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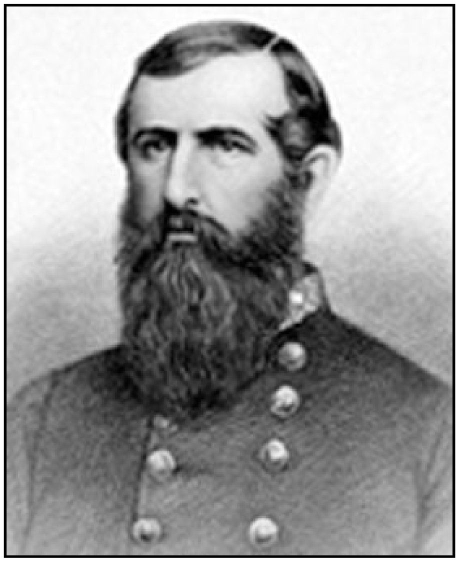
Natural Resource Condition Assessment for Vicksburg National Military Park

Natural Resource Report NPS/VICK/NRR—2014/769



ON THE COVER
Clockwise from Top Left: Conf. Lt. Gen. John C. Pemberton, Sunset over Fort Hill, Mint Spring Lower Falls
Photographs courtesy of National Park Service

Natural Resource Condition Assessment for Vicksburg National Military Park

Natural Resource Report NPS/VICK/NRR—2014/769

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Executive Summary

This report provides an assessment of the state of selected natural resources at Vicksburg National Military Park (VICK). It discusses threats and stressors that affect these resources. This assessment focuses on vital signs outlined by the Gulf Coast Inventory and Monitoring Network (GULN), as well as other attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: atmospheric deposition, weather and climate, water quality, vegetation, animal communities, and adjacent land use.

Data used in the assessment included I&M reports and bio-inventories, spatial information, park-commissioned reports, publicly-available data (e.g. SSURGO, National Landcover Dataset), peer reviewed literature, unpublished National Park Service (NPS) data, and personal communication with VICK and GULN staff. No new field data were collected for this report. When available, published criteria were used to derive a condition assessment based on available data, and when appropriate, we identify opportunities for improved data collection to allow for stronger assessment in the future.

Vicksburg National Military Park is located in the heart of Vicksburg, MS adjacent to the Yazoo Diversion Canal flowing into the Mississippi River. The park area encompasses over 700 ha and is notable for the thick loess glacial deposits that result in highly variable topography. Three main streams flow through the park, which, along with their tributaries, play a large role in the erosive action of the loess soils. The unique vantages afforded by the area that now comprises the park made it a strategic prize for both the Confederate and Union armies during the Civil War.

Although VICK was originally created to commemorate an important Civil War site, it harbors a variety of important natural resources. Although the forest in the park is less than 100 years old, it represents an important island of protected forest within a largely urban setting. Wetland areas are common in low-lying areas of the park, some of which are dominated by giant cane (Arundinaria gigantea) understories that were present at the time of the battle. According to NPSpecies, 305 species of vascular plants are recognized in the park, including the regionally rare prairie nymph (Herbertia lahue ssp. caerulea) and several other species with state conservation ranks. Vertebrate inventory and monitoring efforts in the park have reported 18 species of fish, 120 species of bird, 30 species of mammals, and 48 species of reptiles and amphibians. No state or federally endangered animal species have been reported. The park supports a notably rich assemblage of native birds and has been designated by the National Audubon Conservation Society as an important bird area.

Several classes of potential threats and stressors to natural resources are applicable to VICK and are addressed in this report. They include:

- **Atmospheric pollutants** – There are several sources of atmospheric pollution within the vicinity of VICK, which can react in the atmosphere to produce acid rain. Nitrogen and sulfur deposition can debilitate terrestrial and aquatic systems, while mercury deposition can pose human health hazards via bioaccumulation.

- **Decreased water quality** – Because of the highly erodible loess soils at VICK, runoff and siltation are significant management concerns, not only because of the difficulties with ravines and unstable areas that can result, but also because of the resulting high turbidity in nearby streams.

- **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. Kudzu likely presents the greatest danger at VICK, in part due to how quickly it spreads. Recent park efforts to control this invasive species have been successful in reducing its spread.

- **Non-native or invasive wildlife** – Exotic animals, and animals expanding outside their historic ranges, pose serious threats to biodiversity on a global scale. Due to its position in an urban landscape, VICK is highly susceptible to invasion by these species. Of the four vertebrate assemblages assessed, three (fishes, birds, and mammals) included significant numbers of non-native or range-expanding species. Fathead minnows (*Pimephales promelas*) and feral hogs (*Sus scrofa*) are recognized as important threats in the park and their control is being addressed by park management. Domestic dogs (*Canis familiaris*) and cats (*Felis catus*) have been noted in the park and their presence has the potential to negatively impact native species. The distribution of Brown-headed cowbirds (*Molothrus ater*) is fairly widespread throughout the park during the breeding season and previous studies of this species have indicated that their presence can negatively affect native birds nesting success. As of this report, VICK has not yet investigated the influence of cowbirds on nesting success of breeding birds in the park, thus the effect of this species on native organisms is currently unknown.

- **Landscape change** – An expansive category, landscape change can refer to negative impacts from development, human population increases, agricultural land uses, and habitat alteration and fragmentation. This issue is particularly relevant at VICK due to its location in a relatively urban setting.

Eleven ecological attributes were assessed at the park level for this report. Based on the number of rankings falling within each condition category, the overall summary of natural resource assessments is as follows: 27.3% good, 36.3% fair, 18.2% poor, and 18.2% not ranked. Trend was not assessed for most attributes. For assessed attributes, 18% had improving trends, 18% had stable trends, and no trend was assigned for the remaining 64%. For assessed attributes, data quality was very good for 36.3%, good for 27.3% marginal for 27.3% and poor for 9.1%. Assessment method and data quality were both highly variable among assessed attributes, and therefore condition rankings are not necessarily directly comparable.

Attribute Assessment Summary

Atmospheric Deposition

Data for wet atmospheric deposition came from four monitoring stations ranging from 40 km to 209 km from VICK. Data was available from as early as 1983 to as late as 2010. Dry deposition data was also available from the Coffeeville, MS CASTNET station. All four of the stations showed decreases in wet sulfur deposition over available data periods, while the Washington

Parish, LA station south of VICK showed a significant decrease in wet nitrogen. The Coffeeville, MS station showed a significant decrease in dry S deposition, but not dry nitrogen. Overall, mean wet deposition over the latest five years of monitoring for all four stations was slightly above the NPS Air Resources Division threshold for posing a threat to ecosystem health. Two stations located 80 km and 180 km southwest of VICK monitor mercury deposition, for which data is available from 1998 to 2010. Measurements between stations were only slightly correlated, suggesting that regional patterns of deposition may vary at a fine scale. Results from the closer Chase, LA station are likely more accurate to depict deposition rates at VICK. Because of the consistently high nitrogen and sulfur deposition rates, atmospheric deposition received a condition status of poor. Due to the majority of decreasing trends, however, the condition is qualified as improving.

Data quality

Data quality for atmospheric deposition received a ranking of good. Several sites were available from CASTNET and NADP observation networks relatively close to VICK, though depositional patterns may vary at such a fine scale that actual rates at VICK are not reflected by analyzed stations. As a result, monitoring at VICK would be ideal, and the proximity check for data quality is withheld.

Weather and Climate

Data from weather stations around VICK show long-term trends in temperature and precipitation. A single Remote Automated Weather Station (RAWS) collected data within the park from 2004 to 2007, while another station from the Cooperative Observer Program (COOP) collected data from 1967 to 2004. Based on monitoring for temperature and precipitation, none of the stations showed trends over the course of the data period. Frequency of daily maximum precipitation observations also showed no trend, indicating no change in number of intense storm events. Wind data was also available from the RAWS during its monitoring period, for which the predominant direction of origin was SSE – SE. Although much data were available for long-term monitoring in and around VICK, it is inappropriate to assign a valuation, and thus no condition is assigned for weather and climate.

Data Quality

The combination of data collected inside VICK from the RAWS and data from the COOP stations fulfilled all data requirements, resulting in a data quality ranking of very good. The data quality for this attribute is ranked as good.

Water Quality

Water quality data at VICK is collected by VICK staffed trained in the protocols of and by the Gulf Coast I&M Network. Water sampling with the assistance of park staff, began in 2007 and will continue for the foreseeable future. Three sampling stations represent each of the three main streams flowing in the park, which are visited quarterly. During the four years of available data, water quality appeared normal with the exception of elevated turbidity measurements on Durden Creek and Glass Bayou. Some measurements did not correspond to periods of rainfall and on Durden Creek in particular, may be related to operations within the park (e.g., bridge repair work). Decreasing pH values over the period of monitoring are likely related to the gradually earlier-shifting sample time. Overall, samples revealed no major issues at the park, and as a result a good condition status was assigned, along with a stable trend.

Data Quality
Data quality for water quality sampling was very good over the period of monitoring. Because of the observed decrease in pH values, it is important the future sampling occurs during the same time of day to avoid variability.

Exotic Plants

Multiple reports at VICK have documented a variety of exotic plants– the most recent count available from NPSpecies shows that over a quarter of vascular plant species at VICK are exotic. Of greater concern are those species that represent significant threats to native species or their habitats. The main current and potential future threats to native plant communities at VICK include the following invasive species: kudzu (Pueraria lobata), Johnsongrass (Sorghum halepense), Chinese privet (Ligustrum sinense), Chinese parasol tree (Firmiana simplex), and Chinese tallow tree (Sapium sebiferum). Regular treatments by both park staff and the Gulf Coast Exotic Plant Management Team have helped reduce the area infested by kudzu and Johnsongrass, though it is an ongoing battle due in part to how quickly the species spread, and in some cases how difficult they are to treat. Because of the ongoing problem of exotics at VICK, it is assigned a condition status of fair. Because conditions have been improving as a result of treatment efforts, an improving trend is also assigned.

Data Quality
A recent infestation map is available for kudzu at VICK, though no areal extent or treatment information is available for any other exotic. As a result, data quality for this attribute is ranked fair.

Terrestrial Vegetation

Almost three-quarters of the park is under forest cover of some type. The remaining area is mostly maintained as mowed grassy areas to aid in the interpretation of the battle setting. Areas under forest cover vary from sparse woodland to older hardwood forest. Riparian and wetland areas are sometimes dominated by Chinese privet, while in others includes they include areas of the native species of cane (giant cane) which better prevents soil erosion and facilitates understory diversity. Roughly one-fifth of the park is composed of Cherrybark Oak- Water Oak Loess Bluff Forest, a unique community type which is an ideal candidate for protection from exotic threats. Although vegetation throughout the park receives high levels of management attention, there are many areas that are dominated by non-natives, the most damaging of which is likely kudzu. Native vegetation has been overtaken in some areas by this invasive vine. Bermudagrass (*Cynodon dactylon*) was determined to work best to quickly stabilize the loess soil in more open areas of the park. Thus, it exists in the mowed backfields of the park in combination with several other species (e.g., bahia grass). Gradual replacement with warm-season native grasses could provide better wildlife habitat and has been included in future management plans (V. DuBowy personal communication). Because of these areas of vegetation that are exotic-dominated, the condition status for terrestrial vegetation receives a condition status of fair. Because of the ongoing treatments that have reduced the kudzu-dominated vinelands, a trend of improving is also assigned.

Data Quality
Data quality for this attribute is very good, and includes a detailed vegetation classification for the park. As of this writing, a new vegetation map is underway. It will be important to continue

to track changes in vegetation communities by conducting periodic monitoring. This will ensure that unique vegetation communities remain unimpacted, and that exotic-dominated communities are reduced in size.

Rare Plants

The most significant rare plant at VICK is the prairie nymph, which has a state conservation rank of imperiled (S2). Although rare throughout its range, prairie nymph grows abundantly at VICK in open grassy areas. Ongoing monitoring will determine effects of mowing on this species. Other significant plant species at VICK include climbing bittersweet (*Celastrus scandens*), Southern thimbleweed (*Anemone berlandieri*), and Southern slender lady's tresses (*Spiranthes lacera* var. *gracilis*). Bandana of the Everglades (*Canna flaccida*) may also be present, though identification of this species is not certain (V. DuBowy personal communication). Because of the status of prairie nymph at VICK, rare plants are assigned a condition status of good. However, this rank does not include consideration for other species due to a lack of data.

<u>Data Quality</u>

Data quality for rare plants at VICK received the lowest data quality ranking. No spatial information was available, and distributional information was only available for prairie nymph from recent monitoring, and as a result the temporal coverage was not fulfilled. Overall, this attribute received a poor data quality ranking. However, a project to study the prairie nymph in VICK has been formulated for 2017 (V. DuBowy personal communication).

Fish Assemblages

VICK contains two streams that support fish. Mint Spring and Glass Bayou are proximal tributaries of the Yazoo Diversion Canal that drain westward through the park. The entire length of Mint Spring is contained within park boundaries. Mint Spring descends two waterfall barriers within the park, effectively isolating the fish assemblages in the uppermost section. Fish data were available from a 1995-2003 stream assessment that included Mint Spring and Glass Bayou. This assessment yielded 18 species of fishes, none of which are listed as being threatened or endangered at the state or federal level. All 18 species, including the non-native common carp (*Cyprinus carpio*) and the fathead minnow, were found in Mint Spring. Glass Bayou contained three native species. Samples collected in Mint Spring were numerically dominated by the fathead minnow. A plan was created to remove fathead minnows from the uppermost portion of Mint Spring and to re-introduce native species. The first stages of this plan were implemented in 2008 and the final assemblage structure resulting from these actions are not known. A modified IBI, and qualitative assemblage characteristics were used to assess VICK fish assemblages. Because VICK fish assemblages were dominated by non-native and tolerant native species, the condition of fish assemblages was ranked as poor. No trend was assigned to fish assemblage condition.

<u>Data Quality</u>

The quality of data used to assess VICK fish assemblages was marginal. The summarized data available were insufficiently explicit to separate out the results of individual sample events. Furthermore the data were collected before 2003 and were therefore insufficiently recent to reliably reflect current conditions.

Bird Assemblages

The park supports a rich diversity of bird species during the breeding season, during migratory periods, and during the winter. Several efforts have studied migrating birds in the park, finding that a dense assemblage of migratory species occurred in the park during spring migration. Comprehensive sampling efforts including breeding season point counts and winter area constrained surveys were conducted starting in 2008, and the results of these surveys from 2008-2010 were the primary source of data for the bird assessment. These efforts reported 120 species, although roughly another 60 species have been reported from the park by various sources. No state or federal threatened or endangered species were reported, although over 20 birds of conservation concern were observed. Brown-headed cowbirds were common in breeding season samples and may contribute to low nest success for some park species. However, the effect of cowbirds is not known in the park. An index of biotic integrity and qualitative factors were used the assess bird assemblage condition. The condition of bird assemblages was ranked as good. No trend was assigned to bird assemblage condition.

Data Quality

The quality of the data used to make the assessment was good. Data were collected recently, at a comprehensive park-wide spatial scale, using appropriate standardized techniques.

Mammal Assemblages

VICK supports a regionally typical mammal fauna dominated by common species. A comprehensive mammal inventory was conducted in 2005 and reported 23 species of terrestrial mammals and seven bats. Raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), white-footed mice (*Peromyscus leucopus*), and white-tailed deer (*Odocoileus virginianus*) were among the most commonly reported mammals in VICK. Evening bats (*Nycticeius humeralis*) and big brown bats (*Eptesicus fuscus*) were the most commonly reported bat species, and six species of bats were found in reproductively active condition. Domestic dogs and cats were commonly reported in the mammal inventory. No state or federal threatened or endangered species were reported from the park. A baseline white-tailed deer study found that deer were near, but not exceeding, estimated carrying capacity and that signs of overpopulation were not seen in the park. A colony of big brown bats was roosting in the Illinois State Memorial monument and alternative roosting sites were established through construction of several bat boxes behind the monument (V. DuBowy personal communication). Feral hogs have occurred in the park in recent years, and are a cause for concern to managers. Hog damage to historic landscapes and wildlife habitat has been observed. A hog removal program has been implemented and hog management is an ongoing issue. The condition of VICK mammal assemblages was ranked as fair. No trend was assigned to the mammal assemblage condition.

Data Quality

The data used to assess VICK mammal assemblage condition was very good. It was collected relatively recently, using a variety of appropriate methods, and provided excellent temporal and spatial coverage of the park.

Herpetofaunal Assemblages

Although the park is a relatively isolated habitat near an urban area, it supports a number of native reptile and amphibian species. A 2001-2002 herpetofaunal inventory reported 44 species from the park. Ongoing monitoring efforts by GULN have documented 22 species, including four not reported by the previous inventory. Combined, these efforts have reported 48 species, including 13 anurans, seven salamanders, four lizards, 15 snakes, and nine turtles. No state or federal threatened or endangered species have been reported. Because efforts to understand VICK herpetofauna assemblages were ongoing, and because the data used in this report may not have reflected an accurate estimate of present and expected species, no rank was assigned to VICK herpetofauna assemblages.

Data Quality

The quality of the data used to assess reptiles and amphibians at VICK was ranked as marginal. This ranking resulted from the lack of a current dataset collected specifically with the goal of estimating maximum species richness for the park. For the purposes of this report, an understanding of current species richness was considered key to assessing assemblage quality. Ongoing efforts continue to provide high-quality data on the current location, identification, and relative abundance of key indicator assemblages. These efforts are expected to greatly increase the understanding of herpetofauna assemblage condition in the park, and will benefit future assessments. The inventory used was relatively old and did not employ the full variety of sampling methods commonly used in assemblage-scale inventories.

Landscape Dynamics

The NPScape set of landscape analysis products is helpful in analyzing the impact of landcover use and change in the landscape surrounding VICK. This section of analysis was divided into five main considerations: landcover, roads, population and housing, pattern, and conservation status. What is obvious from analysis of the surrounding landscape is that VICK harbors a large tract of mostly forested land immediately surrounded by the developed Vicksburg area. At an even broader scale, much of the alluvial plain of the Mississippi River includes woody undeveloped wetland areas and intense agricultural use. These features preclude a high population density, although proportion of higher density housing classes is increasing. According to the Conservation Risk Index, which weighs protected area and converted area, the landscape around VICK likely falls within the intermediate endangered class, due in part to low proportion of converted and protected areas. Because of the mixture of positive and negative landscape aspects, this condition received a ranking of fair. A stable trend was assigned based on lack of changes in recent landcover products.

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. As of this writing, the second phase of NPScape was just recently completed, but due to its timing could not be incorporated into this section. As a result data quality is good but missing the check for temporal currency.

Acknowledgements

We would like to thank staff of Vicksburg National Military Park and of the Gulf Coast Network (principally Whitney Granger and Jeffery Bracewell) for their contributions, edits, and overall assistance with this project. Additionally, Virginia DuBowy of VICK and Bob Woodman of GULN provided invaluable input and guidance throughout the process for which we are very grateful. Thanks also to Dale McPherson, for his comments and logistical support throughout the NRCA process.

Acronyms and Abbreviations

ABC – American Bird Conservancy
ANC – Acid Neutralizing Capacity
ARD – Air Resources Division (NPS)
BBS – Breeding Bird Survey
BCI – Bird Community Index
BOD – Biochemical Oxygen Demand
CASTNET – Clean Air Status and Trends Network
CLI – Cultural Landscape Inventory
COOP – Cooperative Observer Program
CRI – Conservation Risk Index
DO – Dissolved Oxygen
EMF – Ecological Monitoring Framework
EPA – Environmental Protection Agency
EPMT – Exotic Plant Management Team
EVT – Existing Vegetation Type
GAP – Gap Analysis Program
GIS – Geographic Information System
GULN – Gulf Coast Monitoring Network
HUC – Hydrologic Unit Code
IBI – Index of Biotic Integrity
I&M – Inventory and Monitoring
IUCN – International Union for Conservation of Nature
MDN – Mercury Deposition Network
MRLC – Multi-Resolution Land Characteristics Consortium
MSNHP – Mississippi Natural Heritage Program
MSPA – Morphological Spatial Pattern Analysis
NAAQS – National Ambient Air Quality Standards
NABCI – North American Bird Conservation Initiative
NADP – National Atmospheric Deposition Program
NLCD – National Landcover Dataset
NPS – National Park Service
NRCA – Natural Resource Condition Assessment
NRCS – Natural Resource Conservation Service
NTU – Nephelometric Turbidity Unit
PAD – Protected Areas Database
PIF – Partners in Flight
RAWS – Remote Automated Weather Station
SE – Southeast
SSE – South-southeast
SSURGO – Soil Survey Geographic
UGA – University of Georgia
USGS – United States Geological Survey
VICK – Vicksburg National Military Park

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

[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.

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

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

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

Important NRCA Success Factors

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

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

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

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

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

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

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

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

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

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Vicksburg National Military Park (VICK) was established in 1899 to commemorate the campaign and siege of Vicksburg during the spring and summer of 1863. In 1933, management of the Memorial Battlefield and Vicksburg National Cemetery was transferred from the War Department to the National Park Service. The Vicksburg National Cemetery is 47 ha (116 acres) and serves as the final resting place for 17,000 Union soldiers who died in the battle of Vicksburg during the Civil War (Figure 1). Confederate soldiers who fought at Vicksburg are buried in the Vicksburg City Cemetery (Cedar Hill Cemetery) near the park. The park also contains over 1,370 monuments and other markers, an extensive archival collection, and a restored Union gunboat - the *USS Cairo*, which was sunk in the Yazoo River in 1862 by a Confederate mine (NPS 2012a). This incident was the first successful sinking in history of a boat by a mine.

2.1.2 Geographic Setting

VICK is located adjacent to the Yazoo Diversion Canal flowing into the Mississippi River in Vicksburg, MS, about 60 km west of Jackson in west-central MS. The park unit covers 726 ha (1795 acres), in addition to the 47 ha comprising the National Cemetery (Figure 1). Park lands enclose the northern and a portion of the eastern edge of the city of Vicksburg and also include five small detached parcels: Grant's Canal in Louisiana, Louisiana Circle, Navy Circle, South Fort along the Mississippi River, and Pemberton's Headquarters in downtown Vicksburg (Figure 2).

Figure 1. Vicksburg National Cemetery, established in 1866, encompasses 47 ha and contains the remains of over 17,000 Union soldiers from the Civil War, more than any national cemetery (NPS 2012a).

At the time leading up to the Civil War siege, the land included open areas, agricultural fields, and woodland. During the war, much of the vegetation throughout the area was removed for view lines, which in turn exacerbated erosion of the loess soils. This erosion continued after the war, when the land returned to agriculture in the uplands. Slopes became gullied, and lowlands were awash with silt. In the 1930s, the Civilian Conservation Corps (CCC) worked to restore much of the damage from erosion by filling and regrading, in addition to planting native trees and sodding with Bermudagrass (*Cynodon dactylon*). However, non-native species were also planted at this time, including Chinese privet (*Ligustrum sinense*) and some of these legacies still remain (V. DuBowy personal communication). Today, much of the park is forested—about 70%--and some sections of the park such as Graveyard Road, Thayer's Approach, Great Redoubt, Railroad Redoubt, and Fort Garrott are maintained as expansive mowed fields to approximate the unobstructed view during the time of the war. The recent cultural landscape report completed by the park proposed 36 ha of area for clearing to restore the historic condition of the landscape, with another 9 ha proposed for reforestation. As of this writing, these restoration activities have been completed (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009, V. DuBowy personal communication).

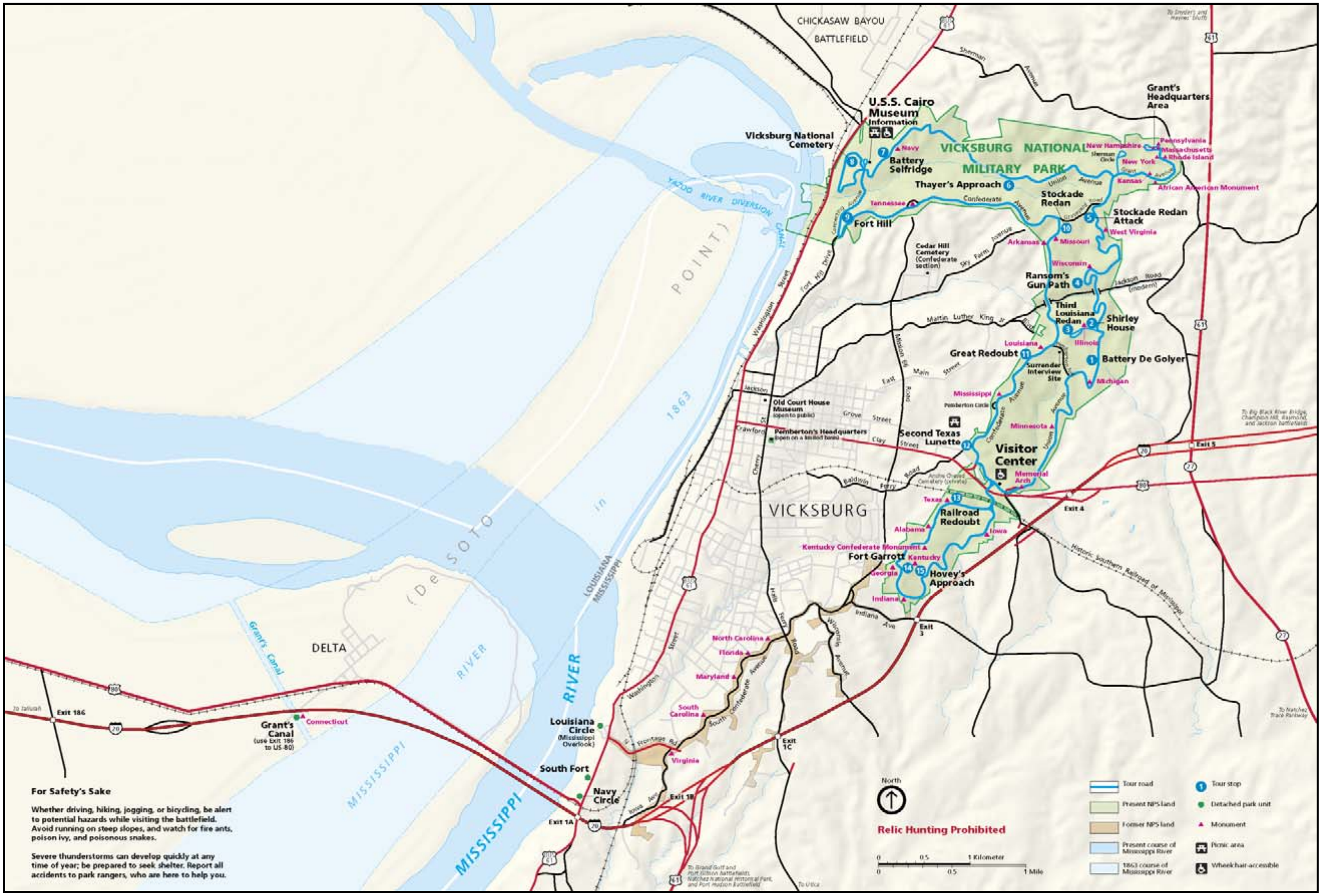


Figure 2. Vicksburg National Military Park is located in Vicksburg, MS and covers roughly 700 hectares. Navy Circle, South Fort, and Louisiana Circle are detached units in the southern part of town.

2.1.3 Park History

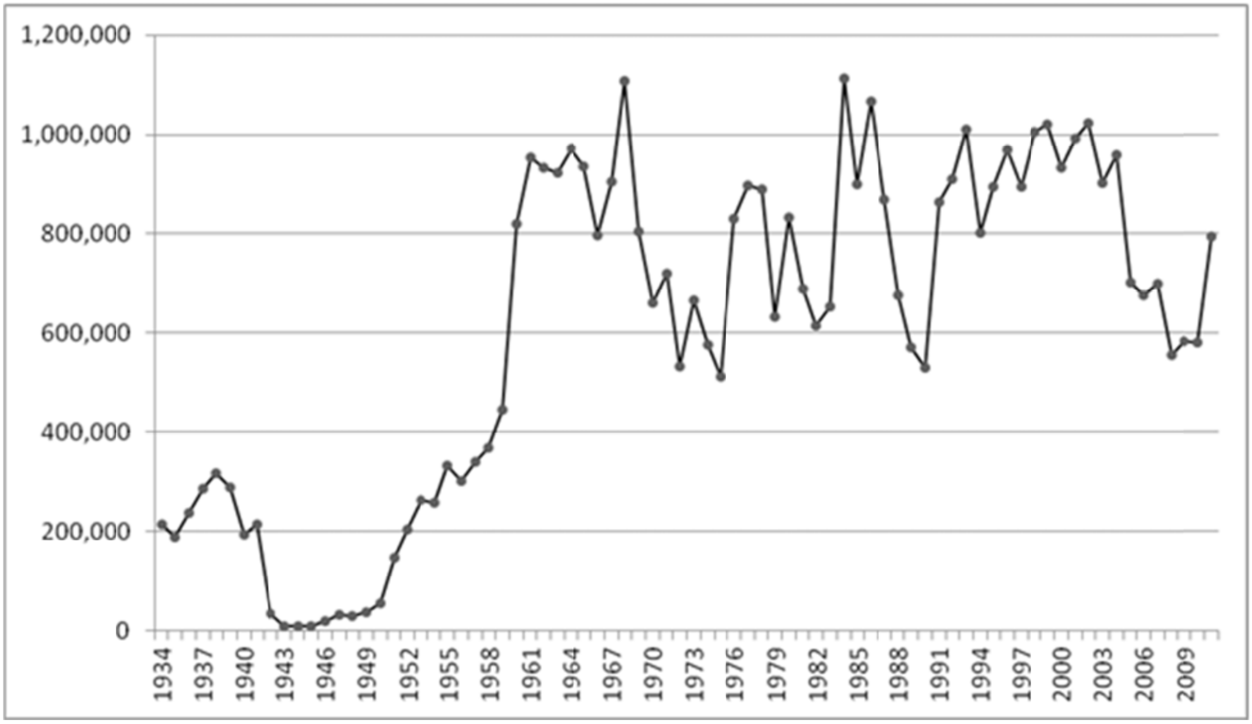
The significance of Vicksburg during the Civil War was in large part due to its strategic location along the Mississippi River, a vital shipping channel, the importance of which was quickly recognized by President Abraham Lincoln. Lincoln began a campaign to capture the city, speaking of its pivotal role in the war efforts:

> *See what a lot of land these fellows hold, of which Vicksburg is the key! The war can never be brought to a close until that key is in our pocket…We can take all the northern ports of the Confederacy, and they can defy us from Vicksburg.* (NPS 2012a)

Major General Ulysses S. Grant led the Union campaign against Vicksburg, and in spring 1863 began his approach from the west side of the Mississippi River, eventually joining Rear Admiral David Dixon Porter of the Union navy. Grant fought his approach from south of Vicksburg, detoured to capture Jackson, the state capital, and intercepted supply and communication lines. From there he turned back towards Vicksburg, directed an assault and 47-day long siege that soon led to surrender by Confederate Lt. General John C. Pemberton on July 4, 1863.

