small range, or high threats" (Nuttle et al. 1993, Panjabi et al. 2005, Table 25). Other species reported from FODO that have relatively high priority regional conservation concern include the Prairie Warbler (*Dendroica discolor*) and Worm-eating Warbler (*Helmitheros vermivorum*).

Table 25. Bird species of conservation concern reported from a 2003-2005 bird survey of FODO (Stedman and Stedman 2005). Table indicates whether the species were endangered (E), were deemed in need of management (D) in Tennessee, or had high conservation scores based on PIF regional ranks (Nuttle et al. 2003). From Stedman and Stedman 2005: * = confirmed to breed in park, ** = possibly breed in the park, WR = winter resident, TR = transient, SR = summer resident, VR = visitor, .

Scientific Name	Common Name	TN	PIF	Status
*Haliaeetus leucocephalus**	Bald Eagle	D		WR
Vermivora pinus	Blue-winged Warbler		X	TR
*Dendroica cerulea***	Cerulean Warbler	D	X	SR
Ardea alba	Great Egret	D		VR
Ammodramus savannarum	Grasshopper Sparrow		X	TR
Egretta caerulea	Little Blue Heron	D		VR
*Seiurus motacilla**	Louisiana Waterthrush		X	SR
Ictinia mississippiensis	Mississippi Kite	D		TR
Circus cyaneus	Northern Harrier	D		WR
Falco peregrinus	Peregrine Falcon	E		TR
Cistothorus platensis	Sedge Wren		X	VR
Accipiter striatus	Sharp-shinned Hawk	D		WR
Sphyrapicus varius	Yellow-bellied Sapsucker	D		WR

4.8.3 Threats and Stressors
North America forest birds face a number of general threats including land conversion, development, exotic species, forest pests, and poor land management (USGS 2009). FODO is relatively small, and is located within a largely urban environment with fragmented forested habitat. Birds nesting in fragmented habitat are subjected to high levels of nest parasitism and nest predation, relative to birds nesting in undisturbed forest habitats (Robinson et al. 1995). In such cases, even apparently diverse assemblages containing native species of concern could be population sinks at the meta-population level (Robinson et al. 1995). In urban and suburban environments, feral and free-roaming cats and dogs can pose a threat to nesting songbirds (Watson 2005). Invasive plants, especially those plants that change the vegetation structure of the forest such as shrubs, may have negative effects on FODO birds as well (Schmidt and Whelan 1999, Watson 2005).

4.8.4 Data
For our analyses, we used the data collected by Stedman and Stedman (2005). These data included raw data on individual point counts and summaries of all birds recorded by season during the course of the inventory.

4.8.5 Methods
We used an index of biotic integrity to evaluate FODO bird assemblages. Such indices were originally developed for use with fish data to evaluate the level of anthropogenic disturbance to aquatic habitat (Karr 1981). Similar approaches have been developed using sampled bird assemblages to assess the ecological integrity of terrestrial habitat (Bradford et al. 1998, Canterberry et al. 2000, O’Connell et al. 2000). O’Connell et al. (1998) developed a breeding Bird Community Index (BCI) for the region of the eastern U.S. including the Mid-Atlantic Highlands. The index was developed by analyzing forest bird assemblages and referencing them to independently measured levels of anthropogenic habitat disturbance. Higher scores result

when more disturbance-sensitive species and species with forest-specialist life history traits are present in a bird list relative to nest disrupting species, urban-tolerant species, and exotic species (O'Connell et al. 1998). The BCI was developed with data collected in the Mid-Atlantic Highlands, and is designed to be used for breeding birds in this region. However, the authors suggest that the tool has application to the Appalachians generally and that it can be adjusted for application in other regions (O'Connell et al. 1998; O'Connell et al. 2003). With the exception of the Prothonotary Warbler, all of the birds of the appropriate taxa found in FODO point counts were included on the BCI analysis bird list, indicating that they were found in the point counts used to develop the index. We added the Prothonotary Warbler to the BCI analysis list and assigned it attributes based on the literature (Petit 1999).

To apply the BCI, bird species are grouped into guilds based upon breeding season life history traits, and the relative proportions of species in each guild are used to create overall scores ranging from 20 (low integrity) to 77 (highest integrity, O'Connell et al. 1998). Table 26 provides the reference range for interpreting BCI scores.

Table 26. Reference range for interpreting scores from a Bird Condition Index for the Appalachian and Mid-Atlantic Highlands (O'Connell et al.1998).

Score Range	Interpretation
60.1 - 77.0	Highest Integrity
52.1 - 60.0	High Integrity
40.1 - 52.0	Medium Integrity
20.0 - 40.0	Low Integrity

When assessing quality, we also considered overall species richness and more qualitative factors. These included the comments of knowledgeable ornithologists working the park, the presence of species of concern, and the presence of nest-parasitic species.

4.8.6 Condition and Trend

Individual plot BCI scores for the two sample years indicated interpretations from "low integrity" to 'highest integrity" (Figure 24). The grand mean of the 30 individual BCI scores (15 each year) was 51.0 (SD±6.7) corresponding to an interpretation of medium integrity (Table 26). In 2004, nine plots had scores of high or highest integrity and six had scores of medium integrity (Figure 24). The mean BCI score for 2004 was 53.1 (SD±5.0), corresponding to an interpretation of high integrity. In 2005, five plots had scores of high integrity, nine had scores medium integrity, and one plot scored as low integrity (Figure 24). The mean BCI score for 2005 was 49.0, corresponding to an interpretation of medium integrity. High scores should represent areas with intact forest experiencing minimal anthropogenic disturbance. Most scores indicated some level of anthropogenic disturbance, as expected, though many scores indicated relatively high integrity habitat for forest birds.

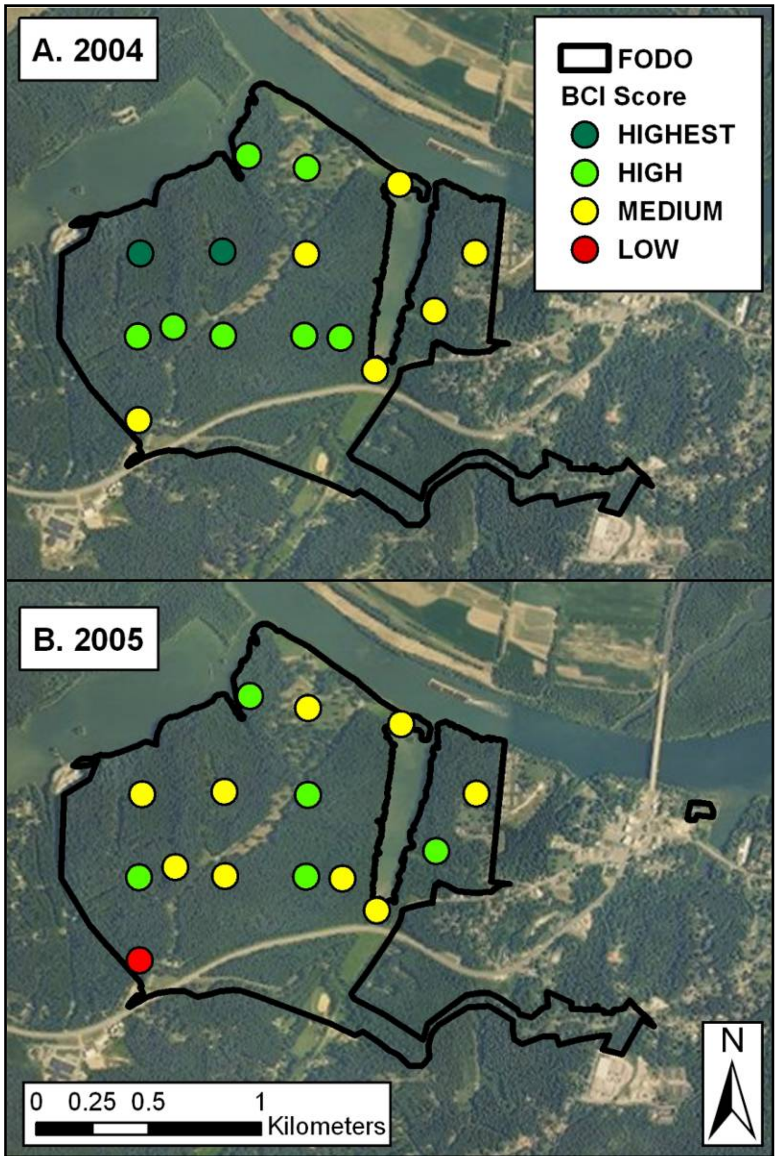

Figure 24. Bird point count locations and Bird Community Index (BCI) scores for individual counts in A. 2004, and B. 2005 taken during a bird inventory of FODO by Stedman and Stedman (2005).

The richness of the reported assemblage was high relative to park size and contained some species of conservation interest. Stedman and Stedman (2005) found bird richness higher than expected, commenting on the high number of raptors, the relatively dense population of breeding Prothonotary Warblers, and presence of Cerulean Warblers (*Dendroica cerulea*). Stedman and Stedman (2005) also stated that the numbers of some interior forest obligates seemed high given the park's small area. A significant portion of the overall bird richness of FODO was attributable to the high number of water bird species observed in the park. Although many of these species primarily use areas adjacent to the park as wintering or migratory stopover habitat, some species are likely to use park land as foraging or nesting habitat. An obvious example is the Bald Eagles that have nested annually in the park for several years, the Prothonotary Warblers that nest in tree cavities on park lands, and species such as Wood Ducks and several species of herons that may find suitable nesting habitat within FODO. The park also provides habitat to species identified by state agencies and PIF as species of conservation priority.

We ranked the condition of FODO bird assemblages as good (Table 27). A bird condition index indicated that bird habitat was not pristine, but showed low or moderate levels of anthropogenic disturbance, as expected for a park in this setting (Figure 24). The overall bird richness was high, and contained species of conservation concern. The data used to make the assessment was fair (Table 27). It was collected within the park using a variety of appropriate methods and provided good coverage of park area and habitats. Because the data were collected more than five years ago, the temporal category did not receive a check. The bird inventory by Stedman and Stedman (2005) had a primary goal of identifying as many species as possible. It also used a standardized method (i.e. breeding season point counts) to provide a repeatable baseline dataset which can be used for future monitoring. No trend was assigned to bird assemblage quality; a single baseline inventory is insufficient to establish trend.

Table 27. The condition of FODO bird assemblages was good. The quality of data used to make the assessment was fair. No trend was assigned to bird assemblage condition.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Bird Assemblages	(green circle)	✓	✓	
		2 of 3: Fair		

Assessment of bird assemblage quality might be better served by studies of breeding success, adult survivorship, or individual bird condition. However, such research is beyond the mandate of the I&M program under which the data were collected. Such results are achieved through expensive and time-consuming field research and it is unreasonable to expect such information to exist for most bird populations. In summary, we believe the data suggests that FODO represents an island of relatively good quality bird habitat and is of high conservation value to the region.

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4.9 Mammal Assemblages

4.9.1 Relevance and Context

Mammals are important components of grassland and forest ecosystems where they affect plant communities, engineer landscapes, and play roles at multiple trophic levels (Ryszkowski 1975, Marti et al. 1993, Rooney and Waller 2003). Because of great variation in size, behavior, and life history, they are inherently difficult to sample.

4.9.2 Resource Knowledge

Kennedy et al. (2007) conducted a comprehensive inventory of FODO mammals. They used Sherman live traps, unfenced pitfall traps, automatic cameras, baited track stations, mist netting, spotlight surveys, and incidental observations to report 188 individuals of 30 species from FODO (Kennedy et al. 2007, Table 28). One species, gray fox (*Urocyon cinereoargenteus*), was only reported from sightings by FODO personnel. Kennedy et al. (2007) sampled within established NatureServe plots, and within other likely habitats in the park. From the summer of 2004 through fall 2007 they conducted approximately 8,000 trap nights with Sherman live traps, 9,000 trap nights with pitfall traps, 80 nights with camera and scent stations, and 75 mist net nights (Kennedy et al. 2007). The five most commonly sampled mammals, across all methods, were the white-footed mouse (*Peromyscus leucopus*), white-tailed deer (*Odocoileus virginianus*), hispid cotton rat (*Sigmodon hispidus*), gray squirrel (*Sciurus carolinensis*), and raccoon (*Procyon lotor*). Combined, these species represented 63% of all individuals reported from the survey. One federal and state endangered species, the gray bat (*Myotis grisescens*), was reported from the park from two mist net captures. The southern bog lemming (*Synaptomys cooperi*), listed by Tennessee as “deemed in need of management”, was reported from a single capture in a Sherman live trap. Three non-native species were reported from FODO; they were: coyote (*Canis latrans*), domestic dog (*Canis familiaris*), and domestic cat (*Felis catus*).

Table 28. Mammal species reported from a 2004-2007 inventory at Fort Donelson National Battlefield (Kennedy et al. 2007).

Scientific Name	Common Name	Scientific Name	Common Name
Order Artiodactyla		**Order Insectivora**	
Odocoileus virginianus	White-tailed deer	*Blarina brevicauda*	Northern short-tailed shrew
Order Carnivora		*Cryptotis parva*	Least shrew
*Canis familiaris**	Domestic dog	*Scalopus aquaticus*	Eastern mole
*Canis latrans**	Coyote	**Order Lagomorpha**	
*Felis catus**	Feral cat	*Sylvilagus floridanus*	Eastern cottontail
Lynx rufus	Bobcat	**Order Rodentia**	
Mephitis mephitis	Striped skunk	*Castor canadensis*	Beaver
Procyon lotor	Raccoon	*Marmota monax*	Woodchuck
Urocyon cinereoargenteus	Gray Fox	*Microtus ochrogaster*	Prairie vole
Vulpes vulpes	Red Fox	*Microtus pinetorum*	Woodland vole
Lasiurus borealis	Eastern red bat	*Ondatra zibethicus*	Muskrat
Order Chiroptera		*Peromyscus gossypinus*	Cotton mouse
*Myotis grisescens***	Gray bat	*Peromyscus leucopus*	White-footed mouse
Myotis septentrionalis	Northern myotis	*Sciurus carolinensis*	Gray squirrel
Nycticeius humeralis	Evening bat	*Sigmodon hispidus*	Hispid cotton rat
Pipistrellus subflavus	Eastern pipistrelle	*Synaptomys cooperi*	Southern bog lemming†
Order Didelphimorphia		*Tamias striatus*	Eastern chipmunk
Didelphis virginiana	Virginia opossum		

* Non-native species
**Listed endangered: federal and Tennessee
†Listed “deemed in need of management”: Tennessee

Kennedy et al. (2007) prepared a list of mammalian species that could potentially occur within the park. This list was prepared using the literature and from the personal experience of the principal investigator, and included 56 species. Kennedy et al. (2007) divided these expected species into those highly likely to occur (33) and those less likely to occur (23). All species on the list had been reported from Stewart County or from western Tennessee, based upon published accounts or museum records (Kennedy 1991).

4.9.3 Threats and Stressors
Threats and stressors to native mammals generally include habitat fragmentation, habitat alteration, consumptive use, disease, and non-native species. Habitat fragmentation can cause loss of species and lowered abundance of some species (Andren 1994). Because FODO is located adjacent to an urban area, habitat fragmentation is likely to be one of the most important stressors limiting the mammal community of the park. Non-native species may pose threats to FODO mammals, although these effects are not well-understood. Feral or free-ranging cats and dogs were reported from the park and are expected based upon the presence of private residences on park borders. Feral cats are known to prey upon small mammals, and because of the relatively small forest patches in FODO, are expected to access most of the suitable mammal habitat of the park (Baker et al. 2005, Warner 1985). Coyotes have expanded into the southeastern U.S. in recent decades, often directly assisted by human transplantations (Hill et al. 1987), and occur in FODO (Kennedy et al. 2007). In their new ranges in the eastern U.S., coyotes are apex predators in areas where historic large predators such as wolves and cougars have been extirpated (Gompper 2002). Coyotes may exert a top-down control on deer and smaller carnivores (including feral domestic pets), with results that could be perceived as

ecologically beneficial in terms of small mammal populations and habitat quality (Gompper 2002). Conversely, with sufficiently dense populations, coyotes could directly depress small mammal populations (Gompper 2002).

White-nose syndrome (WNS) is a severe and emerging threat to hibernating bats throughout the eastern U.S. (Cyran 2011). This disease, caused by infection with the *Geomyces destructans* fungus (Lorch et al. 2011), was discovered in New York in 2006, and has spread rapidly westward including occurrences in Tennessee in 2010 and Kentucky in 2011 (Cryan 2011). The disease affects hibernating bats and may result in catastrophic declines of >75% in local hibernating populations (Blehert et al. 2009). Of the 13 species of bats listed by Kennedy et al. (2007) as potentially occurring in FODO, nine are hibernating species, and WNS has been confirmed in six of these species (Cryan 2011). Of the five bat species reported from FODO, four are species hibernating in caves, and WNS has been confirmed in two of these species. Species at risk from this disease include the endangered gray bat. Because FODO does not include any communal bat hibernacula, mitigating for the WNS threat in the park can probably only be accomplished by maintaining the best possible bat habitat for at- risk species that forage there.

4.9.4 Data
For our assessment we used the data collected by Kennedy et al. (2007). Data included information provided in the narrative of the report as well as data provided in tabular format in the report. We termed this data the analysis dataset.

4.9.5 Methods
We compared mammals reported in the analysis dataset to expected mammal lists prepared by Kennedy et al. (2007), and to lists reported from other studies in western and central Kentucky and Tennessee. The expected list prepared by Kennedy et al. (2007) was divided into mammals believed highly likely to occur and less likely to occur. Because the species less likely to occur had all been reported in Stewart County or in western Tennessee (Kennedy 1991) we used the entire expected list as our baseline. We removed non-native species from both the expected list and from the list of occurring species. We compared observed FODO mammal richness to that observed in mammal inventory data from Big South Fork National River and Recreation Area (Britzke 2007), Mammoth Cave National Park (Thomas 2012), and the Milan Army Ammunition Plant in western Tennessee (Hopkins and Kennedy 2004). We compared the richness of shrews and native rats, mice, and voles among these locations. We chose these groups because they are the most commonly captured small mammals using trapping techniques common among the compared studies. We plotted species richness against natural log transformed area of the sampled locations because smaller areas are expected to have fewer species than larger areas.

4.9.6 Condition and Trend
The recent inventory of FODO mammals reported 27 (55%) of 49 potential native species (Table 29). This represented 93% of the native species considered by Kennedy et al. (2007) to be “highly likely” to occur. Bats were the least well-represented group with five of 13 expected species documented. Kennedy et al. (2007) note that FODO provides good habitat for tree roosting species, but lacks significant caves, mines, or human structures attractive to bats that roost in such areas. Therefore, these species are likely to occur sporadically during foraging. However, Kennedy et al. (2007) note that FODO has good foraging habitat and that future efforts

are likely to find more species using the park. Six potentially-occurring species of native rats and mice were not reported from FODO. Kennedy et al. (2007) note that FODO contains habitat suitable for some of the missing species and they are likely to be encountered in future efforts. The two species of shrews not found in FODO are relatively rare, but have been reported in the county and could potentially occur in the park. Three species of native carnivores not reported were all mustelids. Mink (*Mustela vison*) and long-tailed weasels (*Mustela frenata*) are reported from the general region (Kennedy 1991, Kennedy et al. 2007), though weasels are rare, and both are highly cryptic and difficult to document. The river otter (*Lontra canadensis*) has been reported from the area (Kennedy 1991). Future efforts may document one or more of these species.