2.1.4 Visitation Statistics

Data for annual number of visitors at VICK is available starting in 1934. After a low point during WWII, visitation rose steadily until the 1960s (Figure 3. Annual visitation at VICK from 1934 to 2011 (top) and mean monthly visitation from 2002 – 2011 (bottom). The vertical axis shows annual number of visitors and the horizontal axis shows years.). Since that time, annual visitation has fluctuated around a mean of 800,000. Visitation dropped following Hurricane Katrina in 2005. General visitation is highest during the summer months, and is also influenced by holidays and park events such as fee-free days and memorial dedications (NPS 2012b).



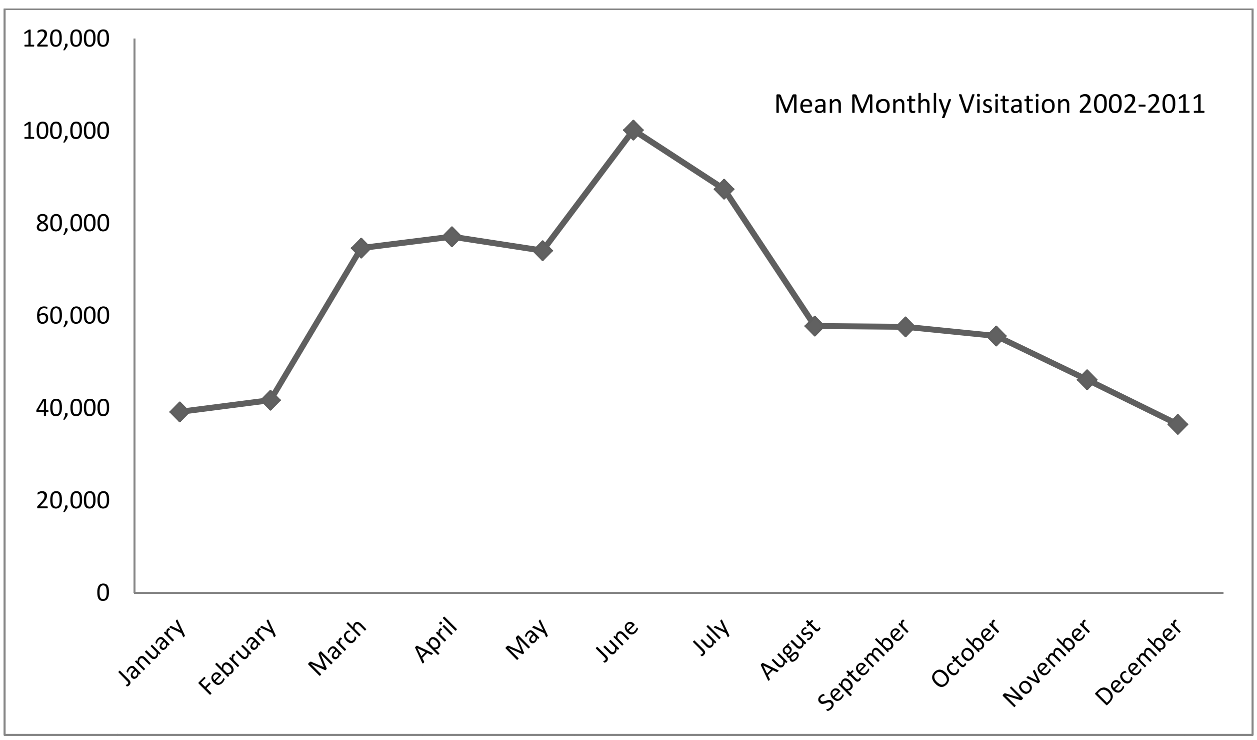


Figure 3. Annual visitation at VICK from 1934 to 2011 (top) and mean monthly visitation from 2002 – 2011 (bottom). The vertical axis shows annual number of visitors and the horizontal axis shows years.

2.2 Natural Resources

2.2.1 Soils and Geology

Vicksburg NMP is located on a portion of a 16 km wide deposit of rolling loess hills. Loess soils are typically wind or glacial deposits characterized by a mixture of fine-grained particles. They are highly prone to erosion, and as a result VICK contains steep hills, bluffs, ravines, and an overall highly variable topography. Mint Spring Bayou and Glass Bayou have cut deep, steep-sided ravines into the loess soils (KellerLynn 2010). These erosion and drainage issues are important considerations for park hydrology and management (KellerLynn 2010). The loess deposits around Vicksburg are thickest at the bluffs close to the river, which become thinner as they stretch towards the east. Elevation ranges from 23 m at Mint Spring Bayou in the western portion of the park to 119 m around the Great Redoubt where the Louisiana Memorial stands. Loess soils are also highly fertile, lending to the agricultural background of the Warren County area (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009).

Loess bluffs have formed steep cliffs (Figure 4) along the Mississippi River, and VICK, situated as it is within this loess bluff formation, exhibits the abrupt ravines and cuts typical of this easily-eroded formation. Many of these cliffs form vertically due to the crystalline structure of the particles. As a result, loess bluffs provided key lookout points for Confederates during the time of the battle, and also allowed citizens and soldiers alike to dig somewhat elaborate caves for hiding and protection. Pleistocene deposits of loess in the area around Vicksburg have revealed various fossils including mastodon (*Mammut americanum*), though no vertebrate fossils have been discovered inside the park. Underlying the park is also a layer of fossiliferous limestone that includes shells of marine invertebrates deposited when the Gulf reached farther inland, including current-day Vicksburg. This layer is exposed at Mint Spring, where it is considered a significant paleontological resource (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009).

According to the Soil Survey Geographic database (SSURGO) for VICK, the most common soil series mapped in association is Memphis silt loam, comprising 304 ha, or almost one-half, of the park unit. These soils occur on ridgetops and hillslopes and are typically susceptible to erosion. Other predominant classes include the Adler series and an association which are formed from alluvium (river-derived deposits) on bottomlands and floodplains. These soils are subject to flooding during winter and early spring. The Adler series and its single association comprise 54 ha at VICK. The remainder of the parkland consists of silty and gullied areas that have not developed into distinct classes.

As a result of the variable terrain and erodibility of the landscape, management and maintenance efforts are often necessary to repair sinkholes, cave-ins, erosion, and other problems. Failed slopes necessitate recovery, and new construction involves grading and filling, such as during the construction of the visitor center and *USS Cairo* exhibit (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009, KellerLynn 2010).

Figure 4. The predominant soil types at VICK are loess-derived. Although highly erodible, vertical loess slopes are somewhat stable and are a unique feature throughout the park.

2.2.2 Hydrology

Vicksburg National Military Park overlaps the Lower Yazoo (HUC 8030208) and Lower Mississippi-Natchez (HUC 08060100) hydrologic sub-basins, the latter of which buffers the Mississippi River as it flows south from Vicksburg to New Orleans, Louisiana (Figure 5). Directly to the west of the park is the Yazoo River Diversion Canal, which connects the Yazoo River to the Mississippi River.

There are three main streams that flow through the park unit: Mint Spring Bayou, Glass Bayou, and Durden Creek. Generally, the term "bayou" refers to slow-moving waters in the lower flat regions of the Mississippi River basin, which can be stagnant or swampy (MACTEC 2009). Together, drainage areas of these three main branches encompass 445 ha, including sections outside of the park boundary draining from Mint Spring and Glass Bayous. Two waterfalls, Upper (Figure 6) and Lower Mint Spring Falls, are located on Mint Spring Bayou in the park unit, separated by about 250 m. The lower falls, at 10 m, are higher than the upper falls and serve as a natural impediment to fish. As a result, the lower reach is also impacted by hydrologic variations in the Yazoo River Diversion Canal into which it flows.

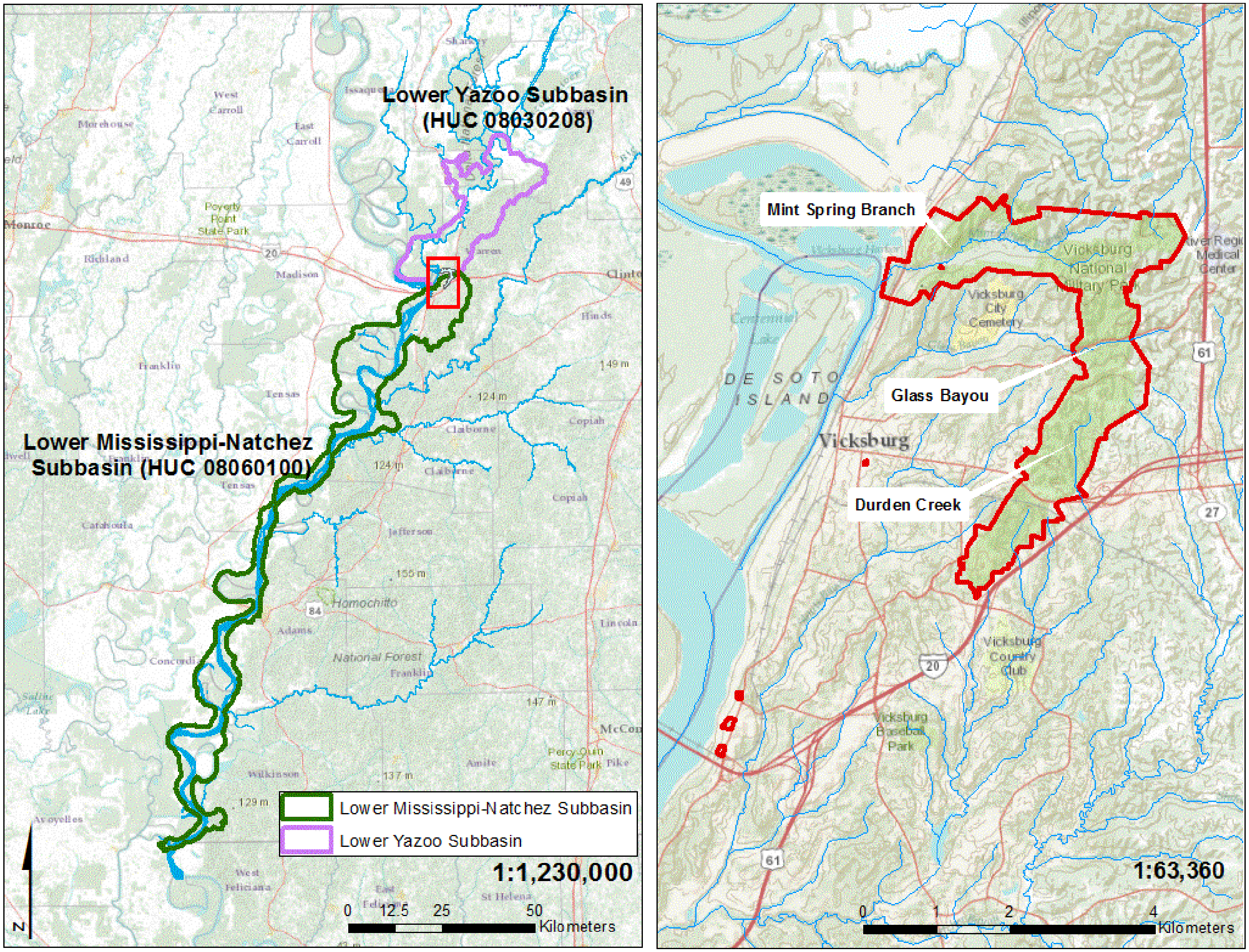


Figure 5. Vicksburg NMP straddles the Lower Yazoo and Lower Mississippi-Natchez Hydrologic Sub-basins.

Figure 6. Upper Mint Spring Falls, the smaller of two waterfalls located on Mint Spring Bayou, is located approximately 250m upstream from the lower falls.

2.2.3 Resource Descriptions

Wetlands

Several wetland areas are located throughout the park, mainly in the vicinity of the South Loop where there are many low areas. These areas serve as habitat for herpetofauna such as the dusky salamander (*Desmognathus conanti*) and box turtles (*Terrapene carolina*). Ephemeral wetland areas also develop throughout the park. Several of the wetland areas are forested, which helps reduce erosion, though some wetlands are invaded by Chinese privet, an exotic shrub that can outcompete other cover types, leaving the soil susceptible to erosion. Wetland areas that include giant cane (*Arundinaria gigantea*) are generally more effective at retaining soil moisture and reducing erosion due to roots in the upper part of the soil (MACTEC 2009, Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Although much of the forested area throughout the park is the result of planting by the CCC, some of the bottomland forests associated with these wetland communities existed prior to these efforts.

Fishes
Two park streams, Mint Spring Bayou and Glass Bayou, support fish assemblages. Both streams are tributaries of the Yazoo River Diversion Canal near the confluence of the Yazoo and Mississippi Rivers, and descend from the bluffs of the park to the floor of the Mississippi alluvial plain through a series of high gradient reaches. Eighteen fish species were reported from VICK during a 1997-2003 fish inventory (Dibble 2003). All species reported by the inventory occurred in lower Mint Spring, below the lowest barrier falls. No federal or state threatened or endangered species were reported from the park. VICK fish samples for Mint Spring reported by the 1997-2003 fish inventory (Dibble 2003) were dominated by the invasive fathead minnow (Pimephales promelas) in all reaches. Removal of fathead minnows and restoration of native fishes was proposed and assessed by the NPS (NPS 2006). This project was implemented in April 2008, with an 80% kill rate of fathead minnows (V. DuBowy personal communication).

Birds
VICK supports a diversity of bird species, and the park has been declared an Important Bird Area by the National Audubon Society. The park is centrally located along the Mississippi Flyway bird migration route. Almost half of North American bird species use this flyway (NACS 2013). VICK provides stopover habitat to many of these species. The forested loess bluff habitats which compose much of the park represent among the most intact and mature examples of this habitat in the region (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). A recent restoration project created more open habitat within the park, resulting in a potential increase of habitat for early successional bird species. A variety of efforts have reported around 180 bird species from the park (Twedt and Hunt 2001, Somershoe et al. 2003 and 2006, NPS 2012f, NPS/Twedt unpublished data). Around 120 species have been reliably reported in recent years from samples collected with scientifically sound and standardized methods (NPS/Twedt unpublished data). No threatened or endangered species are included in this dataset, although at least 23 species of conservation concern use the park (NPS/Twedt unpublished data), including Swainson's Warbler (*Limnothlypis swainsonii*), Wood Thrush (*Hylocichla mustelina*), and Painted Bunting (*Passerina ciris*). Six exotic or range-expanding species occurred in recent park sampling data (NPS/Twedt unpublished data). Of these, the Brown-headed Cowbird (*Molothrus ater*) was the most commonly reported in breeding season point counts.

Mammals
The park supports a diversity of mammals. Although park lands have been subject to significant anthropogenic alterations, VICK contains one of the largest and most relatively intact examples of loess bluff forest habitat in Mississippi (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Recent restoration projects in the park have increased the amount of edge and early successional habitat in the park, resulting in potential increase in habitat for white-tailed deer and early successional habitat specialists (Kissel and Bomar 2009, Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Recent inventory efforts reported 30 terrestrial and seven bat species from VICK (Linehan 2007, Linehan et al. 2008). Mammal assemblage samples from the Linehan (2007) inventory included over 80% of all species believed likely to occur. The park provides habitat for at least six species of bats that were found to be reproductively active while foraging on park lands (Linehan 2007). These included the evening bat (*Nycticeius humeralis*), the big brown bat (*Eptesicus fuscus*), and eastern red bat (*Lasiurus borealis*). Big brown bats had established a maternal colony inside the Illinois Memorial at the park, and presented a health risk and a negative impact on visitor

experience (unpublished park document). As of this report, park staff are actively excluding bats from the monument through establishment of six suitable bat houses behind the Memorial. Six non-native or domestic species were reported from the park (Linehan 2007). These included domestic dog (*Canis familiaris*), house mouse (*Mus musculus*), and domestic cat (*Felis catus*). Feral hogs (*Sus scrofa*) were not reported from the inventory, but have been documented in the park in recent years (NPS 2009). Hogs cause damage to habitat and are potential vectors of disease; therefore a management plan has been developed to control hogs on park lands (NPS 2009). White-tailed deer (*Odocoileus virginianus*) were among the most commonly reported mammals in the recent inventory (Linehan 2007). In uncontrolled populations, white-tailed deer have the potential to negatively impact vegetation communities and therefore habitat for other species. A baseline deer survey determined that deer in the park were probably near carrying capacity, but that the population was not sufficiently dense to cause over-browsing at the time the study was conducted (Kissel and Bomar 2009).

<u>Reptiles and Amphibians</u>
A 2001 – 2002 herpetofaunal inventory, combined with ongoing amphibian monitoring efforts have reported 44 species of reptiles and amphibians at VICK (Keiser 2002). Further monitoring by GULN has increased the number of species to 48. No threatened or endangered species were reported from the park. The effort directed at herpetofaunal inventories was relatively low, and further species will likely be discovered in the park if more intensive efforts are conducted. The park receives ongoing monitoring for terrestrial amphibians and monitoring, and this data will increase the understanding of park herpetofauna (NPS 2012e).

<u>Water</u>
Quarterly water quality sampling began at VICK in summer 2007 on the three main streams in the park. Monitored parameters include temperature, specific conductance, pH, dissolved oxygen, and turbidity. Data from sampling are available using the GULN water quality data tool (NPS 2012c). Meiman (2012) assessed water quality over the first three-and-a-half years of monitoring, concluding that condition was overall good.

2.2.4 Resource Issues Overview
In addition to the specific resources outlined above, there are other factors that actively affect natural resources at VICK 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, changes in the larger landscape scale surrounding the park can represent significant factors that may also affect visitor experience. Because of these considerations at virtually all NPS units, they are a common target for monitoring throughout all Inventory and Monitoring (I&M) networks, including GULN.

<u>Exotic Plants</u>
Exotic plants are a significant management concern at VICK, where they threaten to outcompete other native plants (NPS undated). Since the Civil War, the land around Vicksburg has been used for many years for agriculture and livestock, both of which introduced exotic species that persist today (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Kudzu (*Pueraria lobata*), Johnsongrass (*Sorghum halepense*), Chinese privet, Chinese parasol tree (*Firmiana simplex*), Chinaberry (*Melia azedarach*), mimosa (*Albizia julibrissin*), and Chinese tallow (*Sapium sebiferum*) represent particular problems at the park. Chinaberry and mimosa

occur mainly at the park periphery; Johnsongrass is a difficulty at Fort Hill (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Kudzu has been one of the most aggressive exotics at the park, known to grow up to a foot per day. A concentrated treatment program has reduced its overall distribution in the park in recent years. Different techniques, mainly herbicide treatment but also burning and cutting, have been used to manage these invasives, though the problem is ongoing. The Gulf Coast Exotic Plants Management Team (EPMT) conducts much of the treatment at VICK (Cooper et al. 2004, V. DuBowy personal communication).

Fire Management

Vicksburg NMP contains large forest tracts and is located in the middle of the developed city of Vicksburg, MS. As a result, fire management is a concern not only for the vegetation inside the park unit, but also for the surrounding areas. Roughly 120 ha are maintained as mowed open areas in order to accommodate monuments and viewscapes, while most of the remaining area (575 ha) is forested. Other areas include kudzu vinelands and grassy fields mowed at least 1-2 times per year, referred to as backfields.

In the past, Vicksburg NMP has operated under a policy of complete fire suppression. Since 1980, all but one of 18 wildland fires have been human-caused, and total area burned for all fires was less than 4 ha. Between 1997 and 2003, when the fire management plan was completed, nine prescribed fires were administered mainly for exotic species control, historic landscape restoration, and fuels reduction. Because some invasive species like Japanese honeysuckle (*Lonicera japonica*), kudzu, and Johnsongrass may increase following prescribed fire, manual fuel reduction is necessary as a site preparation technique or overall alternative (Gorder and Whitney 2003).

The park is divided into two main northern and southern fire management units separated by Jackson Road, with a third smaller management unit for areas with historic earthworks and monuments such as Louisiana Circle, South Fort, Navy Circle, and Grant’s Canal. Specific areas targeted by prescribed burns include Fort Hill, Old Graveyard, Thayer’s Approach, Railroad Redoubt, and Fort Garrott (Figure 7). The latter two units were added in 2009, overall comprising 23 ha (56 acres) among the five burn units. The target fire return interval for these areas is every two years, with a goal of supporting a mix of native grasses (Gorder and Whitney 2003, V. DuBowy personal communication).

Figure 7. The Graveyard Road burn unit, looking west—one of three prescribed burn areas in the northern section of the park.

Weather and Climate

The GULN relies on existing weather monitoring stations to develop a long-term record of meteorological data, which may in turn be used to track changes in climate and other vital signs. A single Remote Automated Weather Station (RAWS) collected weather data inside the park from 2004 to 2007, after which it was transferred to the Vicksburg Airport. Another station collected data from 1967 to 2004 at the park as part of the Cooperative Observer Program (COOP). There are also 8 weather stations within 30 km of the park, including 6 COOP stations and two real-time weather stations monitoring as part of the Surface Airways Observation (SAO) Network (Davey et al. 2007).

Landscape Change

Many of the other vital signs established for VICK interact and respond to changes of the landscape within and surrounding the park, including invasive species introductions, water quality issues, and air quality problems. At VICK, adjacent land-use impact has resulted in altered viewsheds, domestic or feral animal intrusion, and increased damage to monuments resulting from both vandalism and air quality impacts.

The NPScape landscape dynamics program created an organized protocol for landscape scale assessment for all park units in the U.S. To achieve that goal, landscape analysis was divided 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 2012d).

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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 VICK (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 GULN 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 2 shows a general outline of the data sources used for identified categories of interest.

Table 1. Ecological Monitoring Framework used to organize and identify natural resource areas of interest at VICK (Fancy et al. 2009). Entries in blue indicate resources natural resources discussed in this Natural Resource Condition Assessment report.

Ecological Monitoring Framework—VICK			
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	Temperature, Precipitation, Wind
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	
		Marine Hydrology	
	Water Quality	Water Chemistry	Temperature, specific conductivity, pH, DO, turbidity
		Nutrient Dynamics	
		Toxics	
		Microorganisms	Escherichia coli
		Aquatic Macroinvertebrates and Algae	

Table 1. (continued)

Ecological Monitoring Framework—VICK			
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	
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	Soil stability, distribution, presence of invasives
		Riparian Communities	
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	
		Desert Communities	
		Grassland/Herbaceous Communities	Soil stability, distribution, presence of invasives
		Shrubland Communities	
		Forest/Woodland Communities	Species composition, distribution, biological integrity, presence of invasives
		Marine Invertebrates	
		Freshwater Invertebrates	
		Terrestrial Invertebrates	
		Fishes	Richness, biological integrity, prevalence of invasives
		Amphibians and Reptiles	Richness, expected vs. observed
		Birds	Richness, distribution, community integrity, invasives
		Mammals	Richness, distribution, invasives
		Vegetation Complex (use sparingly)	
		Terrestrial Complex (use sparingly)	
	At-risk Biota	T&E Species and Communities	Prairie nymph

Table 1. (continued)

Ecological Monitoring Framework—VICK			
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 Vicksburg National Military Park.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Atmospheric Deposition	Wet/ Dry Deposition	National Atmospheric Deposition Program (NADP) Interpolation maps; Coffeeville and Clinton, MS Clean Air Status and Trends Network Stations (CASTNET)	Wet deposition nitrate and sulfate concentrations	2010; 1989 to 2009 (Coffeeville); 1985 to 2010 (Clinton)
	Mercury Deposition	National Atmospheric Deposition Program (NADP) Mercury Deposition Program (MDP) stations at Chase, LA and Oak Grove, MS	Mercury deposition	1998 to 2010 (Chase); 2000 to present (Oak Grove)
Weather and Climate	Temperature, Precipitation, Wind	Warren Remote Automated Weather Station (RAWS) in VICK	Temperature, precipitation, wind speed/direction	2004-Present
		Vicksburg Cooperative Observer Program (COOP) station	*Same as above*	1967 to 2004
Water Chemistry	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), Turbidity	Meiman (2012) water quality assessment	Water quality summary	2007-2011
Invasive/Exotic Plants	Presence, relative predominance, and invasibility of exotics	Walker (1997)	Plant inventory and general vegetation description at VICK	1996-1997
		Exotic Vegetation Management Plan	Predominant Exotics and Treatments	--
Terrestrial Vegetation	Status of significant communities	Rangoonwala and Ramsey (2007)	Vegetation Map	2007
Rare Plants	Protection status, predominance	NPS (2011)	Prairie nymph site bulletin	--
Fish Communities	Spp. richness, IBI, dominance of invasives	Dibble (2003) fish inventory	Narrative report with summaries of 7 years of sampling in park's two main streams Electronic data summarizing results by location	1997-2003

Table 2. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Bird Communities	IBI, conservation value index, richness, non-native species	GULN bird sampling database of Twedt's sampling	Breeding season point count and winter area surveys	2008 - 2010
		Somershoe et al. (2003 & 2006)	USGS report on bird density/abundance at VICK, and peer-reviewed pub on same data	2002-2003
Mammal Communities	Richness, reported vs. expected, prevalence of invasives	Linehan (2007) and Linehan et al. (2008) narrative, and associated database and spreadsheets	Master's thesis (inventory report) and peer reviewed pub. on same data, included fully spatially explicit raw data and summarized effort data	2005
Reptile and Amphibian Communities	Comparisons of reported vs. expected	Keiser (2002) and brief data summary	Narrative report on herpetofauna inventory with spreadsheet summary of voucher specimens	2001 - 2001
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
		LANDFIRE	Vegetation classification for VICK landscape	2001-2007
		GAP	Vegetation classification for VICK landscape	--
General	--	Gulf Coast Network (2010)	Biological Inventory Data; invasive plant treatment recommendations	--
	--	Cooper et al. (2004)	Natural Resource Summary	--
	--	MACTEC (2009)	Landscape Rehabilitation Environmental Assessment	--
	--	Wiss, Janney, Elstner Associates, Inc. and John Milner Associates. 2009	Cultural Landscape Report	--

3.2.2 Reporting Areas

Vicksburg NMP is a small, urban-based park unit located within the city limits of Vicksburg, MS. For the purposes of this report, VICK was treated as a single reporting unit and all attributes were assessed and reported at the park scale.

3.2.3 General Approach and Methods

Condition and Trend Status Ranking Methodology

Data collected as part of the NPS Inventory and Monitoring (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 GULN (Segura et al. 2007), 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. IBI, NAAQS) 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 general categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al. (2009) NRCA report for Fort Pulaski National Monument. Each category is further subdivided into two sub-ranks, as shown in Table 3. The thematic category is divided into relevancy and sufficiency sub-ranks, answering the questions of whether the data are directly relevant to the category being assessed, and whether there is enough data or if it is sufficiently detailed. The spatial general category, which focuses on whether the data are spatially explicit, is divided into proximity and coverage sub-ranks. These sub-ranks address whether data are specific to the park and its boundaries, and whether the spatial coverage of the data includes the entire park unit. The temporal general category includes the currency and coverage sub-ranks. Respectively, these refer to whether data are recent enough to be currently relevant, and whether they cover a sufficient breadth of time. To give an overall rank to the data quality, the number of sub-ranks fulfilled are summed and translated into a very good (6), good (5), fair (4), marginal (3), poor (2), or very poor (1) ranking and reported alongside the overall condition assessment (Table 4).

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 showing six sub-ranks.

Data Category	Sub-Rank	Criteria
Thematic	Relevance	Are data directly relatable to assessment of the attribute?
	Sufficiency	Are data sufficient to conduct a thorough assessment?
Spatial	Proximity	Are data collected within or close to the park unit?
	Coverage	Is there sufficient areal coverage of the park unit?
Temporal	Currency	Were data sufficiently recent to reflect current conditions?
	Coverage	Do the data cover sufficient temporal breadth?

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. Dark green = 6 of 6 possible checks (very good), light green = 5 of 6 possible checks (good), bright yellow = 4 of 6 possible checks (fair), light yellow = 3 of 6 possible checks (marginal), red = 2 of 6 possible checks (poor), dark red = 1 of 6 possible checks (very poor).

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal	Interpretation
Example 1:		Relevancy ✓ Sufficiency ✓	Proximity ✓ Coverage ✓	Currency ✓ Coverage ✓	Condition: Excellent Trend: Improving Data Quality: Very Good
		6 of 6: Very Good			
Example 2:		Relevancy ✓ Sufficiency ✓	Proximity ✓ Coverage ✓	Currency Coverage ✓	Condition: Good Trend: Stable Data Quality: Good
		5 of 6: Good			
Example 3:		Relevancy ✓ Sufficiency ✓	Proximity Coverage ✓	Currency ✓ Coverage	Condition: Fair Trend: Declining Data Quality: Fair
		4 of 6: Fair			
Example 4:		Relevancy ✓ Sufficiency	Proximity Coverage ✓	Currency ✓ Coverage	Condition: Poor Trend: None Assigned Data Quality: Marginal
		3 of 6: Marginal			
Example 5:		Relevancy Sufficiency	Proximity Coverage ✓	Currency ✓ Coverage	Condition: Not Ranked Trend: None Assigned Data Quality: Poor
		2 of 3: Poor			
Example 6:		Relevancy ✓ Sufficiency	Proximity Coverage	Currency Coverage	Condition: Not Ranked Trend: None Assigned Data Quality: Very Poor
		1 of 6: Very Poor			

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Chapter 4 Natural Resource Conditions

4.1 Atmospheric Deposition

Atmospheric deposition is an issue at VICK due to the proximity of air pollution sources near the park unit. Airborne constituents can affect ecological systems through acidification, soil fertilization, and surface water loading. Deposition resulting from the production of nitrogen oxides (NO_x) and sulfur dioxides (SO_2) are particular issues. These pollutants are typically divided into wet (e.g. precipitation, condensation) and dry (e.g. adsorption, particulate, direct contact) sources, which can debilitate growing conditions for biota, among other effects.

Anthropogenic sources of sulfur dioxides typically include power plants, vehicle emissions, and other industrial sources, while natural sources may include volcanoes, organism emissions, and decaying organic material. The U.S. Clean Air Act, originally passed in 1970, was amended in 1990 to include further controls on atmospheric deposition rates. As a result, during the 18 years from 1990 to 2007, total nitrogen and sulfur deposition in the U.S. decreased by 17 and 34 percent, respectively (MACTEC 2008). Sulfur dioxide can react in the atmosphere to form sulfuric acid (H_2SO_4) and ammonium sulfate [$(NH_4)_2SO_4$], the latter of which is a significant constituent of potentially harmful fine particulate matter ($PM_{2.5}$).

Particulate sulfate (SO_4^{2-}) is a resultant product of sulfur dioxide that often takes the form of ammonium sulfate [$(NH_4)_2SO_4$]. Sulfate deposition is greatest in the Ohio River Valley region around the Great Lakes (Figure 8). Concentrations of sulfate at eastern U.S. reference sites show a 26% decline during the period from 1990 to 2007 (MACTEC 2008).

In addition to sulfur dioxide, nitrogen oxides also react in the atmosphere to produce other pollutants. Nitric acid (HNO_3), for example, is a contributing factor to acid rain while particulate nitrate (NO_3^-) can take the form of ammonium nitrate (NH_4NO_3), a fine particulate matter. Farm production of ammonia (NH_3) can also react with sulfate and nitrate particles to produce particulate ammonium (NH_4^+). Ammonium deposition is highest in the Upper Midwest region of the U.S., while nitrate deposition closely follows the distribution of sulfate (Figure 8). Figure 9 shows a hierarchical format of atmospheric deposition and its constituents.

4.1.1 Assessment

The NPS ARD outlined an approach for assessing deposition values, noting that background wet deposition in the eastern U.S. is roughly 0.25 kg ha^{-1} yr^{-1} for both nitrogen (N) and sulfur (S) (Ray 2009). To gauge condition, the ARD stipulates a threshold of 3 kg ha^{-1} yr^{-1} for total deposition, or about 1.5 kg ha^{-1} yr^{-1} for wet deposition. The ARD primarily concentrates on wet deposition data rather than dry deposition to establish thresholds, mainly because dry deposition data is not as readily available. In the east, dry deposition is usually a smaller proportion than wet deposition of total deposition. Between 2003 and 2006, sulfur dry deposition averaged between 11% and 60% of total deposition in the eastern U.S. (EPA 2007). Below 1 kg ha^{-1} yr^{-1}, wet deposition is not generally considered harmful to ecosystem function, while wet levels above 3 kg ha^{-1} yr^{-1} are considered a significant threat.

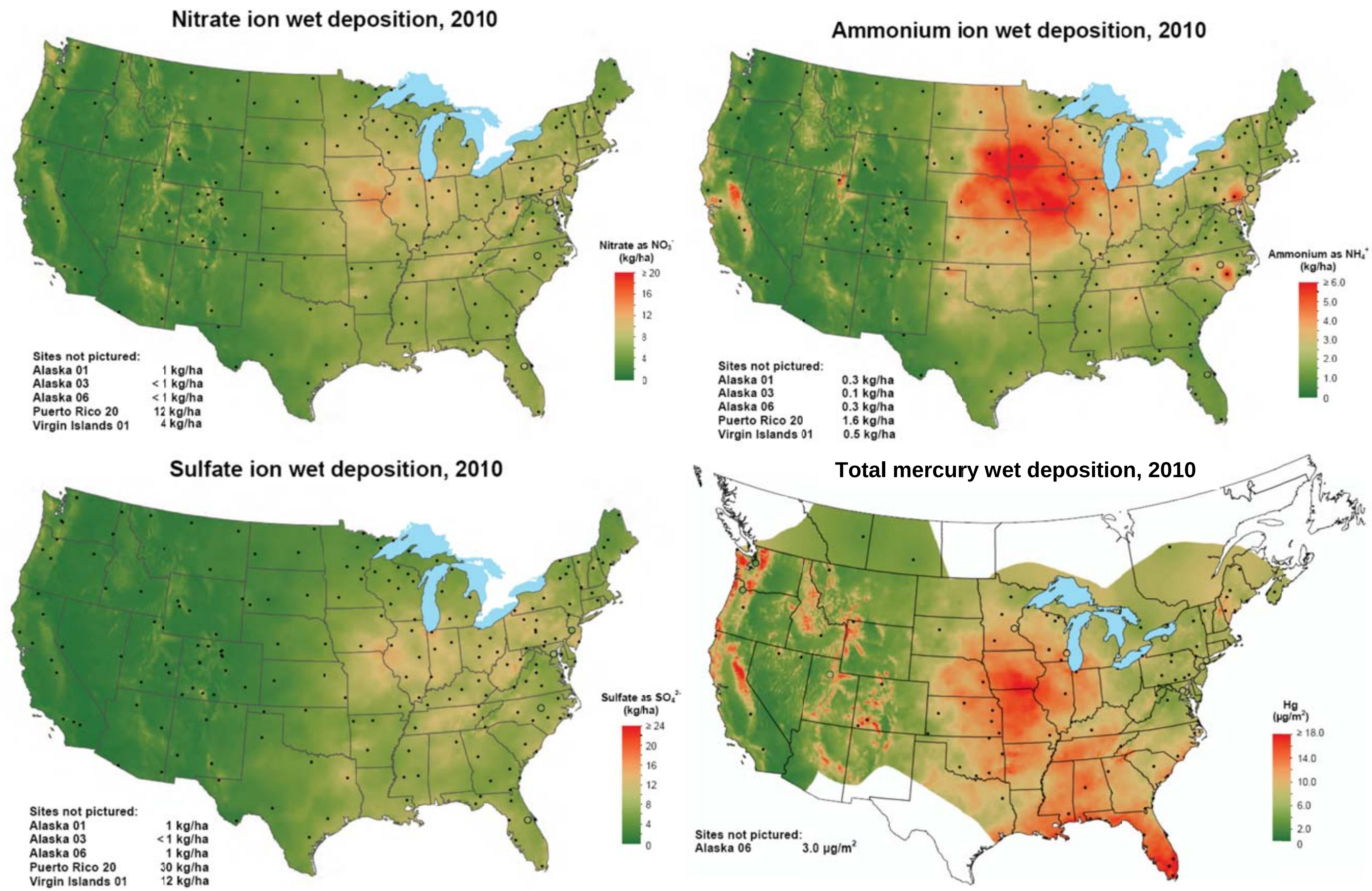

Figure 8. Atmospheric wet deposition maps interpolated for U.S. in 2010. Clockwise from top left: nitrate (NO_3^-), ammonium (NH_4^+), mercury (Hg^+), and sulfate (Eastern U.S. nitrate (left) and sulfate (SO_4^{2-})) [Source: http://nadp.sws.uiuc.edu/].

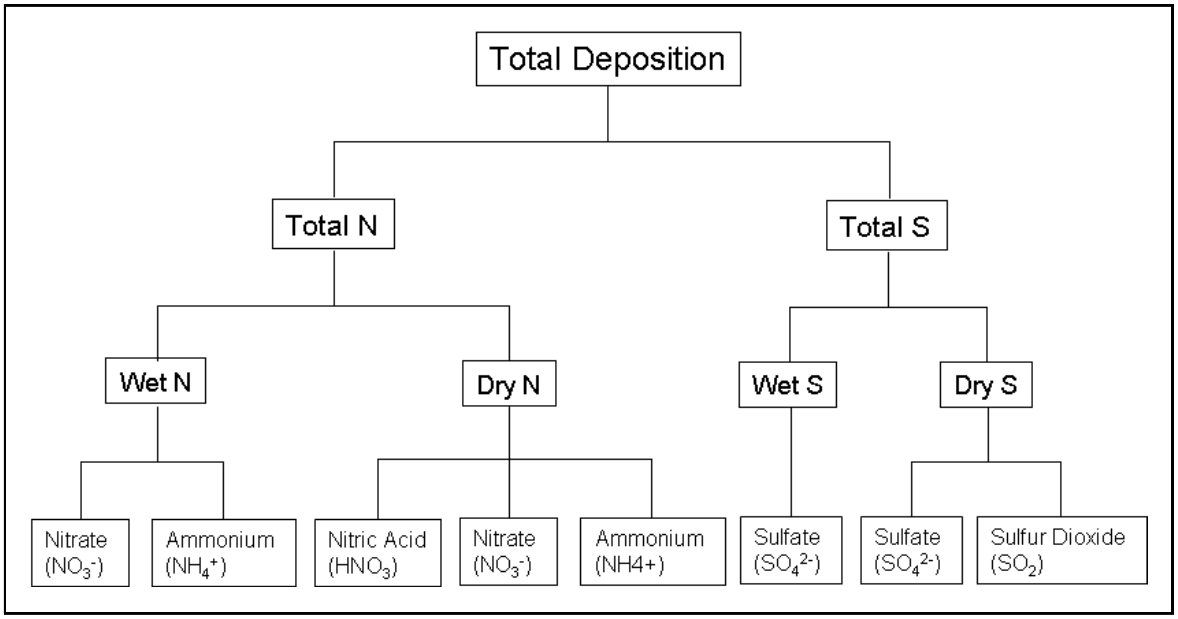

Figure 9. Total atmospheric deposition is typically divided into nitrogen (N) and sulfur (S) portions, each with wet and dry means of deposition.

4.1.2 Deposition Data

Other sources concentrating solely on N deposition suggest more lenient thresholds, such as Fenn et al.'s (2003) assessment that the lower limit of ecosystem effects from total N deposition ranges from 3 to 8 kg ha^{-1} yr^{-1} for sensitive species such as lichens and phytoplankton. Krupa (2003), on the other hand, suggests 5 to 10 kg ha^{-1} yr^{-1} total N as the critical range for sensitive terrestrial systems such as heaths and bogs, and values of up to 10 to 20 kg ha^{-1} yr^{-1} for forests. A USFS report by Pardo and Duarte (2007) examined deposition effects on forest types in GRSM, and generally found an acceptable limit of 3 kg ha^{-1} yr^{-1} for N deposition in low elevation mixed hardwood forests and 7 kg ha^{-1} yr^{-1} for higher elevation spruce-fir types.

While there are several references discussing critical thresholds for N deposition, less are available concerning rates of S deposition. In a description of developing critical loads for deposition, Porter et al. (2005) notes that S deposition has altered the acid neutralizing capacity (ANC) of aquatic resources in Shenandoah National Park in Virginia. Based on modeling, a reduced range of S deposition rates between 0 and 4 kg ha^{-1} yr^{-1}would be necessary to even begin to restore ANC values to pre-industrial levels.

4.1.3 Monitoring

There are four sites around VICK that collect wet deposition data either as part of the EPA Clean Air Status and Trends Network (CASTNET) or the National Atmospheric Deposition Program (NADP, Figure 10). The CASTNET station is located in Coffeeville, MS (CVL151, ~209 km NE), while the closest NADP station is located in Clinton, MS (~40 km E). Two other NADP stations, the Southeast Research Station (SRS) in Washington Parish, LA (LA 30, ~180 km SSE) and Warren 2WSW (AR02, ~180km NW) in Bradley County, AR, also provide reference for wet deposition data. The Coffeeville CASTNET station collected wet and dry deposition data over the period 1989 to 2009, and the Clinton NADP station recorded data from 1985 to 2010. Data from the SRS and Warren stations are available over the periods 1983 to 2010 and 1982 to 2009, respectively. All sites showed significant decreases in S wet deposition over the period of monitoring, while the CASTNET station also showed a decrease in S dry deposition. Only the Washington Parish, LA station showed a significant decreasing trend for N deposition (

Table 5. Slopes and p-values for sulfur and nitrogen deposition trends at Coffeeville, MS (CVL151), Washington Parish, LA (LA30), Bradley County, AR (A02), and Clinton, MS (MS10). Bold trends show significance (α = 0.05).).

Table 5. Slopes and p-values for sulfur and nitrogen deposition trends at Coffeeville, MS (CVL151), Washington Parish, LA (LA30), Bradley County, AR (A02), and Clinton, MS (MS10). Bold trends show significance (α = 0.05).

Station	**S (Wet) -**	**S (Dry)**	**N (Wet)**	**N (Dry)**	**n**
		-----kg ha^{-1} yr^{-1}-------			**yrs**
CASTNET					
CVL151	**-0.076 (*p* < 0.01)**	**-0.043 (*p* < 0.01)**	-0.004 (*p* = 0.90)	-0.017 (*p* = 0.41)	21
NADP					
MS10	**-0.072 (*p* < 0.01)**	--	-0.027 (*p* = 0.26)	--	26
AR02	**-0.048 (*p*=0.007)***	--	0.019 (*p*=0.49)*	--	28
LA30	**-0.104 (*p*<0.0001)**	--	**-0.064 (*p*=0.032)**	--	28

* Outlier removed

Mean deposition values for all years of monitoring and for the final five years of monitoring are shown in Table 6. Annual deposition values for N and S are shown for Clinton, MS, Bradley County, AR, Washington Parish, LA, and Coffeeville, MS respectively in Figures 11, 12, 13, and 14. Mean annual deposition values at the Clinton, MS station, the closest to VICK, fall within the overall range of values for both averaging periods among stations. Although a reduction over the period of monitoring is apparent (

Table 5. Slopes and p-values for sulfur and nitrogen deposition trends at Coffeeville, MS (CVL151), Washington Parish, LA (LA30), Bradley County, AR (A02), and Clinton, MS (MS10). Bold trends show significance (α = 0.05).), values are fairly consistent between sites, all of which exceed the ARD threshold of 3 kg ha^{-1} yr^{-1}.

Table 6. Mean annual wet deposition values for all sites for all years as well as for the last five years of data.

Station	**Mean Annual Wet Deposition (kg ha^{-1})**	
	S (past 5 years)	N (past 5 years)
CVL151	4.61 (3.66)	4.58 (4.14)
MS10	4.49 (3.33)	4.08 (3.31)
AR02	4.88 (4.45)	4.94 (4.88)
LA30	5.16 (3.69)	4.67 (3.83)

Figure 10. Three NADP stations, one CASTNET station, and two NADP stations monitor atmospheric deposition near VICK.

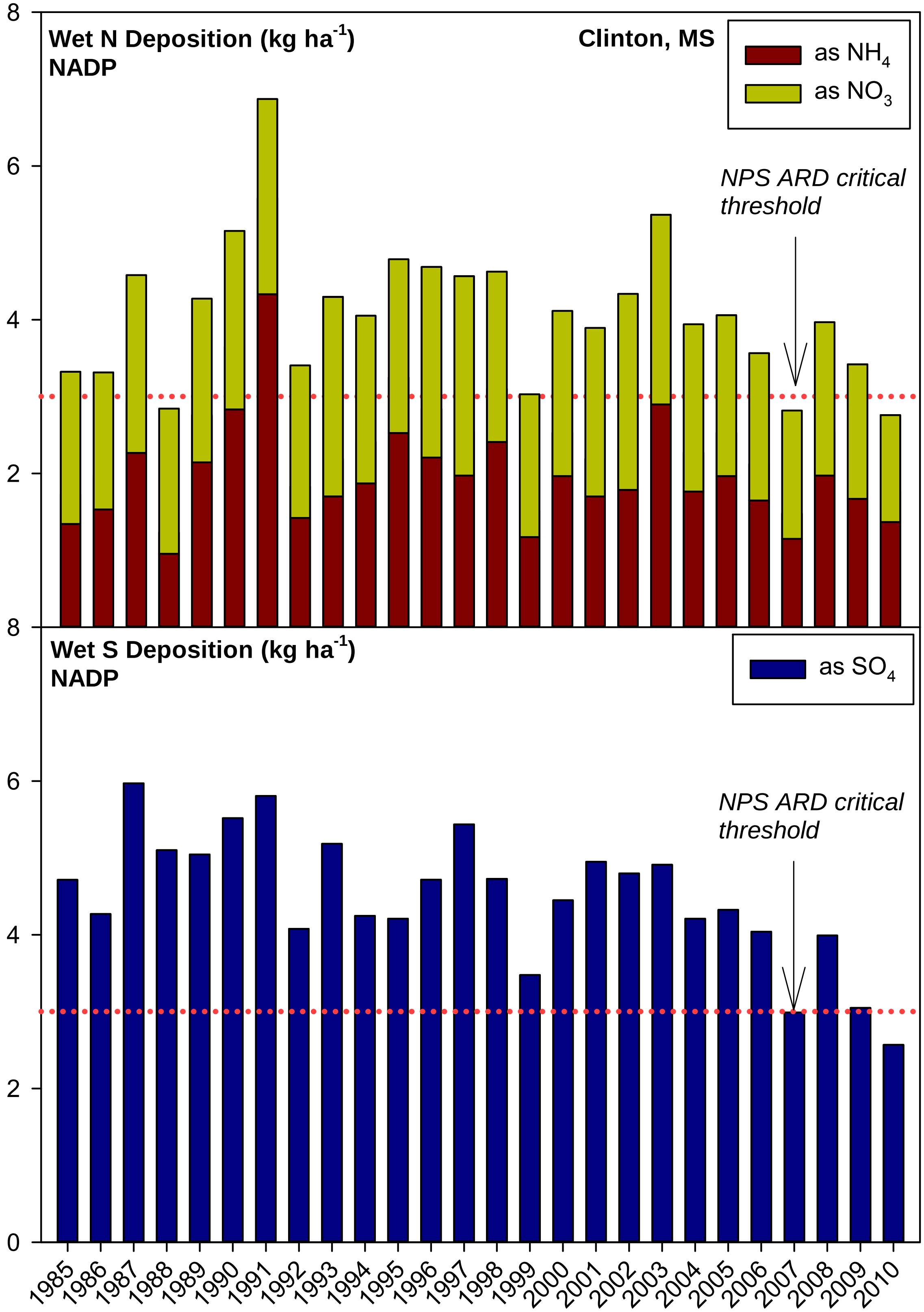

Figure 11. Annual wet N (top) and S (bottom) deposition values measured at the Clinton NADP station over the period 1985 to 2010.

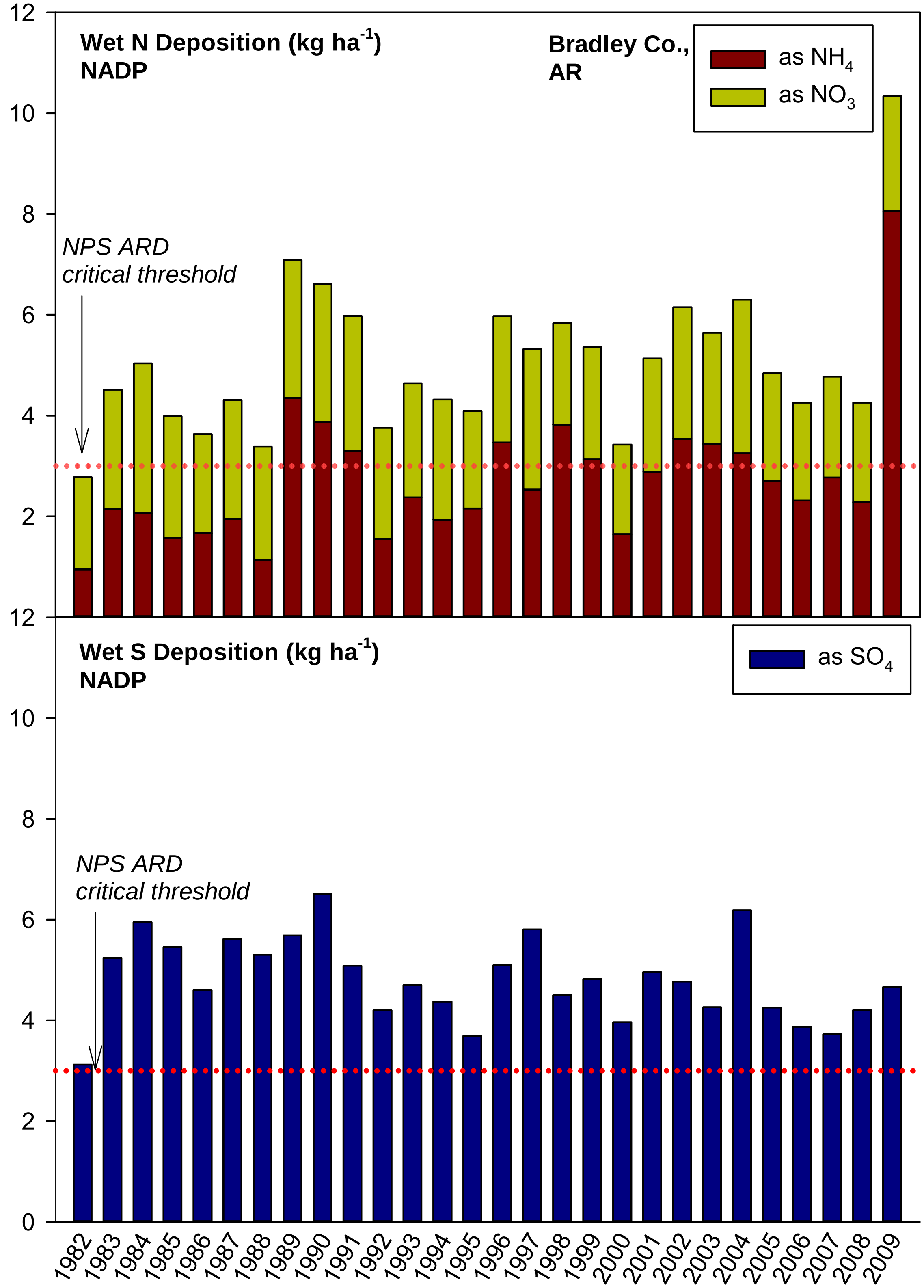

Figure 12. Annual wet N (top) and S (bottom) deposition values at the Warren 2WSW (AR02) NADP monitoring station over the period 1982 to 2009.

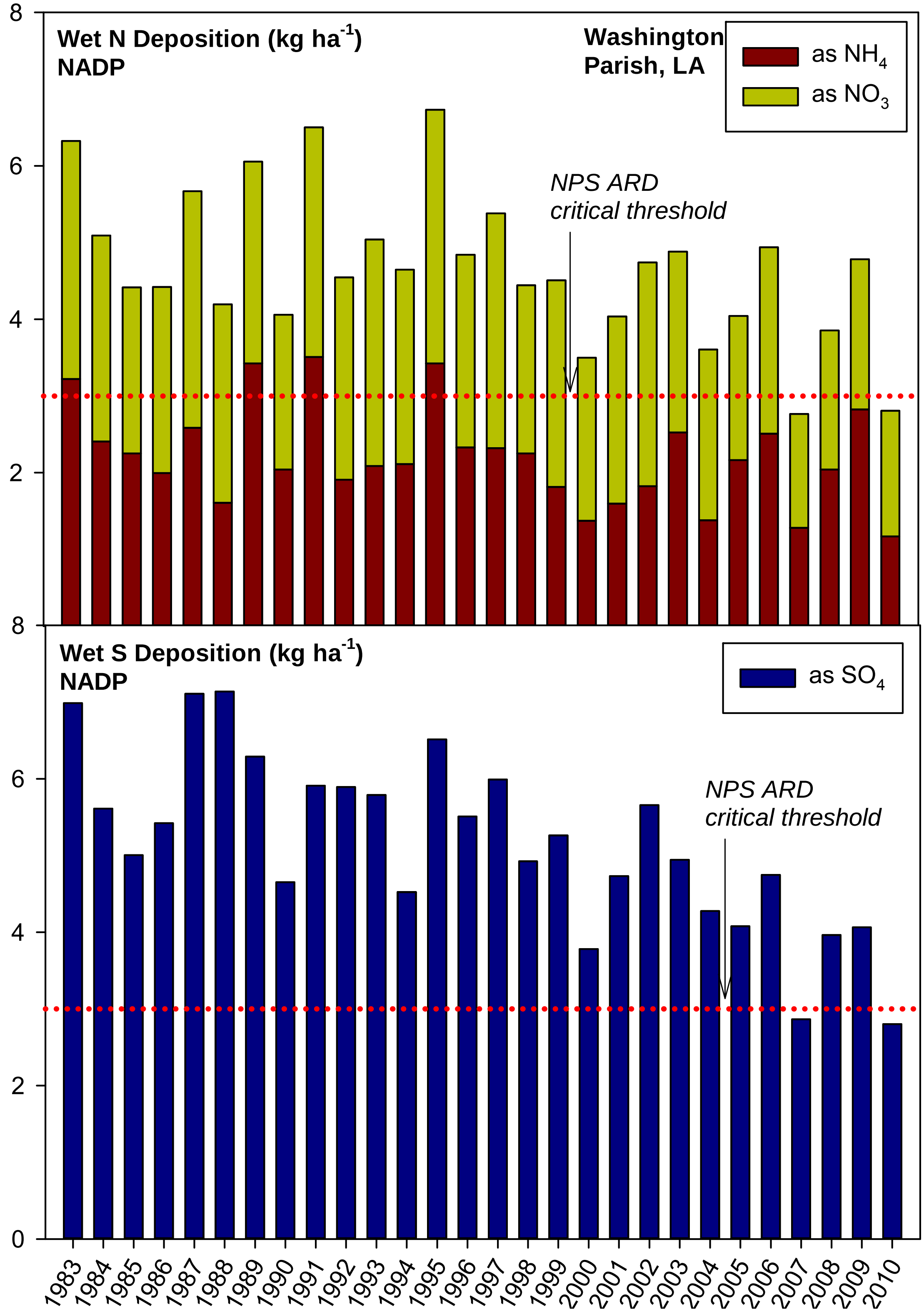

Figure 13. Annual wet N (top) and S (bottom) deposition values at the Southeastern Research Station (LA30) NADP monitoring station over the period 1983 to 2010.

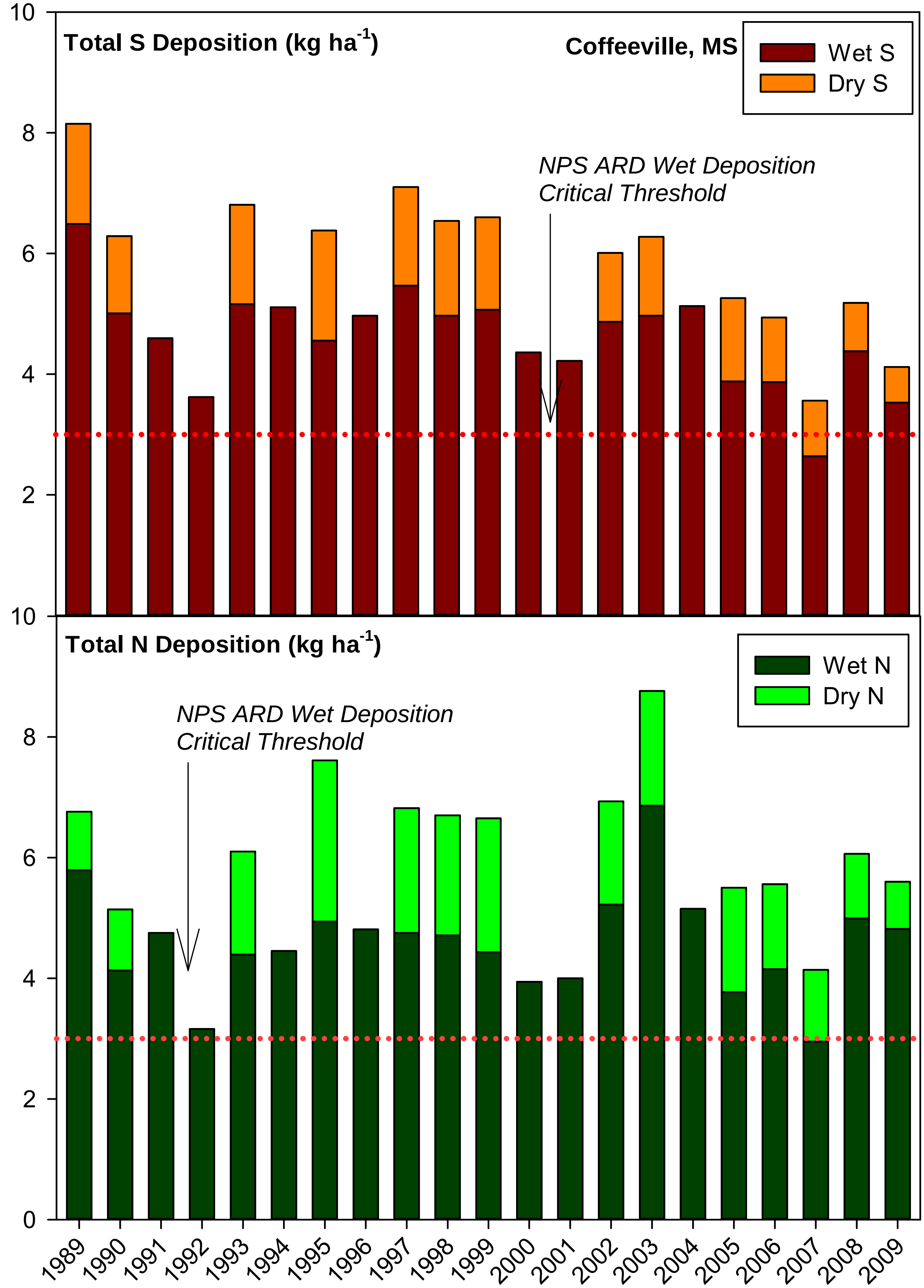

Figure 14. Wet and dry N and S deposition measured at the EPA CASTNET station in Coffeeville, MS over the period 1989 to 2009.

4.1.4 Mercury Deposition

Mercury (Hg) finds its way into ecosystems via similar vectors as N and S. Concentrations of Hg may be transferred long distances in the atmosphere before deposition occurs. Like N and S, Hg may be deposited as either wet or dry mostly in elemental (Hg) or ionic (Hg^{2+}) versions (NADP 2012). Deposition of Hg is particularly a problem in forested areas, because forest canopies can act as a filter that traps dry particles, which are in turn either re-emitted or transported to the ground as throughfall. Terrestrial transport can also lead to contamination of aquatic systems, which can result in human health issues, though generally amounts of mercury transported as runoff are considered to be far less than those which are retained in the soil (EPA 1997a). Once Hg reaches aquatic environments, it can persist in the water column, be carried away, revolatize into the atmosphere, enter the sediment, or be taken up by biota, where it is converted to a different form known as methyl-mercury ($[CH_3Hg]^+$). The accumulation of methyl-mercury in organisms, known as bioaccumulation, is particularly evident in aquatic ecosystems, where organisms higher in the food chain (e.g. fish) can build up relatively high concentrations of mercury (NADP 2012). Fortunately, effects of Hg deposition on vegetation are minimal because most plants do not uptake Hg, thereby limiting a similar bioaccumulative terrestrial pathway (EPA 1997). In 2010, mercury deposition rates were highest in the Midwest and Gulf Coast regions (Figure 8). There are no federal or state standards for mercury deposition, but there are defined thresholds for different organisms that indicate mercury contamination risk from consumption (Landers et al. 2008). The mercury toxicity threshold for humans, for example, is 185 ng g^{-1}, while for kingfishers (*Megaceryle alcyon*) it is 30 ng g^{-1} (Landers et al. 2008).

The NADP Mercury Deposition Network (MDN) monitors stations throughout the U.S. that collect weekly measurements of total mercury deposition. Two MDN stations collect measurements near VICK. The closest is in Chase, LA, approximately 80 km southwest, and collected measurements from 1998 to 2010. The closest station that still collects measurements is in Oak Grove, MS, about 180 km southwest, which began collecting in 2000. Because of its proximity, the station in Chase, LA is likely more representative of mercury deposition at VICK. Figure 15 depicts weekly measurements at both sites. Pearson correlation between sites is 0.39. No significant trends are apparent for either dataset, and mean deposition rates were 311 ng*m^{-2} and 286 ng*m^{-2} at Oak Grove and Chase sites, respectively.