Table 29. Number of native mammal species in different categories expected to occur, and the number and percent of expected species actually reported by Kennedy et al. (2007) from Fort Donelson National Battlefield.

Native Species Group	Expected	Reported	% Expected Reported
All Native Species	49	27	55
Bats	13	5	38
Native Rats/mice/voles	13	7	54
Non-Rat/mice/vole Rodents	6	4	67
shrews/moles	5	3	60
Carnivores	8	5	63
Cervids	1	1	100
Lagomorphs	2	1	50
Marsupial	1	1	100

The comparison of selected FODO mammal trapping results with the results from other studies showed that the number of shrews and native murid rodents in the park was lower than numbers reported from other studies, and that richness was correlated with area (Table 30, Figure 25). While such comparisons provide a broad context to the results of the FODO inventory they must be viewed with caution because there are differences in habitat; also differences in the amount and type of effort were not rigorously accounted for (Table 30).

Table 30. Species of shrews and native rats, mice, and voles reported from mammal inventories conducted at Ford Donelson National Battlefield and at three other locations in western/central Tennessee and Kentucky. Included are general descriptions of location, size, habitat, and effort of each study.

	Kennedy et al. 2007	Hopkins and Kennedy 2004	Thomas 2012	Britzke 2007
Location	Fort Donelson National Battlefield, north west/central Tennessee	Milan Army Ammunition Plant, western central Tennessee	Mammoth Cave National Park, western central Kentucky	Big South Fork National River and Recreation Area, southern central Kentucky, north central Tennessee
Area (ha)	224	9,080	20,907	50,586
Habitat	All types including fields, wetlands, forests	Managed forests, fields, edges, agriculture	All types including fields, wetlands, forests	All types including fields, wetlands, forests
Effort	Approx. 17,000 trap nights with live traps and unfenced pitfalls	53,550 trap nights using live trap grids	117,121 trap nights using live traps, pitfalls, and drift fence pitfall arrays	9,128 trap nights using snap traps, live traps, and unfenced pitfalls
Total Species	8	9	12	13
Shrews	2	1	5	4
Native Rats/mice/voles	6	8	7	9
Unique Species	0	1	2	1

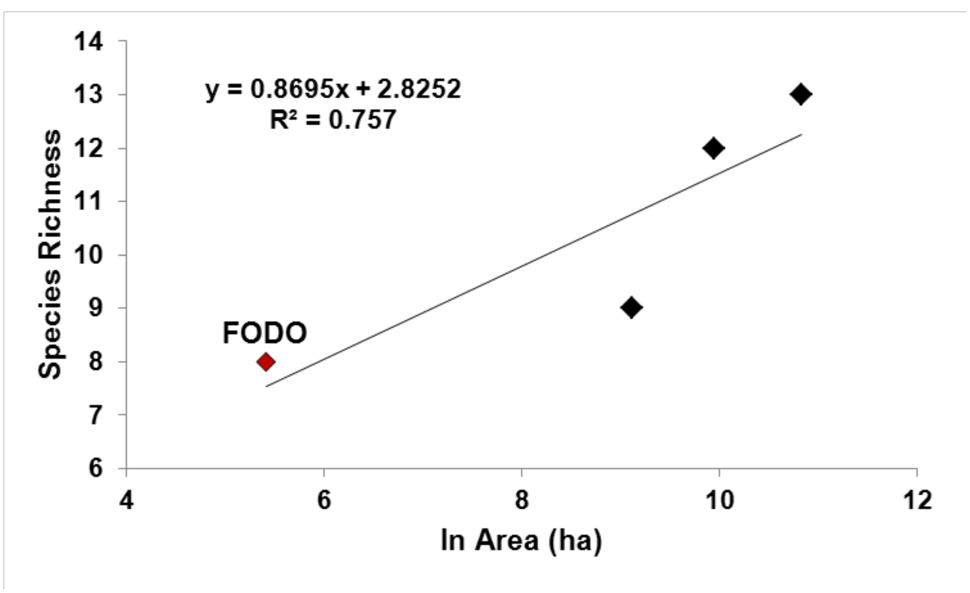

Figure 25. Species richness of small native mammals at FODO and at three comparison locations plotted against the natural log transformed study area. For study details see Table 30.

We ranked FODO mammal assemblages as good (Table 31). This assessment is based primarily upon the observation that the mammal richness reported at FODO is similar to the richness of other circumscribed protected areas in the broad region when accounting for size. The park has a mammal fauna typical of the region and provides foraging habitat for at least one endangered mammal. FODO has potential to provide habitat for more mammal species than have been documented, and any future efforts are likely to add new species. We ranked the quality of the data used to make this assessment as fair. The data were collected using a variety of appropriate techniques and provided good spatial coverage of the park. Because the data were more than five years old, the temporal category did not receive a check. Data on reproductive success, survival, or individual condition could be useful in determining assemblage quality. However, such data are difficult to collect and beyond the scope of the I&M program funding the initial inventory. We did not assign a trend to mammal assemblage condition; a single baseline survey is insufficient to establish a trend.

Table 31. The condition of FODO mammal assemblages was ranked as good. The data used to make the assessment were fair. No trend was assigned to mammal assemblage condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
Mammal Assemblages	Good (green circle)	✓	✓	
		2 of 3: Fair		

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4.10 Reptile and Amphibian Assemblages

4.10.1 Relevance and Context

The southeastern US contains the highest diversity of herpetofauna in North America, and amphibians and reptiles are important components of southeastern US ecosystems (Gibbons and Buhlmann 2001). Global declines in amphibians (Stuart et al. 2004) and reptiles (Gibbons et al. 2000) have been noted for decades, and herpetofauna have become the focus of increasing management concern and effort.

4.10.2 Resource Knowledge

Scott and Davenport (2005) conducted a comprehensive inventory of FODO herpetofauna from January 2004 to August 2005, and reported 37 species including 14 snakes, 10 frogs and toads, seven salamanders, four lizards, and two turtles. Scott and Davenport (2005) used a standardized sample protocol at 15 established 1-hectare NatureServe plots. Within each plot they sampled on 40 days using cover boards and area-constrained searches of subplots (Scott and Davenport

2005). From two to eight species were observed at each plot over the course of the study (Figure 26). Scott and Davenport (2005) also used drift fences with pitfall and funnel-trap arrays, stream reach searches, road cruising, coverboard transects, and haphazard searching. The most abundant species in the samples included the northern zigzag salamander (*Plethodon dorsalis*), northern slimy salamander (*Plethodon glutinosus*), Fowler's toad (*Bufo fowleri*), and eastern box turtle (*Terrapene carolina,* Table 32). No federal or state threatened or endangered species were reported from the park.

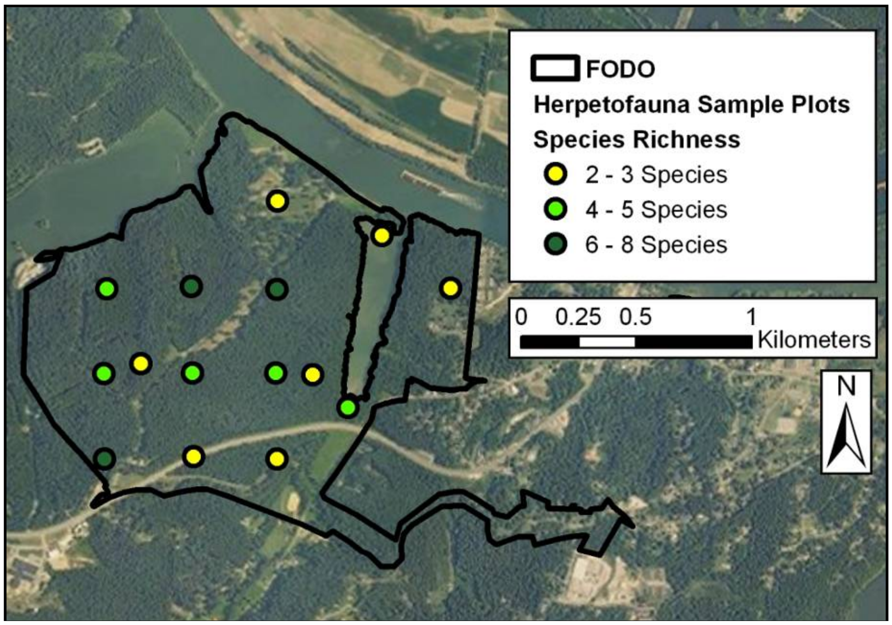


Figure 26. Location and herpetofaunal species richness of 15 random plots where standardized samples were conducted 2004-2005 (Scott and Davenport 2005).

Davenport and Scott (2005) used museum records, the literature, and extensive personal herpetofaunal sampling data and experience to compile an expected list of reptiles and amphibians for FODO. Their list included 56 species and was categorized into species highly likely, somewhat likely, and possible but not likely to occur (Scott and Davenport 2005).

Table 32. Most common herpetofaunal species, by total individuals sampled, by all methods combined and by standardized plot sampling, from a FODO inventory 2004-2005 (Scott and Davenport 2005).

	All Sampling Methods	
Scientific Name	**Common Name**	**Tot. Obs.**
Plethodon dorsalis	Northern Zigzag Salamander	74
Bufo fowleri	Fowler's Toad	54
Terrapene carolina	Eastern Box Turtle	41
Plethodon glutinosus	Northern Slimy Salamander	39
Bufo americanus	American Toad	29
Diadophis punctatus	Ring-necked Snake	22
Rana sphenocephala	Southern Leopard Frog	21
Desmognathus conanti	Spotted Dusky Salamander	15
Scincella lateralis	Little Brown Skink	15
Coluber constrictor	Eastern Racer	14
	Standardized Plot Sampling	
Scientific Name	**Common Name**	**Tot. Obs.**
Plethodon glutinosus	Northern Slimy Salamander	33
Plethodon dorsalis	Northern Zigzag Salamander	25
Diadophis punctatus	Ring-necked Snake	17
Terrapene carolina	Eastern Box Turtle	12
Scincella lateralis	Little Brown Skink	10
Bufo fowleri	Fowler's Toad	8
Bufo americanus	American Toad	7
Lampropeltis getula	Common Kingsnake	3
Coluber constrictor	Eastern Racer	3
Virginia valeriae	Smooth Earth Snake	3

4.10.3 Threats and Stressors

General threats to herpetofauna include habitat loss and fragmentation, habitat degradation, pollution, disease, climate change, direct consumptive use, and invasive species (Gibbons et al. 2000, Semlitsch 2000). Disease threats specific to amphibians in FODO include infestations of pathogens including *Ranavirus* spp. and the chytrid fungus (*Batrachochytrium dendrobatidis*). Both pathogens are implicated in the decline or failure of amphibian populations in the U.S. The chytrid fungus is an emerging disease that is the cause of local declines and extinctions of anuran populations in the western U.S. (Briggs et al. 2005). The fungus has been found to be widely occurring in frog and plethodon salamander populations in the northeastern (Longcore et al. 2007) and southeastern (Rothermel et al. 2008) U.S. However, it has not been specifically implicated in large-scale amphibian die-offs but is believed to result in sub-clinical infestations in many cases. *Ranavirus* is known to kill larval amphibians including spotted salamanders (Petranka et al. 2007).

4.10.4 Data

We used the data collected by Scott and Davenport (2005) for our analyses. These data were termed the analysis dataset. For comparison purposes, we used datasets listed by Scott and Davenport (2005), as well as data available from other parks and from peer reviewed literature.

4.10.5 Methods

We compared species lists from the analysis dataset to lists of species expected in the park. For our expected list, we adapted the list compiled by Scott and Davenport (2005) to include all species highly likely and somewhat likely to occur in FODO. The list included 52 species.

We compared the species list from the analysis dataset to species lists compiled from other efforts in the broad region surrounding FODO. We compared the species richness of FODO to the species richness reported from surveys conducted at other protected areas in Tennessee and Kentucky. For comparison studies we used peer reviewed publications, an inventory at Big South Fork National River and Recreation Area (BISO), and comparison studies listed by Scott and Davenport (2005) in Table 7 of their FODO report. The size differed greatly among these studies. Therefore, we plotted species richness against the natural log transformed area of each study site. The purpose of these comparisons is to provide a broad context for the FODO results.

4.10.6 Condition and Trend

About 71% of the expected herpetofaunal species were reported from FODO during the 2004-2005 inventory (Table 33). Turtles were the best-represented group, although the comparison list contained only two expected species. Frogs and toads were the next best represented with 83% of expected species reported. Snakes and salamanders were represented by 64% of the expected species. The compilation of expected lists is somewhat subjective. However, these results are consistent with the theory that FODO harbors a herpetofaunal assemblage with regionally typical members and supports over 70% of the species reasonably expected to occur in the park.

Table 33. Numbers of species of herpetofauna expected to occur in FODO, numbers actually observed during a recent inventory, and the percentage of expected observed. Data and expected list adapted from Scott and Davenport (2005).

Species Group	Observed	Expected	% Observed
All	37	52	71
Amphibians	17	23	74
Reptiles	20	29	69
Anurans	10	12	83
Salamanders	7	11	64
Lizards	4	5	80
Snakes	14	22	64
Turtles	2	2	100

Fort Donelson National Battlefield had an observed species richness that was intermediate among the values reported from the comparison studies (Table 34). Herpetofaunal richness was correlated to the sampled area (Figure 27). The "quality" of the comparison sites was not known from independent assessments. However all sites had some level of protection and included habitat expected to have a lower level of anthropogenic disturbance than would be found in urban or agricultural areas.

Table 34. Location, area, herpetofaunal species richness, and citation for studies conducted at FODO and at seven other locations in central and northern Tennessee.

Study Location	Area (ha)	Sp. Richness	Author/Date
Barnett Woods Natural Area	28	25	Scott 1991
Dunbar Cave Natural Area	44	26	Fitch 1998*
Shelton Ferry Wetland	176	34	Rozelle and Scott 1995*
FODO	224	37	Scott and Davenport 2005
Haynes Bottom WMA	393	35	Scott and Williamson 1999*
Protected Cedar Glades	2,052	49	Niemeller et al. 2011
Fort Campbell	42,699	48	Zirkle 1993*
BISO	50,586	57	Stephens et al. 2008

* See Scott and Davenport (2005) for details

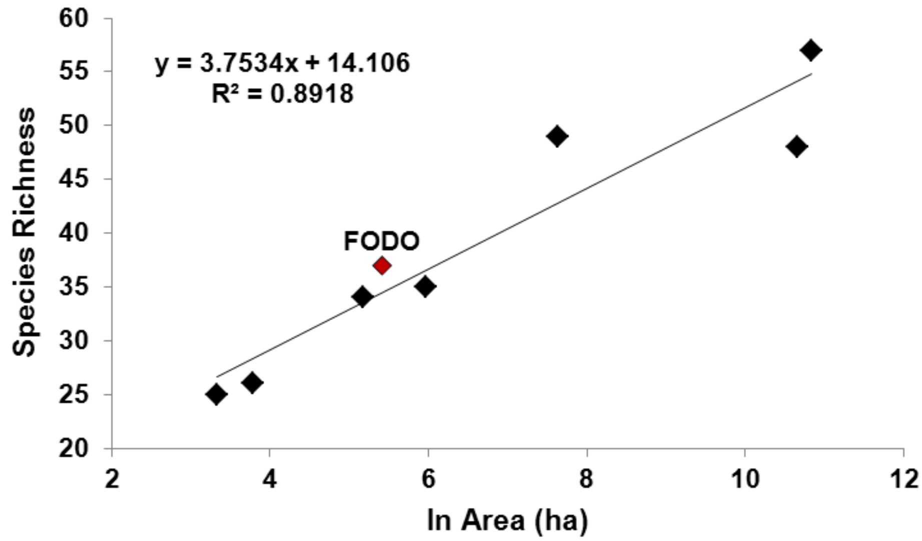
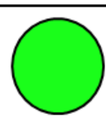


Figure 27. Herpetofaunal species richness from studies conducted in central and northern Tennessee plotted against natural log transformed area. For list of studies, see Table 34.

These findings suggest that FODO has a regionally typical herpetofaunal assemblage that is similar, in species richness, to similarly-sized protected natural areas in central and northern Tennessee. The samples collected do not suggest the park protects species of known high priority conservation value. However, given its size and location, the park may represent an island of relatively high-quality habitat for reptiles and amphibians in an area experiencing significant pressure from anthropogenic sources.

We ranked the quality of the FODO herpetofauna assemblages as good (Table 35). Fort Donelson National Battlefield protects at least 37 species of reptiles and amphibians, a species richness that is consistent with expectations for a protected natural area of its size in northern central Tennessee. We did not assign a trend to herpetofauna assemblage condition. A single baseline study is insufficient to establish trend. The quality of the data used to make the assessment was fair. Data were collected using a variety of scientifically-sound methods, and were collected throughout the park with adequate coverage of park habitats. Because the data were more than five years old, the temporal category did not receive a check. The researchers conducting the study had extensive experience sampling the reptiles and amphibians of the region.

Table 35. The condition of FODO herpetofaunal assemblages was good. No trend was assigned to herpetofauna assemblage condition. The data used the make the assessment was good.

		Data Quality		
Attribute	Condition & Trend	Thematic	Spatial	Temporal
Herpetofauna Assemblages		✓	✓	
		2 of 3: Fair		

This assessment was based significantly upon species richness. We acknowledge that other community parameters such as abundance, survival, breeding success, or individual condition might provide better measures of assemblage condition. However, such research is beyond the scope of the I&M program under which these data were collected. The recent inventory provided an excellent baseline for understanding herpetofauna in the park. A significant effort was made to collect data at set plots using a standardized approach. This will facilitate any future efforts to monitor community changes.

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4.11 Landscape Dynamics

4.11.1 Relevance and Context

Landscape dynamics is a broad category that can potentially utilize a variety of metrics or measures to describe land characteristics and how they change over time. It falls within the category of landscape change—one of the vital signs assigned to the CUPN. Multiple processes can affect resources in a park, which in turn may depend on temporal and spatial scale of consideration (Kotliar and Wiens 1990). One of the most relevant considerations associated with landscape dynamics at FODO is habitat loss and fragmentation, which, though independent of each other, often happen in association and can have a tremendous impact on biodiversity and other natural resources (Bender et al. 1998, Fahrig 2003, Neel et al. 2004). Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself. Because species ranges are not defined by the park boundary, peripheral area can play a large role in determining which species are present within the park. In addition, changes in the landscape can alter communities over vastly different temporal scales such that effects of a disturbance may not be apparent for many years (Kuussaari et al. 2009). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of the biological habitat in the park (Gross et al., 2009).

It is often difficult to relate large scale landscape monitoring into succinct and specific land management goals at the level of a park unit. Several studies have attempted to do this by identifying land use change thresholds that generally affect certain changes in ecosystems. Stranko et al. (2008), for instance, found that brook trout (*Salvelinus fontinalis*) populations in Maryland generally did not occur in watersheds with greater than 4% impervious surface. In a review of habitat fragmentation and its effects on species populations, Andrén (1994) notes that patch size and isolation become important only when less than 30% suitable habitat is available. Although it is certainly difficult to assign a single critical proportion for multiple species and ecosystems, such a threshold may serve as a guideline for general changes in the landscape (Gross et al., 2009). Another guideline for assessing area of suitable habitat is the notion of percolation theory in landscape ecology, which states that some critical habitat threshold, often identified theoretically as 60%, defines when habitat is essentially connected throughout a landscape, wherein habitat area approaches interconnectedness throughout a landscape, as opposed to just existing as a series of isolated patches (Gross et al. 2009, Gardner and Urban, 2005). Field studies suggest that this threshold may, in reality, be much lower, and several offer critical thresholds closer to Andrén's (1994) stated proportion of 30% habitat (With and Crist, 1995).

Besides its placement in the small town of Dover, TN, FODO is located in a rural area, with only a few small settlements within its immediate vicinity. Two large influences on the landscape are the presence of Land Between the Lakes NRA, managed by the US Forest Service, and Fort Campbell, an army installation. Gross et al., (2009) point out that even though natural disturbances may alter landscapes in various ways, they are generally temporary and affected habitats typically return to their original condition. Conversely, anthropogenic disturbances such as agriculture, forest clearing, and urbanization often result in a permanent loss of habitat. In particular, infringements on the boundary of the park can serve as vectors for invasive species, contribute to increased air and depositional pollution, or facilitate water quality degradation.

4.11.2 Data and Methods

NPScape and Landcover Analyses

In order to document land use change and provide landscape-scale information, the NPS created a series of analyses outlines and data products called NPScape. One of the main goals of NPScape is to facilitate natural resource management at a landscape scale for individual park units, and allow users to manipulate the data and products in such a way to meet their own needs (Gross et al. 2009). NPScape data focuses on six main landscape measures: landcover, housing, roads, population, pattern, and conservation status. Landscapes were analyzed at two main scales defined by a 30 km buffer and 3 km buffer around the park.

NLCD

Several sources of landcover information are available to analyze anthropogenic land use alteration. The National Landcover Dataset (NLCD) produced by the Multi-Resolution Land Characteristics Consortium (MRLC) generated a retrofit change product that allows analysis of landcover change between periods of 1992 to 2001 and 2001 to 2006. Although classifications schemes were not identical for the two periods, the change product reconciles the different classes to common landcover names. As part of the NPScape product, Gross et al. (2009) reclassified the change product to include two main classes: natural and converted areas. The categories used to generate these main classes are outlined in Table 36. The ratio of these categories (converted area/natural area) is referred to as the U-index (O'Neill et al. 1988), and is intended as a direct representation of landscape anthropogenic disturbance. Figure 28 shows the natural proportion of FODO, excluding Ft. Heiman, compared to other NPS units.

Table 36. Aggregation of NLCD landcover classes into general categories of converted and natural land. [Source: Gross et al., 2009]

General Category	NLCD classes
Converted	Low intensity developed; Medium intensity developed; High intensity developed; Open space developed; Pasture/Hay; Cultivated crops
Natural	Grassland/herbaceous; Shrub/scrub; Mixed forest; Evergreen forest; Deciduous forest; Barren land; Perennial ice/snow; Woody wetlands; Emergent herbaceous wetlands; Open water

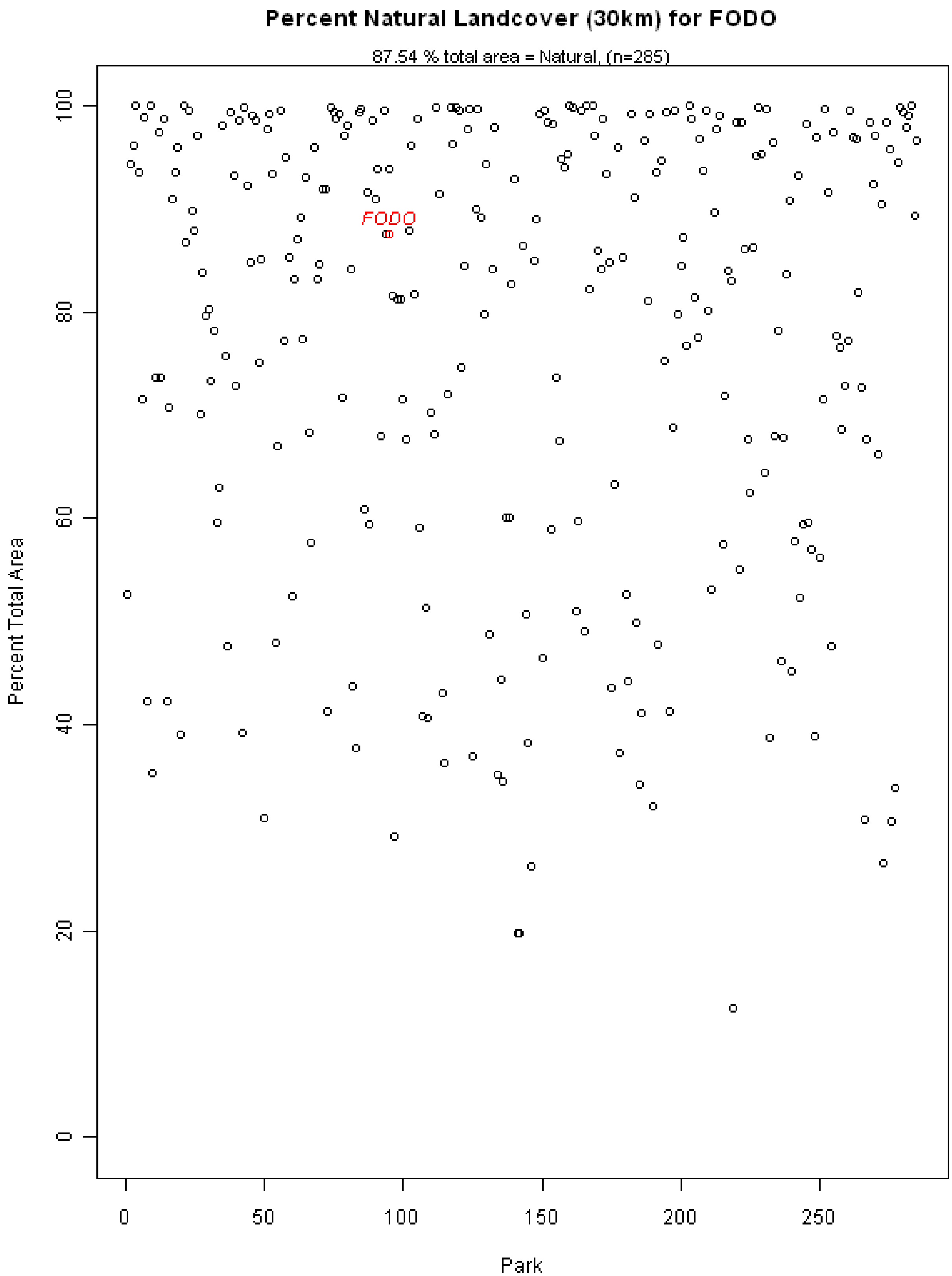


Figure 28. Proportion of natural landcover in FODO landscape compared to other NPS units.

Table 37 depicts landcover proportions for 2001 and 2006 at each buffer width, for both Fort Heiman and Fort Donelson combined, as well as the change product between those two time periods, adjusted for their different classifications schemes. For the 2001 NLCD classification, the proportion of forested land decreases beyond the park boundary to the first 3 km buffer width (87.7% to 57.8% forested), but is slightly higher within the largest extent 30 km buffer (64.8%). In turn, relative proportions of pasture/hay and agriculture classes increase across scales. In 2006, forested and cultivated proportions show a similar pattern across scales. Figure 29 depicts the 2006 NLCD classification for Ft. Donelson and Ft. Heiman.

The change product shows 7.0% change within the park unit between 2001 and 2006, all of which corresponds to development on the eastern boundary of Fort Donelson. This represents a misclassification, as this property is not technically within the park boundary, but rather on the edge. The other buffer widths show negligible conversions over the 2001-2006 period. U-indices calculated for the park boundary and 3 km buffer were low—0.13 and 0.09, respectively. The U-index for the 30 km buffer was 0.27. Much of this higher conversion ratio at the 30 km buffer width reflects large amounts of crop and pasture land surrounding Murray, KY, about 30 km to the northwest. In addition, 23.0% of land is open water around both forts, lending to the low U-index at the 3 km buffer width. Table 37 depicts the proportion of natural area within the 30 km FODO landscape, excluding Fort Heiman, compared to other NPS units. Despite the relatively large proportion of natural landcover throughout the landscape, FODO appears close to the median among all park units. Natural landcover proportions show an overall negative skew.

Table 37. Landcover area and proportions of FODO for each buffer class based on two separate NLCD classifications and change product, as aggregated by Gross et al. (2009). The five highest proportions are highlighted for each buffer width and dataset.

	-30 km buffer-		-3 km buffer-		-no buffer-	
NLCD 2001	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	331.6	8.0	23.1	25.2	0.1	2.5
Developed Open Space	122.6	3.0	1.9	2.0	0.1	3.3
Developed Low Intensity	11.0	0.3	0.4	0.5	<0.1	0.5
Developed Medium Intensity	4.6	0.1	0.3	0.3	0	0
Developed High Intensity	2.2	0.1	0.1	0.1	0	0
Barren Land	1.8	<0.1	0.1	0.1	0	0
Deciduous Forest	2507.2	60.6	50.7	55.3	2.7	85.0
Evergreen Forest	172.4	4.2	2.3	2.5	0.1	2.7
Mixed Forest	0.3	<0.1	0	0	0	0
Scrub/Shrub	4.5	0.1	0.1	0.1	0	0
Grassland/Herbaceous	113.0	2.7	1.4	1.5	<0.1	0.4
Pasture/Hay	266.1	6.4	1.5	1.7	0.1	2.0
Cultivated Agriculture	471.4	11.4	2.9	3.2	<0.1	<0.1
Woody Wetlands	119.5	2.9	6.8	7.4	0.1	3.6
Emergent Herbaceous Wetlands	7.1	0.2	0.2	0.2	<0.1	0.1
NLCD 2006						
Open Water	322.8	8.0	23.0	25.1	<0.1	1.2
Developed Open Space	120.5	3.0	1.9	2.0	0.1	2.9
Developed Low Intensity	11.4	0.3	0.4	0.5	<0.1	0.6
Developed Medium Intensity	5.0	0.1	0.3	0.3	0	0
Developed High Intensity	2.1	0.1	0.1	0.1	<0.1	<0.1
Barren Land	2.1	0.1	0.1	0.1	<0.1	<0.1
Deciduous Forest	2430.5	60.3	50.6	55.2	2.7	86.6
Evergreen Forest	177.7	4.4	2.2	2.4	0.1	2.8
Mixed Forest	0.3	<0.1	0	0.1	0	0
Scrub/Shrub	7.2	0.2	0.1	0.1	0	0
Grassland/Herbaceous	114.0	2.8	1.4	1.6	<0.1	0.4
Pasture/Hay	259.4	6.4	1.5	1.7	0.1	1.9
Cultivated Agriculture	451.5	11.2	3.0	3.3	0	0
Woody Wetlands	116.0	2.9	6.7	7.3	0.1	3.5
Emergent Herbaceous Wetlands	7.7	0.2	0.2	0.2	<0.1	0.1
NLCD Change (2001-2006)						
--Unchanged--						
Converted	878.6	21.1	8.1	7.8	0.2	4.7
Natural	3275.4	78.5	96.1	92.2	3.8	88.4
--Changed--						
Natural to Agriculture	3.2	0.1	0.1	0.1	0	0
Natural to Urban	2.3	0.1	<0.1	<0.1	0.2	4.7
Agriculture to Urban	1.4	<0.1	<0.1	<0.1	0.1	2.3
Converted to Natural	9.5	<0.1	<0.1	<0.1	0	0
U-Index	**0.27**		**0.09**		**0.13**	

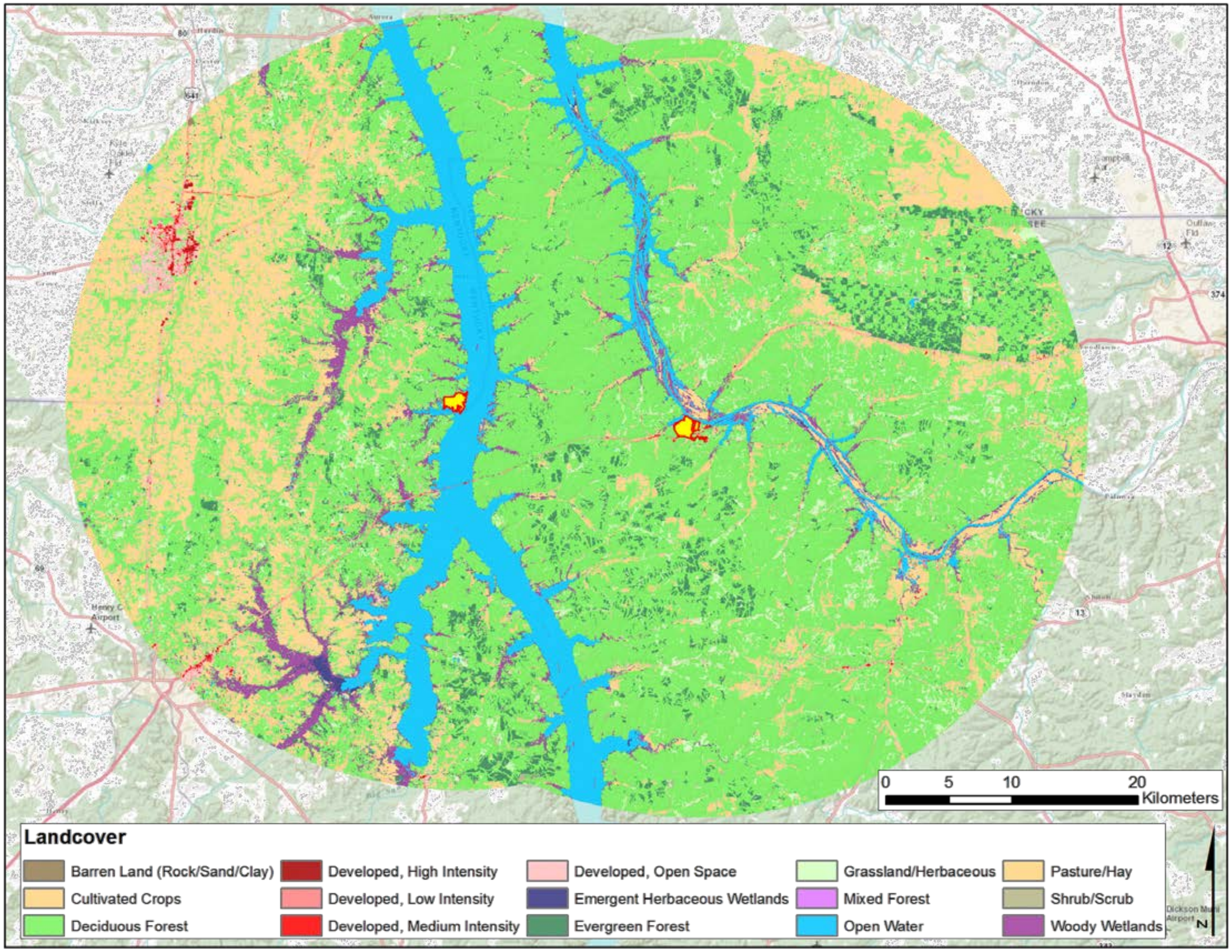


Figure 29. NLCD landcover showing 2006 classification for Fort Donelson and Fort Heiman with 30 km buffer.

LANDFIRE

Another source of landcover information is the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) Existing Vegetation Type (EVT) dataset, which includes several national data products. The landcover map is based on a mid-scale ecological systems classification outlined by Comer et al. (2003). This LANDFIRE dataset is classified at a 30m resolution and is mainly intended at a large landscape-scale, such as at a state or sub-regional level. Figure 30 depicts the LANDFIRE map and legend for the 30 km buffer at FODO. Table 38 shows the amount and proportions of 30 landcover classes at FODO with 3km and 30km buffer widths. At the 3 km and 30 km buffer widths, the most abundant classes are open water and Southern Interior Oak Forest, respectively, while within the park boundary the most abundant class is South-Central Interior Mesophytic Forest. U-index calculations show a different pattern among the park and buffer widths than NLCD. LANDFIRE shows a steadily increasing U-index from the park boundary to successive buffer widths, though the difference between the park boundary and 3 km buffer datasets is minimal. All LANDFIRE U-indices are higher than respective U-indices for NLCD extents. Story et al. (unpublished) caution, however, that landcover analysis revealed that LANDFIRE data tends to focus on the predominant fuel type in an area, possibly resulting in an overestimation of that type of landcover. The finer division of classes may explain the higher LANDFIRE U-indices. For NLCD, classes such as tree plantation, ruderal (disturbed successional) forest, and transitional vegetation may have been lumped into natural vegetation types. As a result, higher LANDFIRE U-indices may be more accurate due to the finer classification.

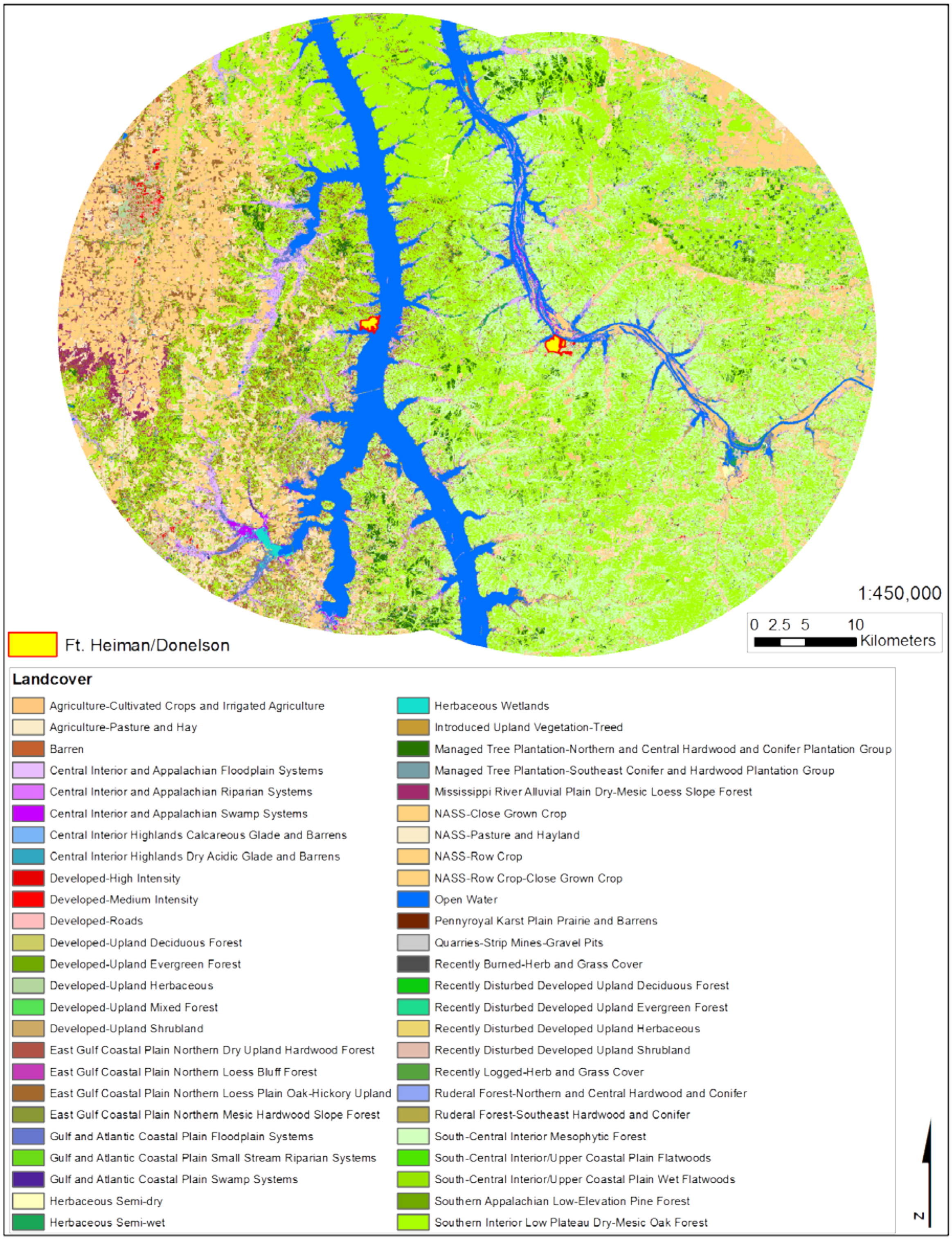


Figure 30. LANDFIRE landcover classification for FODO shown at the 30 km buffer width.