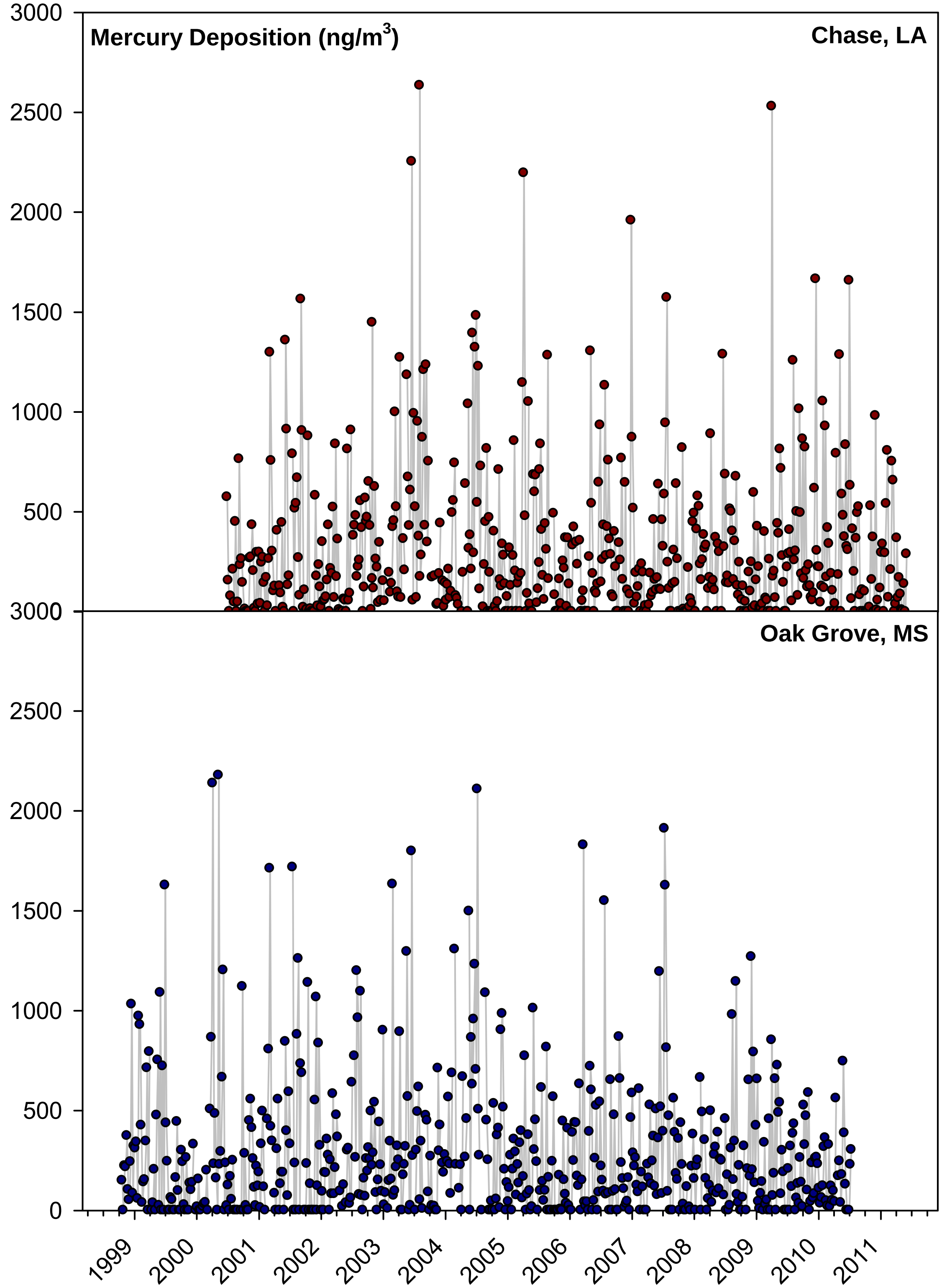

Figure 15. Total mercury weekly deposition measurements collected at Chase, LA (top) and Oak Grove, MS (bottom).

4.1.5 Condition and Trend

Overall, the EPA CASTNET and NADP stations provide a continuous and relatively complete data source for deposition throughout the region. Both wet and dry S deposition shows significantly decreasing trends over monitoring periods, though N and mercury deposition demonstrated no trends. According to the NPS ARD wet deposition threshold of 3 kg ha^{-1} yr^{-1}, most (93%) of the annual observations for N and S from the NADP and CASTNET stations near VICK represent a significant threat to ecosystem health. Because of these factors, VICK is assigned a condition status of poor for atmospheric deposition (Table 7). All deposition measurements were decreasing over monitoring periods, though sulfur was the only one that demonstrated a significant trend. As a result, deposition is assigned a status of improving. A spatial proximity data quality check was not awarded because monitoring locations are located from 40 km to 200 km beyond the park boundary, and thus actual deposition patterns at VICK may be different. Ideally, monitoring would take place in the park. The difference is likely minimal, however, as values between sites shown in Table 6 show similar values for MS, AR, and LA.

Table 7. The condition status for atmospheric deposition at VICK was poor with an improving trend. Data quality was fair.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Atmospheric Deposition		Relevancy ✓	Proximity	Currency ✓
		Sufficiency ✓	Coverage	Coverage ✓
		4 of 6: Fair		

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4.2 Weather & Climate

4.2.1 Monitoring

Climate patterns can provide insight into other processes and natural resource conditions such as water quality, vegetation dynamics, and animal communities. For the purposes of monitoring, "weather" generally refers to present and short-term conditions, whereas "climate" is the long-term trend, or norm, representing the entire distribution of atmospheric activity and its associated set of statistical descriptors. Associating weather monitoring datasets with biological data is the primary method for detecting how meteorology affects ecosystem processes. The behavior of many natural resource systems (e.g. groundwater, species patterns, pollutant loads, and plant productivity across the landscape) fluctuates as a consequence of weather events in the short-term. If the frequency or intensity of weather events changes over a longer-term (decades to centuries), this can alter the essential properties of natural resource systems. For this reason, the analysis of long-term records can reveal gradual and more permanent changes in climate, which may in turn cause fundamental alterations in the environment of the GULN region.

One significant factor affecting short-term weather variation in the Gulf region is the El Niño Southern Oscillation (ENSO), which alternates between periods of warmer temperatures with intense thunderstorms and cooler periods that are overall wetter. Severe weather disturbances such as tropical storms and hurricanes also tend to be less frequent during the warm ENSO cycle (Davey et al. 2007).

There are several weather monitoring stations in the vicinity of VICK that provide observations of temperature, precipitation, wind, and humidity, among other observations. A Remote Automated Weather Station (RAWS) previously operated at the park from 2004 to 2007 (WRCC 2012), while a National Weather Service Cooperative Observer Program (COOP) monitor collected data from 1967 to 2004 (SERCC 2012).

4.2.2 Precipitation

Precipitation is one of the most influential drivers for many ecosystem processes. Precipitation patterns affect fire regimes, primary production by plants, stream flow, and pollutant deposition. The latest Weather and Climate Inventory Report for the GULN (Davey et al. 2007) points out that precipitation has increased in some places in the GULN over the last century (Figure 16).

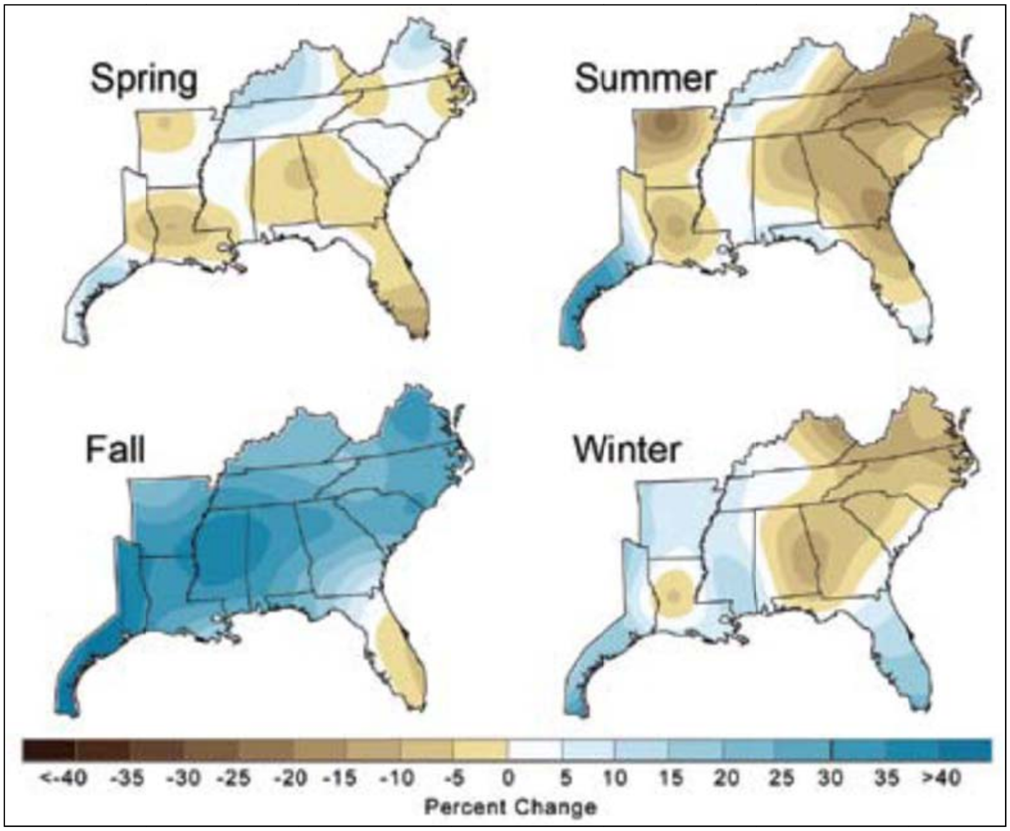

Figure 16. Changes in precipitation in the southeastern U.S. observed from 1901 to 2007. [Source: Karl et al. 2009]

Figure 17 shows annual precipitation levels at the COOP and RAWS stations over the period 1970 to 2008. Linear regression shows no significant trend over this period. The lowest annual rainfall throughout the monitoring history occurred in 2007, when only 75 cm of precipitation fell. ENSO cycles are evident in the precipitation data over a roughly 4-5 year cycle.

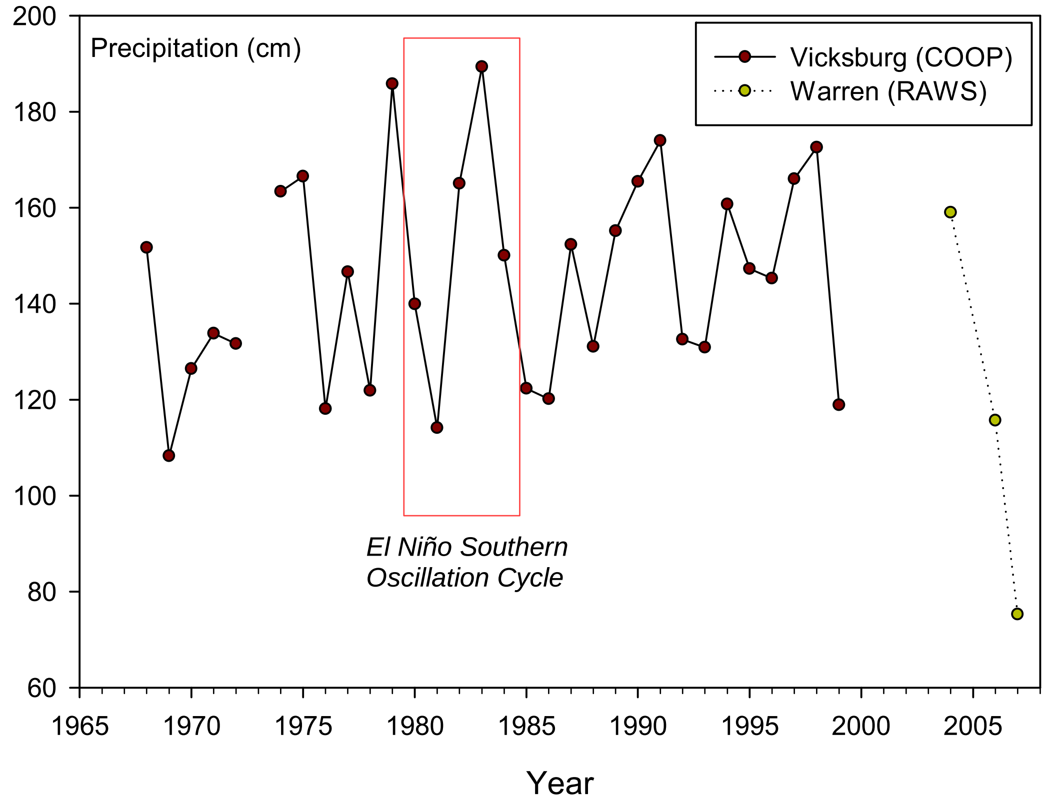

Figure 17. Precipitation data at Vicksburg from COOP and RAWS monitoring within the park over the period 1970 to 2007. The red bracket indicates an example period of the El Niño Southern Oscillation (ENSO) which results in cyclical precipitation variation. Gaps in the graph occur when stations are missing either one entire month of data or three months with at least three days of data.

4.2.2 Temperature
Long-term temperature monitoring in the GULN has also shown noticeable patterns over the past decades. Large-scale changes in temperature could be the result of climate change, as are changes in frequency of extreme weather events such as storms and droughts. These changes can also lead to ecosystem effects such as disease spread and susceptibility to invasive species (Davey et al. 2007). The GULN Weather and Climate Monitoring Plan noted that temperatures cooled throughout the region during the 1960s and 1970s, but warmed after that period in the central and western portions of the network.

Figure 18 shows average daily, maximum, and minimum annual temperatures at the COOP and RAWS monitoring locations at VICK. Years with insufficient data were not included in the plot. While data for the RAWS is relatively limited, the COOP station appears to have relatively consistent min, max, and mean temperatures over the monitoring period. Linear regression shows no significant trends over this period. There is a gap in the monitoring period between the end of the COOP period in 1998 and the start of the brief RAWS period in 2004, after which each of the three temperature metrics jump considerably. This phenomenon could be the result of site placement.

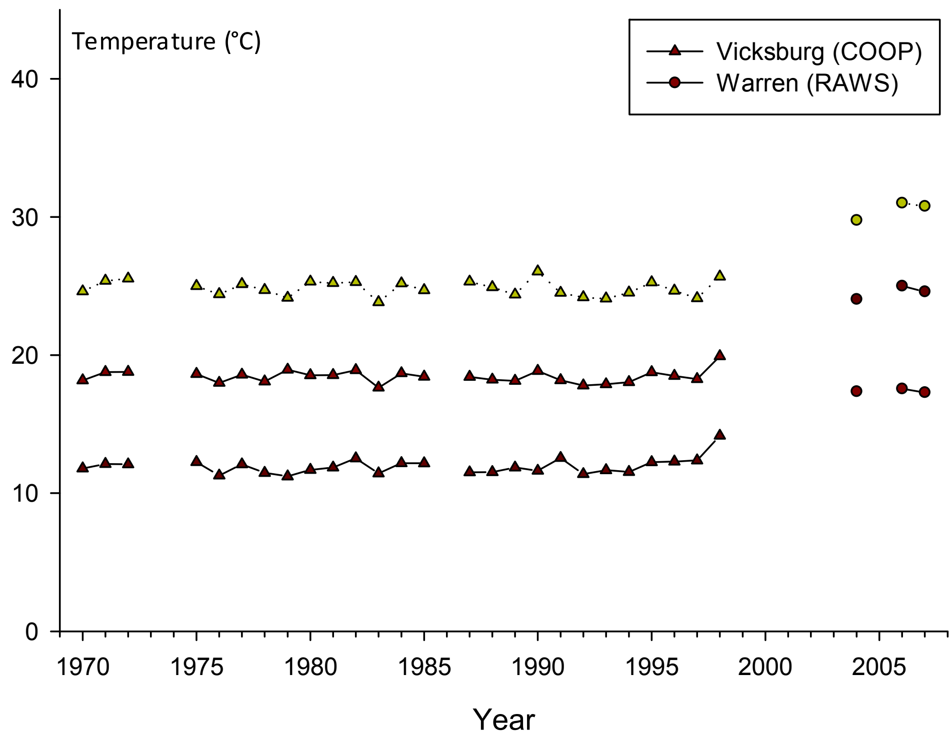

Figure 18. Average daily, maximum, and minimum annual temperatures at the COOP and RAWS monitors located at VICK over the period 1970 to 2008.

4.2.3 Wind Speed and Direction

The Warren RAWS also monitors wind speed and direction. Figure 19 shows a 16-point wind rose depicting cumulative wind speed and direction over the history of the monitoring station. At the Warren RAWS, winds were calm (<1.3 m s^{-1}) approximately two-thirds the time, and the predominant direction of wind origin was out of the southeast.

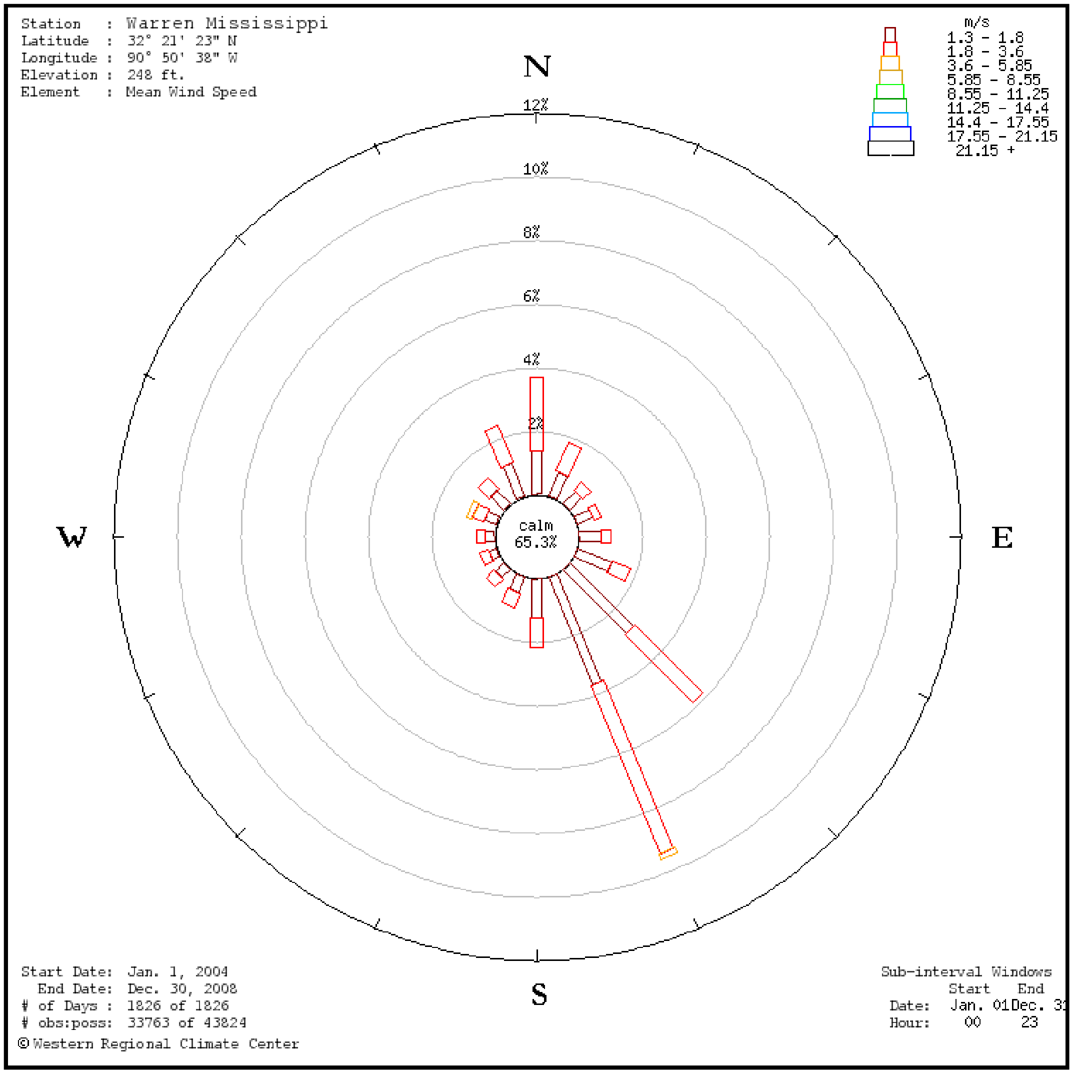

Figure 19. Directional wind rose for the Warren RAWS monitor over the period 2004-2008. Colors represent wind speed classes, and length of individual colored bars represent proportion of wind measurements blowing in the indicated direction.

4.2.4 Condition and Trend

Overall, the two data sources from VICK provide a reliable history of weather and climate monitoring at the park. Although neither station remains active, monitoring by the RAWS began not long after the COOP period ended, thus providing a relatively continuous dataset. Nearby stations such as "Tallulah," 29 km to the west, or "Port Gibson," 40 km to the south, have long monitoring periods and are still actively collecting data (Davey et al. 2007). Although the data available from the COOP station at VICK spans a long period, it is still relatively short and inappropriate to assess climate change.

Neither temperature nor precipitation data showed discernible trends over the monitoring period, though multi-year ENSO cycles were apparent in the latter. Continued monitoring at nearby stations is essential to ensure detection of longer-term climate. Overall, an assessment of condition for weather and climate is untenable, and so this attribute is left without a rank or trend (Table 8).

Table 8. The condition status for weather and climate at VICK was not assigned a rank or trend. The data quality for this attribute was very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Weather and Climate		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

4.2.5 Literature Cited

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4.3 Hydrology and Water Quality

4.3.1 Sampling Schedule

Three water quality monitoring stations at VICK are sampled by park staff using GULN protocols on a quarterly basis. Sampling began during August 2007 on Durden Creek (UADC), Glass Bayou (UAGB), and Mint Spring Bayou (UPMS) (Figure 20). Monitored parameters include temperature, specific conductance, pH, dissolved oxygen, and turbidity. In addition to periodic monitoring, GULN also deployed multiparameter datasondes to automatically collect parameters at 15-minute intervals. The datasondes were deployed for month-long periods on Durden Creek and Upper Mint Spring Bayou during late-winter and spring 2008 to 2010.

4.3.2 Use Classification

As Meiman (2012) points out, VICK is considered a Category III park in regard to its water resources, because they are not central to the park mission or interpretation. This also implies a lack of recreational use and the absence of state or federally sensitive species. In addition, because none of the streams at VICK are assigned a specific use by the Mississippi Department of Environmental Quality (MSDEQ) classification criteria, they become automatically classified as Fish and Wildlife use streams (Table 9) (MSDEQ 2007, Meiman 2012).

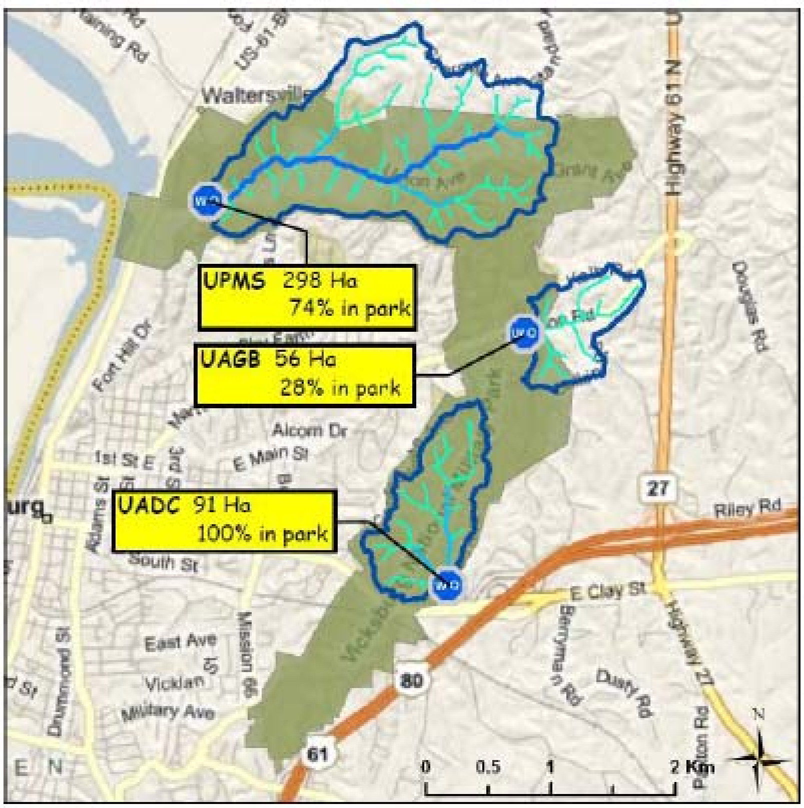

Figure 20. Location of three water quality sampling stations at VICK shown with drainage areas: Durden Creek (UADC), Glass Bayou (UAGB), and Mint Spring Bayou (UPMS). Quarterly samples began in 2007. [Source: Meiman 2012]

Table 9. Water quality standards for streams at VICK according to Fish and Wildlife criteria (MSDEQ 2007, Meiman 2012).

Parameter	Standard
Temperature	≤ 32.2˚C
Specific Conductance	≤ 1000 µS/cm
Dissolved Oxygen	≥ 5.0 mg/L daily mean; ≥ 4.0 mg/L instantaneous
pH	6.0 to 9.0 SU
Turbidity	≤ 50 NTUs above natural conditions

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. DO is sensitive to natural or anthropogenic alterations to the stream, since this type of alteration can impact the aquatic plants that are a main sources of oxygen in the stream. Mixing of atmospheric O_2 into the water occurs at waterfalls and other locations where water moves rapidly over physical barriers (like rocks). Concentrations of DO are also important to the survival of nearly all aquatic species (Palmer et al. 1997). Nutrient enriched runoff from agricultural and urban areas, septic fields, or discharge from wastewater treatment plants can result in high biochemical oxygen demand (BOD) from microorganisms that thrive in high nutrient environments, which can in turn deplete oxygen available to aquatic species (EPA 1997).

Dissolved oxygen measurements (mg/L) at VICK showed consistent seasonal fluctuations over four years of monitoring (Figure 21). Measurements never fell below the state standards of 4.0 mg/L instantaneous and 5.0 mg/L daily mean minimums. Meiman (2012) attributed higher dissolved oxygen concentrations at Mint Spring Bayou and Glass Bayou to increased aeration rates a result of more rapidly flowing, shallow reaches that occur on steep slopes.

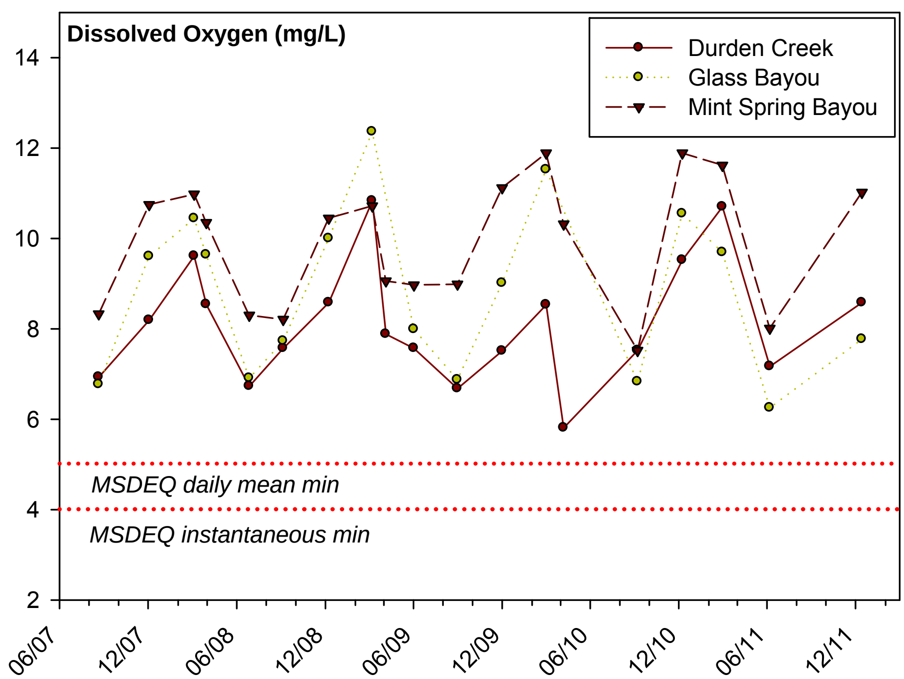

Figure 21. Dissolved oxygen measurements at VICK since monitoring began in 2007.

Temperature

Temperature is an important factor for water quality because it functions as a driver of critical biological processes. The microbial community is most strongly influenced by temperature. As temperature increases, breakdown of organic material generally accelerates, which can lead to elevated oxygen demand through microbial activity. This, combined with lower solubility of oxygen at warmer temperatures, can quickly lead to oxygen depleted water and reduced survival of sensitive organisms. Higher temperatures also correspond to greater toxicity rates of certain substances (EPA 1986). The MSDEQ specifies a limit of 32.2˚C for fish and wildlife, and all measurements at VICK fell below this standard (MSDEQ 2007, Figure 22). Samples fluctuated seasonally over the range of 10 - 25˚C.

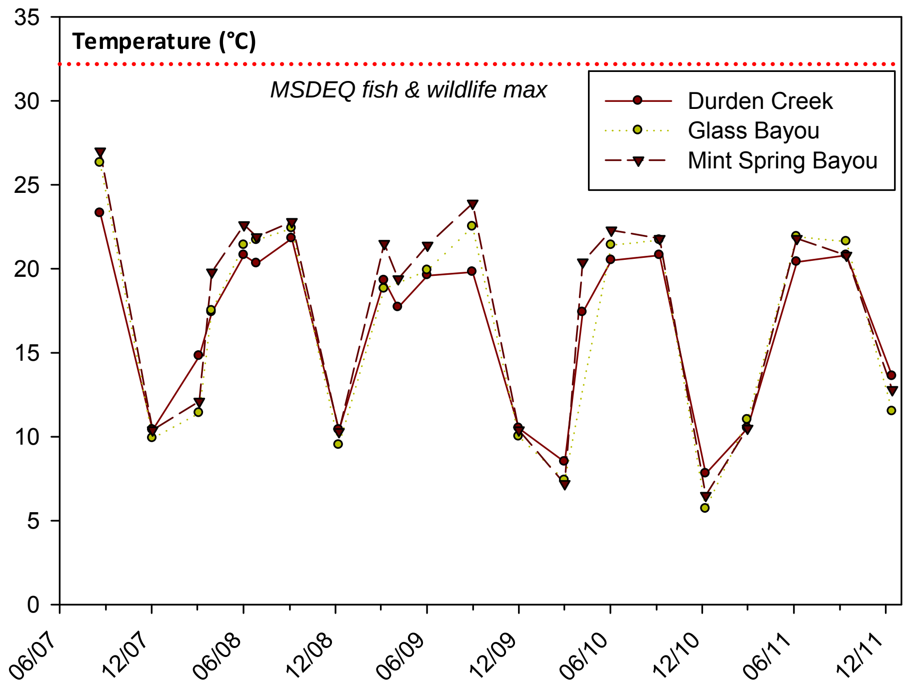

Figure 22. Temperature measurements at VICK since monitoring began in 2007.

pH

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). The MSDEQ requires pH measurements between 6.0 and 9.0 standard units for fish and wildlife use (MSDEQ 2007). The waters at VICK are unique due to the high levels of bicarbonate derived from limestone parent material, which buffers the pH to some degree.