Table 38. Landcover area and proportions of FODO based on LANDFIRE classification. Data is presented for two buffer widths and no buffer. '*' denotes 'converted' landcover used to calculate U-index. The five classifications with highest proportions are highlighted for each buffer width.

LANDFIRE	-30 km buffer- Area (km^2)	% Area	-3 km buffer- Area (km^2)	% Area	-no buffer- Area (km^2)	% Area
Open Water	333.0	8.1	17.8	25.3	0.1	0.9
Developed Upland Vegetation*	45.8	1.1	0.6	0.8	0.1	1.2
Developed-Medium Intensity*	3.2	0.1	0.1	0.2	0	0
Developed-High Intensity*	1.9	<0.1	<0.1	<0.1	0	0
Developed-Roads*	91.5	2.2	1.4	2.0	0.4	3.7
Barren	2.0	<0.1	0.1	0.1	0	0
Quarries-Strip Mines-Gravel Pits*	1.0	<0.1	0	0	0	0
Herbaceous wetlands-Semi-wet/dry	18.4	0.4	0.2	0.3	0.3	2.8
Agriculture-Pasture and Hay*	261.6	6.3	1.1	1.6	<0.1	0.1
Agriculture-Cultivated Crops and Irrigated Agriculture*	551.4	13.3	3.0	4.2	<0.1	<0.1
Introduced Upland Vegetation—Tree/Shrub*	<0.1	<0.1	0	0	0	0
Transitional Herbaceous*	4.3	0.1	0	0	0	0
Southern Interior Low Plateau Dry-Mesic Oak Forest	1436.0	34.7	16.2	23.0	3.0	28.0
East Gulf Coastal Plain Northern Loess Plain Oak-Hickory	112.3	2.7	0.9	1.2	<0.1	0.1
East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	54.1	1.3	1.9	2.7	0.6	5.3
South-Central Interior Mesophytic Forest	746.5	18.1	16.1	22.9	4.8	44.5
East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	0.1	<0.1	0	0	0	0
South-Central Interior/Upper Coastal Plain Flatwoods	0.2	<0.1	<0.1	<0.1	<0.1	<0.1
East Gulf Coastal Plain Northern Loess Bluff Forest	1.7	<0.1	<0.1	<0.1	<0.1	<0.1
Southern Appalachian Low-Elevation Pine Forest	28.5	0.7	0.2	0.3	<0.1	<0.1
Central Interior Highlands Dry Acidic/Calcareous Glade and Barrens	11.0	0.3	0.1	0.2	<0.1	0.2
Pennyroyal Karst Plain Prairie and Barrens	2.3	0.1	<0.1	<0.1	<0.1	0.1
South-Central Interior/Upper Coastal Plain Wet Flatwoods	3.7	0.1	<0.1	<0.1	0	0
Central Interior and Appalachian Floodplain/Riparian Systems	90.0	2.2	2.9	4.2	0.2	1.5
Gulf /Atlantic Coastal Plain Floodplain/Small Stream Riparian Systems	29.1	0.7	1.8	2.5	<0.1	0.3
Central Interior and Appalachian Swamp Systems	10.4	0.2	0.6	0.9	<0.1	0.4
Gulf and Atlantic Coastal Plain Swamp Systems	0.7	<0.1	0	0	<0.1	0.3
Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest	25.7	0.6	0	0	0	0
Ruderal Forest-Hardwood and Conifer*	187.1	4.5	4.7	6.7	1.1	10.1
Managed Tree Plantation*	82.1	2.0	0.6	0.9	0.1	0.8
U-Index	**0.34**		**0.20**		**0.19**	

Gap Analysis Program (GAP)
The third source of landcover information is the Gap Analysis Program (GAP) dataset, for which initial efforts were launched in the 1980s in the Upper Midwest region. Like the NLCD program, GAP is part of the MRLC and is intended for use at a relatively large ecoregional scale. The original and main purpose of the GAP project is to monitor the amount of protected area for plant communities and animal habitat in order to "keep common species common" (GAP 2010). A main use of the data products is to compare biodiversity patterns with networks of protected lands in order to identify potential areas for additional conservation efforts (i.e. the "gaps") (Story et al. unpublished). Table 39 shows the comparison of GAP landcover types for FODO by buffer class. Like LANDFIRE, the map legend is based on a mid-scale ecological system level. For both the 30 km and 3 km buffer classes, the two most predominant landcover types are the Southern Interior Low Plateau Dry-Mesic Oak Forest and the South-Central Interior Mesophytic Forest. Crop and pastureland cover 17.9% of the landcover at the 30 km buffer. Overall, about 88.8% of FODO is forested land, according to GAP data, and with subsequent buffer classes decreases to 62.8% (3 km) and 63.1% (30 km). Calculated U-Indices increase across buffer classes.

Summary
As stated earlier, landscape ecology widely supports a critical habitat threshold of 60% to meet connectivity requirements—referred to as percolation theory (Wade et al. 2003, Gardner and Dean 2005. Gross et al. 2009); empirical data support even lower thresholds (With and Crist 1995, Andrén 1994). The U-Index is one method of assessing the impact of anthropogenic change on an area via converted landcover, as opposed to natural landcover that provide essential habitat (O'Neill et al. 1988). Viewed in this context, the U-Indices representing the ratio of converted to natural habitat for the GAP, LANDFIRE, and NLCD classifications are encouraging. The U-indices are conservative when compared to the above critical habitat threshold because they represent a ratio and not proportion of habitat. Respectively, the 30 km buffer, 3 km buffer, and no buffer classes average U-Indices plus or minus standard error of 0.33 ± 0.03, 0.14 ± 0.03, and $0.14 \pm 0.03$for the three landcover databases. Nevertheless, the indices are encouraging, and are well below even the conservative theoretical threshold for connectivity.

Table 39. Landcover area and proportions of FODO based on GAP classification. Data is shown for two buffer widths and no buffer. '*' depicts 'converted' landcover used to calculate U-index. The five classifications with highest proportions are highlighted for each buffer width.

Gap Analysis Program (GAP) Landcover	-30 km buffer- Area (km^2)	% Area	-3 km buffer- Area (km^2)	% Area	-no buffer- Area (km^2)	% Area
Developed Open Space*	120.6	3.0	1.5	2.1	0.1	3.1
Low Intensity Developed*	11.0	0.3	0.3	0.5	<0.1	0.6
Medium Intensity Developed*	4.4	0.1	0.2	0.3	<0.1	<0.1
High Intensity Developed*	2.2	0.1	<0.1	0.1	<0.1	<0.1
Quarries, Mines, Gravel Pits, and Oil Wells*	1.9	<0.1	0	0	0	0
Cultivated Cropland*	454.7	11.3	2.3	3.3	0	0
Pasture/Hay*	267.5	6.6	1.3	1.9	<0.1	2.3
Open Water (Fresh)	322.5	8.0	17.6	25.1	0.1	2.8
Undifferentiated Barren Land	1.8	<0.1	<0.1	0.1	<0.1	<0.1
Central Interior Calcareous Cliff and Talus	0.1	<0.1	<0.1	<0.1	0	0
East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland	37.3	0.9	0	0	0	0
Southern Interior Low Plateau Dry-Mesic Oak Forest	1051.2	26.1	19.5	27.7	1.1	46.1
East Gulf Coastal Plain Northern Dry Upland Hardwood	89.2	2.2	0	0	0	0
East Coastal Plain Northern Mesic Hardwood	113.4	2.8	0	0	0	0
Northern Atlantic Coastal Plain Dry Hardwood Forest	20.8	0.5	0.2	0.4	<0.1	0.8
South-Central Interior Mesophytic Forest	1084.8	26.9	19.1	27.2	0.9	38.9
Disturbed/Successional*	1.7	<0.1	0	0	0	0
Harvested Forest*	121.2	3.0	1.2	1.8	<0.1	0.3
Evergreen Plantation or Managed Pine*	141.4	3.5	1.5	2.2	<0.1	2.0
East Gulf Coastal Plain Stream, River, and Floodplain Forest	35.7	0.9	0	0	0	0
South-Central Interior Stream, Riparian, and Floodplain Forest	88.7	2.2	5.3	7.6	0.1	3.1
East Gulf Coastal Plain Jackson Plain Dry Flatwoods	56.2	1.4	0	0	0	0
U-Index	**0.39**		**0.14**		**0.09**	

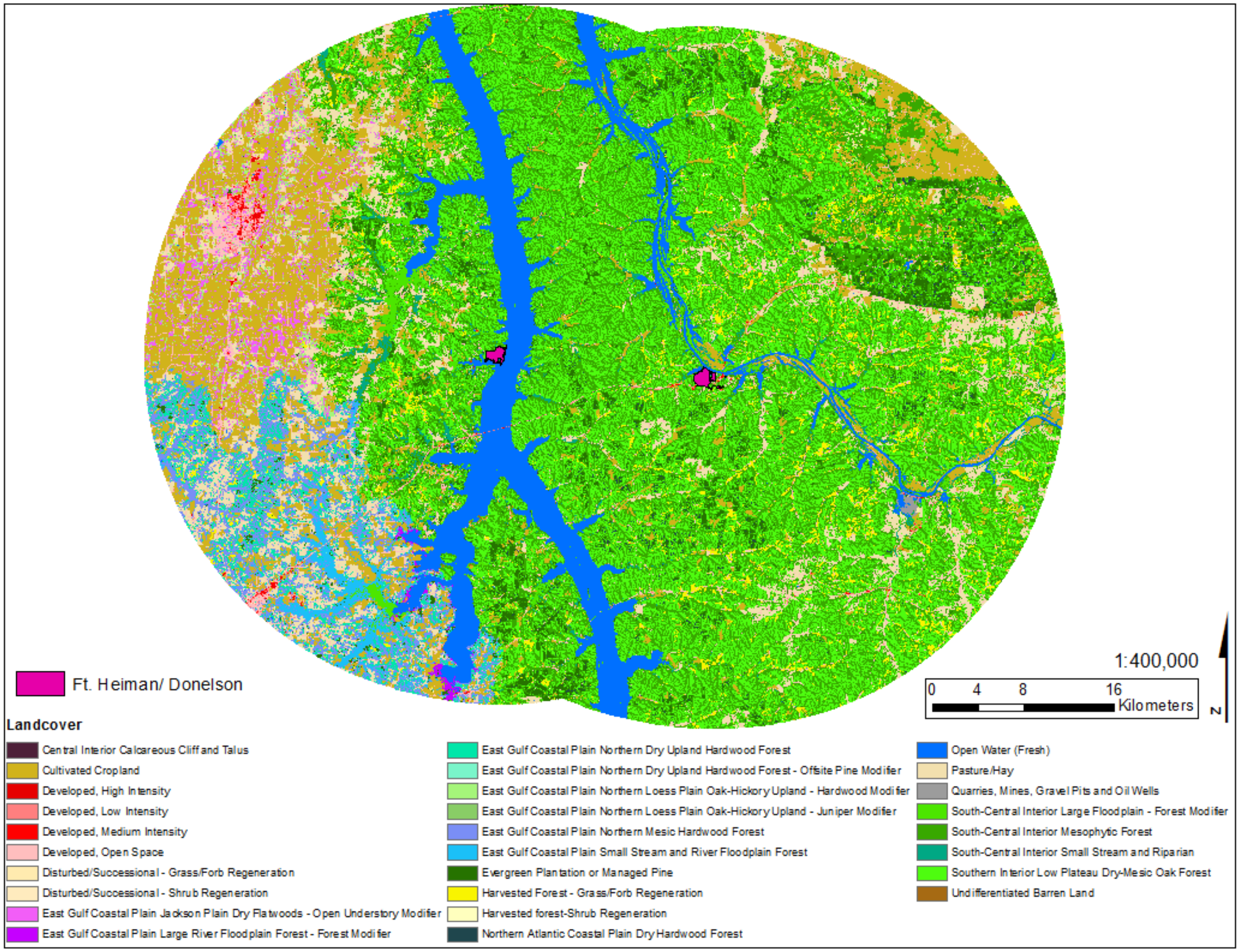


Figure 31. Gap Analysis Program (GAP) landcover shown for FODO with 3km and 30 km.

Impervious Surface

One of the most direct influences of anthropogenic conversion on natural areas comes from the amount of impervious surface within a watershed. Highly urbanized areas with large amounts of impervious surface can disrupt hydrologic regimes in several ways, such as increased amounts of flow and decreased infiltration rates. This, in turn, can result in lower water tables, stream flashiness, and intermittent flow (Arnold and Gibbons 1996, Harbor 1994). Decreased water tables in areas with high areas of impervious surface can negatively affect wetland areas maintained by ground water flow. In smaller catchments, storm events can also greatly increase peak flow over a short period of time.

Many studies have outlined threshold levels of impervious surface at different scales for biotic integrity, and like the thresholds of connectivity for essential habitat, these values vary widely. A study in Maryland by Klein (1979) reported a threshold of 12 - 15% imperviousness before encountering a drop in stream quality, while severe inhibition was generally associated with levels of imperviousness 30% and above. Klein (1979) further recommended a limit of 10% imperviousness for areas with trout populations. These higher levels of imperviousness resulted in poorer quality benthic communities, lower species diversity indices, and overall reduction of fish populations. In several Wisconsin watersheds, Wang et al. (2001) measured the effects of urbanization on fish habitat using several biotic and abiotic factors and found 8% imperviousness as a threshold for negative effects. Above 12% imperviousness, minor increases in urbanization resulted in sharply declining quality of fish communities. In a review of the effects of impervious cover and urbanization, Paul and Meyer (2001) outlined an even lower threshold for change in geomorphological characteristics, starting at 2 - 6%.

The 2006 NLCD version of impervious surface includes different levels of development intensity in addition to developed open space. Using this classification, percentage impervious area with each successive buffer class is 4.0% within the park boundary, 2.8% at the 3 km buffer, and 3.1% at the 30 km buffer width. While it is somewhat surprising to observe a highest proportion of imperviousness inside the park unit, this mainly stems from the incorporation of Hwy-76, which technically is not part of the park unit. From a regional scale, imperviousness levels are quite low and likely result in only minimal geomorphological effects, if any.

<u>Roads</u>

Roads are one of the main drivers of landscape fragmentation (Gross et al. 2009), and can also disrupt hydrological processes (Jones et al., 1999). Trombulak and Frissell (1999) outline the seven main effects of roads on biotic integrity as follows: (1) construction-related mortality, (2) vehicle mortality, (3) animal behavior modification, (4) alteration of the physical environment, (5) alteration of the chemical environment, (6) spread of exotics, and (7) increased use by humans. Even in relatively undeveloped areas, effects are pervasive and can impact areas several hundred meters beyond the roadside (Forman et al. 2002, Forman 2000). Gross et al. (2009) outlines several sources of information documenting the effects of roads on natural resources and terrestrial biodiversity. The NPScape analysis of roads selected three main metrics to describe their effects: road density, distance to road, and effective mesh size.

Road density, or total road length (km) per area (km^2), can directly affect wildlife populations. Steen and Gibbs (2004) reported altered sex ratios and populations of painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) in high road density sites (>1.5 km km^{-2}) in central New York. Gibbs and Shriver (2002) found that areas with >1 km km^{-2} and >100 vehicles $lane^{-1}$ day^{-1} were likely to contribute to the mortality of land turtles, especially in the eastern US where road densities are higher. Analysis of roads in the FODO vicinity reveals that combined road density within Fort Heiman and Fort Donelson is 2.7 km/ km^{-2}, which decreases to 2.1 km/ km^{-2} at the 3 km buffer width. Excluding Fort Heiman, at the 30 km buffer width, road density is 1.9 km km^{-2}. Figure 32 shows the NPScape product for weighted road density within the 30 km buffer, which does not include Fort Heiman.

The distance to nearest road metric can help determine how much roads can influence certain ecological factors. Roads, for example, are a main contributor to human-caused vertebrate mortality in addition to altered population densities around zones of road avoidance. Exotic plant species and forest pests can also be introduced and spread via road corridors up to 1 km from the roadside. Traffic exhaust can influence roadside vegetation up to 200 m away (Forman and Alexander 1998). Using the NPScape product, average distance to roads is 140 m within the park unit, 293 m at the 3 km buffer, and 326 km at the 30 km buffer width.

In an attempt to address the influence of roads on landscape fragmentation, the final measurement, effective mesh size, refers to road-created contiguous patches greater than 500 m from a road, or the area enclosed by the road network. Girvetz et al. (2007) define this metric as “the average size of the area that an animal placed randomly in the landscape would be able to access without crossing barriers.” At 30 km buffer (excluding Fort Heiman), average roadless patch area is 1.2 km^2, while at 3 km, average patch size is 0.9 km^2. Within the park unit, average patch size is <0.1 km^2, though this metric is hardly calculable at this scale. Fort Heiman contains only three small patches greater than 500 m from a road, and Fort Donelson contains none. Figure 33 shows the NPScape version of effective mesh size within the 30 km buffer for just Fort Donelson. The large mean roadless patch area at the 30 km buffer width is mainly due to the Tennessee River, which encloses the only two patches in the landscape greater than 100 km^2; the remainder of the landscape is highly dissected.

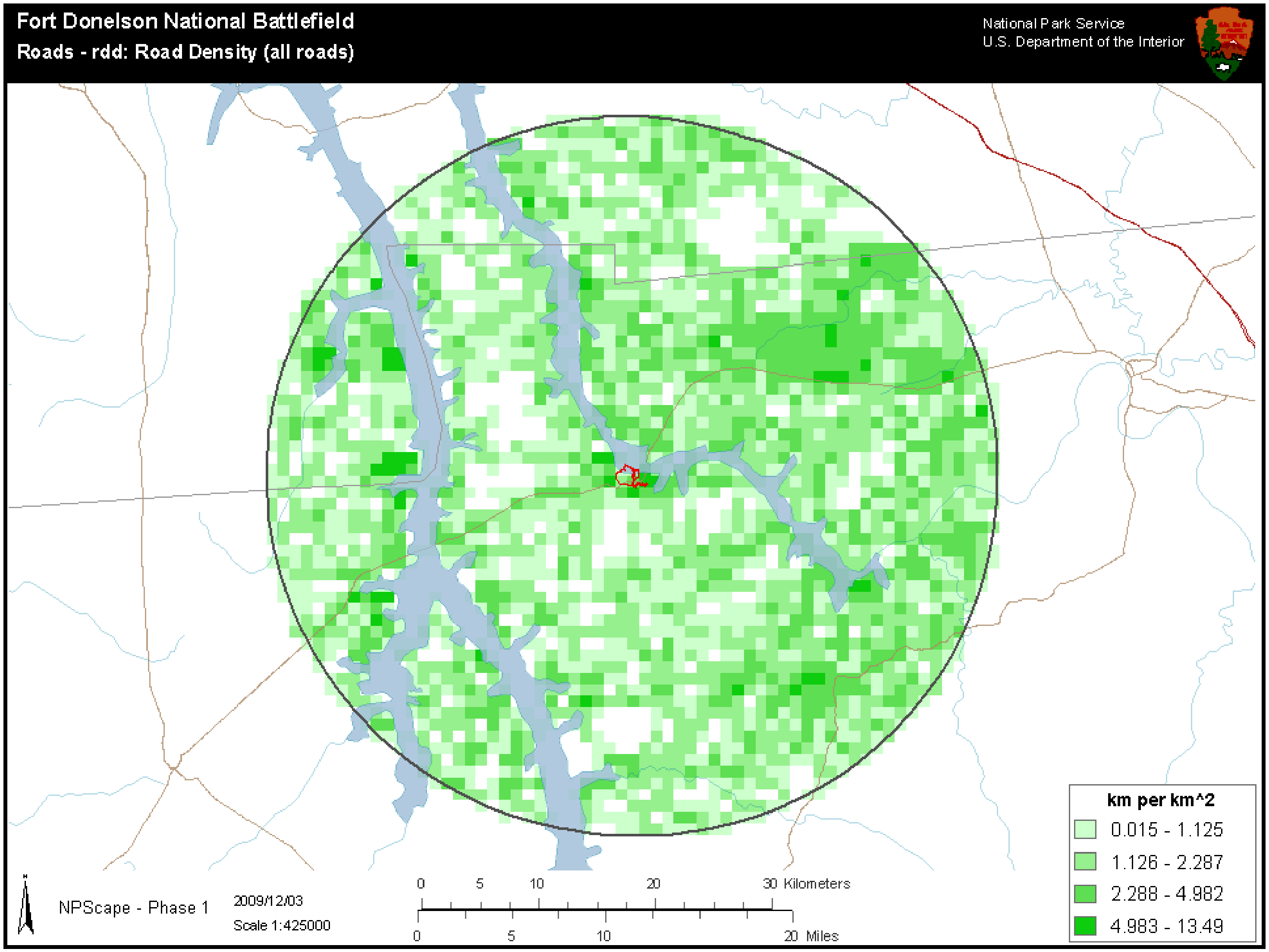


Figure 32. NPScape product (Gross et al. 2009) showing FODO with weighted road density at a 30 km buffer width.

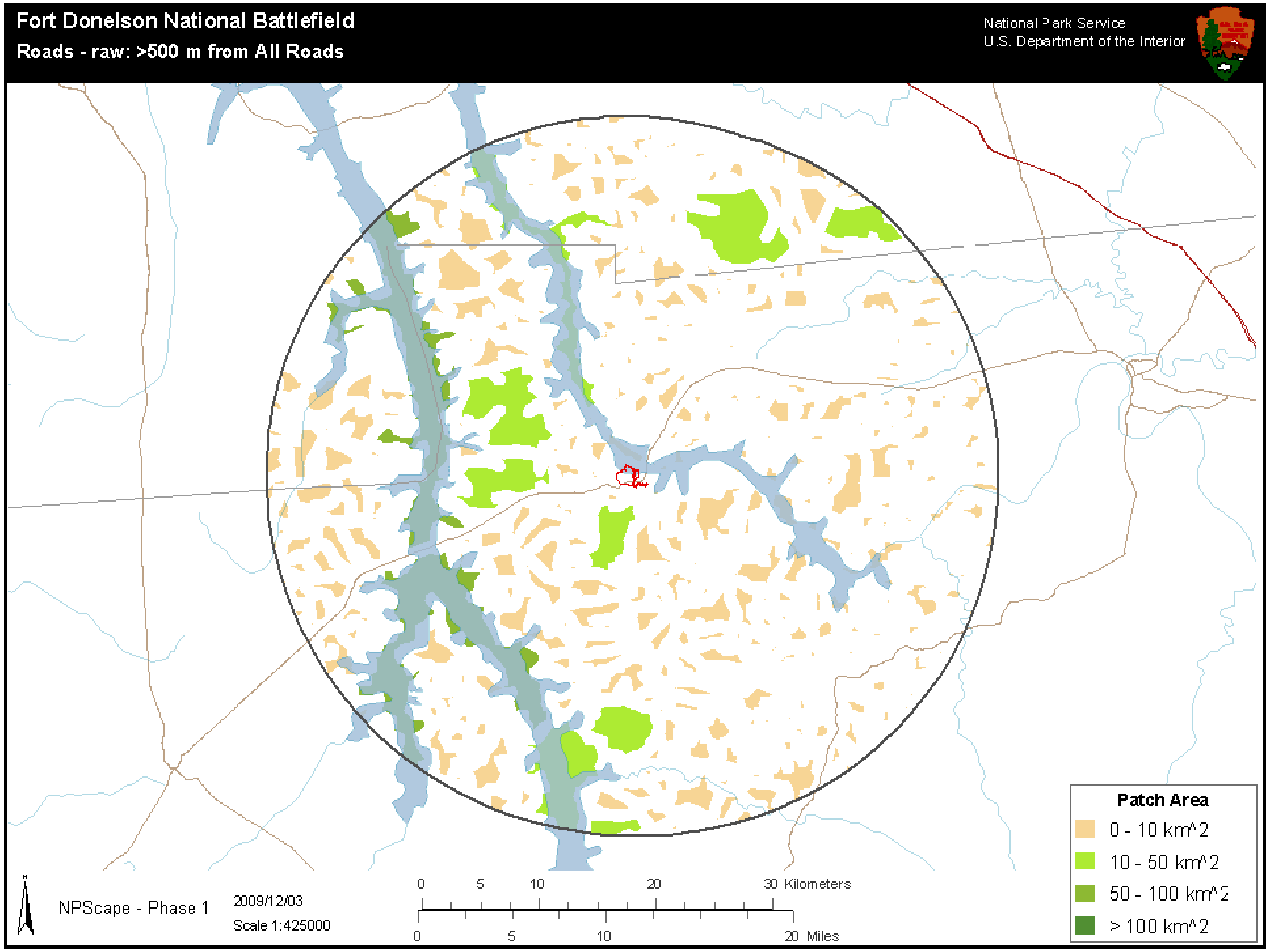


Figure 33. NPScape product (Gross et al. 2009) showing effective mesh size created by roads at a 30 km buffer width.

Population and Housing

Population pressure can provide an approximation of how much impact humans have on the landscape in a given area. Areas of high population have been shown to contribute to the decline of terrestrial biodiversity (Kerr and Curie 1995), which is usually the result of habitat loss stemming from land use conversion (Wilcove 1998). Gross et al. (2009) provide a comprehensive reference list for the effects of population pressure on different taxa, and outline the following six main effects resulting from human settlements: (1) loss of habitat to structures and non-habitat cover types, (2) habitat fragmentation, (3) resource consumption, (4) disturbance by people and their animals (pets, livestock, etc.), (5) vegetation modification, and (6) light and noise pollution. In general, they offer that the impact of human settlements is far-reaching, and certain species are more sensitive to humans and their effects than others.

NPScape products developed to analyze trends include population and housing density maps created at the county level from US Census Bureau data. Gross et al. (2009) report that housing density is closely correlated with population density, but as Liu et al. (2003) point out, housing density also accounts for changing household demographics, such as average household size and per capita consumption. The NPScape product for housing density divides developed areas into 13 classes plotted for ten-year periods from 1950 and 2000. Figure 34 depicts the change in proportion represented by each housing density class within the 30 km buffer for just Fort Donelson. There is a visible decrease in proportions of least density housing classes over this time period, though linear regression shows a significant decrease only for the <1.5 units per km^2 class. Regression similarly shows a significant increase for all except the two densest and commercial/industrial housing classes. This is consistent with the findings of Hansen et al. (2005), who noted that beginning in 1950, exurban development (6-25 units km^{-2}) became the fastest-growing form of land use in the US. Population data for counties within the 30 km buffer show mostly steady increases during the period 1790 to 1990 (Figure 35), with large jumps in population reflecting growth of Hopkinsville, KY in Christian County and Clarksville, TN in Montgomery County.

Table 40 shows the breakdown of housing density classes in the 2010 prediction for each buffer size. With the exception of the two lowest density classes, which represent a smaller land proportion in the 3 km buffer, higher density development classes dominate the landscape in the area immediately surrounding the park unit. The overall lower proportion of developed area at the 30 km buffer width reflects the large area of federal land occupied mainly by Fort Campbell and Land Between the Lakes NRA.

Gross et al. (2009) acknowledge that housing density might be most useful when used as a constituent of other, more complex and ecologically-relevant landscape metrics. Although population and housing also correlate highly with other more ecologically-relevant factors like impervious surface and road density, their ease of use makes them valid for comparisons across scales and regions. To that end, NPScape also produced a plot of population densities for all areas of NPScape analyses in 1990 and 2000 (Figure 36), which shows that FODO falls among the lowest of overall population density classes in both 1990 (13.8 individuals km^{-2}) and 2000 (15.2 individuals km^{-2}) relative to other NPS units.

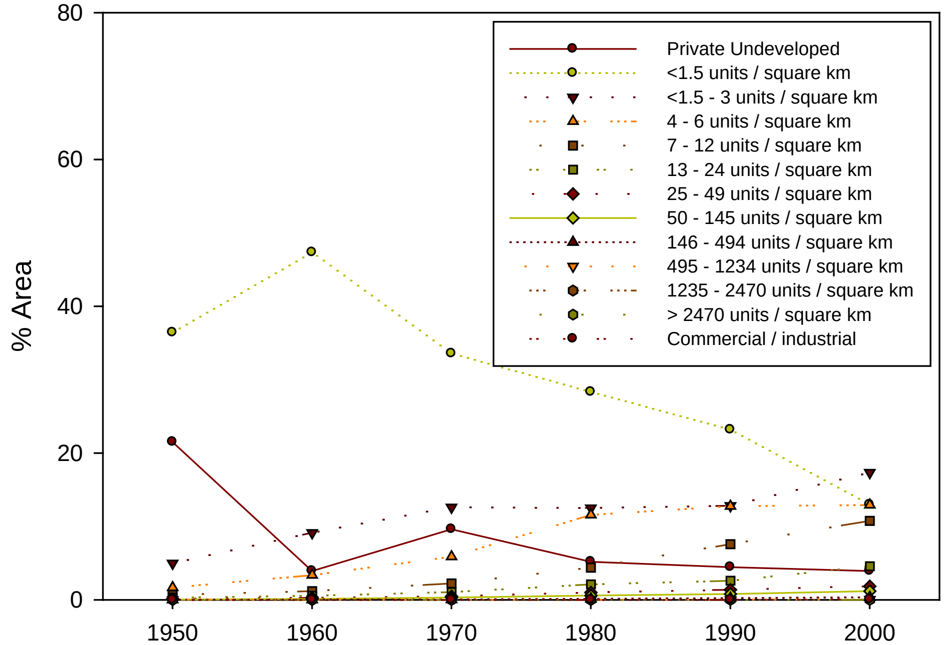


Figure 34. Historical NPScape data for housing density classes within the 30 km buffer.

Table 40. Proportion of housing density classes for the 2010 NPScape prediction for 30 km and 3 km buffers, excluding Fort Heiman. Development classes are according to Theobald (2005).

Density Class	**-30 km buffer-**	**-3 km buffer-**	**Development Class**
	-%-		
Private undeveloped	2.4	0.8	Rural
< 1.5 units / square km	13.6	8.2	|
1.5 - 3 units / square km	16.5	17.1	|
4 - 6 units / square km	13.4	15.7	↓
7 - 12 units / square km	11.0	12.5	Exurban
13 - 24 units / square km	5.1	18.2	|
25 - 49 units / square km	2.2	8.8	|
50 - 145 units / square km	1.2	14.8	↓
146 - 494 units / square km	0.3	3.4	Suburban
495 - 1,234 units / square km	<0.1	0.2	Suburban/Urban
1,235 - 2,470 units / square km	<0.1	<0.1	Urban
Commercial/industrial	<0.1	0.4	↓

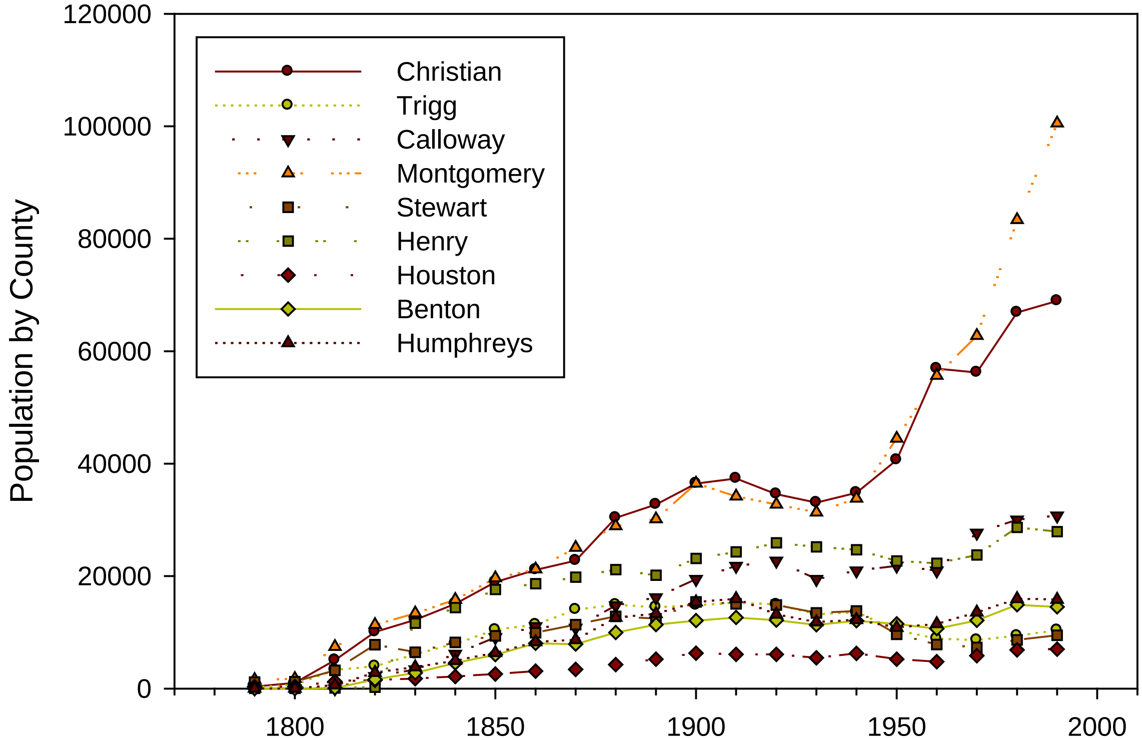
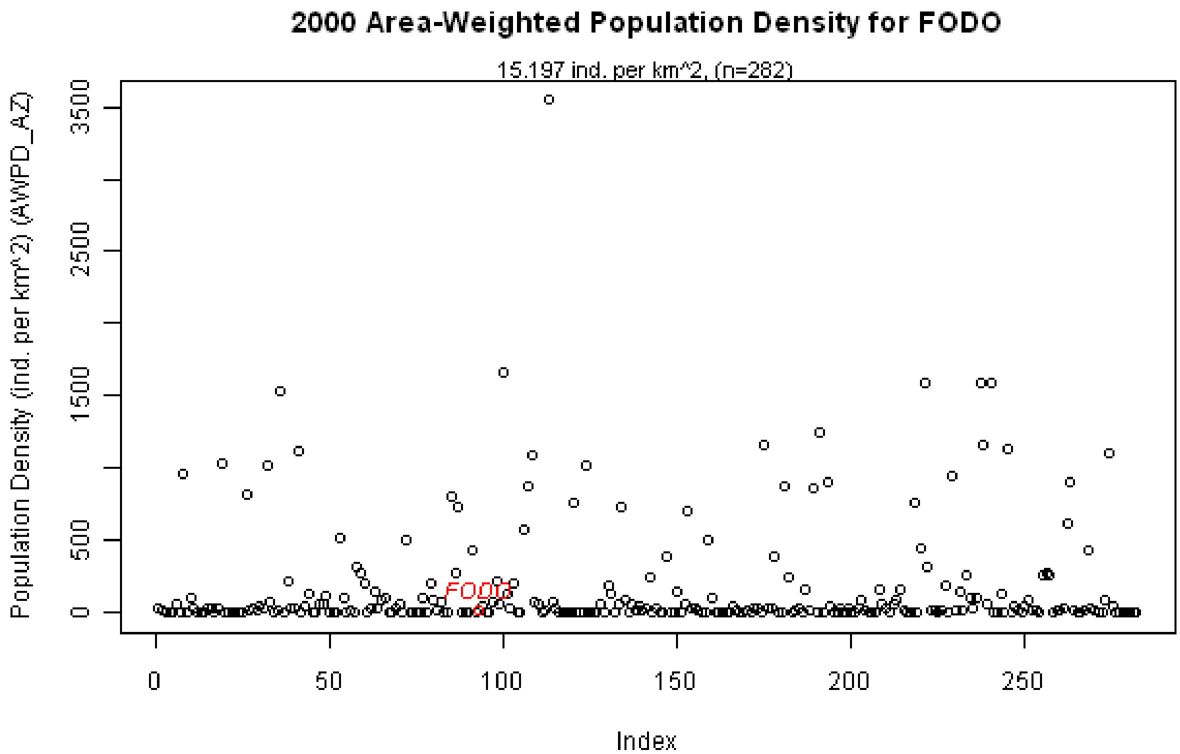


Figure 35. Population for counties within the FODO landscape for the period 1790 to 1990.