All measurements for pH fell between 6.0 and 9.0 during the course of monitoring. However, all three sites appeared to show decreasing values over that period, which is supported by linear regression on Glass Bayou and Mint Spring Bayou. This trend may be due to a gradual shift from sampling in the afternoon to morning when pH values are lower (J. Meiman personal communication). Respectively, these sites show average annual decreases of 0.096 (p = 0.0005) and 0.163 (p = 0.0006) (Figure 23). Precipitation measured at VICK for the week prior to each sampling event showed no trend over the monitoring period that might correspond to the overall decrease in pH values. The same is true for precipitation and associated pH measurements collected at the Clinton NADP (1984-2009) and Coffeeville CASTNET (1989 – 2009) sites.

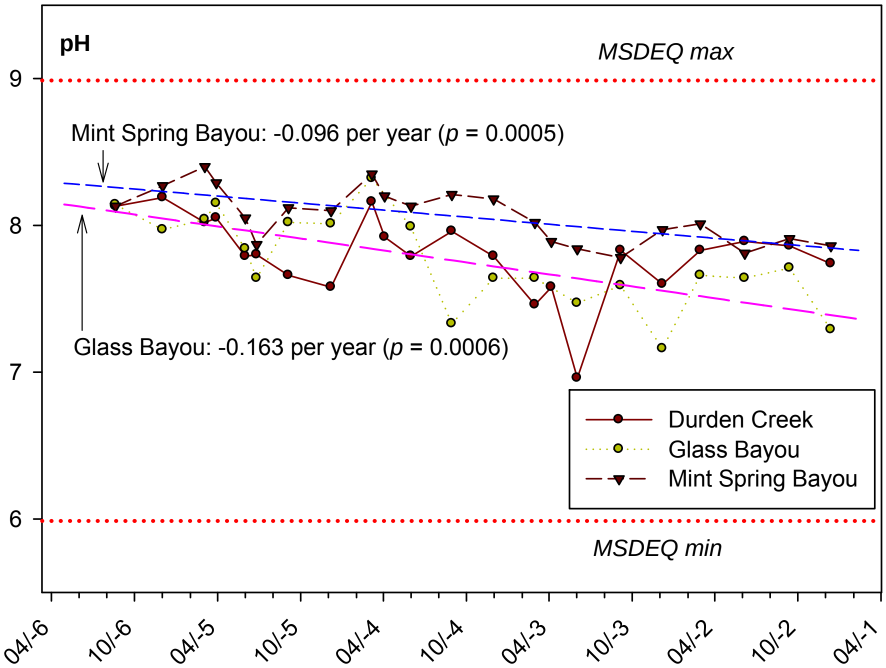

Figure 23. pH measurements at VICK since monitoring began in 2007. Measurements on Mint Spring Bayou and Glass Bayou were significantly decreasing over the monitoring period.

Specific conductance

Specific conductance gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Parent material is one of the main influences on conductance, because bedrock types that do not contribute many dissolved materials, such as granite, can result in a much lower conductivity than materials that freely contribute ionized components, such as limestone (EPA 1997). However, anthropogenic factors such as sewage discharge can also affect conductivity, which may raise or lower conductance from natural levels. As a result, it is difficult to discern the potential for pollution from conductance values alone, and is perhaps more useful to compare measurements to a baseline value. Conductance is measured as the reciprocal of resistance and expressed in micro-Siemens/cm (µS/cm). The MSDEQ standard for specific conductance is ≤ 1000 µS/cm.

At VICK, specific conductance values are particularly high due to the presence of limestone parent material. Groundwater contains high concentrations of ionic calcium and bicarbonate, resulting in highly buffered outflow to streams in the park. Figure 24 shows average specific conductance values at VICK in the range 700 to 800 µS/cm, which are below the state standard, though as Meiman (2012) reports, are the highest in the freshwater parks of the GULN.

Continuous datasonde monitoring on Mint Spring Bayou in spring 2010 showed marked drops in specific conductance after rain events due to the low ionic strength of the rainwater, which displaced waters rich in dissolved ions. Durden Creek observed a different pattern in 2009, wherein rainfall events were immediately followed by an increase in specific conductance values. Meiman (2012) attributes this response to the prevalence of pools that flush waters enriched with carbonate into the stream.

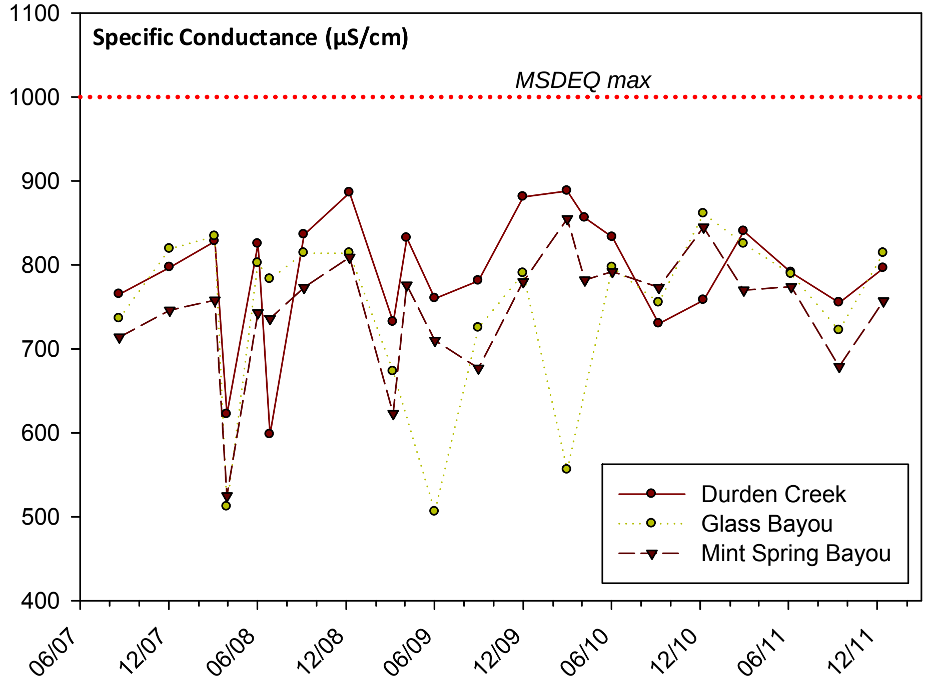

Figure 24. Specific conductance measurements at VICK since monitoring began in 2007.

<u>Turbidity</u>
Turbidity at VICK is extremely variable due to the high erodibility of the loess soils throughout the area. Small particle size and variable topography contribute to turbid streams during and after rainfall events. The MSDEQ standard for turbidity is no more than 50 nephelometric turbidity units (NTU) above natural background conditions. Because turbidity monitoring has not been previously conducted at VICK, a goal of the current monitoring is to help determine background values. It should be noted that while there have not been exceptionally high turbidities captured in the quarterly sampling effort, this is a result of coincidence rather than the lack of high-turbidity events. Each site can easily exceed 1000 NTU during and immediately following rainfall, as evident in data from datasonde deployments.

Based on monitoring, Meiman (2012) suggests that background turbidity during low flow periods is around 10 NTUs or less. Turbidity exceeded 50 NTUs once each on Glass Bayou and Durden Creek (Figure 25). The first exceedance on Glass Bayou in late summer of 2008 corresponded to significant rainfall the week prior. The spike on Durden Creek in late fall 2010 did not correspond to a rainfall event, and turbidity was overall the highest at this site of the three sampling locations. Meiman (2012) notes that the drainage area of Durden Creek is wholly contained within the park boundaries, and as a result, park operations may be contributing to elevated turbidity levels. Datasonde monitoring on Durden Creek during early spring 2009 showed multiple spikes in turbidity up to 1,000 NTUs. Although many sudden increases correspond to rainfall measured at the nearby Vicksburg-Tallulah Regional Airport, there are several spikes that do not, suggesting influences beyond that of precipitation (Meiman 2012).

Continuous datasonde monitoring the following year on Mint Spring Bayou was paired with a rain gauge and confirmed that several increases in turbidity did not correspond to rain events at that site. Meiman (2012) suggests these increases may be due to human-caused disturbance in the stream such as recreation, or due to feral pig activity, which may be the result of activity in the stream itself, or rooting activity that facilitated erosion into the stream. Alternatively, the increases in turbidity could have been the result of a road construction project conducted on Connecting Avenue, which runs over Mint Spring Bayou (V. DuBowy personal communication).

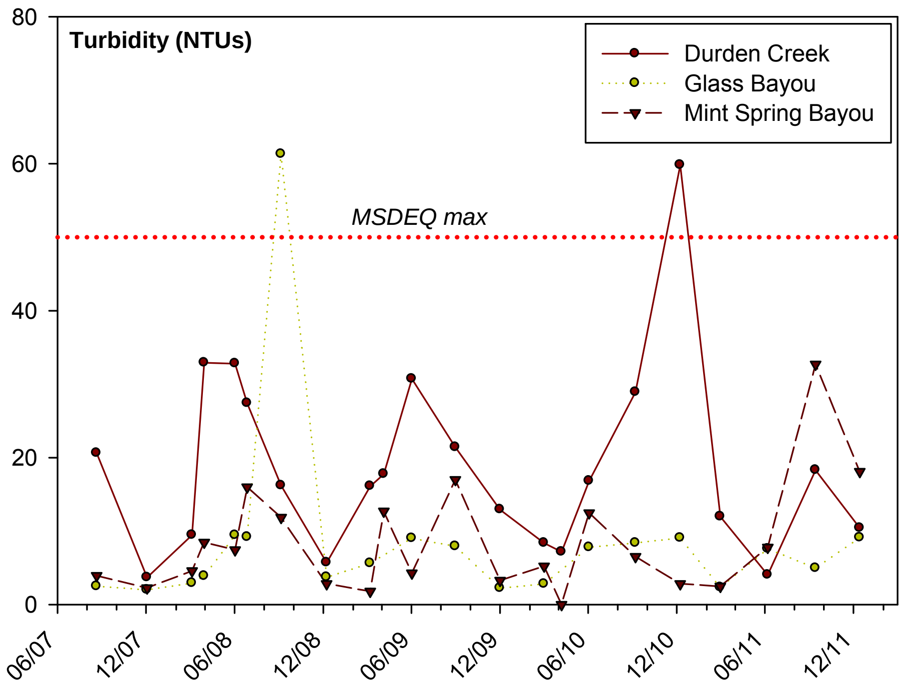

Figure 25. Turbidity measurements at VICK since monitoring began in 2007.

4.3.4 Summary

Water quality at VICK has been within state standards for all parameters measured since sampling began in 2007. The only possible exception is turbidity, which is restricted to 50 NTUs above background value. Assuming that the true background value is greater than 0 NTUs and representative of low-flow periods, it is likely that even the ~60 NTU spikes seen in quarterly monitoring data would be considered within the standard. Elevated turbidity values on Durden Creek are of note, however, as they do not always match with rainfall events. Because the entire drainage area of Durden Creek is within park boundaries, activity within the park or human or animal use may be contributing to elevated values.

Another interesting phenomenon is the steady decrease in pH values amidst seasonal cycles at all three sampling locations, though this trend is only significant at Mint Spring and Glass Bayous. Modeling pH as a function of time sampled demonstrates that it is a significant explanatory variable for the trend seen in pH values. Consistent sampling time during subsequent measurements would ensure that other factors are not involved in a gradual pH reduction. Water quality at VICK is assigned a condition status of good, while the data quality is very good (Table 10).

Table 10. The condition status for water quality at VICK is good; the data quality is very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Water Quality		Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

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4.4 Exotic Plants

Exotic plant species are one of the most significant resource management concerns at VICK. Several species of non-natives have infested areas throughout the park. A vascular plant survey by Walker (1997) reported 83 exotic species, representing 28% of taxa identified at the park. Open areas in particular contain high richness of native and exotic species (Canfield et al. 2008). Some of the most significant invasives at VICK include kudzu, Johnsongrass, Chinese privet, Chinese parasol tree, and Chinese tallow.

4.4.1 Treatments

Treatments by the Gulf Coast Exotic Plant Management Team have been effective in reducing the occurrence of invasives. Figure 26 depicts kudzu-infested areas within the park in 2010. An undated exotic vegetation management plan indicates that up to 80 ha of land (11.5% of the total area of the park) was infested by kudzu at one time. Between 1992 and 1997, kudzu spread from 6 ha to 10 ha (Canfield et al. 2008). In 1998, 4 ha were treated using a combination of herbicides and prescribed fire. Despite replanting with native grasses, kudzu returned to this site. Since then, treatment has continued and reduced infestation to less than 6 ha, most of which occur on or along the park boundary (V. DuBowy personal communication).

The natural resource summary at VICK (Cooper et al. 2004) indicates that kudzu is perhaps the greatest threat to the native landscape due mainly to how quickly it spreads (Figure 27). The growth pattern of kudzu exerts strong ecological impact through reducing both tree species abundance and longevity and their recruitment into the system (R. Woodman personal communication).

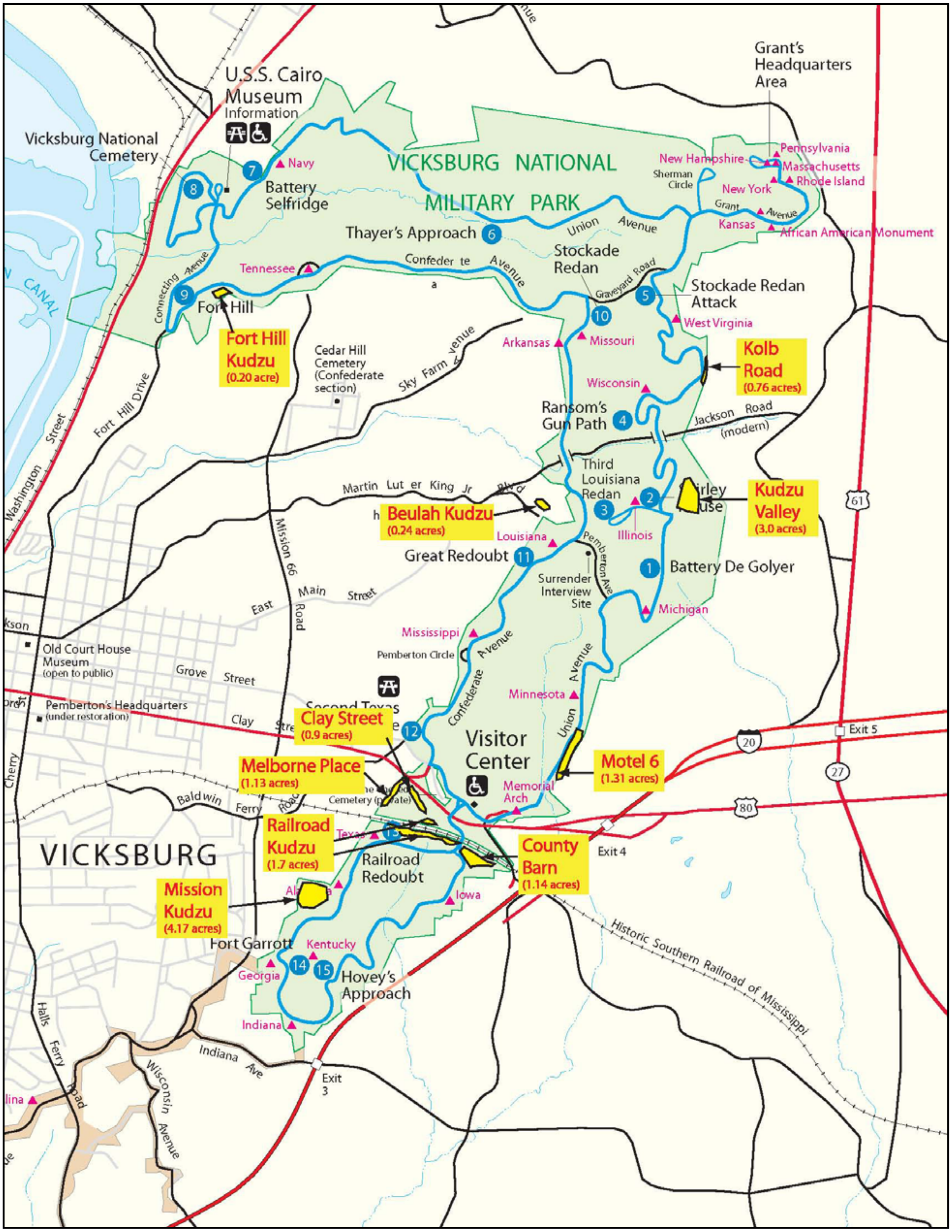

Figure 26. Areas infested with kudzu at VICK as of 2012. [Source: V. DuBowy personal communication]

Johnsongrass is being effectively treated with prescribed burning on Ft. Hill, a major site of infestation (V. DuBowy personal communication). A review of fire treatments on Johnsongrass by Howard (2004), however, show mixed results. Torching can be effective for spot treatments, though Johnsongrass may potentially resprout from rhizomes. Repeated burning may be sufficient to destroy seeds and eventually deplete rhizome regeneration. Howard (2004) also suggests that mowing seedlings within 13 days of emergence is an effective control measure, although the topography of Fort Hill would likely require the use of weedeaters instead of mowers (V. DuBowy personal communication).

Other plants mentioned in the exotic vegetation management plan include ragweed (*Ambrosia artemisiifolia*) and Japanese honeysuckle. Though not exotic, ragweed overtakes open areas and can interfere with native grasses in kudzu recovery areas (NPS, undated). Allergens generated by this species also make it a nuisance. The natural resource summary (Cooper et al. 2004) and biological inventory summary (2010) mention several additional exotics at VICK, the most notable of which include English ivy (*Hedera helix*), Japanese stiltgrass (*Microstegium vimineum*), and oriental bittersweet (*Celastrus orbiculatus*). Cooper et al. (2004) suggest that, behind kudzu, Japanese honeysuckle, Chinese privet, and English ivy represent the major problems at VICK.

Figure 27. Kudzu is one of the most harmful invasives threatening vegetation communities at VICK. [C. Evans, River to River CWMA, Bugwood.org]

4.4.2 I-Ranks

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. This method is also used by the Mississippi Exotic Pest Plant Council (MSEPPC) to provide an overall risk rating for individual pest species (MSEPPC 2012). The MSEPPC adds an additional category of economic impact which addresses impact on agriculture costs of management.

To offer a further quantitative assessment of the invasive exotics present at VICK, 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 11 and are expressed on a scale of zero to three, with three representing the greatest threat to park resources. Species included are exotics recognized by Cooper et al. (2004), Walker (1997), or GULN (2010). Following this approach, two species resulted in an I-Rank in the highest category (≥2.00): Chinese tallow and Japanese honeysuckle.

Seventeen species were classified between one and two, while eight species were included in the lowest I-Rank risk category. The remaining six species did not have I-Ranks available.

Table 11. Modified I-Ranks shown for invasive exotics at VICK (Walker 1997, Morse et al. 2004, Cooper et al. 2004).

Species	Common Name	Family	I-Rank*	Habitat
Sapium sebiferum	Chinese tallow	Euphorbiaceae	2.67	Bottomlands, riparian areas
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae	2.33	Forest interior, edge
Celastrus orbiculatus	Oriental bittersweet	Celastreaceae	2.00	Disturbed forest and edges
Hedera helix	English ivy	Araliaceae	2.00	Forest gaps/ edges
Microstegium vimineum	Japanese stiltgrass	Poaceae	2.00	Bottomland forests, floodplains
Cynodon dactylon	Bermudagrass	Poaceae	1.83	Disturbed wet areas
Sorghum halepense[†]	Johnsongrass	Poaceae	1.83	Old field
Pueraria montana	Kudzu	Fabaceae	1.83	Disturbed areas, roadsides
Nandina domestica	Nandina	Berberidaceae	1.83	Floodplains, woodlands
Ligustrum sinense[†]	Chinese privet	Oleaceae	1.67	Forest interior, floodplain
Lolium pratense	Meadow fescue	Poaceae	1.67	Disturbed open areas, roadsides
Phyllostachys aurea	Golden bamboo	Poaceae	1.67	Open woodlands, forest edges
Poa pratensis	Kentucky bluegrass	Poaceae	1.67	Open areas
Ailanthus altissima	Tree-of-heaven	Simaroubaceae	1.50	Disturbed areas
Melia azedarach	Chinaberry	Meliaceae	1.50	Disturbed areas, floodplains
Wisteria sinensis	Chinese wisteria	Fabaceae	1.50	Disturbed areas, forest edges, roadsides
Paulownia tomentosa	Princesstree	Scrophulariaceae	1.33	Disturbed areas, forest edges
Dactylis glomerata	Cocksfoot	Poaceae	1.17	Moist open areas
Trifolium repens	White clover	Fabaceae	1.17	Disturbed open areas
Capsella bursa-pastoris	Shepherd's purse	Brassicaceae	1.00	Disturbed areas
Perilla frutescens	Beefsteak plant	Lamiaceae	1.00	Disturbed open areas
Duchesnea indica	Indian mock strawberry	Rosaceae	0.83	Disturbed open areas, open forest, edges
Rosa multiflora	Multiflora rose	Rosaceae	0.83	Woodlands, forest edges
Lagerstroemia indica	Crapemyrtle	Lythraceae	0.75	Mainly escaped cultivations
Trifolium pratense	Red clover	Fabaceae	0.75	Disturbed open areas, open forest, edges
Prunus persica	Peach	Rosaceae	0.67	--
Chenopodium murale	Nettle-leaf goosefoot	Amaranthaceae	0.50	Disturbed open areas
Ambrosia artemisiifolia	Ragweed	Asteraceae	Not Ranked	--
Broussonetia papyrifera	Paper mulberry	Moraceae	Not Ranked	Waste areas, disturbed thickets
Bromus catharticus	Rescue brome	Poaceae	Not Ranked	Disturbed open areas
Firmiana simplex	Chinese parasol tree	Malvaceae	Not Ranked	--
Paspalum notatum	Bahia grass	Poaceae	Not Ranked	Abandoned pasture
Poncirus trifoliata	Trifoliate orange	Rutaceae	Not Ranked	--

* I-Rank is calculated as a mean of ecological impact, trend in distribution and abundance, and general management difficulty, each of which is assigned a value of 1 to 3 (Morse et al. 2003). Each category is assigned a number based on its categorical rating, the average of which is the overall I-Rank: low (0-0.99), medium (1.00-1.99), or high (2.00+). Ranks do not reflect overall abundance within the park unit.

4.4.3 Condition and Trend

Overall, it is clear that exotics pose a threat to the natural landscape at VICK. Based on personal communication, kudzu represents the highest-priority management target, though ongoing treatments by the Exotic Plant Management Team (EPMT) have greatly reduced the amount of infested area over the past years. Other threats like Chinese tallow may not be as widespread as kudzu, but still have a high rate of spread and the ability to outcompete native plant species. Based on I-Rank alone, Japanese honeysuckle may also represent a high-priority target for removal because of its ability to spread quickly and its difficulty of removal.

Because exotics represent a high portion of identified flora at VICK, the condition status for exotic plants is fair (Table 12). Fortunately, recent treatments by the Gulf Coast EPMT are reducing kudzu infestation at the park. As a result, an improving trend is assigned. Finally, although recent inventory summaries (Cooper et al. 2004, GULN 2010) provide some information on the status of exotics at VICK, with the exception of kudzu, little information exists regarding specific infested area, treatments, and their efficacy. It is possible that headway made against kudzu may be offset at least in part by the proliferation of other exotics, though this is unknown. Only a single inventory has been conducted by Walker during 1996 and 1997, and as a result, thematic sufficiency and temporal currency and coverage do not receive data quality checks (Table 12).

Table 12. The condition of exotic plants at VICK is fair. The data quality is marginal.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Exotic Plants		Relevancy ✓	Proximity ✓	Currency
		Sufficiency	Coverage ✓	Coverage
		3 of 6: Marginal		

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4.5 Terrestrial Vegetation

Of the roughly two-thirds forested area at VICK, Canfield et al. (2008) reported that southern red oak (*Quercus falcata*) and white oak (*Quercus alba*) were the most dominant tree species. In 2007, Rangoonwala and Ramsey (2007) completed a vegetation classification at VICK based on color infrared photography collected in September 2004 (Table 13). Combined with this data were ground classifications performed by park personnel at 43 plots within the park. These ground assessments were used as training data along with image classification to produce a vegetation map for VICK. Figure 28 shows the generalized landcover classification for the main park area and satellite sites with a 100 m buffer.

Following the Civil War, the area comprising Vicksburg was mainly open fields used for agriculture (Cooper et al. 2004). Today, forests at VICK are in the southern portion of a region known as the Blufflands. The composition of the VICK forest is "atypical" of the loess-bluff forests of the MS River and the region. Walker (1997) observed that this vegetation type was dominated by American beech (*Fagus grandifolia*) and cucumbertree (*Magnolia acuminata*). However, according to the most recent certified species list at VICK, cucumbertree is not present at the park. The presence and distribution of species at VICK may reflect planting and subsequent re-seeding more so than outside recruitment or forest age effects (R. Woodman personal communication). Newly discovered photographs taken in the 1930's demonstrate substantial existing forest, thus the history of the vegetation at VICK is still unclear (M. Segura personal communication).

The most common vegetation type throughout VICK is the sweetgum-pecan-water oak association (261 ha/ 36.6% of landscape), followed by the cherrybark-water oak association (150 ha/ 21% of landscape). These forests originated in the 1930s when the Civilian Conservation Corps planted trees to combat erosion (Canfield et al. 2008). Many areas throughout the park have been managed to create the open field habitat that was present at the time of the battle. Bermudagrass is commonly planted in the grassland associations that comprise much the rest of the park; these areas exist in various stages of mowing. Cooper et al. (2004) suggests that bermudagrass comprises 30% of the landscape.

Table 13. Vegetation classes mapped at VICK by Rangoonwala and Ramsey (2007).

Class	Area -ha-	Proportion -%-
Cherrybark-water oak association	149.853	21.0
Sweetgum-pecan-water oak association	261.0	36.6
Tulip tree-oak association	47.4	6.6
Black willow association	7.4	1.0
Loblolly pine planted association	5.4	0.8
Paper mulberry association	0.5	7.3
Black locust association	1.5	0.2
Sycamore mix association	36.1	5.1
Isolated trees	2.8	0.4
Unclassified (scattered trees, vines, shrubs)	17.3	2.4
Smooth sumac shrubland	0.1	1.9
Kudzu vine Shrubland-treated association	6.2	0.9
Kudzu vine and grapevine association	34.0	4.8
Kudzu vine shrubland association	6.8	1.0
Grassland alliance	108.2	15.2
Bamboo	<0.1	2.7
Water	0.5	7.4
Developed-bare	26.9	3.8

4.5.1 Significant Communities

The most significant vegetation community present at VICK is likely the Cherrybark Oak – Water Oak Loess Bluff Forest, classified as a vulnerable (G3) community type by NatureServe (2011). This community type only occurs on loess bluffs along the Mississippi River and is mainly threatened by conversion to pine plantation and invasion by Chinese privet. Throughout the buffer area, this community type comprises 197 ha.

4.5.2 Condition and Trend

The main issue facing vegetation communities at VICK is invasion by exotic species—particularly kudzu, whereas the significant Cherrybark Oak – Water Oak Loess Bluff Forest complex is potentially threatened by Chinese privet. Large areas in the northern part of the park were mapped as kudzu association by Rangoonwala and Ramsey (2007), though many areas have been treated. Rangoonwala and Ramsey (2007) also noted that canopy-kudzu areas were less accurately mapped because they were difficult to distinguish from grapevine (*Vitis sp.*) (Figure 29). As a result, these areas were combined into a single class. Overall, the non-treated kudzu classes (kudzu-grapevine/Shrubland associations) comprised 39.8 ha (5.8%). According to most recent data from staff at VICK, current area of infestation is much less than that, which likely reflects aggressive treatments and some classification error (

Figure 26).

There is a dichotomy between desired vegetation types at VICK such as mowed lawn and forests with fewer invasive species, and unintended vegetation, such as the areas overtaken by kudzu. Kudzu areas next to patches of Cherrybark Oak – Water Oak Loess Bluff Forest may present a threat to these vulnerable areas and may represent best targets for control. Because of this, the condition of vegetation communities at VICK is ranked as fair, and no trend is assigned (

Table 14). The classification performed by Rangoonwala and Ramsey (2007) provides thorough insight to the types and distribution of vegetation types at VICK and is strengthened by observations from initial on-the-ground surveys. It will be important, however, to track vegetation over time to document changes in the condition of these communities.

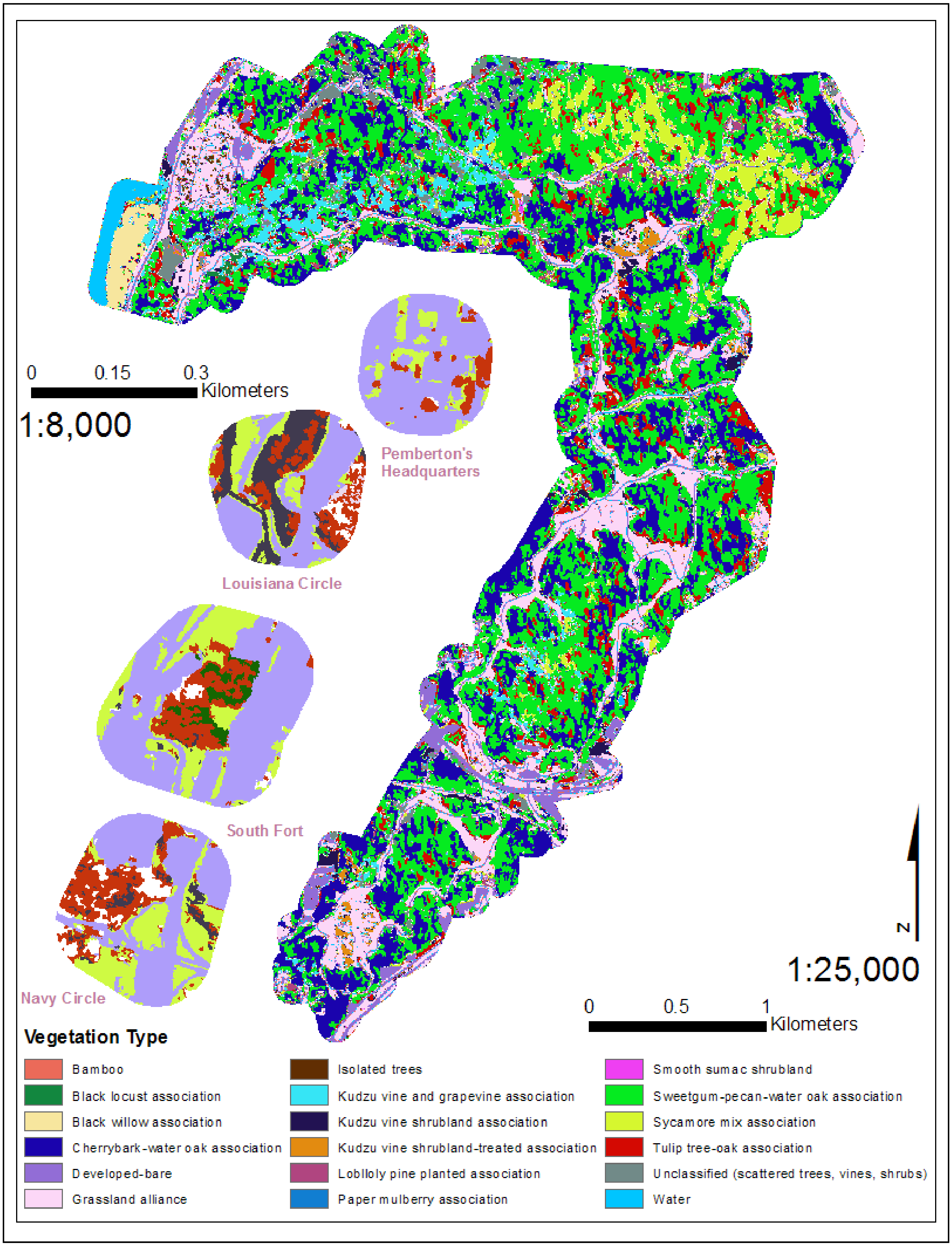

Figure 28. Rangoonwala and Ramsey (2007) produced a generalized landcover classification map for VICK with a 100 m buffer.