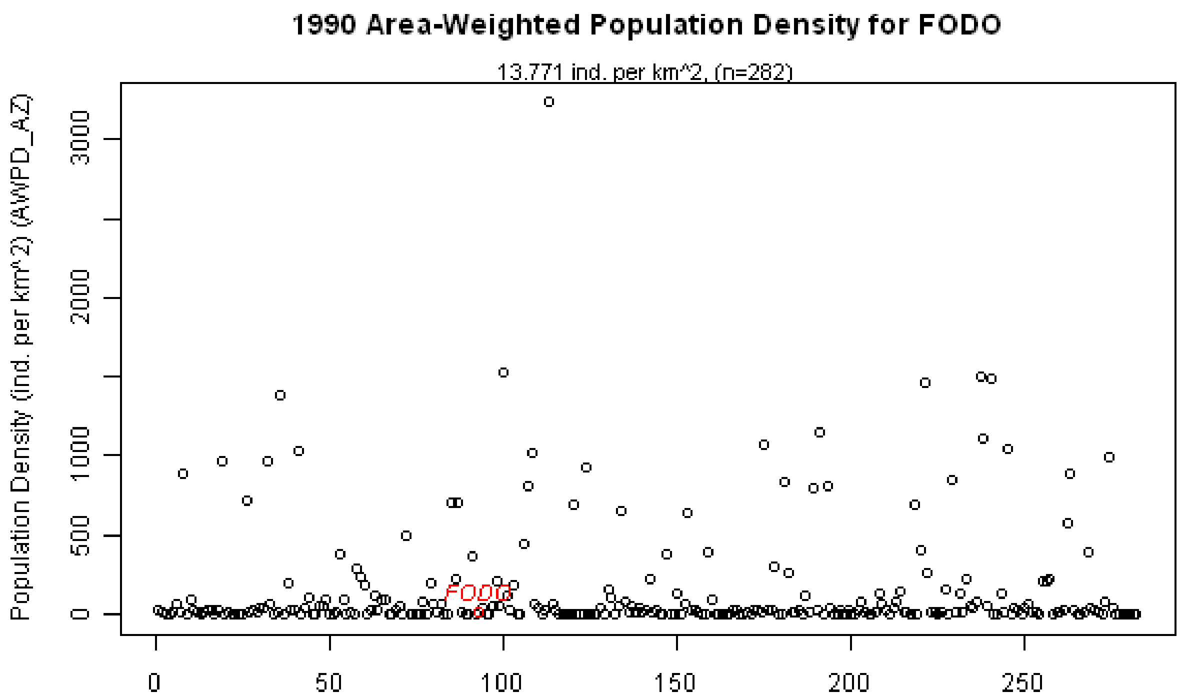


Figure 36. NPScape product showing population density of FODO in 1990 and 2000 relative to landscapes of other NPS units.

<u>Pattern</u>

The configuration and composition of landcover types and specific landscape features play a large role in the dynamics of ecological processes, and more specifically can play a role in determining the species assemblages found in a certain area (Turner 1989). Natural landcover and the amount of suitable habitat it provides is one component of species composition, though it is also affected by the arrangement of that habitat. These two components of landcover are often confounded, and thus individual effects are difficult to identify (Trzcinski et al. 1999). However, landscape metrics intended to describe general patterns of landcover can be helpful in determining which features strongly influence patterns of species distribution. Gross et al. (2009) point out that some of the most commonly used landscape metrics include patch size and shape, connectivity, core habitat, and edge habitat.

Edge. Edges are the boundary between two different patch types, and as certain landcover types are divided and become more patchy, edge density increases, which can affect numerous ecological processes. Conditions at patch edges may be intermediate of those at adjacent patches, such that a forested edge next to an open patch may be hotter, drier, windier, and lighter than interior forest conditions, which may in turn also result in different species composition (Ries et al. 2004). Edges may also alter species composition by facilitating the transport of pollen or other organisms into interior habitat area. Species interactions may also be affected by the presence of edges. Numerous studies report that birds undergo increased rates of parasitism and predation within edge habitats and demonstrate greater rates of nest success in larger patches (Paton 1994, Donovan et al. 1997, Andrén and Angelstem 1988).

Patch Size. The patch size of individual landcover types is closely related to the effects of edges on organism interactions and resource movement. A larger patch will usually contain more core habitat than a smaller patch size, meaning that the habitat is not subject to the higher predation rates and other outcomes associated with edge effects. The amount of edge, however, can increase or decrease depending on the shape of the patch, which lends usefulness to the perimeter (edge) to area ratio—another commonly used landscape metric. However, as Andrén (1994) notes, patch size is also confounded by fragmentation, and thus each of these three metrics (patch size, edge, and fragmentation) must be considered in tandem.

The NPScape project constructed maps of core habitat using edge widths of 30 m and 150 m. In an assessment of microclimate variation along forest edges, Matlack (1993) found that edge effects for several factors were detectable at sites of eastern deciduous forest up to 50 m from the edge. Another estimate by Ranney (1977) suggested that edge habitats extend from 5 m up to 20 m and may affect a variety of factors including tree species composition, primary productivity, structure and development, animal activity, and propagule dispersal. Both of these estimates most closely match the 30 m edge width used in the NPScape product describing forest habitat types shown in Figure 37. In this product, landscape elements are classified according to morphological spatial pattern analysis (MSPA) types, which include core, islet, perforation, edge, bridge, branch, and background. Table 41 shows definitions for these features and their respective contribution for each of the classes using a 30 m edge definition. Although edge proportion is highest within the park unit and decreases at successive buffer widths, core forest area is also highest within the park unit. Background area is highest in the buffer regions and low within the park unit, reflecting higher amounts of developed land (i.e. non-forested) within the surrounding park landscape. Figure 38 depicts proportion of core and edge area within the vicinity of FODO compared to other NPS units. Proportion of core forest within the 30 km landscape is among the highest of NPS units, whereas proportion edge appears to fall close to the median.

Table 41. Morphological spatial pattern analysis (MSPA) class types used by NPScape for FODO forest patches at 30 km (excluding Fort Heiman), 3 km, and no buffer widths. Edge width was defined as 30 m.

		-30 km buffer-		-3 km buffer-		-No buffer-	
Pattern type	**Definition**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Core	Interior forest area not influenced by edge	1912.7	62.5	55.5	52.5	3.1	76.8
Islet	Patch too small to contain core area	7.6	0.2	0.2	0.2	<0.1	0.1
Perforated	Edge (linear) internal to core forest type (30 km)	135.2	4.4	3.6	3.5	0.1	1.8
Edge	Perimeter (linear) of forest patch (30 km)	140.4	4.6	6.5	6.2	0.5	11.8
Bridge	Non-core (linear) forest connecting disjunct core patches	36.6	1.2	1.1	1.0	<0.1	0.5
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	38.0	1.2	1.3	1.2	<0.1	0.8
Background	Non-forested area	791.0	25.8	37.0	35.4	0.3	8.1

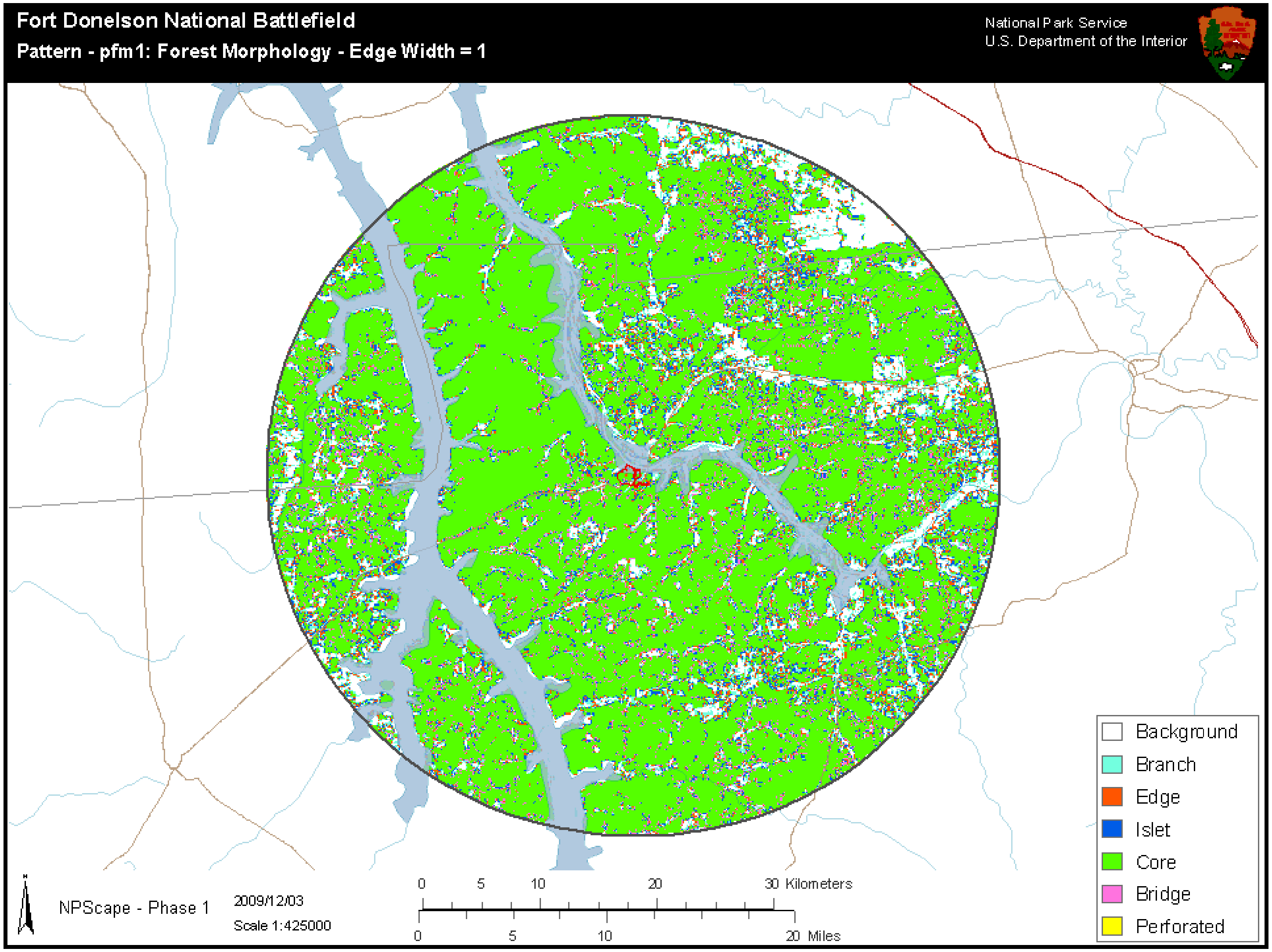
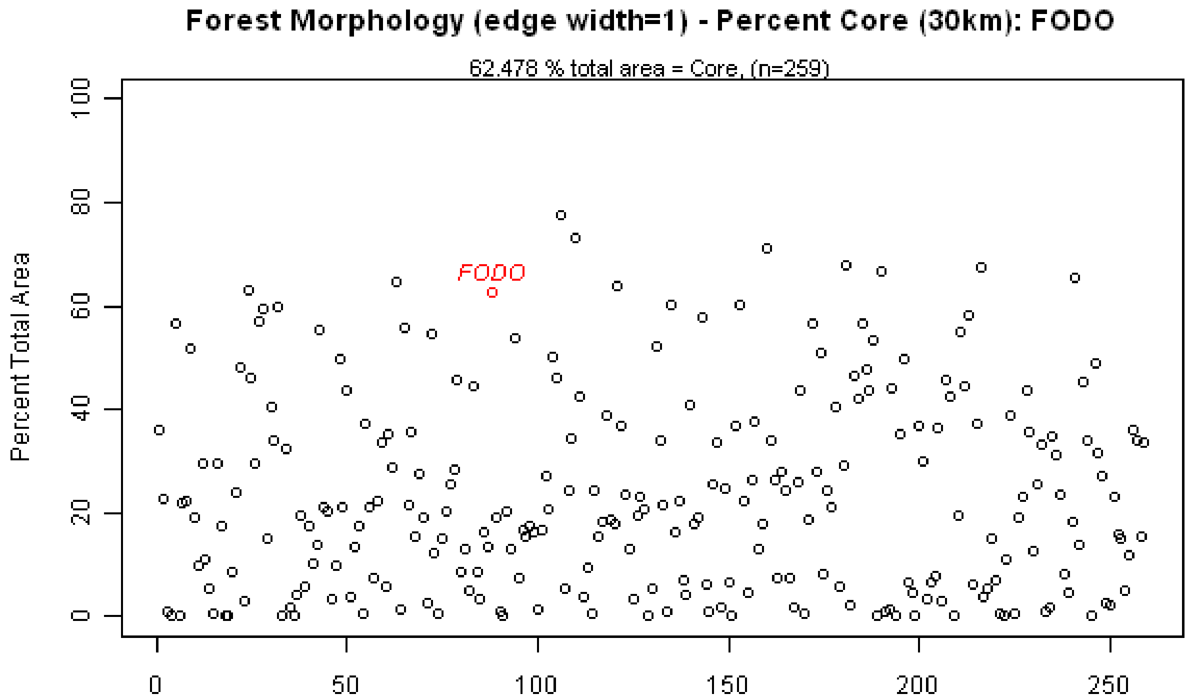


Figure 37. NPScape product showing forest morphology metrics for FODO with a 30 km buffer. Edge width is defined as 30 m.



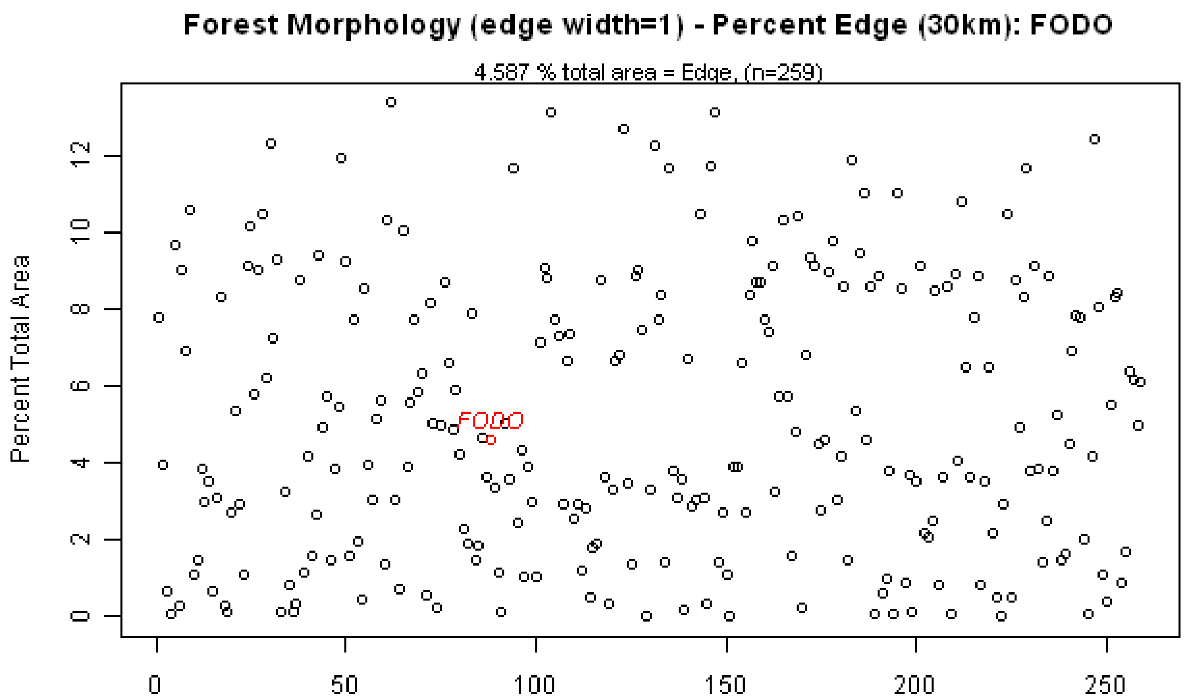


Figure 38. NPScape pattern product showing percent core (top) and percent edge (bottom) for FODO compared to other NPS units.

Conservation Status

The creation of protected areas is generally considered a safeguard against habitat loss and degradation. These protected areas, in combination with other landscape factors posing a risk to natural resources, can help prioritize areas for further conservation at fairly large scales. To this end, the Gap Analysis Program (GAP) has developed the Protected Areas Database (PAD) of the US, based primarily on the prescribed management of individual land units. This database ranks protected areas on a scale of 1 (highest protection) to 4 (lowest protection) depending on the relative degree of biodiversity protection offered by each unit (Gross et al. 2009). Figure 39 depicts the landscape surrounding FODO with PAD GAP protection statuses. FODO is assigned to status 2, which connotes permanent protection from landcover conversion, though with the possibility of degrading management, such as suppression of natural disturbances (Gross et al. 2009). Gross et al. (2009) point out that the level-3 protection class is considered typical of "multiple-use" areas, such as those managed by the Bureau of Land Management (BLM) or the USFS.

Overall, there are 6750 ha of protected area within the buffer, or approximately 11.8% of the land area. Most of this area includes portions of Land Between the Lakes NRA and Cross Creek National Wildlife Refuge (NWR), though the two small areas Beechy Creek Wildlife Management Area (WMA) and Barnett's Woods State Natural Area (SNA) comprise about 64 ha. All of these areas are classified as either GAP level-2 or level-3 status. When calculating using just level-2 protected areas, the proportion is 3.5% protected area. This is close to the calculated proportion of 3.7% in Figure 39, which compares amount of protected area within the FODO landscape relative to other NPS units. The protected area proportion of 3.7% includes water. While this number is low, it appears close to or slightly below the overall median due to the positive skew of the distribution.

Similar to the variety of thresholds discussed for critical habitat, impervious surface, and road density, Gross et al. (2009) point out that conservation goals describing ideal amounts of protected area also vary widely. As Soulé and Sanjayan (1998) note, preservation goals such as 10% to 12% protected area are posed frequently for their political appeal (Rodrigues and Gaston 2001, Svancara et al. 2005), but such low proportions, when considered in the context of species-area relationships, are grossly inadequate and could translate into a loss of up to 50% of species richness. A review of evidence-based studies outlining conservation targets by Svancara et al. (2005) yielded an average threshold of 41.6 % ± 7.7 % (*n* = 33), wherein the studies considered were ones whose "research results…identified thresholds at which habitat fragmentation or loss has deleterious effects on the feature of interest." This threshold was much higher than the average threshold value of 13.3 % ± 2.7% for policy-based targets that were based in little or no scientific grounding. Although it is difficult to identify a one-size-fits-all threshold, evidence-based examples express the need for much higher thresholds of protected area, as well as ones that are individually targeted toward the biological needs of communities, species, and ecosystems of the area in question (Svancara et al. 2005).

Besides thresholds of protection, Gross et al. (2009) outline out a metric described by Hoekstra et al. (2005) called27 the Conservation Risk Index (CRI). Similar to the U-Index calculated as the ratio of natural to converted land, the CRI is calculated as the ratio of area converted to the area protected. Hoekstra et al. (2005) outlines thresholds for the index based on the IUCN Red List species, such that areas where habitat conversion is > 20% and CRI > 2 is classified as vulnerable; those with conversion > 40% and CRI > 10 as endangered; and those with conversion > 50% and CRI > 25 as critically endangered. Although originally created as a means to gauge human alteration threats to regional biomes, the CRI is still a useful reference for the FODO landscape, despite its much finer park-level scale of analysis.

When applied to FODO using GAP level-1 and -2 protected areas (i.e. excluding FODO itself) and NLCD 2006 converted area over the 30 km buffer, the CRI yields a value of 7.7, wherein 27.0% of the area is classified as converted landcover according to 2006 NLCD. This meets the "vulnerable" designation for CRI. Including level-3 areas in the definition of protected lands, the CRI decreases to 2.3 within the same 30 km buffer landscape.

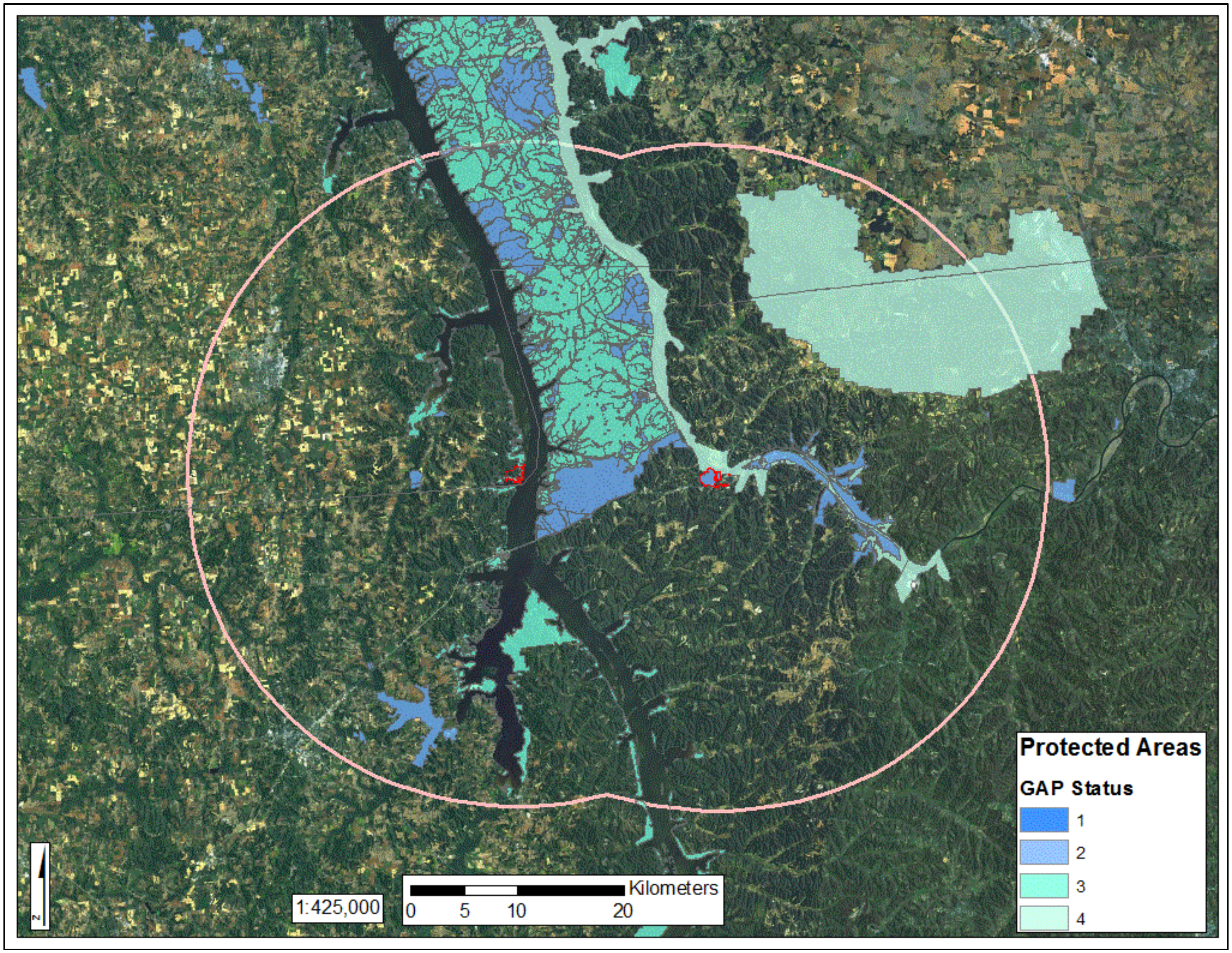


Figure 39. NPScape product depicting protected areas, as defined by the Gap Analysis Program (GAP), within a 30 km buffer of Fort Donelson and Fort Heiman.

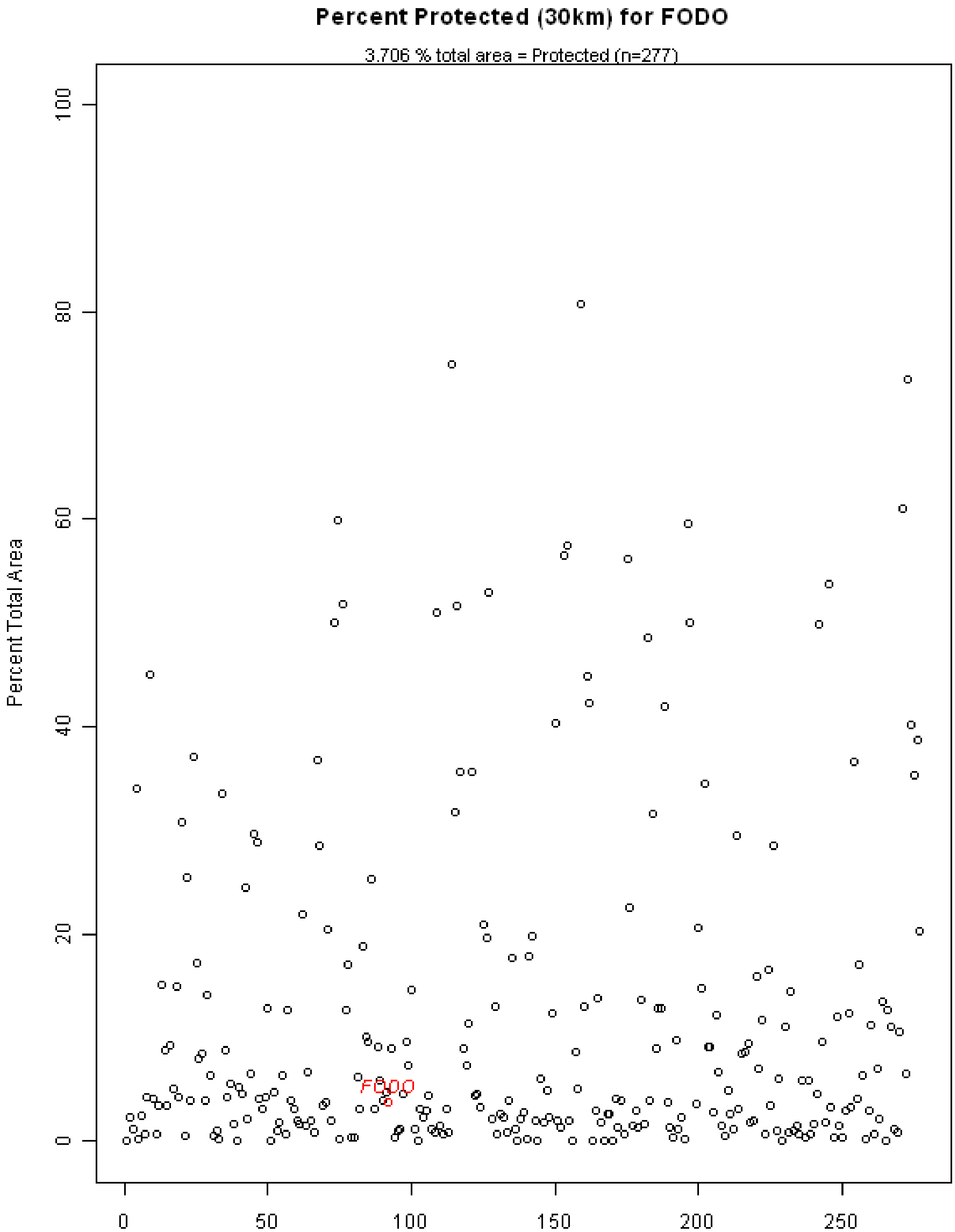


Figure 40. NPScape conservation status product showing percent protected area of FODO within the 30 km buffer relative to landscapes of other NPS units.

Landscape Synthesis and Considerations

The NPScape effort that directs much of the landscape dynamics section was designed to outline specific measureable features that would reflect resource condition within individual park units. Because most of the park units lie within larger ecosystems and exchange and affect resources far beyond their own boundaries, three spatial scales were considered for analysis. Gross et al. (2009) also indicates that additional scales will be analyzed in future NPScape products. In an effort to strike a balance between reproducibility among park units and relevancy across scales and regions, analysis was divided among five main landscape aspects: landcover, roads, population and housing, pattern, and conservation status. Below, each of these five sections is summarized with a general description, key references, and challenges describing the landscape aspect, followed by the main points pertaining to FODO for each section.

Landcover

Analyses of landcover was based mainly on data from the National Landcover Dataset (NLCD), which includes 2001 and 2006 classifications, in addition to a change product between the two periods that outlines them as natural or converted areas. The other two classifications included Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) existing vegetation type (EVT) layer and the Gap Analysis Program (GAP) landcover layer. For each of the three data sources, a U-index representing the ratio of converted to natural area was derived, with the results as shown in Table 42.

Table 42. U-indices for three landcover sources at each buffer width.

	-U-Index-		
-Data Source-	**-30 km-**	**-3 km-**	**-No buffer-**
NLCD	0.27	0.09	0.13
LANDFIRE	0.34	0.20	0.19
GAP	0.39	0.14	0.09
Average	**0.33**	**0.14**	**0.14**

O'Neill et al. (1988) showed a correlation between the U-Index and the domination of different landcover types. Forested landscapes tended to show a high fractal dimension and correlated positively with the U-Index, while the opposite was true for agricultural landscapes. Either way, the index corresponded well to the level of human manipulation within the landscape.

Amount of impervious surface area is another metric used often in landcover analyses. Perhaps more than several other aspects of landscape change and analysis, the effects of imperviousness has a large literature base attempting to relate specific thresholds to changes in water and habitat quality. Some of the lowest thresholds, identified by Paul and Meyer (2001), indicate potential for changes in geomorphological characteristics—mainly stream channel enlargement and destabilization—at levels of 2% to 6% imperviousness. Several studies also focus on how impervious surface affects stream habitat quality. Klein (1979) defined a limit of 10% imperviousness for areas with trout populations, while Stranko et al. (2008) found a much lower threshold of 4% imperviousness for brook trout populations in Maryland stream catchments. Klein (1979) suggests that larger thresholds such as 12% - 15% imperviousness are where stream water quality begins to degrade.

- Average values of imperviousness for FODO are around 4% within the park unit, which places it below the threshold for effects on stream quality. Some geomorphological effects may be present; roads adjacent to earthworks may be potentially sensitive areas.

- Imperviousness for successive buffer widths of 3 km and 30 km are respectively 2.8% and 3.1%. While low, these proportions are still potentially in the range that could result in changes in geomorphological characteristics (Paul and Meyer 2001).

Roads

NPScape used three main metrics to describe the effects of roads in the landscape: road density, distance to road, and effective mesh size. Mean rates of traffic were not used in the NPScape assessment but were a used to estimate land turtle mortality by Gibbs and Shriver (2002), who suggested a road density threshold at 1.0 km km^{-2}. Steen and Gibbs (2004) offered another threshold of 1.5 km km^{-2} for a central NY study involving aquatic turtles, while Forman and Alexander (2002) suggest that 0.6 km km^{-2} represents the upper threshold of a landscape that can support large predators such as wolves and mountain lions. In addition, Frair et al. (2008) found a low threshold between 0.25 km km^{-2} and 0.50 km km^{-2} where elk populations in Alberta, Canada began to be affected, while effect on the landscape reached a saturation level at 1.6 km km^{-2}. Lin (2006) offers that the average road density throughout the US is 0.67 km km^{-2}.

- At FODO, road density decreases from 2.7 km km^{-2} with no buffer, to 2.1 km km^{-2} at the 3 km buffer, and 1.9 km km^{-2} at the 30 km buffer width. Road densities at both buffer widths and for the park boundary are greater than all the thresholds presented from literature above, though the park itself demonstrates a much higher density and suggests a potential effect on wildlife populations.

- Average distance to road measure is much lower within the park boundary—140 m—than for the 3 km (293 m) and 30 km (326 m) buffer widths.

- The average roadless patch area for FODO is <0.1 km^2, but because the park unit itself is so small, this metric holds limited meaning. Only three small parcels in Fort Heiman even allow this metric to be calculable at the park boundary level. The 3 km and 30 km buffer widths have respective roadless patch areas of 0.9 km^2 and 1.2 km^2.

- Although distance to road measure is lowest for the park boundary among the 3 scales of analyses, road density is highest, and average roadless patch is lowest for the park boundary scale. These metrics are highly influenced by the small area of the park unit. Realistically, roads account for a small portion of area in the park (3-4%) according to each of the three landcover classifications.

Population and Housing

These two measures are highly related and correlate well with other landscape metrics like impervious surface and road density. Unlike other metrics, perhaps, it becomes more difficult to identify thresholds of housing or population densities that affect specific changes in the landscape. However, Gross et al. (2009) point out several studies that make general observations regarding influences of human settlements on plants and vertebrates. In a study involving exurban areas in Colorado, for example, Maestas et al. (2002) found (1) increased richness and cover of non-native plant species, (2) increased densities of human-commensal bird species such as blue jays (*Cyanocitta cristata*) and black-billed magpies (*Pica hudsonia*), and (3) high densities of domestic dogs and cats. In a study in California, Merenlender et al. (2009) found lower proportions of temperate migrant bird species in exurban and suburban areas, and in dense housing areas found higher relative abundances of urban adapter species like American crow (*Corvus brachyrhynchos*) and turkey vulture (*Cathartes aura*).

- Relative to other NPS units, FODO falls within one of the lowest population density classes for its surrounding vicinity (Figure 36). Within the 30 km^2 buffer, average population density was 15.2 individuals per km^2 in 2000, which falls in the exurban development class outlined by Theobald (2005).

- The highest proportion of developed area in the park vicinity falls within the exurban class for the 3 km buffer width and in the rural class for the 30 km buffer scale.

- Proportion developed area is overall highest at the 3 km buffer scale for all except the least dense development classes. This is due in part to the greater proportion of protected area within the 30 km buffer and the influence of the development of Dover, TN at the local scale.

- Since 1950, private undeveloped land and the lowest density housing classes (<1.5 units km^{-2}) show a decreasing trend within the 30 km buffer. Most of the other higher density classes show a steady increase.

Pattern

The NPScape product used the GUIDOS package to derive a set of eight metric classes for the landcover around FODO. Metrics were derived using both a 30 and 150 m definition for forest edge width. Several papers have identified thresholds for edge effects. Matlack (1993) selected 50 m as the width of influence for several microenvironmental factors, while Ranney (1977) stipulated 5 m to 20 m as the range of influence.

Besides edge effect, patch size is a fundamental landscape metric that addresses habitat availability. Although the effect of patch size is dependent on scale, both spatially and temporally, small patches often offer insufficient levels of habitat to maintain high levels of biodiversity.

- Although core forest proportion is highest within the park boundary among buffer widths, edge is also highest at this scale. Background proportion, or unforested area, is lowest for the park boundary scale.

Conservation Status.
The NPScape assessment used the Protected Areas Database (PAD) created by the Gap Analysis Program (GAP) to analyze the amounted of protected area within the vicinity of FODO. Protected areas are assigned a rating of 1 to 4 corresponding to a descending scale of the amount of biodiversity protection offered by each land unit. As a guideline, 10% to 12% protected area is often posed as a minimum objective (Rodrigues and Gaston 2001), though a review of evidence-based studies by Svancara et al. (2005) yielded a considerably higher minimum threshold of 41.6% ± 7.7%.

An additional guideline for amount protected area outlined by Gross et al. (2009) is the Conservation Risk Index (CRI), which is the ratio of converted to protected area. Hoekstra et al. (2005) describes thresholds based on the amount of habitat conversion and the CRI, beginning with minimal threat when habitat conversion reaches 20% and CRI > 2.

- Using Hoekstra et al.'s (2005) CRI rating, the ratio of converted area to protected area within the vicinity of FODO is 7.7. Combined with the 27.0% classification of converted area taken from the 2006 NLCD, this yields a conservation risk rating within the criteria for a vulnerable classification (Hoekstra et al. 2005).

4.11.3 Condition and Trend

Each of the five components assessed by NPScape presents a slightly different outlook on the state of the landscape within the vicinity of FODO. Considered individually, there are several aspects of the analysis that are encouraging, such as

1. Natural resource protection afforded by FODO certainly makes a difference beyond the park boundary, an effect which may be evident in the lower U-indices in the proximate 3 km buffer class than the 30 km class (Table 42).
2. Compared to other NPS units nationwide, the landscape of FODO at a 30 km buffer has a relatively high proportion of natural landcover (87.5%).
3. Low population density in the surrounding landscape (15.2 per km^2).
4. Pattern metrics reveal higher core forest and lower background proportions within the park unit than successive buffer widths.

Other aspects of the analysis are less encouraging, especially when viewed across all buffer classes:

1) Road metrics reflect a highly dissected landscape at all three scales of analyses.
2) Although regional population density is low, all except the lowest density housing classes show a steady increase since 1950, which can indicate increasing pressure on landscape resources.
3) The CRI of 7.7, combined with the high proportion of converted area (27.0%) at the 30 km buffer width, results in a "vulnerable" designation of the landscape surrounding FODO.

The complexity of the landscape change vital sign makes it difficult to summarize into a single condition status ranking. By combining NPScape aspects into key points as above, it becomes easier to pick out the most significant landscape qualities. As a result, landscape change is assigned an overall ranking of "fair" (Table 43). Due to the large proportion of protected area, in addition to the negligible rates of conversion observed in the NLCD change product, this suggests that landscape change is minimal, and thus this condition receives a stable trend (Table 43).

Table 43. The condition status for landscape change at FODO was fair, qualified with a stable trend. The data quality for this ranking was good.

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

4.11.4 Literature Cited

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4.12 Viewscapes – Night Sky

4.12.1 Relevance and Context

Nighttime darkness is an important component of natural landscapes. Perceiving skies without the influence of urban light can enhance appreciation of a cultural landscape, such as at FODO, while at the same time dark skies are important as nocturnal habitat for certain organisms. Nighttime light in the sky is referred to as skyglow, and can be either the result of natural sources, such as scattering of planetary and astral light, or of artificial sources, such as light from cities and street lamps. Artificial skyglow of this latter type is what comprises light pollution (NPS 2012). Cinzano et al. (2001) point out that 99% of the contiguous US population lives in an area with at least some light pollution, while over two-thirds lives in area where the Milky Way galaxy is not visible. Light pollution can also be exacerbated by air quality conditions, wherein hazy night air can dim views from stars and scatter city lights (NPS 2012).

Artificially lit nighttime areas can result in various ecological changes, such as altering predator-prey dynamics or mating behaviors, and it can also disorient nocturnal animals such as frogs, or migratory animals such as birds (Longcore and Rich 2004). Some birds alter nesting location based on nighttime light, while in other cases community structure of insects may be changed based on exploitation of their light-attraction by predators. The effect of artificial light on community structure may even be more pronounced in areas like FODO, where organisms are adapted to dark natural conditions provided by the predominant forest cover.

4.12.2 Data and Methods

One of the most common ways to measure nighttime visibility and light pollution is using the Bortle dark sky scale, which is an index rating perceived darkness on a scale of one to nine, with one reflecting dark skies free of skyglow, and nine being the highly light-polluted characteristic of dense urban areas (NPS 2012). Another method is using the limiting magnitude average, where the limiting magnitude is the highest magnitude (i.e. dimmest) star visible to the naked eye.