Figure 29. Kudzu canopy vines were difficult to distinguish from grapevines using aerial imagery, resulting in a combined classification. [Source: Rangoonwala and Ramsey (2007)]

Table 14. The condition status for vegetation communities at VICK is fair. The data quality is very good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Terrestrial Vegetation		Relevancy ✓	Proximity ✓	Currency ✓
		Sufficiency ✓	Coverage ✓	Coverage ✓
		6 of 6: Very Good		

4.5.3 Literature Cited

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4.6 Rare Plants

4.6.1 Prairie Nymph

The main plant species of concern present at VICK is a species of iris called prairie nymph (*Herbertia lahue* ssp. *caerulea*), which has a state conservation rank of imperiled (S2) in MS (NatureServe 2011, MSNHP 2012, Figure 30). Although rare rangewide, prairie nymph is relatively abundant at VICK, where it blooms in April and May and occurs mainly on southwest-facing slopes in open grassy areas (NPS 2011, V. DuBowy personal communication). In 2010, plots were established in prairie nymph habitat to study the effects of mowing on their growth. Prairie nymph can propagate via bulb storage, though seed set is more common. For this reason, it is particularly important that mowing does not interfere with population persistence (NPS 2011). Mowing not only after the blooming period, but also after seed set may be the best way the help the persistence of this species. Since 2010, prairie nymph at VICK has continued to spread throughout open areas in the park.

Figure 30. Prairie nymph is a state-listed species of iris at VICK. [Photo courtesy of National Park Service]

4.6.2 Other Sensitive Species

In addition to prairie nymph, several state rare species are present at VICK. The Mississippi Natural Heritage Program (MSNHP) maintains two lists of rare species. The first tracks species of special concern, which are species that occur in low numbers throughout the state. In addition to prairie nymph, species on this list that occur at VICK include bandana of the Everglades (*Canna flaccida*), climbing bittersweet (*Celastrus scandens*), and Southern slender lady's tresses (*Spiranthes lacera* var. *gracilis*). The other list is a watch list that designates species that may be listed as special concern, which includes Southern thimbleweed (*Anemone berlandieri*) and beaked spikerush (*Eleocharis rostellata*) (MSNHP 2012).

Bandana of the Everglades is listed with a state conservation rank of critically imperiled (S1), while climbing bittersweet is ranked as imperiled (S2, Figure 31). It is possible that bandana of the Everglades was confused with another *Canna* sp., possibly the hybrid *Canna x generalis,* because *C. flaccida* was not specifically identified during wetland delineation efforts at the park (V. DuBowy personal communication). Resolution of the identity of this species is important to start monitoring its occurrence in case it is the state critically imperiled *C. flaccida*. Climbing bittersweet, a rare species, is often confused with Oriental bittersweet, an exotic species, though the latter has not been identified at VICK by park staff (V. DuBowy personal communication). Southern slender lady's tresses has a conservation rank of vulnerable (S3). Although not abundant, distribution of this species in the park is fairly widespread (V. DuBowy personal communication).

Figure 31. Bandana of the Everglades (*Canna flaccida*, top left), climbing bittersweet (*Celastrus scandens*, top right), and Southern slender lady's tresses (*Spiranthes lacera* var. *gracilis*, bottom right) are species of special concern occurring at VICK [Source: *C. flaccida* - FL Museum of Natural History 2012, *C. scandens* – Duke Univ. 2012, *S. lacera* var. *gracilis* – L. Allain USDA-NRCS Plants Database].

Although Southern thimbleweed does not have a state conservation rank, it is listed as imperiled (S2) in Louisiana and vulnerable (S3) in Alabama. The same is true for beaked spikerush, which does not have a conservation rank in MS but is listed as critically imperiled in Alabama.

Populations of these two species in MS are few and likely require special attention to persist (NatureServe 2012), although populations in VICK seem to be particularly common along manicured roadsides (V. DuBowy personal communication).

Figure 32. Southern thimbleweed (*Anemone berlandieri*) and beaked spikerush (*Eleocharis rostellata*) occur at VICK and are on the MS watch list. [Source: *A. berlandieri* - R. Buckallew USDA-NRCS Plants Database, *E. rostellata* – B. Coffin MN Dept. Natural Resources]

4.6.3 Condition and Trend

Although prairie nymph is the main plant species of concern present at VICK, little data currently exists on its status in the park. Recently established plots for FY17 study will greatly aid in tracking the survival and distribution of this species (V. DuBowy personal communication). The condition status of rare plants as it pertains to prairie nymph at VICK is assigned a rank of good. The information available for prairie nymph is mostly anecdotal and from recent accounts, so the data quality is assessed as poor. There is also no park-specific information available on species at VICK listed as rare by the MSNHP. As regular surveys inform and update the status of prairie nymph, temporal coverage, spatial proximity, and thematic sufficiency should improve, ultimately resulting in a data quality ranking of good and likely the assignment of a trend (Table 15). Ideally, surveys could also incorporate the other five rare plant species listed by the MSNHP.

Table 15. The condition status for rare plants at VICK was good. No trend was assigned to rare plant condition. The data quality was poor. Because of the disparity between the condition ranking and data quality, particular consideration is advised when interpreting this attribute.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Rare Plants		Relevancy ✓	Proximity	Currency ✓
		Sufficiency	Coverage	Coverage
		2 of 6: Poor		

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4.7 Fish Assemblages

4.7.1 Context and Relevance

The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000). Many stream fishes are not widely distributed and southeastern drainages harbor fish assemblages characterized by high species richness and endemism (Sheldon 1988). The Mississippi River, the largest North American river, drains over 40% of the landmass of the contiguous United States (Saikku 2005), and supports over 300 species of freshwater fishes within its drainages (Sheldon 1988). Over geological time, the river has created an extensive alluvial plain in its lower drainage. Within this plain, the Yazoo-Mississippi delta is defined on the west by the Mississippi River, and on the east by the bluffs that form the eastern boundary of the Yazoo River floodplain (Saikku 2005, Bryant 2010). This delta region harbors a rich and abundant fish fauna including over 100 species (Love and Taylor 2004, Killgore et al. 2008, Bryant 2010), and has experienced extensive environmental degradation from agriculture, flood control, and deforestation (Saikku 2005, Bryant 2010). The streams of the upland regions of the Yazoo River basin, east of the delta, also contain a relatively rich and variable fish fauna of at least 65 species (Shields et al. 1995, Adams et al. 2004). Streams in this region have suffered from extensive erosion and channelization (Shields et al. 1995). Vicksburg National Military Park is ecologically tied to both the Yazoo-Mississippi delta and the upland region of the Yazoo drainage. The park is located in the upland bluffs at the southern tip of the Yazoo-Mississippi delta (Figure 33), near the confluence of the two rivers. Streams in the northern park flow into the Yazoo River Diversion Canal and streams in the southern portion of the park flow into the Mississippi River. Therefore, although VICK is located within upland habitat on the delta border, its streams are proximal tributaries to the large rivers characterizing the delta.

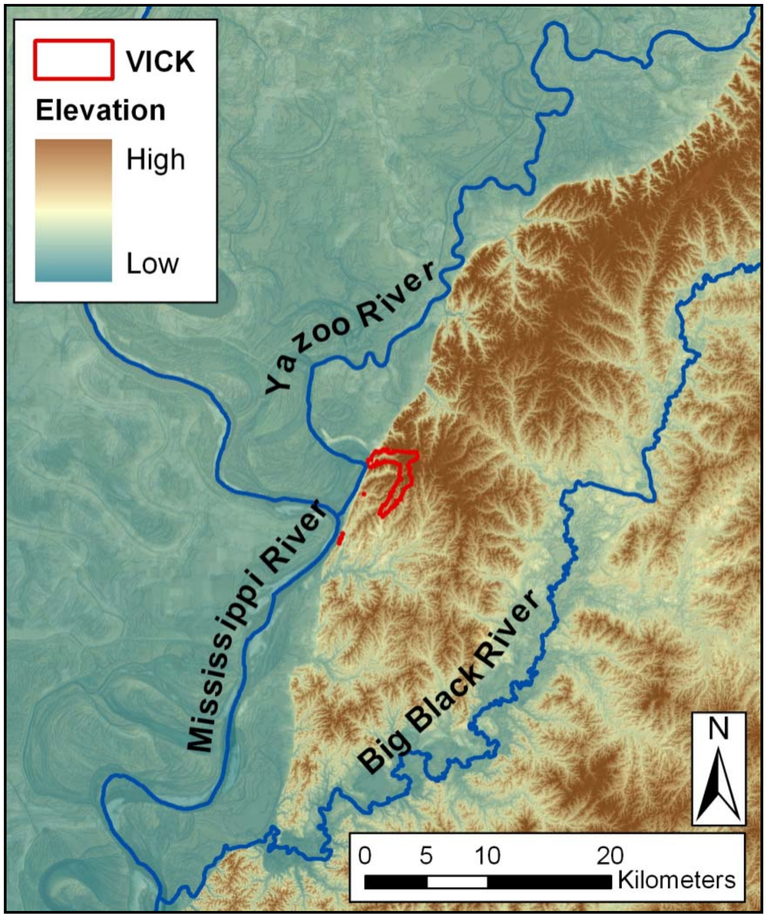


Figure 33. Vicksburg National Military Park is located on upland bluffs near the confluence of the Mississippi and Yazoo Rivers and bordering the Mississippi River alluvial plain.

4.7.2 Resource Knowledge

Although VICK is located in a region of high fish species richness, the park contains relatively limited fish habitat. The two largest park streams are Mint Spring and Glass Bayou (Figure 34). Both are small streams and drain into the Yazoo River. Mint Spring has a drainage area of 3.3 km^2, of which 75% occurs within park boundaries. Glass Bayou has a drainage area of 6.0 km^2, of which 23% occurs in park boundaries. These streams are short and drain from the bluffs to the floor of the alluvial plain. Therefore, they contain relatively high gradient reaches where there are barriers or partial barriers to upstream fish passage. Two waterfalls on Mint Spring within the park result in distinctly different fish assemblages in the sections below (lower), between (middle), and above (upper) the barriers. Barriers to upstream fish passage in Glass Bayou occur downstream of park boundaries.

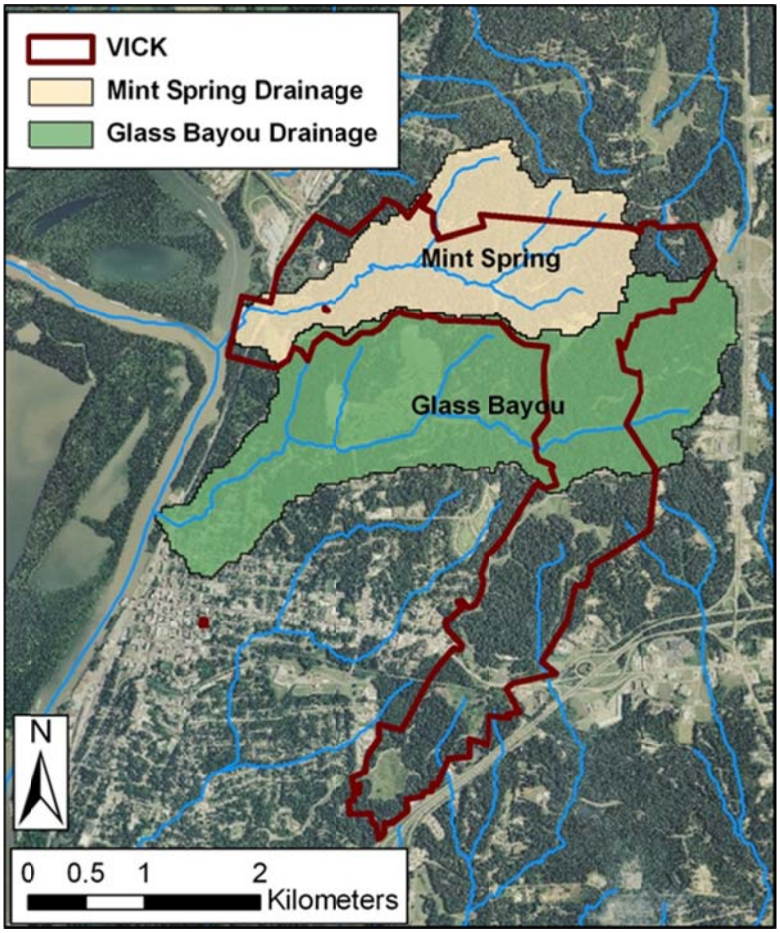


Figure 34. Streams and their drainages in VICK that were sampled for fish during a 1995-2003 stream assessment (Dibble 2003).

From 1995-2003 Dibble (2003) conducted a stream assessment of VICK including fish sampling in Mint Spring and Glass Bayou. Samples were collected on multiple occasions from 1997-2003 using backpacking electrofishing equipment at 18 locations on Mint Spring and at six locations on Glass Bayou (Dibble 2003). These efforts resulted in 2,884 fish of 18 species from six families (Table 16). No state or federal threatened or endangered species were reported from the park. Two non-native species, fathead minnow and common carp (*Cyprinus carpio*) were found in Mint Spring.

Table 16. Species of fish reported from VICK streams during a 1995-2003 stream assessment (Dibble 2003). An "*" indicates non-native species.

Scientific name	Common Name
Aphredoderidae	
Aphredoderus sayanus	Pirate Perch
Centrarchidae	
Lepomis cyanellus	Green Sunfish
Lepomis gulosus	Warmouth
Micropteraus salmoides	Largemouth Bass
Cyprinidae	

Scientific name	Common Name
Campostoma anomalum	Central Stoneroller
*Cyprinus carpio**	Common Carp
Hybognathus nuchalis	Mississippi Silvery Minnow
Notomegonus chrysoleucas	Golden Shiner
Notropis atherinoides	Emerald Shiner
Pimephales notatus	Bluntnose Minnow
*Pimephales promelas**	Fathead Minnow
Semotilus atromaculatus	Creek Chub
Ictaluridae	
Ameiurus melas	Black Bullhead
Ameiurus natalis	Yellow Bullhead
Percidae	
Etheostoma asprigene	Mud Darter
Etheostoma chlorosoma	Bluntnose Darter
Etheostoma fusiforme	Swamp Darter
Poeciliidae	
Gambusia affinis	Mosquito Fish

Fish assemblages observed by Dibble (2003) varied between Mint Spring and Glass Bayou and among sections (i.e. lower, middle, upper) within Mint Spring (Table 17). Over the course of the sampling effort 18 species were reported from Mint Spring, including all species reported from the study (Dibble 2003) (Table 16). Three species were reported from Glass Bayou: bluntnose minnow (*Pimephales notatus*), creek chub (*Semotilus atromaculatus*), and mosquito fish (*Gambusia affinis*). Lower Mint Spring, downstream of all fish barriers, had greater richness than middle or upper Mint Spring or Glass Bayou (Table 17). No site at lower Mint Spring had more than 13 reported species. All locations in Mint Spring were numerically dominated by the non-native fathead minnow and the environmentally tolerant green sunfish (*Lepomis cyanellus*), and these species accounted for all fish found above the upper barrier. Green sunfish were rare in upper Mint Spring, where they were apparently translocated in an attempt to control fathead minnows (Dibble 2003). In Glass Bayou, the creek chub was numerically dominant.

Table 17. Fish sample and assemblage summary for a 1997-2003 VICK fish inventory (Dibble 2003), showing number of sites sampled, species richness, total individuals, mean richness across sites, and the two numerically dominant species for each section of Mint Spring and for Glass Bayou. P. p. = fathead minnow (*Pimephales promelas*); L. c. = green sunfish (*Lepomis cyanellus*); S. a. = creek chub (*Semotilus atromaculatus*); P. n. = bluntnose minnow (*Pimephales notatus*).

	Lower Mint Spring	Middle Mint Spring	Upper Mint Spring	Glass Bayou
# Sample Sites	5	5	8	6
Species Richness	18	5	2	3
Total Individuals	629	430	684	1141
Mean Richness (SD)	10.8 (2.2)	2.6 (0.9)	1.1 (0.4)	2.3 (0.5)
Dominant sp. #1 (proportion)	*P. p.* (37%)	*P. p.* (88%)	*P. p.* (99%)	*S. a.* (68%)
Dominant sp. #2 (proportion)	*L. c.* (23%)	*L. c.* (11%)	*L. c.* (1%)	*P. n.* (31%)

The park prepared an environmental assessment for the eradication fathead minnows above the lower barrier on Mint Spring (NPS 2006). The preferred alternative called for the use of a piscicide to remove all fish above the barrier (NPS 2006). Eventually, native fish would be re-introduced above the barrier. This project was implemented in April of 2008, with an 80% kill rate of fathead minnows. The effort was disrupted to some degree by heavy rain and high water (V. DuBowy personal communication). Future sampling efforts will determine the success of this restoration effort.

4.7.3 Threats and Stressors

Southeastern stream fishes face many anthropogenic threats, with as much as 17% of native taxa considered in need of conservation actions (Warren et al. 1997). General threats to southeastern fishes include deforestation and urbanization, impoundment and channelization of rivers, and competition with invasive species (Warren et al. 2000). The streams of the Yazoo-Mississippi delta and the Yazoo drainage have suffered severe anthropogenic degradations for many generations (Saikku 2005). In the last 150 years, the entire Mississippi alluvial plain has been deforested and largely converted to agriculture; less than 17% of the land currently exists in forests (Bryant 2010). Extensive flood control projects have changed the essential ecology of the region (Bryant 2010). The upland regions of the Yazoo River drainage currently have greater levels of forest cover than the delta region. However, the streams in this drainage suffer from historical deforestation, sedimentation, and channel erosion (Shields et al. 2005).

In addition to the general threats applicable within the Yazoo drainage, VICK fish assemblages in Mint Spring were subject to competition from abundant non-native fathead minnows. Within the upper sections of the creek, fathead minnows dominated heavily and were apparently the only established species above the upper barrier falls. They were also the most relatively abundant species sampled in the lower section. Dense populations of fathead minnows can result in significant reductions in macroinvertebrate abundance and increased turbidity (Zimmer et al. 2001, Herwig et al. 2004), which are expected to negatively impact native species. The project to remove this species was implemented in 2008, although the current assemblage structure in the restoration area was unknown at the time of publishing.

4.7.4 Data

For our analysis we used the data presented by Dibble (2003) summarizing the results of seven years of fish sampling in Mint Spring and Glass Bayou. These data were summarized by total numbers of individual species sampled over time at each sampling site and did not include the results of individual sampling events.

4.7.5 Methods

For our assessment of VICK fish assemblages we relied largely upon qualitative understanding of expected natural fish assemblages for the region. This involved reviewing the findings of other studies in the region as well as discussions of general patterns expected in undisturbed fish assemblages. We acknowledge that the small loess-bluff streams found in VICK are relatively unique habitats, even within this region. We were unable to find comparable studies that conducted inventory-style sampling in small loess-bluff streams feeding directly into the Yazoo River. Therefore, some caution is warranted when comparing among observed assemblages. Nevertheless, our assessment was significantly informed by the observation that VICK fish assemblages were, at the time of the Dibble (2003) inventory, dominated by an invasive species that causes well-documented negative impacts on native fishes in other regions of the country.

We used aspects of an index of biotic integrity (IBI) to explore VICK fish assemblages. 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. The IBI we used was adapted from the original Karr (1981) index by Shields et al. (1995) who tested its correlation with physical habitat degradation in upland Yazoo drainage streams.

Although IBIs are designed to provide information on the quality of fish assemblages and fish habitat, the index we used in this report was only suitable for providing broadly suggestive information about VICK fishes. The fish IBI was developed to use assemblage data; however it was intended for use with data from individual samples. The available data from the park included data summarized for a single sample location across multiple samples. Therefore, the data used was probably unnaturally species rich because greater sampling effort resulted in more rare species than would typically be found in a single sampling event. Shields et al. (1995) found that the modified IBI was only moderately correlated to a physical habitat quality index, and noted that their study region lacked pristine reference sites and that the IBI was therefore a relative measure of quality at best. The IBI used scores of one, three, or five for 12 metrics, providing scores between 12 (poorest quality) and 60 (best possible quality). Because we did not have individual samples or data on fish abnormalities, we used only 10 of the 12 possible metrics of the modified IBI. We multiplied our raw scores by 1.2 and rounded to the nearest whole number to reference our results to the original 12 – 60 scale. For tolerant designation we used those provided by Shields et al. (1995) except in the case of the fathead minnow which we designated tolerant based on other research (Killgore et al. 2008).

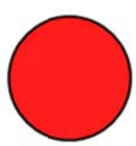
4.7.6 Condition and Trend
We applied the modified IBI to the combined samples for each of the five sites in lower Mint Spring. Other sites within Mint Spring, and sites in Glass Bayou, did not contain enough species for application of the IBI. Scores ranged from 26 to 29 (Table 18) and the mean score across the five sites was 28 (SD ± 1.6). These scores would correspond to a quality ranking of “poor” if the modified IBI was validly referenced to a range of sites including pristine sites. Shields et al. (1995) found that IBI scores ranged from 24 to 50 in the upper Yazoo drainage basin, and classified sites less than and greater than the midpoint (37) as “relatively poor” and “relatively good” respectively. Their mean IBI scores for sites in the relatively poor category were 31 for 1992 and 33 for 1993 (Shields et al. 1995). Therefore, the scores observed in VICK were lower than the averages observed in the streams of the upper Yazoo drainage. Shields et al. (1995) found that relatively poor sites averaged 33% and 42% tolerant individuals for the two study years, and that averages ranged as high as 80% for some sites. Because of the predominance of tolerant fathead minnows, VICK sites ranged from 31% to 69% (Table 18). Darters were uncommon in Yazoo drainage streams, which averaged one or two species in all sites of all qualities (Shields et al. 1995). Two darter species were reported from VICK and they occurred in very low numbers (four individuals out of 2,884 collected).

Table 18. Selected metrics and IBI scores for combined data at five sites on lower Mint Spring.

	Site				
	1	**2**	**3**	**4**	**5**
Species Richness	12	9	13	12	8
# Darter Spp.	0	2	1	1	0
# Sunfish Spp.	2	2	1	2	2
# Intolerant Spp.	1	0	1	0	0
Percent Tolerant Ind.	31	51	69	69	69
IBI Score	29	29	26	26	29

We ranked the condition of VICK fish assemblages as poor (Table 19). This ranking was based primarily upon the fact that the park's fish assemblages were dominated by invasive species and tolerant species. IBI scores were low, even for expectations within the region, although several caveats must be considered when interpreting these scores. The data used to make the assessment were marginal (Table 19). The data did not receive a check for sufficiency in the thematic category because, although it was collected over a multi-year period, the summarized data were not sufficiently detailed to determine the results of individual sample events. For this same reason, the data did not receive a check for coverage in the temporal category. The available data were summarized by site, but we were unable to determine the seasonality or year of any individual sample. And because the data were collected before 2003, they did not receive a check for currency. No trend was assigned to fish assemblage condition. There may be improvement in the negative conditions responsible for the poor ranking. An effort to restore native assemblages in Mint Spring has been at least partially implemented. Further inventory efforts will determine the success of these efforts.

Table 19. The condition of VICK fish assemblages was poor. The data used to make the assessment were marginal. No trend was assigned to VICK fish assemblage condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Fish Assemblages		Relevancy ✓	Proximity ✓	Currency
		Sufficiency	Coverage ✓	Coverage
		3 of 6: Marginal		

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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 (NABCI 2009). VICK is located on loess bluffs bordering the Mississippi alluvial valley. Both the river alluvial plain and the coastal plain of the Mississippi support a number of breeding birds of conservation concern (ABC 2001, Watson 2005). The Mississippi River valley is a major migration route, making VICK an important stopover location for migrating birds. The park has been designated an Important Bird Area by the National Audubon Society (NPS 2012). Most of the original hardwood forests in the alluvial valley have been converted to non-forest habitat (Twedt and Loesch 1999, Saikku 2005), thus VICK provides valuable protected areas of forest in the region that could serve as important habitat for forest-dwelling wildlife. The loess bluffs and the upland regions bordering the alluvial plain are relatively more forested than the river valley, and may be important stopover habitat for migrating birds (Twedt and Hunt 2001). In addition to the importance of intact forest for forest interior species, VICK is actively managing for a diversity of habitats within the park, to encourage persistence of open grassland and edge species as well (V. DuBowy personal communication).

4.8.2 Resource Knowledge

Breeding, migratory, and wintering bird assemblages have been researched at VICK. At least 180 bird species have been reported from the park (NPS 2012). In the spring of 2001, Twedt and Hunt (2001) used area searches and mist netting to study migrating birds in VICK. They reported 68 species from their efforts, including 41 migratory species (Twedt and Hunt 2001). From March to June of 2003 and 2004 Somershoe et al. (2003, 2006) studied migratory and breeding bird species in VICK using Breeding Bird Survey (BBS) point count protocols and distance sampling techniques (USGS 2001). They reported 106 species and estimated density of some species during the migration and breeding seasons (Somershoe et al. 2006). Somershoe et al. (2006) estimated that 14 migrant species accounted for >7,000 individuals within VICK during the migration period, and that the 18 most common breeding species accounted for >8,150 individuals in the park. Dan Twedt conducted surveys of VICK birds from 2008-2010 (unpublished data). These efforts consisted of 695 individual spring and breeding seasons point counts at 101 locations and 558 winter time and area constrained surveys at 150 locations. These efforts reported 23,894 individuals of 120 species—104 species observed in breeding season counts, and 68 species observed in winter counts. NPSpecies, the NPS biodiversity database, lists 65 species of birds as “present” in the park, and 186 as “probably present”. These sources are not an exhaustive summary of all bird work conducted in the park, but represent relatively recent activities using standardized sampling methods for which data were available.

The 10 most common birds reported by Twedt (unpublished data) during the breeding seasons and winters of 2008-2010 included year-round resident species, neotropical migrant breeding species, and non-breeding wintering species (Table 20, Table 21). Six resident species were among the 10 most common birds during both summer and winter. During the breeding season, the five most detected species were residents (Table 20). During winter, the three most detected species were migrants or included a migratory component (Table 21).

Table 20. The ten bird species with the greatest number of detections reported from 695 point counts conducted at 101 locations during late spring and summer in Vicksburg National Military Park, 2008-2010. Shown are ranks (1 = highest) by total observed “abundance” (based only on number of birds detected), by number of counts where species occurred, and by number of sites where species occurred. For example, the Northern Cardinal had the greatest number of detections for all species observed during point counts, occurring in the most number of counts and the greatest number of sites. Also shown is occupancy type with YR = year-round resident and BR-M = neotropical breeding season migrant.

Scientific Name	Common Name	Abundance Rank	Count Rank	Site Rank	Type
Cardinalis cardinalis	Northern Cardinal	1	1	1	YR
Melanerpes carolinus	Red-bellied Woodpecker	2	2	2	YR
Molothrus ater	Brown-headed Cowbird	3	7	10	YR
Parus carolinensis	Carolina Chickadee	4	5	6	YR
Thryothorus ludovicianus	Carolina Wren	5	3	5	YR
Vireo griseus	White-eyed Vireo	6	4	3	BR-M
Polioptila caerulea	Blue-gray Gnatcatcher	7	6	4	BR-M
Parus bicolor	Tufted Titmouse	8	8	7	YR
Cyanocitta cristata	Blue Jay	9	10	8	YR
Empidonax virescens	Acadian Flycatcher	10	9	15	BR-M

Table 21. The ten bird species with the greatest number of detections reported from 558 area surveys conducted at 150 locations during winter in Vicksburg National Military Park, 2008-2010. Shown are ranks (1 = highest) by total observed “abundance” (based only on number of birds detected), by number of counts where species occurred, and by number of sites where species occurred. Also shown is occupancy type with YR = year-round resident, YR-M = combined resident and migratory population, and WI-M = nearctic wintering migrant.

Scientific Name	Common Name	Abundance Rank	Count Rank	Site Rank	Type
Turdus migratorius	American Robin	1	10	5	YR-M
Setophaga coronata	Yellow-rumped Warbler	2	4	8	WI-M
Zonotrichia albicollis	White-throated Sparrow	3	7	6	WI-M
Parus carolinensis	Carolina Chickadee	4	3	7	YR
Melanerpes carolinus	Red-bellied Woodpecker	5	1	1	YR
Cardinalis cardinalis	Northern Cardinal	6	6	2	YR
Thryothorus ludovicianus	Carolina Wren	7	2	3	YR
Bombycilla cedrorum	Cedar Waxwing	8	21	19	WI-M
Cyanocitta cristata	Blue Jay	9	5	4	YR
Parus bicolor	Tufted Titmouse	10	8	9	YR

Although no state or federally endangered species were reported, the recent breeding season and winter bird surveys at VICK (Twedt unpublished data) reported a number of species of conservation concern by Partners in Flight (PIF) criteria (Table 22, Table 23). Partners in Flight, a bird conservation organization including federal, state, academic, and NGO partners, assigns a variety of conservation scores to North American birds (Panjabi et al. 2005). These scores are designed to summarize the level of threat to birds within specific Bird Conservation Regions (BCRs) (Panjabi et al. 2005). PIF scores have been further used by Nuttle et al. (2003) to rank birds on scale of 0 to 4, with 4 representing the most threatened birds in a region. Because VICK is located on the border of the Mississippi Alluvial Plain BCR and East Gulf Coastal Plain BCR, we used scores from both regions to determine concern species. During the summer point counts by Twedt (unpublished data) 2008-2010, 23 species of concern were reported (Table 22). These species accounted for 19% of the observed breeding season assemblage. During the winter surveys, eight species of conservation concern were reported (Table 23), and they represented 3% of the observed assemblage.

Table 22. Breeding season bird species of conservation concern reported from 695 point counts conducted at 101 locations during late spring and summer in Vicksburg National Military Park, 2008-2010. Conservation concern species were those defined by Partners in Flight as of continental concern (CC) or regional concern (RC) in the Mississippi Alluvial Plain (MAP) Bird Conservation Region or the East Gulf Coastal Plain (EGCP) Bird Conservation Region. Also shown are birds receiving a conservation rank of 4 (PIF4), which indicates especially high conservation importance as determined by a ranking system based on regional PIF scores (Nuttle et al. 2003).

			MAP			**EGCP**		
Scientific Name	**Common Name**	**Tot**	**CC**	**RC**	**PIF4**	**CC**	**RC**	**PIF4**
Vireo griseus	White-eyed Vireo	526		X				
Hylocichla mustelina	Wood Thrush	282	X	X	X	X	X	
Coccyzus americanus	Yellow-billed Cuckoo	243		X			X	
Contopus virens	Eastern Wood-pewee	204		X			X	
Icterus spurius	Orchard Oriole	201		X				
Icteria virens	Yellow-breasted Chat	166		X				
Chaetura pelagica	Chimney Swift	156					X	
Pipilo erythrophthalmus	Eastern Towhee	135					X	
Limnothlypis swainsonii	Swainson's Warbler	120	X	X	X	X	X	X
Geothlypis formosa	Kentucky Warbler	105	X			X		
Setophaga americana	Northern Parula	98		X				
Helmitheros vermivorum	Worm-eating Warbler	88				X		
Toxostoma rufum	Brown Thrasher	27		X			X	
Tyrannus tyrannus	Eastern Kingbird	25		X			X	
Ictinia mississippiensis	Mississippi Kite	25		X	X			
Lanius ludovicianus	Loggerhead Shrike	18		X			X	X
Protonotaria citrea	Prothonotary Warbler	17	X	X	X	X		
Setophaga virens	Black-throated Green Warbler	14					X	X
Icterus galbula	Baltimore Oriole	13		X				
Buteo platypterus	Broad-winged Hawk	6					X	
Colaptes auratus	Northern Flicker	5		X			X	
Passerina ciris	Painted Bunting	5	X	X	X	X	X	X
Vermivora cyanoptera	Blue-winged Warbler	1				X		

Table 23. Winter bird species of conservation concern reported from 558 area surveys conducted at 150 locations during winter in Vicksburg National Military Park, 2008-2010. Conservation concern species were those defined by Partners in Flight as of continental concern (CC) or regional concern (RC) in the Mississippi Alluvial Plain (MAP) Bird Conservation Region or the East Gulf Coastal Plain (EGCP) Bird Conservation Region. Also shown are birds receiving a conservation rank of 4 (PIF4), which indicates especially high conservation importance as determined by a ranking system based on regional PIF scores (Nuttle et al. 2003).

			MAP			EGCP		
Scientific Name	**Common Name**	**Tot**	**CC**	**RC**	**PIF4**	**CC**	**RC**	**PIF4**
Colaptes auratus	Northern Flicker	205		X			X	
Pipilo erythrophthalmus	Eastern Towhee	64					X	
Spizella pusilla	Field Sparrow	40					X	
Toxostoma rufum	Brown Thrasher	30		X			X	
Lanius ludovicianus	Loggerhead Shrike	8		X			X	X
Icterus galbula	Baltimore Oriole	1		X				
Setophaga cerulea	Cerulean Warbler	1	X	X	X	X	X	X
Chaetura pelagica	Chimney Swift	1					X	

Several exotic, range expanding, or obligate nest parasitizing bird species were reported from VICK in recent surveys (Table 24). These species accounted for approximately 9% of the observed breeding season assemblage and for <1% of the observed winter assemblage. The Brown-headed Cowbird was detected most often and only occurred during the breeding season.

Table 24. Exotic, range expanding, and nest parasitizing bird species reported from VICK during recent surveys, 2008-2010, and the numbers observed during the breeding season (BRS) and during winter (WIN).

Scientific Name	**Common Name**	**BRS Tot**	**WIN Tot**
Carpodacus mexicanus	House Finch	34	24
Columba livia	Rock Pigeon	126	3
Molothrus ater	Brown-headed Cowbird	758	0
Passer domesticus	House Sparrow	67	42
Streptopelia decaocto	Eurasian Collared Dove	24	0
Sturnus vulgaris	European Starling	99	1

A battlefield restoration project was recently completed in the park. The primary goal of the project was to restore key historical battlefield sites to a condition more representative of the conditions found at the time of the Civil War (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). The work was completed following an assessment of the environmental impacts of several alternatives (MACTEC 2009). Around 90 acres were cleared, and will be managed as open, savannah-like grasslands (V. DuBowy personal communication). The cleared areas were second-growth woodlands and included several species of exotic trees. This project will result in a greater amount of grassland and edge habitat in the park.

Although VICK is significantly forested, the park is also characterized by many open fields surrounded by edge and transitional habitats. Many species of birds prefer this edge and grassland habitat. The Eastern Kingbird (*Tyrannus tyrannus*), Eastern Towhee (*Pipilo erythrophthalmus*), Loggerhead Shrike (*Lanius ludovicianus*), and Baltimore Oriole (*Icterus* *galbula*) are examples of conservation concern species reported in VICK that nest edge habitats and forage in edge habitats or open grasslands (Greenlaw 1996, Murphy 1996, Yosef 1996, Rising and Flood 1998). In particular, Eastern Kingbirds and Loggerhead Shrikes forage over open grasslands (Murphy 1996, Yosef 1996). The recent battlefield restoration project should produce more favorable habitat for these and other edge and grassland species.

4.8.3 Threats and Stressors

North American forest birds face a number of general threats including land conversion, development, exotic species, forest pests, and poor land management (NABCI 2009). VICK is relatively small, and is located within an urban environment characterized by development and highly fragmented forested habitat. Birds nesting in fragmented habitat are subjected to high level 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). Brown-headed Cowbirds were relatively widespread in distribution during the breeding season (Table 20), suggesting that Cowbird brood parasitism may be a threat faced by birds nesting in VICK. Feral or free roaming domestic pets occur in VICK. 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 VICK birds as well (Schmidt and Whelan 1999, Watson 2005).

4.8.4 Data

For the analyses in this report, we used the data from Twedt's 2008-2010 standardized surveys of the park and these data are referred to in the report at the "analysis dataset". The analysis dataset included samples taken during late spring, early summer, and winter. Data included records of 23,894 individual birds of 120 species. Breeding season observations were collected as early as April and as late as July and therefore included some spring migration data. Winter observations were collected from November to February.

4.8.5 Methods

We used an index of biotic integrity to assist us in evaluating VICK 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. (2003) developed a breeding Bird Community Index (BCI) for the region of the eastern U.S. including the Atlantic piedmont and coastal plain. The BCI 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. 2003). O'Connell et al. (2003) developed the coastal plain BCI primarily using data from Virginia and North Carolina; however, they proposed an area of application including the coastal plain of Mississippi. With the exception of the Painted Bunting, all the expected local breeding birds reported from VICK point counts were included in the BCI bird attribute list, indicating that they were found in the point counts used to develop the index. We added the Painted Bunting to the analysis database using attributes determined from the literature (Lowther et al. 1999). Therefore, although some caution is necessary when interpreting BCI results for VICK birds, we believe the tool is suitably robust to use meaningfully with this assemblage. Scores for the BCI range from 0.250 (humanistic) to 1.00 (Naturalistic) (Table 25).

Table 25. Reference range for interpreting scores from a Bird Condition Index (O'Connell et al. 2003).

Score Range	Interpretation
0.731 - 1.000	Naturalistic
0.601 - 0.730	Largely Intact
0.461 - 0.600	Moderately Disturbed
0.250 - 0.460	Humanistic

We explored the relative number of detections and the park-wide distribution of Brown-headed Cowbirds. For this purpose we analyzed breeding season point count data. Brown-headed Cowbirds have greatly expanded their range in the U.S. in response to forest loss and fragmentation (Lowther 1993). They are obligate brood parasites on many species of native birds and can have negative impacts on species of conservation concern (Fauth 2000, Hoover 2003, Benson et al. 2010). We summarized cowbirds relative rate of detections by point count location. Although cowbirds were commonly observed in VICK, the impact of the species on native birds has not been studied in the park. Therefore, while the density of cowbirds may be cause for concern and further study, we present these data primarily for context and discussion purposes.

We calculated and summarized the rate of detections of selected species of conservation concern using the approach described above. For concern species we selected forest species that are potential victims of cowbird parasitism and that also had PIF-based scores of "4" (Nuttle et al. 2003). The species of conservation concern we analyzed were Black-throated Green Warbler (*Setophaga virens*), Painted Bunting, Prothonotary Warbler (*Protonotaria citrea*), Swainson's Warbler, and Wood Thrush. These species varied from rare (five Painted Buntings) to relatively common (282 Wood Thrushes) in the breeding season data. We combined these species by location for analysis.

4.8.6 Condition and Trend

The mean BCI score across 695 breeding season point counts was 0.633 (SD ± 0.130), corresponding to an interpretation of largely intact. We took the mean of the BCI scores for each location (Figure 35). Of the 101 locations where point counts occurred, one site had only one count and another had 10 counts. All other locations had 6, 7, or 9 counts. Seven locations had mean scores indicating humanistic habitat, 21 had scores indicating moderately disturbed habitat, 55 had scores of largely intact, and 18 sites had naturalistic scores (Figure 35). Most humanistic and moderately disturbed scores occurred near roadways or in open fields, and most of the naturalistic scores occurred in forested habitat relatively far from forest edges. These scores indicate that VICK contains forested habitat that is occupied during the breeding season by forest habitat specialists.

The BCI tool assumes that intact habitat consists of forest. However, some species of conservation concern prefer edge, grassland, or other early successional habitat. Therefore, a caveat of the BCI approach is that it does not accurately assess the quality of grassland bird communities and habitat. Because this habitat is common in the park, and is being actively managed, the BCI results should be viewed as a valuable, though limited, assessment of park bird condition.

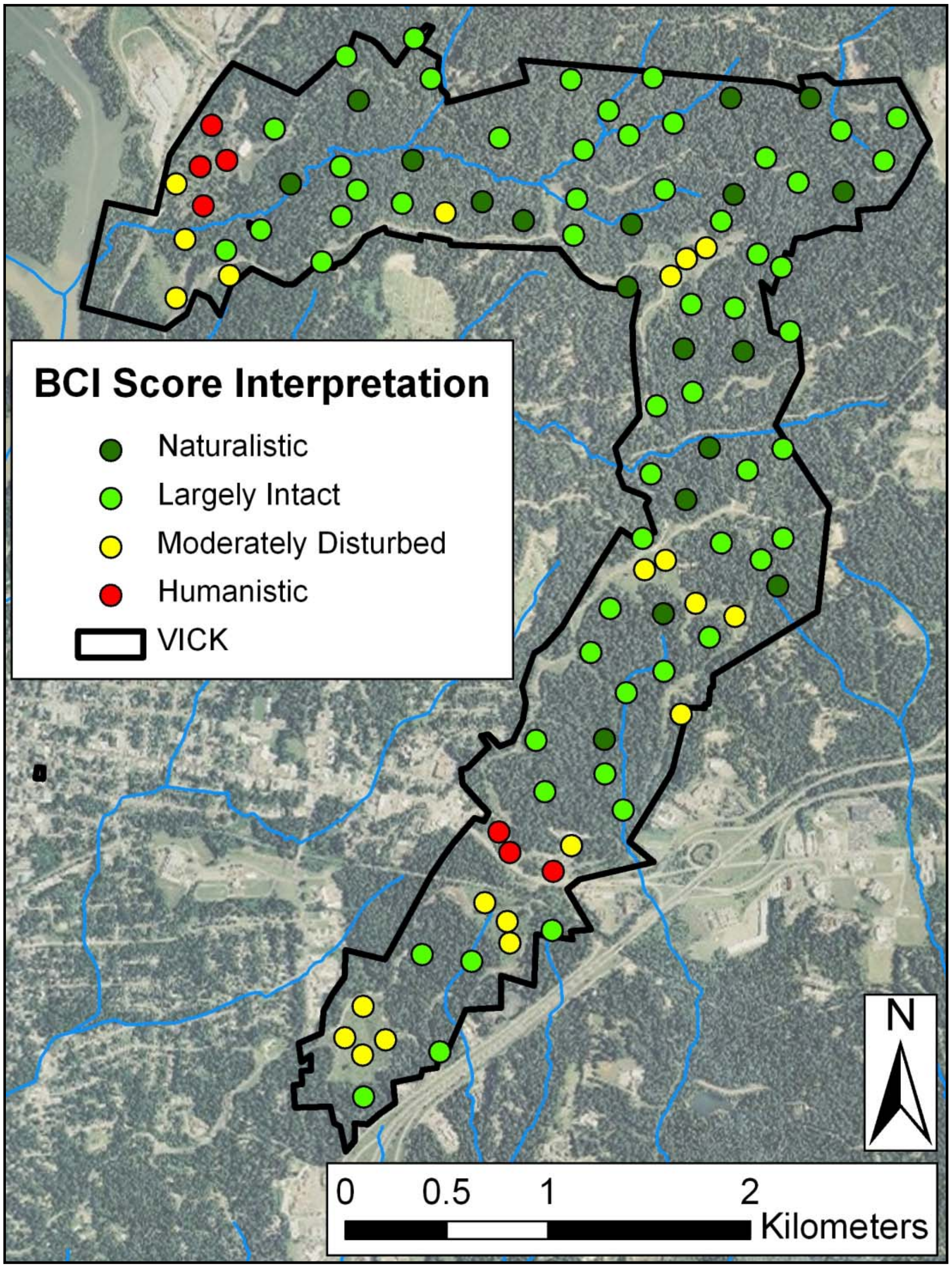

Figure 35. Mean BCI score and interpretation, by location, for breeding season point counts collected in VICK, 2008-2010.

Brown-headed Cowbirds and species of conservation concern were widely distributed throughout the park (Figure 36
Figure 36). Cowbirds were common with 758 individuals reported from 335 (48%) of conducted point counts, and from 94 (93%) of point count locations. They were distributed throughout the

park, but the highest number of detections were observed near roadways and around open field habitat (

Figure 36). Forest species of high conservation concern were widely distributed in the park and were more abundant in interior forest areas (Figure 36).

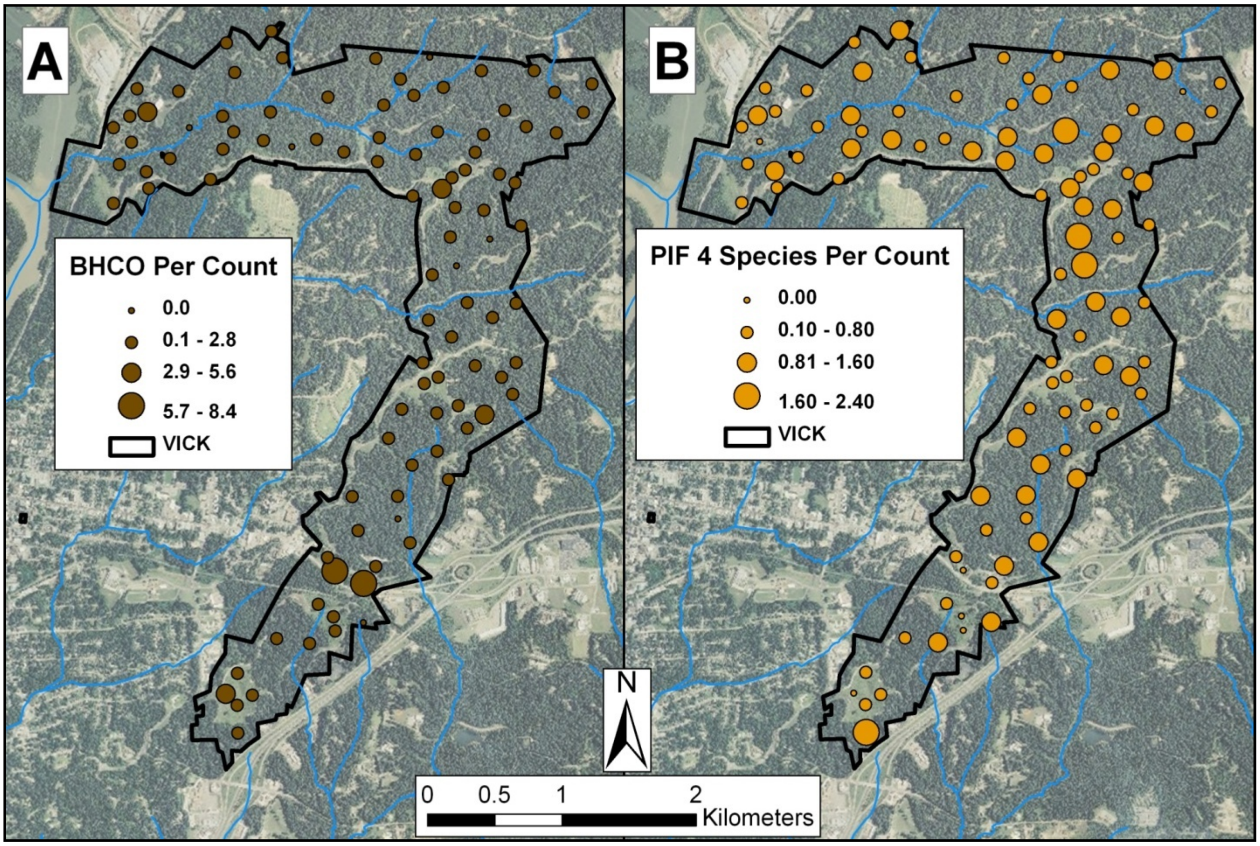

Figure 36. Number of individuals per point count reported in breeding season counts conducted in VICK. Shown are: (**A**) results for Brown-headed Cowbirds (BHCO) and (**B**) for an assemblage of high conservation value forest species including Black-throated Green Warbler (*Setophaga virens*), Painted Bunting (*Passerina ciris*), Prothonotary Warbler (*Protonotaria citrea*), Swainson's Warbler (*Limnothlypis swainsonii*), and Wood Thrush (*Hylocichla mustelina*) (PIF 4 Species).

We ranked the VICK bird assemblage as good (Table 26). The park has a good diversity of species and supports species of conservation concern. A Bird Community Index indicated that much of the park contained largely intact or naturalistic habitat suitable for breeding interior forest specialists. It is evident that VICK provides habitat for a number of valuable and sensitive species and is probably an important refuge for birds, given the urban landscape surrounding the park. The high relative number of detections and park-wide distribution of the Brown-headed Cowbird suggests that most park habitats are potentially subject nest parasitism. In other fragmented systems where cowbirds are present, observed parasitism has been high (Robinson et al. 1995). For this reason we assign a good ranking, but caution that further studies of nest success in VICK are warranted. Estimates of concern species breeding success would be very useful in determining the bird assemblage condition. The importance of park habitat for wintering birds and for migrating birds is apparent, and this value is not negatively impacted by cowbirds. We did not assign a trend to bird assemblage condition. Although several years of data are available, most of the data were collected in 2009 and the analysis dataset was insufficient to determine a trend. The data used to make the assessment were good. Data were collected recently using standardized techniques and provided excellent spatial coverage of the park. We did not assign a check to the thematic relevancy category because the most recent data lacked a narrative descriptive report at the publishing time of this report.

Table 26. The quality of VICK bird assemblages was good. The quality of the data used to make the assessment was good. No trend was assigned to bird assemblage condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Bird Assemblages		Relevancy	Proximity ✓	Currency ✓
		Sufficiency ✓	Coverage ✓	Coverage ✓
		5 of 6: Good		

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4.9 Mammal Assemblages

4.9.1 Context and Relevance

Mammals are important components of all 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, mammal assemblages must be sampled using a variety of methods during all seasons.

4.9.2 Resource Knowledge

A comprehensive inventory of bats and terrestrial mammals was conducted at VICK during 2005, and employed a variety of sampling methods (Linehan 2007, Linehan et al. 2008). Sampling methods included several types of live box traps, pitfalls, remote cameras, snap traps, leghold traps, spotlight surveys, mistnets, and electronic Anabat II detectors (Linehan et al. 2008). Twenty-three small mammal trapping transects were located across four park habitats: riparian, grassland, upland, and edge (Figure 37). Trap type and effort varied among transects and included fenced and unfenced pitfall traps, Sherman live traps, mouse and rat-sized Victor snap traps, and small Tomahawk live traps. Total effort of the combined trap types across all transects was 9,799 trap nights. Linehan (2007) used polymerase chain reaction to distinguish between *Peromyscus* species. Spring-coil leghold traps were deployed in 14 locations for a total of 18 trap nights (Figure 37). Large Tomahawk traps were deployed in 40 locations for a total of 178 trap nights (Figure 37). Remote cameras were deployed at 75 locations for a total of 674 camera nights (Figure 37). Mist nets were used at 17 locations for a total of 119 12-meter net hours (Figure 37). Anabat II electronic bat detectors were used during mist netting and were also deployed in other likely bat habitats. Seven individual evening bats were instrumented with radio transmitters and tracked for up to 10 days. Opportunistic observations of mammals were also recorded. Cumulative species accumulation curves were used to determine that samples of small mammals, large mammals, and bats included most species present in the park (Linehan 2007).

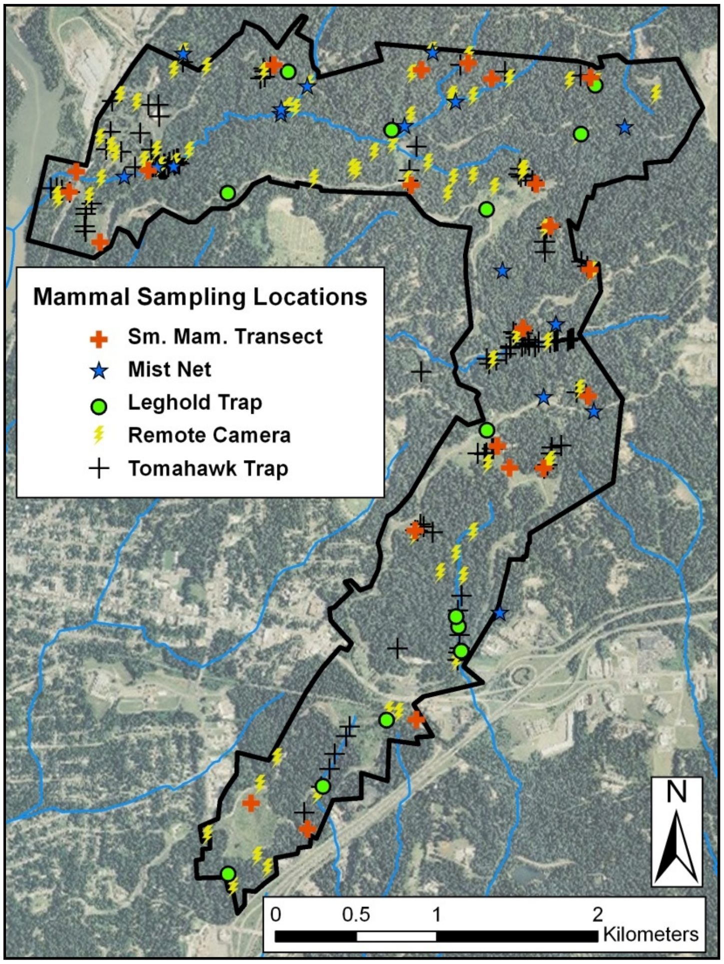

Figure 37. Locations of different types of sampling efforts during a 2005 mammal inventory in Vicksburg National Military Park (Linehan 2007). Small mammal transect symbols show starting locations of line transects.

All inventory efforts reported 737 individual terrestrial mammals of 30 species from 15 families (Linehan 2007, Linehan et al. 2008). Of all terrestrial mammals captured using all trapping methods, including remote cameras, the raccoon (*Procyon lotor*) was the most commonly captured mammal (Table 27). The 10 most relatively abundant captured terrestrial mammals comprised 87% of the total sample of captured animals. The cotton mouse (*Peromyscus gossypinus*) and the white-footed mouse (*Peromyscus leucopus*) were combined because only a subsample of this genus was identified to species level. Capture success for both large and small mammals was greatest in riparian habitats and lowest in open grassland (Linehan 2007). Of the terrestrial mammals observed from opportunistic encounters, the white-tailed deer (*Odocoileus virginianus*) was the most commonly reported (Table 28). The 10 most relatively abundant opportunistically observed mammals comprised 88% of the total opportunistic sample.

Table 27. The 10 most relatively abundant terrestrial mammal species sampled using a variety of capture methods, including remote cameras, at VICK during a 2005 mammal inventory. *Peromyscus* species include the cotton mouse (*Peromyscus gossypinus*) and the white-footed mouse (*Peromyscus leucopus*). An "*" denotes non-native species.

Scientific Name	Common Name	# Captured
Procyon lotor	Raccoon	82
Didelphis virginiana	Virginia Opossum	81
Peromyscus spp.	Cotton/White-footed Mouse	63
Odocoileus virginianus	White-tailed Deer	52
*Canis familiaris**	Domestic Dog	50
Sigmodon hispidus	Hispid Cotton Rat	27
Urocyon cinereoargenteus	Gray Fox	20
Vulpes vulpes	Red Fox	12
Sciurus niger	Eastern Fox Squirrel	11
*Mus musculus**	House Mouse	10

Table 28. The 10 most relatively abundant terrestrial mammal species reported from opportunistic observations in VICK during a 2005 mammal inventory. An "*" denotes non-native species.

Scientific Name	Common Name	# Observed
Odocoileus virginianus	White-tailed Deer	110
*Felis catus**	Domestic Cat	31
Sciurus niger	Eastern Fox Squirrel	29
Tamias striatus	Eastern Chipmunk	22
*Canis familiaris**	Domestic Dog	13
Didelphis virginiana	Virginia Opossum	11
*Dasypus novemcinctus**	Nine-banded Armadillo	10
Procyon lotor	Raccoon	9
Vulpes vulpes	Red Fox	8
Scalopus aquaticus	Eastern Mole	7

Mist-netting, Anabat II electronic detection, and opportunistic observations reported 272 individual bats of seven species from two families (Table 29). Two unidentified species of the genus *Lasiurus* were also reported. The evening bat was most frequently captured in mist nets, and the big brown bat was most frequently observed opportunistically. The high number of observations of big brown bats resulted because this species roosts beneath the Clay Street bridge and within the Illinois Memorial and large numbers were observed emerging from these locations (Linehan 2007). Riparian areas had the highest capture success for all species except the big brown bat, which was more frequently captured over road corridors (Linehan 2007). For most of the captured individuals, sex, reproductive condition, and weight were noted (Table 30). Active reproduction was observed in five of the six captured species, indicating that these species are using maternal roosts inside the park or relatively close to park boundaries (Table 30).

Table 29. Bat species observed in VICK during a 2005 mammal inventory (Linehan 2007), showing the number captured by mist net or observed opportunistically or with Anabat II electronic detection.

Scientific Name	Common Name	# Captured	# Obs/Anabat
Nycticeius humeralis	Evening Bat	40	
Eptesicus fuscus	Big Brown Bat	27	176

Scientific Name	Common Name	# Captured	# Obs/Anabat
Lasiurus borealis	Eastern Red Bat	18	
Pipistrellus subflavus	Eastern Pipistrelle	6	
Lasiurus cinereus	Hoary Bat	1	
Lasiurus seminolus	Seminole Bat	1	
Tadarida brasiliensis	Brazilian Free-tailed Bat		3

Table 30. Sex, reproductive condition, and weight data for bats captured in a 2005 VICK mammal inventory (Linehan 2007). Sample size (N) refers to the number of individuals for which sex data were available. Also shown are the female-to-male sex ratio, the percent of females in active reproduction, and mean weight of females and males. Active reproduction was indicated by females being pregnant, lactating, or showing signs of recent lactation. Numbers in parentheses are standard deviations.

Scientific Name	Common Name	N	Sex Ratio (F/M)	% Reproductive	Mean F. wt. (g)	Mean M. wt. (g)
Nycticeius humeralis	Evening Bat	40	1.5	38	12.8 (1.5)	10.2 (1.8)
Eptesicus fuscus	Big Brown Bat	26	1.17	79	22.3 (1.2)	16.3 (1.7)
Lasiurus borealis	Eastern Red Bat	15	0.5	80	14 (2.6)	11.6 (1.2)
Pipistrellus subflavus	Eastern Pipistrelle	6	2	50	8.2 (1.8)	7.8 (1.1)
Lasiurus cinereus	Hoary Bat	1	Female	Yes	not taken	NA
Lasiurus seminolus	Seminole Bat	1	Female	No	not taken	NA

Six non-native mammal species were reported from the 2005 VICK mammal inventory (Table 31). Domestic dogs and cats (feral or free-ranging) were the most commonly reported non-native species, though cats were rarely captured by trapping methods (including remote cameras).

Table 31. Non-native species reported from VICK during a 2005 mammal inventory (Linehan 2007) showing the number of individuals captured and opportunistically observed.

Scientific Name	Common Name	# Captured	# Observed
Canis familiaris	Domestic Dog	50	13
Mus musculus	House Mouse	10	1
Dasypus novemcinctus	Nine-banded Armadillo	4	10
Felis catus	Domestic Cat	1	31
Canis latrans	Coyote	0	5
Myocastor coypus	Nutria	0	1

Linehan (2007) searched the literature and county museum records to prepare a list of 14 mammal species not reported from the inventory that could potentially occur in VICK. Nine of the unreported species were considered relatively likely to occur in the park, based on published county occurrences and habitat preferences (Linehan 2007). Two of the likely species were non-native species. The missing native species are further discussed in the mammal Condition and Trend section of this report.

Feral hogs have been found in the park in recent years, and park management actively controls for this non-native species. Hogs were not found by Linehan (2007), and were not included on her list of likely expected species. They were first observed in VICK in 2008 (NPS 2009). The initial invasion of hogs in the park resulted from domestic animals that escaped from an adjacent property (NPS 2009). More recent occurrences were the result of massive spring flooding on the Mississippi River in 2011, displacing individuals from the lower regions of the river to higher areas (V. DuBowy personal communication). Feral hogs cause damage to vegetation, wildlife habitat, and cultural resources in VICK, and are potential vectors of diseases to humans and wildlife (NPS 2009). They will compete with native mammals for hard mast and other resources (NPS 2009). Park management calls for the lethal removal and attempted eradication of this species in the park. Since the discovery of the feral population, over 20 animals have been trapped and disposed of, but hogs remain an ongoing problem, necessitating continuous monitoring by park staff (V. DuBowy personal communication).

A study of white-tailed deer was conducted to provide a baseline of deer density in the park and to establish a monitoring protocol (Kissel and Bomar 2009). Distance sampling was conducted during all four seasons using night time spotlight surveys (Kissel and Bomar 2009). Kissel and Bomar (2009) estimated that deer densities were greatest in the winter, and that densities observed in VICK were within the range found at other sites in Arkansas and on the Gulf Coastal Plains of Tennessee and Mississippi. They speculated that the high winter density may result because deer take refuge in the park during the hunting season. Kissel and Bomar (2009) found that the VICK estimated density was within the range of estimated carrying capacity for the habitat for all seasons except winter, and that densities were near the upper limit of capacity during the other seasons. They reported a lack of browse lines in the park, further supporting the theory that deer are not overabundant during the spring, summer, and fall within the park (Kissel and Bomar 2009). They interpreted these findings to indicate that the park was not overpopulated with deer, but that the park was likely near its maximum recommended herd size. They further noted that the battlefield restoration project was expected to increase deer carrying capacity in the park and that deer population would likely increase as a result (Kissel and Bomar 2009).

Big brown bats roosted inside the Illinois Memorial and park staff determined that this created a human health risk and detracted from the visitor experience (unpublished park document). Recognizing the high ecological value of bats, park personnel created a plan to exclude bats from the monument and provide alternative roosting sites in the immediate vicinity. This plan called for the placement of Bat Conservation International-approved bat houses on 15-20 foot high poles near the monument (unpublished park document), which was accomplished in 2012. Bats would be excluded from the monument by placing netting and translucent materials over access points, preventing bat reentry.

A battlefield restoration project was recently completed in the park. The primary goal of the project was to restore key historical battlefield sites to a condition more representative of the conditions found at the time of the Civil War (Wiss, Janney, Elstner Associates, Inc. and John Milner Associates, Inc. 2009). Around 90 acres were cleared, and will be managed as open, savannah-like grasslands (V. DuBowy personal communication). This change is likely to result in increased foraging habitat for white-tailed deer (Kissel and Bomar 2009), and may increase the habitat for some small mammals expected for the region but not reported from the park.

4.9.3 Threats and Stressors

General threats and stressors to native mammals 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 VICK is a relatively small battlefield park located adjacent to an urban area, habitat fragmentation and urbanization are among the most significant general threats to park mammals. Habitat within and around the park has been altered during the last 150 years by deforestation and conversion to agriculture and urban development. Disease transmission and exposure to pollution may be greater for mammals near urban centers than for animals in more rural settings (Ditchkoff et al. 2006).

Negative impacts from non-native mammals may represent an important class of threat in the park. Urban development and habitat fragmentation can exacerbate the problems associated with non-native species. Feral or free-ranging domestic cats and dogs, were commonly sampled in the Linehan (2007) inventory, and occurred throughout the park. Cats are known to prey upon small native mammals, especially near the urban-wild interface (Warner 1985, Baker et al. 2005). Coyotes (*Canis latrans*) occur in the park and may potentially affect mammal communities. Coyotes have expanded into the eastern U.S. in recent decades, probably directly assisted by human transplantations (Hill et al. 1987). In their new ranges in the eastern U.S., coyotes are apex predators in areas where historic large predators have been extirpated (Gompper 2002). Coyotes may exert a top-down control on deer and smaller carnivores, with results that could be perceived as ecologically beneficial in terms of small mammal populations and habitat quality. Conversely, with sufficiently dense populations, coyotes could directly depress small mammal populations (Gompper 2002). Park staff report that coyotes have only been observed in the park on rare occasions and have not been observed to cause serious impacts on other park fauna (V. DuBowy personal communication).

Feral hogs present a current threat to park habitats and native mammals. Hogs may compete for food with native mammals including deer and small rodents (Seward et al. 2004, NPS 2009). Pigs root destructively in soft soil, damaging native species habitat, and may prey directly upon small animals (Seward et al. 2004). Pig rooting has resulted in severe damage to VICK landscapes, and an active control program focuses on trapping and lethal disposal of feral hogs (NPS 2009, V. DuBowy personal communication). Hogs were first observed in the park in 2008, at which time adult males and female animals and piglets were already present; by 2009 the herd was estimated to contain at least two litters of piglets (NPS 2009). By 2013, the hog population had decreased and six individuals recorded by remote camera were trapped and removed (V. DuBowy personal communication). Hogs have been most active north of the park tour road near Thayer's Approach (NPS 2009).

4.9.4 Data
For our analyses we used the narrative reports and data collected by Linehan (2007), and Linehan et al. (2008). Electronic data from these reports was also available. Available data were fully spatially explicit and included all data on all mammals sampled in the park during the 2005 inventory. Data included details on the amount and type of effort at all capture locations. The data also included a set of those mammals captured by all capture methods including remote cameras, and a set of all mammals observed opportunistically from the park. The data from this inventory are referred to as the analysis dataset.

4.9.5 Methods
For our analysis of VICK mammal assemblage condition, we compared reported versus expected species lists and qualitative considerations. We compared species of native mammals reported in the analysis dataset to the expected lists of native mammals compiled by Linehan (2007). Species deemed unlikely to occur were not included in the expected list. We removed non-native mammals from both observed and expected lists. As qualitative factors, we also considered the

abundance and distribution of non-native mammals within the park as well as the relative abundance of urban-tolerant native species prone to overabundance.

4.9.6 Condition and Trend

The 2005 inventory of VICK mammals reported 31 (82%) of 38 expected native species (Table 32). The seven expected and undetected mammals included four rodents and three carnivores. Of the missing species, the marsh rice rat (*Oryzomys palustris*), muskrat (*Ondatra zibethicus*), river otter (*Lontra canadensis*), and mink (*Neovison vison*) are associated with aquatic habitat which is relatively rare within most of the park, and mink is very difficult to trap. The fulvous harvest mouse (*Reithrodontomys fulvescens*) and the golden mouse (*Ochrotomys nuttalli*) prefer dense edges, old fields, and brushy habitats (Linehan 2007). The recent battlefield restoration project will increase the amount of these habitats in VICK. The final missing species was the spotted skunk (*Spilogale putorius*). The relatively high percentage of expected mammals reported from VICK indicates that the park provides habitat for many of the species typical of the region. We acknowledge that creating an expected list is somewhat subjective and that new species not included in the missing list could occur in the park. We feel that the list compiled by Linehan (2007) includes the mammals reasonably likely to occur in a relatively small, urban park in this region.

Table 32. Number of native mammal species in different categories expected to occur, and the number and percent of expected species actually reported by Linehan (2007) from Vicksburg National Military Park.

Native Species Group	Reported	Expected	% Expected Reported
Bats	7	7	100
Native Rats/mice/voles	6	10	60
Non-rat/mice/vole Rodents	4	4	100
Shrews/moles	4	4	100
Carnivores	6	9	67
Cervids	1	1	100
Lagomorphs	2	2	100
Marsupials	1	1	100
All Native Species	31	38	82

Non-native species were relatively common in the VICK samples. Six non-native species were reported from the park (Table 31). Non-native species comprised 16% of the individuals within the captured mammal dataset, and 22% of individuals in the opportunistically observed dataset. Dogs were the fifth most abundant mammal reported from all capture methods (Table 27), and cats were the second most commonly reported species from opportunistic observations (Table 28). Both species occurred throughout the park (Figure 38). Visual examination suggested that dogs and cats were observed near park borders more frequently than they were observed in the inner regions. The mean distance to the park border for all terrestrial mammal reports in the analysis data set was 161 meters (SD ± 99). The mean distance for cats was 127 meters (SD ± 75) and the mean distance for dogs was128 meters (SD ± 89). Particularly in the northern portion of the park, farther from the influence of the city of Vicksburg, the central areas of the park were relatively free of domestic animals (Figure 38). However, evidence suggests that feral or free-ranging domestic pets probably have access to all or most park areas.

Since the Linehan (2007) inventory was completed, feral hogs have been discovered in the park and have been observed to destroy landscape and habitat (NPS 2009). Active control measures are in place for this species. Because the initial VICK hog population resulted from a known, discrete, recent escape event, the possibility of complete eradication of the feral population was theoretically possible. However, hogs are very adaptive and difficult to eradicate, and populations can increase quickly in favorable habitat (Seward et al. 2004). Furthermore, the second invasion caused by the 2011 flood on the Mississippi River created additional challenges to eradication efforts. However, this population has been monitored for the last three years and as of 2013, appears to have been eradicated through trapping efforts and remote cameras (V. DuBowy personal communication). Regardless, after several years of control with over 20 animals removed, feral hogs remain an important issue at VICK.

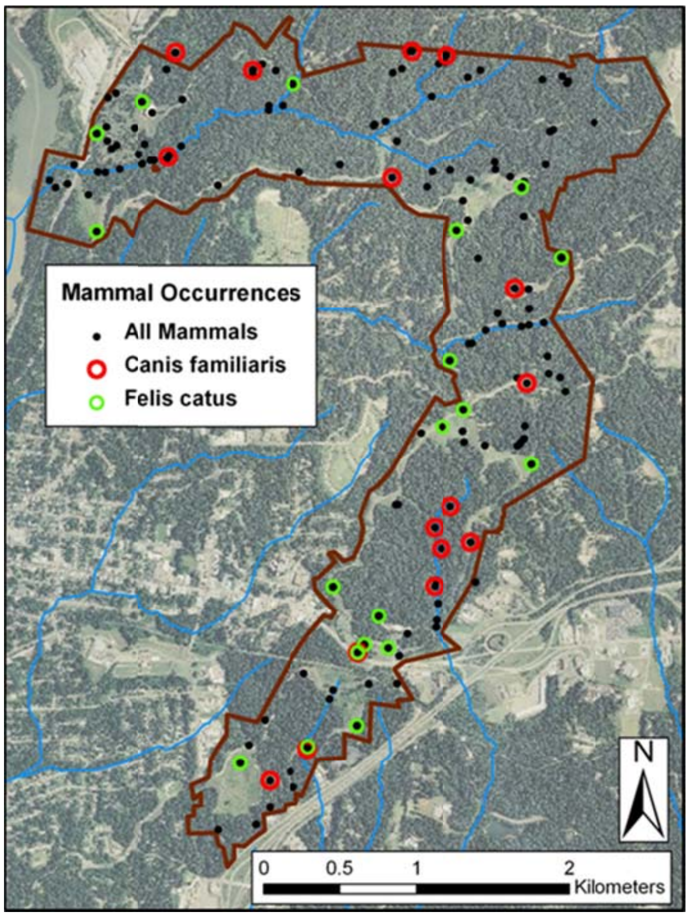

Figure 38. The locations of all mammal observations, including both captured and opportunistically observed, highlighting locations of domestic dog (*Canis familiaris*) and cat (*Felis catus*) reports. Data were from a 2005 mammal inventory at Vicksburg National Military Park.

The observed VICK mammal assemblage is as expected for a fragmented habitat largely surrounded by urban and residential development (Andren 1994). The abundance and coverage of domestic animals in the park has already been discussed. The relatively high abundance of raccoons and white-tailed deer further supports this assessment (Table 27, Table 28). Raccoons were the most frequently captured terrestrial mammals in the park, and deer were the most frequently reported from opportunistic observation. Combined these two species accounted for

33% of the total individual terrestrial mammals captured and 42% of the terrestrial mammals observed opportunistically in VICK. Both raccoons and deer are highly tolerant of human development if basic habitat requirements are met (DeNicola et al. 2000, Prange et al. 2004). A recent study indicated that deer are not overpopulated in the park during most seasons (Kissel and Bomar 2009), and there is no direct evidence that raccoons are overpopulated in the park. We discuss these animals primarily as indications of a mammal fauna typical of near-urban environments.

We ranked the condition of VICK mammal assemblages as fair (Table 33). Many of the species expected in the park were observed there and the species richness was relatively high. Bat richness was good and there was good evidence of successful bat reproduction in or near the park. However, non-native species known to negatively impact native communities were numerically common in samples, and had widespread distribution in the park. Feral hogs are an ongoing management issue. The native mammal fauna samples were numerically dominated by urban tolerant species, including species that can cause habitat and plant community damage at high population levels. We did not assign a trend to mammal assemblage condition. A single inventory is insufficient to establish trend. The quality of the data used to make the assessment was very good. The data was collected recently within the park using a variety of techniques including techniques designed to sample difficult to sample species. The data was fully spatially explicit and summaries of efforts were available.

Table 33. Mammal assemblage condition was fair. No trend was assigned to mammal assemblage condition. The data used to make the assessment were very good.

Attribute	Condition & Trend	Data Quality					
		Thematic		Spatial		Temporal	
Mammal Assemblages	(yellow circle)	Relevancy	✓	Proximity	✓	Currency	✓
		Sufficiency	✓	Coverage	✓	Coverage	✓
		6 of 6: Very Good					

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4.10 Herpetofauna Assemblages

4.10.1 Context and Relevance

The southeastern U.S. contains the highest diversity of herpetofauna in North America, and amphibians and reptiles are important components of southeastern U.S. 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. Standardized amphibian monitoring has recently been started in VICK. The park is located on upland loess bluffs and borders the Mississippi River alluvial plain. This region was historically rich in herpetofauna and has potential for relatively high diversity of reptiles and amphibians. Anthropogenic activities have profoundly altered the landscape in the last two centuries, probably resulting in losses of herpetofaunal species.

4.10.2 Resource Knowledge

Two efforts provided information on VICK herpetofaunal assemblages. A comprehensive inventory of VICK reptiles and amphibians was conducted between March 2001 and March 2002 (Keiser 2002). This study included 57 person days of sampling in the park. Methods included walking transects with active searching, dipnet sampling, glue boards, coverboards, spotlight surveys, spotting scope surveys, road cruising, and nighttime call surveys for frogs. Keiser (2002) surveyed records from seven museums and searched the literature to compile a list of species expected to occur in the park. When unlikely species were excluded, this list, combined with the species recently reported from the park, included 81 species of reptiles and amphibians potentially occurring on VICK. Monitoring for terrestrial and arboreal-active amphibians and reptiles was started in the park under the aegis of the GULN I&M Network from 2011 (NPS 2012). Trial sampling and project development by GULN occurred on the park from 2008- 2009, and the full sampling protocol was started in the spring of 2011 (NPS 2012). This effort employs cover boards arrays and PVC pipe refugia arrays at three locations (Figure 39). Arrays are sampled monthly.

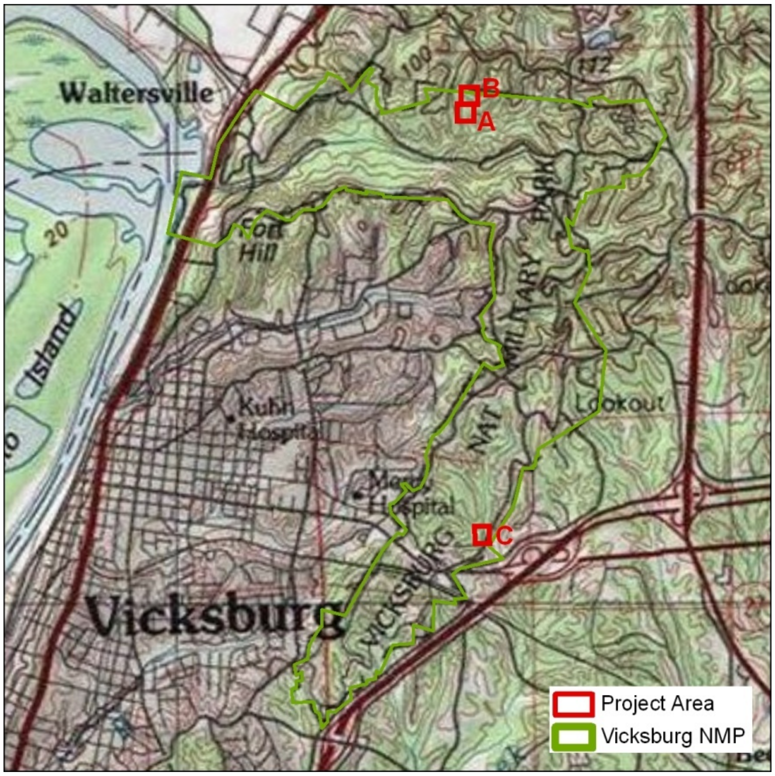

Figure 39. Overview map showing locations of coverboard and PVC refugia pipe arrays used in an ongoing amphibian monitoring program in Vicksburg National Military Park (Source: NPS 2012).

Combined, the efforts described above have reported 48 species of herpetofauna in VICK, including 13 frogs and toads, seven salamanders, four lizards, 15 snakes, and nine turtles. Keiser (2002) reported 44 species from locations throughout the park (Figure 40). Keiser (2002) noted that during his study, ephemeral pools provided breeding habitat for several amphibian species, but that the pools dried before the larvae transformed, resulting in complete mortality. He also noted that two areas that would otherwise provide good herpetofauna habitat were either reduced in quality or were impossible to search because of complete overgrowth with invasive kudzu (*Pueraria lobata*). It is likely that the overgrowth of kudzu and other vegetation (e.g., trifoliate orange, *Poncirus trifoliata*) obscured detection and limited sampling access via PVC methods, but recent frog/toad call surveys indicated that the tree-frog assemblage is abundant in VICK (R. Woodman and V. DuBowy personal communication). One of these areas, along the Yazoo Diversion Canal, is almost constantly underwater, and in the other, kudzu cover has been greatly reduced (V. DuBowy personal communication). From informed opinion and his own sampling results, Keiser (2002) suggested that most of the species sampled from his survey were relatively common within preferred habitat in VICK. He stated that detections from these surveys of the gray treefrog (*Hyla versicolor*), bullfrog (*Rana catesbeiana*), broadhead skink (*Eumeces laticeps*), and cottonmouth (*Agkistrodon piscivorus*) appeared to be relatively rare. However, call surveys conducted in 2013 suggest that the gray treefrog and bullfrog are relatively common at VICK and broadhead skinks are seen regularly, suggesting that these species were likely underrepresented in the surveys conducted by Keiser (2002; V. DuBowy personal communication). Moreover, although no additional data exist to estimate the rarity of cottonmouth in the park, the Keiser (2002) inventories did not specifically target suitable habitat for this species and thus cottonmouths could be fairly abundant in the limited available standing wetlands within VICK (R. Woodman personal communication). Additionally, the copperhead (*Agkistrodon contortrix*), a close relative of the cottonmouth, has been observed multiple times in GULN coverboard sampling, and is likely relatively abundant in higher elevation, forested portions of VICK.

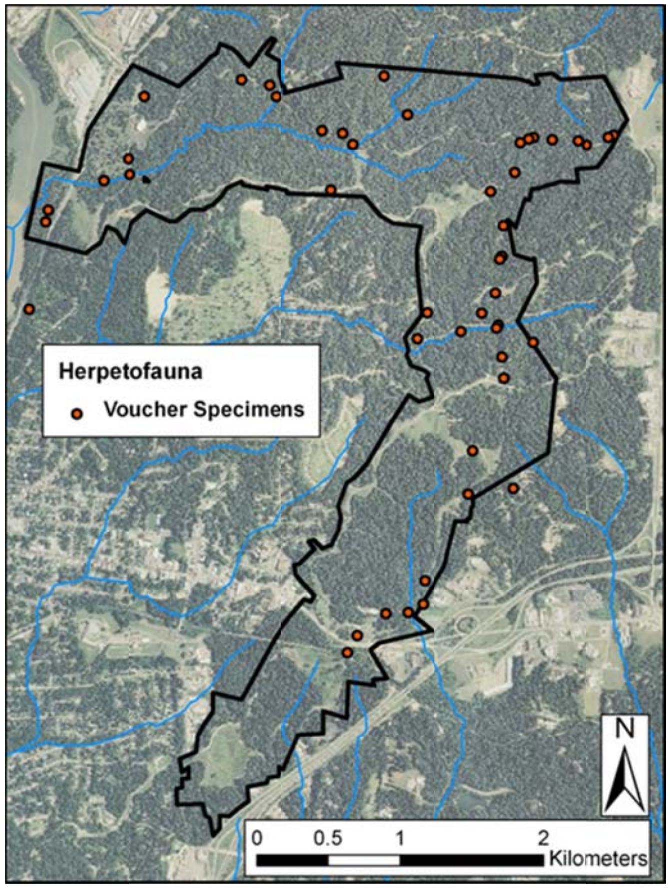

Figure 40. Location of herpetofaunal voucher specimens collected by Keiser (2002) during a reptile and amphibian survey of Vicksburg National Military Park 2001 – 2002.

The amphibian monitoring protocol reported 22 species (including sampling until March 2012). Four species reported by GULN from monitoring had not previously been reported by Keiser (2002). At the time of publishing, the amphibian sampling data included only three months of 2009 data and data from April 2011 – March 2012. These data showed the lowest richness and abundance during the winter and the greatest richness and abundance during the spring and summer (Figure 41). No federal or state listed threatened or endangered herpetofauna species have been reported from the park.

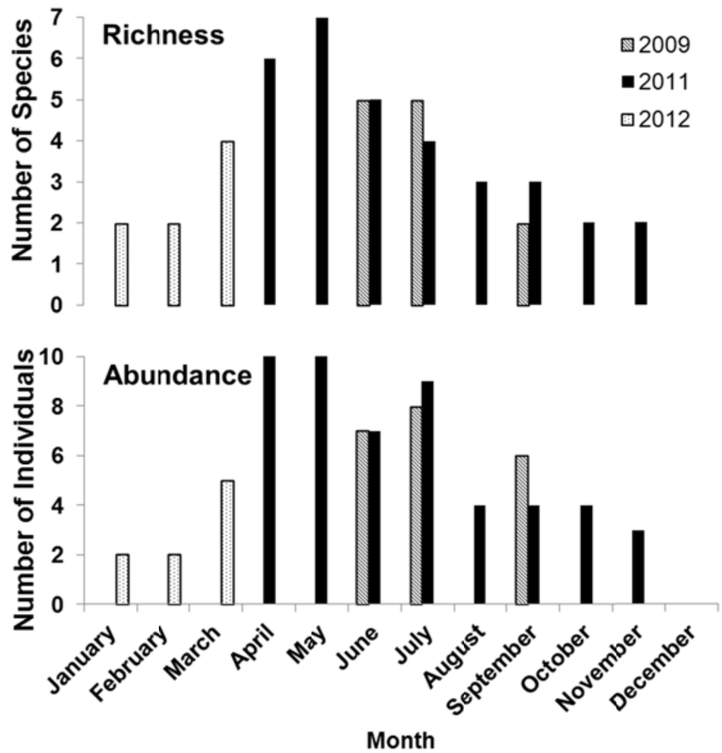

Figure 41. Species richness and numbers of individual herpetofaunal species collected during amphibian monitoring at Vicksburg National Military Park. Only three months were sampled in 2009.

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). Because VICK is a relatively small battlefield park located adjacent to an urban area, habitat fragmentation and urbanization are among the most significant general threats to park herpetofauna. Habitat within and around the park has been altered during the last 150 years by deforestation and conversion to agriculture and urban development. Non-native plants are relatively abundant and widespread in VICK. Feral or free-ranging domestic cats are common in the park (Linehan 2007) and may prey on herpetofauna (Woods et al. 2003). The recent invasion of feral hogs to VICK may damage herpetofauna habitat and some individuals may prey directly upon some herpetofauna species (Seward et al. 2005, Jolley et al. 2010). In particular, species that exhibit mass terrestrial migrations and arboreal species that require ground-level thermal shelter in cooler conditions may be more at risk to depredation events by hogs (Jolley et al. 2010). Moreover, feral hogs have the potential to disrupt monitoring efforts, as was recently observed at other NPS units, including Jean Lafitte National Historic Park and Preserve (JELA), San Antonio Missions (SAAN), and Palo Alto Battlefield (PAAL) (R. Woodman personal communication). In particular, PAAL has recorded multiple mortality events of Texas tortoise (*Gopherus berlandieri*), which may be attributable to hogs. Because many species of herpetofauna are relatively slow to disperse, and because many rely upon rare aquatic habitats, re-population of areas recovering from degradation may be slow. The habitat in the park was severely altered within the last 100 years, and remains relatively isolated within an urban setting. Therefore, even with substantial improvement and recovery of park habitat, many species may be missing.

4.10.4 Data

For our analyses of VICK herpetofaunal condition, we used the data available from the most recent park inventory (Keiser 2002), and from the new and ongoing amphibian monitoring protocol (unpublished park data). Inventory data consisted of a narrative report of the overall project results, and an electronic database of the location and species of voucher specimens. All inventory data were collected in 2001 – 2003. Data for the amphibian monitoring effort included a brief descriptive narrative and an electronic database of results to date. This data included a few months of data from 2009, and the data from monthly monitoring from April 2011 to March 2012. Data from these combined efforts were called the "analysis dataset".

4.10.5 Methods

We compared the species actually reported from the analysis dataset to a list of expected species for the region. Our expected list included all species actually reported from the park, and those reported as potentially present by Keiser (2002). We did not include species that Keiser (2002) considered unlikely to be present. An important caveat about the expected list is that it may poorly represent the species that could actually be expected in VICK, given that the park is situated near an urban area that has experienced extensive anthropogenic alteration.

4.10.6 Condition and Trend

Overall, about 59% of all herpetofaunal species expected in the region were reported from VICK (Table 34). Frogs and toads were the best represented with 72% of expected species reported; only 50% of the expected snake species were reported. However, snake detection could be influenced by sampling methods (i.e., coverboards), as significant available ground cover at VICK may provide more habitat for snakes and in turn make coverboard sampling less effective (R. Woodman personal communication). Additionally, most of the park is not accessible for effective terrestrial herpetofauna sampling, thus results may be biased to accessible regions of the park. The American alligator (*Alligator mississippiensis*) was the only crocodilian on the expected list and was not reported, although it has been seen in the park in 2005 and 2006 (V. DuBowy personal communication). Habitat for this species is uncommon in the park and it is not expected to occur here with any regularity.

Table 34. Herpetofaunal species expected to occur and those actually reported at Vicksburg National Military Park. Expected species are those listed by Keiser (2002) as likely to occur; reported species are those reported by Keiser (2002), and by GULN amphibian monitoring from 2009-2011.

Group	Expected	Reported	% Expected Reported
All species	81	48	59
Amphibians	30	20	67
Reptiles	63	35	56
Anurans	18	13	72
Salamanders	12	7	58
Crocodilians	1	0	0
Lizards	6	4	67
Snakes	30	15	50
Turtles	14	9	64

The relatively high abundance of non-native domestic cats (Table 31) and the presence of feral hogs may negatively impact VICK herpetofaunal assemblages, although these factors have not been quantified in the park. We qualitatively considered these factors to decrease herpetofaunal assemblage quality. There is no evidence that VICK is more impacted by these factors than is typical within the broad region.

Because behavior and habitat associations vary widely among herpetofaunal species, multiple methods should be used when sampling an assemblage (Gibbons et al. 1997, Tuberville et al. 2005). Drift fencing with pitfall traps is among the most effective and commonly used methods of sampling herpetofauna assemblages, and may be especially useful for sampling salamanders (Greenberg et al. 1994, Ryan et al. 2002, Wilson and Gibbons 2009). The Keiser (2002) survey employed a variety of sampling techniques, but did not use pitfall sampling either with or without drift fencing. Keiser (2002) stated that a good area for using these techniques was found in the park, but was discovered too late in the course of the study for sampling to be conducted. We feel that future efforts at discovering the full diversity of herpetofaunal assemblages in VICK should consider using pitfalls, preferably in array with drift fencing, although this may not be a suitable long-term monitoring arrangement per habitat and terrain constraints (V. DuBowy personal communication).

We did not assign a condition to VICK herpetofaunal assemblages (Table 35). The park had a moderately diverse fauna, but the available sample was missing many of the expected species. The data collected at the time of this report likely do not represent the true richness of VICK herpetofaunal assemblages. The Keiser (2002) report did not employ all methods typically used in inventory studies. The data collected by the GULN are designed to assist in detecting change and are not designed to collect the greatest richness possible. Furthermore, the expected species list for the park may be unrealistic given the history and isolation of VICK. Due to these factors, there is low reliability of both the sampled richness and in the expected species list. We did not assign a trend to herpetofaunal assemblage condition. The ongoing efforts to monitor park amphibians promise to be very useful in assessing assemblage health into the future, but are insufficient for such use now. The quality of the data used the make the assessment was marginal. The available inventory was adequately summarized but was not sufficiently explicit to determine the type and amount of efforts used in all locations throughout the park. Sampling did not include pitfall methods, which we believe are important in obtaining a maximally species rich sample. The collected voucher specimens indicate samples were collected throughout park areas, but the level of coverage, especially away from roadways could not be determined. Because the data were more than five years old, they did not receive a currency check.

Table 35. The condition of VICK herpetofaunal assemblages was not ranked. The quality of the data used to make this assessment was marginal. No trend was assigned to herpetofaunal assemblage condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	**Spatial**	**Temporal**
Herpetofaunal Assemblages		Relevancy	Proximity ✓	Currency
		Sufficiency ✓	Coverage	Coverage ✓
		3 of 6: Marginal		

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4.11 Adjacent Land Use

Adjacent land use is considered a high-priority vital sign in the GULN, as it affects many processes inside the park. Changes outside the park can influence spread of non-native species, impact air and water quality, inhibit viewsheds and soundscapes, and generally increase visitor impact. These effects may act differently depending on the temporal spatial scale of consideration (Kotliar and Wiens 1990). 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). At VICK, adjacent development is a particular issue due to the urban setting of the park. Emissions from nearby sources can produce acid rain, which in turn can damage monuments and structures in the park. Development along the periphery of the park can also increase sedimentation rates in streams in the park, resulting in higher temperatures and reduced water quality (Cooper et al. 2004). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of both natural and cultural resources in the park (Gross et al. 2009).

4.11.1 Suitable Habitat

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. In a review of habitat fragmentation and its effects on species populations, Andrén (1994) notes that patch size and isolation become important only when the overall proportion of suitable habitat is low, and offers that this critical threshold occurs 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). This threshold is similar to the notion of percolation theory in landscape ecology, which states that there is some critical habitat threshold, often identified theoretically as 60%, where habitat occurs at a threshold of connectivity in the landscape (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).

4.11.2 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. Currently, the NPScape project is in its second product development phase for NPS units, though as of this writing only first phase products are available for VICK. Landscapes at VICK were analyzed at two main scales defined by a 30km buffer and 3km buffer around the park.

<u>NLCD</u>

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 the period of its two datasets produced in 2001 and 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. Table 37 depicts landcover proportions for 2001 and 2006 at each buffer width for VICK, 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 (75.6%) to the successive 3 km buffer (47.1%) and increases again slightly at the 30 km buffer (57.4%). This reflects the development surrounding the immediate vicinity, though at the larger buffer much of the area is classified as woody wetland (26.3%) rather than deciduous forest. The other notable change across scales is the increase in cultivated agriculture proportion, which changes from 0.5% in the park boundary to 4.7% and 22.9% in the 3 km and 30 km buffers, respectively. Because VICK is situated on the east bank of the Mississippi River, only the 30 km buffer incorporates the MS alluvial plain on the west bank, which consists of low, flat fertile areas suitable for agriculture. In 2006, forested and cultivated proportions show a similar pattern across scales (Figure 42).

The change product shows that only 1.3% of the park area underwent change between 2001 and 2006. A small portion of this change (0.2%) corresponded to a small area in the southwest portion of the main park where deciduous forest was cleared north of the Kentucky Memorial outside the tour loop road (Figure 43). This observed change is the result of a substantial reduction in kudzu cover in this section, and it remains an area targeted for annual treatment by the Gulf Coast EPMT (V. DuBowy personal communication). The remaining change occurred in the field immediately southwest of the Kentucky Memorial and immediately adjacent Ft. Garrott and Hovey's approach. This area is classified as pasture/hay to scrub/shrub conversion, which may reflect some succession over the time period, or simply a more recently mown field in