At FODO, these metrics were observed at nine locations in the Fort Donelson unit, and five locations in the Fort Heiman unit over the course of a week during the summer of 2012. Both the Bortle dark-sky metric and limiting magnitude metric were assessed by three observers and then averaged. In addition, a sky quality meter was used to offer a reliable assessment of brightness in magnitudes per square arc-second – a measure of brightness per area of sky.

4.12.3 Condition and Trend

Figure 41 shows results of skyglow monitoring at eight locations over two nights at Fort Donelson, expressed in magnitudes / arcsecond^2. Higher values indicate darker skies, and were observed more reliably at locations in the northern portions of the park. Grave's Battery recorded the lowest value, indicating the highest amount of skyglow. Values for the Bortle dark-sky scale were also recorded, which ranged from three to five, indicating rural to suburban skies. At Ft. Heiman, five locations were assessed on a single night and showed similar results. All recorded a value of three on the Bortle dark-sky scale; limiting magnitude averaged 6.6 and magnitudes / arcsecond^2 averaged 21.62, which was higher than the darkest point observed at Ft. Donelson at the National Cemetery.

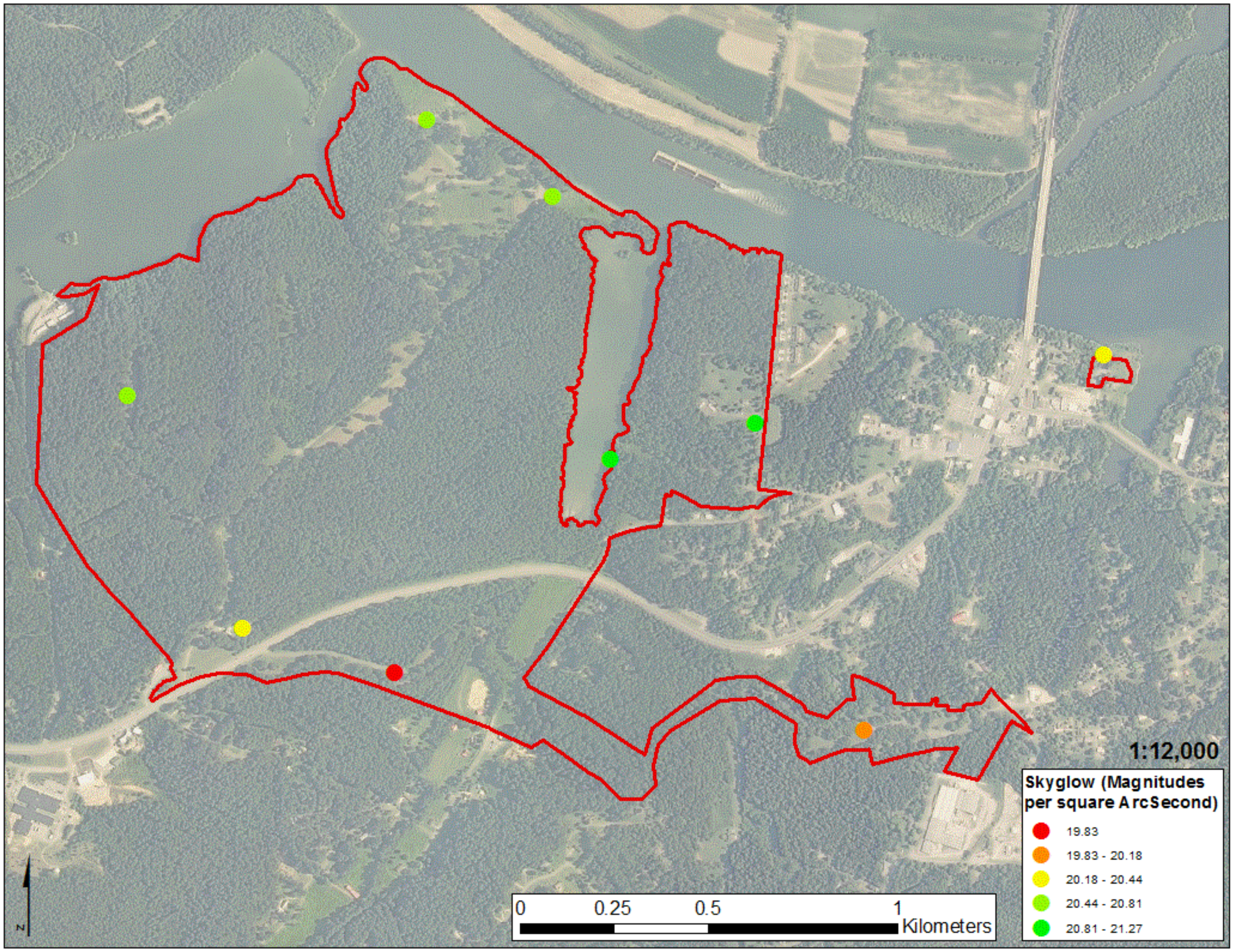

Figure 41. Night sky monitoring was conducted at Ft. Donelson (above) and Ft. Heiman (not shown) in July 2012. Skyglow, a measure accounting for light pollution, was collected at 14 points on multiple dates.

Within the main Ft. Donelson unit, the Bortle dark-sky index averaged 3.8 with a 6.4 limiting magnitude, which places it in the category of skyglow typical to rural/suburban transition areas. In this category, light pollution domes are typically visible on the horizon from cities and distant light sources. The Milky Way may also be visible, but may not be well-defined.

Ideally, night skies around FODO would be free of light pollution, allowing for a completely natural setting, and one that would also be beneficial to wildlife at the park. In reality, most areas in the US are afflicted by some degree of light pollution, especially in the more densely populated eastern section. As a result it is somewhat difficult to assign a condition status. While continued development of the surrounding region could easily reduce nighttime visibility at FODO, the immediate area is not highly developed, and elimination of local light sources would likely not create a much darker sky. This attribute is assigned a condition of good to reflect the above average visibility for the overall region, though it is still far from a natural night sky (Table 44).

While some degree of light pollution is impossible to avoid in developed areas such as that surrounding FODO, it is possible to reduce unnecessary ambient light via conscientious lighting and energy use. At FODO, staff and volunteers have just begun to monitor nighttime light conditions, but their efforts will likely ensure that light pollution is minimized in and around FODO to the degree possible.

Table 44. The condition status for night sky viewscape at FODO was good with no trend assigned. The data quality for this attribute was also good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Viewscape – Night Sky	●	✓	✓	✓
		3 of 3: Good		

4.13.4 Literature Cited

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Longcore, T. and C. Rich. 2004. Ecological Light Pollution. Frontiers in Ecology and the Environment 2:191-198.

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Chapter 5 Discussion

5.1 Summary

Based on a review of available ecological information at FODO, we have addressed the current condition of 13 natural resource attributes in the park. Overall, nine (69%) attributes were ranked as good and four were ranked as fair (31%).

Summarized into broad Level-1 categories the rankings were:

Air and Climate (two attributes)—50% Good, 50% Fair
Water (one attribute)—100% Good
Biological Integrity (eight attributes)—75% Good, 25% Fair
Landscapes (two attributes)—50% Good, 50% Fair

We also characterized the quality of information used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Data were classified as good for nine attributes and as fair for four attributes. Because most datasets were not long-term enough to determine trends, trends were only assigned to three of the attributes.

5.2 Natural Resource Conditions

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

Ozone

Data for ozone concentration came from two monitoring stations: one in nearby Trigg County, KY (2006-2011) and one from a Portable Ozone Monitoring Station at FODO (2005, 2009 ozone seasons). Interpolations from the NPS Air Resources Division were also available for four separate five-year periods. Concentrations collected in Trigg County were much higher than observations in the park, likely to do with the incomplete monitoring period of the POMS. Using the standard ozone metric for EPA NAAQS, which is averaged over a three year period, the station at Trigg County was in violation in 2008, though not since then. The five-year NPS ARD interpolations for FODO were also elevated, overall resulting in a condition ranking of fair. Ozone condition received a trend of fair.

<u>Data quality</u>

Ozone data quality received a good ranking due to the currency of the data. Although on-the-ground monitoring was available within the park from the POMS, this was only briefly and is scheduled to return only every six years. Although this schedule may be the result of budget limitations, more frequent monitoring would be ideal to ensure that ozone concentrations remain low. Ideally, monitoring would also last through the entirety of the ozone season.

Foliar injury

Risk of ozone damage to vegetation is closely tied to ozone concentrations, though it is also affected by exposure duration, species sensitivity, and soil moisture conditions. The severity of the three foliar injury metrics interpreted from national interpolation maps was inconsistent at

FODO, though they overall averaged a moderate risk. Available data for soil moisture showed that a predominance of wet months may have exacerbated foliar injury over the period of prediction. Recent on-the-ground surveys detected minimal evidence of foliar injury. As a result, foliar injury received a condition status of good. No trend was assigned to foliar injury condition.

Data quality

Foliar injury metrics are useful for assessing risk to vegetation, though at FODO they were only available in 1995 through 1999 as interpolations. Ozone concentration data from the POMS at FODO converted to injury metrics would be useful. On-the-ground foliar injury surveys are clearly an efficient way of determining ozone damage at the park. Continued assessments like the one conducted in 2009 would be the most useful method of monitoring foliar injury. Data quality was good for foliar injury.

Water Quality

Quarterly water quality monitoring began at FODO in 2003, with samples collected every other year. Although only two water sources, Hickman Spring and Indian Creek, are located in the park unit, sampling also includes adjacent embayments and the Cumberland River. Based on monitoring thus far, no water quality issues are apparent, and as a result this attribute received a condition status of good. No trend was assigned to water quality condition.

Data Quality

Continued routine sampling at each of the monitoring stations will ensure that any emerging water quality issues are detected at FODO. Data quality was good for this attribute.

Exotic Plants

Invasive exotic plants are potentially one of the largest management issues at the park from a natural resource perspective. The most recent inventory documented 109 exotic species in the park, including 26 considered particularly invasive. According to the most recent plant inventory, species whose removal would be the most beneficial include Chinese privet (*Ligustrum sinense*), autumn olive (*Elaeagnus umbellata*), Japanese stiltgrass (*Microstegium vimineum*), English ivy (*Hedera helix*), Johnsongrass (*Sorghum halepense*), jointgrass (*Arthraxon hispidus*), bicolor lespedeza (*Lespedeza bicolor*), sericea lespedeza (*Lespedeza cuneata*), and multiflora rose (*Rosa multiflora*). Because of the threat these species represent, this attribute received a condition ranking of fair.

Data Quality

The recent plant inventory provides a good basis by which to gauge threats from exotics. Keeping close tabs on what exotics are present, the rate at which they spread, and the areas they are affecting will help target further management efforts. Data quality received a good ranking. No trend was assigned to exotic plant condition.

Rare Plants

FODO provides habitat for several rare plant species, the most significant of which is Price's potato bean, which occurs at a single location in the park. Populations appear to be stable, though Chinese yam, an exotic, is also present near nearby and may pose a future threat. This area may, as a result, represent a prime opportunity for exotic control treatments. Other species with state conservation ranks are present in FODO, including purple milkweed, barbed rattlesnake-root, and southern nodding trillium, though little park-specific information is available for these species. Monitoring for these sensitive species would be beneficial. A condition status of fair was assigned based partly on the precarious nature of the population due to its occurrence in a disturbed area of the park. In addition, there lacks a targeted management plan for this species. Even though the park offers protection from development, it is important to ensure that operations do not contribute to its decline. Based on the most recent assessment, the population appears stable, and thus a stable trend is assigned.

<u>Data Quality</u>
The data quality for this attribute was good, though gaps still exist. A monitoring plan appears to be in place for Price's potato-bean, but not for other sensitive species. Locations of previously documented sensitive species not appearing in the most recent NatureServe inventory should be checked to see if populations are still present, and if so, monitored.

Vegetation Communities
FODO contains a variety of vegetation types, including wetlands and thirteen vegetation associations. Of these, four are considered natural vegetation types. Overall, these forest types are typical of the general region, with perhaps the exception of the Cherrybark Oak / Eastern Hophornbeam Forest, which is prevalent at the park unit but relatively uncommon throughout its range. Exotic species likely represent the greatest threat to vegetation communities at the park, particularly to this community and forested wetland areas. Although some areas are affected by exotic plants, most of the vegetation in the park is intact forest/woodland. As a result this attribute received a good condition status.

<u>Data Quality</u>
The recent vegetation map, wetlands assessment, accuracy assessment, and NatureServe plot surveys at FODO provide a strong foundation for the status of vegetation communities at the park. As a result, the data quality of this attribute received a good ranking. No trend was assigned to vegetation community condition.

Forest Pests and Pathogens
Overall, FODO is relatively free from forest pests and pathogens, the exceptions being dogwood anthracnose and an unidentified oak pathogen. Dogwood anthracnose was detected in only two locations during a recent vegetation survey; this disease will likely only have a minimal impact on trees in the park, with few, if any, experiencing mortality. However, its effect on vegetation should be monitored and treated it necessary. The oak pathogen could be sudden oak death or oak wilt, and if it continues to cause mortality in the park, should be identified to determine treatment options. Other potential pests at FODO include 1) the native southern pine beetle, which can outbreak unpredictably and may infest the successional loblolly communities at FODO, and 2) the non-native gypsy moth, which generally follows a southward-moving invasion front that is just recently less than 200 km from FODO. Because of the overall lack of pest issues at FODO, this attribute is assigned a condition of good. Monitoring of the spread of dogwood anthracnose would also be valuable.

Data Quality
The data quality for this attribute is overall good, owing to the vegetation inventory and information supplied by park staff. Updates are necessary however, especially in the case of dogwood anthracnose, which could spread throughout the park.

Fish Assemblages

FODO contains relatively little fish habitat within its boundaries. A single small tributary of the Cumberland River, Indian Creek, is the only stream large enough to contain a significant fish assemblage. The observed assemblage in Indian Creek includes 11 species, lacks species of identified high conservation concern, and contains one non-native species (Zimmerman 2007). The observed assemblage is regionally-typical and is not indicative of major habitat degradation. The condition of FODO fish assemblages was ranked as good. No trend was assigned to fish assemblage condition.

Although the park is bounded by a large river, the fish habitat in this river is outside of the park's sphere of significant influence, so it is unreasonable to consider this a significant park resource. However, if future fish sampling is conducted in FODO, it may be desirable collect some samples within the embayed area of Indian Creek at its confluence with the Cumberland River. This area is surrounded by park lands, and knowledge of fishes present might be of some interest to park managers.

Data Quality
The quality of the data used to assess FODO fish assemblages was fair. It was collected using appropriate techniques and provided sufficient coverage of the fish assemblage resource in the park. Because it was over five years old, it did not meet the temporal quality criterion.

Bird Assemblages

Fort Donelson has a relatively rich bird assemblage for its size and 175 species were reported from a recent inventory (Stedman and Stedman 2005). The species count is substantially increased because a number of water birds use areas adjacent to the park as overwintering or migratory stopover habitat. Several species of conservation concern occur in the park. A pair of Bald Eagles has nested repeatedly in FODO. The condition of FODO bird assemblages was good. No trend was assigned to bird assemblage condition.

Data Quality
The quality of the data used to assess FODO bird assemblages was fair. Data were collected within park boundaries using appropriate techniques. Samples were collected during all seasons and within all major park habitats. Because data was over five years old, it did not meet the temporal quality criterion

Mammal Assemblages

The mammals found in the park are indicative of a regionally typical fauna. A recent park inventory (Kennedy et al. 2007) found 30 species of mammals. One state and federal endangered species, the gray bat (*Myotis grisescens*), was reported from the park. Species richness was consistent with expectations for a small and relatively protected area. The condition of FODO mammal assemblages was good. No trend was assigned to mammal assemblage condition

Data Quality

The quality of the data used to assess FODO mammal assemblages was fair. Data were collected within park boundaries using appropriate techniques. Samples were collected using a variety of methods in all major park habitats. Because data were over five years old, they did not meet the temporal quality criterion

Herpetofauna Assemblages

A recent inventory of FODO herpetofauna reported 37 species (Scott and Davenport 2005). No threatened or endangered species were reported, and no non-native species were reported. The park harbors a regionally typical fauna that includes around 70% of the species expected, and is consistent with expectation for a small and relatively well-protected area. The condition of FODO herpetofauna assemblages was good. No trend was assigned to herpetofauna assemblage condition.

Data Quality

The quality of the data used to assess FODO herpetofauna assemblages was fair. Data were collected within park boundaries using appropriate techniques. Samples were collected using a variety of methods in all major park habitats. Because data were over five years old, they did not meet the temporal quality criterion

Landscape Dynamics

The NPScape set of landscape analysis products is helpful in analyzing the impact of landcover use and change in the landscape surrounding FODO. This section of analysis was divided into five main considerations: landcover, roads, population and housing, pattern, and conservation status.

- Landcover analysis shows a relatively undeveloped landscape surrounding FODO with high proportion of natural landcover (87.5%).
- Both FODO and the surrounding landscape show high proportions of core forest habitat.
- Large areas of protected land will likely ensure continued protection from conversion. The NLCD change product shows negligible conversion in the landscape between 2001 and 2006.
- Road influence is high within the park unit
- Higher density housing classes show a steady increase since 1950.
- The Conservation Risk Index for FODO results in a “vulnerable” landscape designation, meaning that protected areas may be at risk of ecological isolation and species loss.

Because of this overall mix of positive and negative effects, the condition status for landscape dynamics at FODO receives a ranking of fair. Due to the negligible conversion rates between 2001 and 2006 shown by the NLCD, a trend of stable is assigned.

Data Quality

The NPScape suite of data products are a recently developed set of standardized metrics that make landscape analysis easy for individual park units. These data cover a breadth of landscape considerations, resulting in a quality ranking of good.

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

Night Sky Viewscape

A natural nighttime landscape is important at FODO not only because it benefits wildlife populations adapted to nocturnal habitat, but also because of the contemplative atmosphere fostered by the park and its battle setting, of which natural nighttime skies are an important component. Initial monitoring this summer (2012) showed that skies at Ft. Donelson and Ft. Heiman were slightly to moderately light-polluted. A condition status of good was assigned – although some amount of light pollution is apparent, night sky viewing is likely above average for the overall region. No trend was assigned to night sky viewscape condition.

Data Quality

Because monitoring just began, insufficient information was available to assess a trend. However, data quality was ranked good. Standard and defensible metrics were used, and their repeatability will ensure that changes over time are clearly observable.

Appendix A. List of Initial Scoping Meeting Attendees

Fort Donelson National Battlefield:

Michael Manning, Chief Park Ranger
Bill Barley, Integrated Resources Manager
Doug Richardson, Chief of Interpretation
Garnet Tritt, Park Ranger

Cumberland Piedmont Inventory and Monitoring Network:

Teresa Leibfreid, Coordinator
Bill Moore, Ecologist/Data Manager

University of Georgia:

Nate Nibbelink, Principal Investigator
Mike Mengak, Co-Principal Investigator
Gary Sundin, Research Professional
Luke Worsham, Research Professional

Southeast Regional Office:

Dale McPherson, Regional NRCA Program Coordinator

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov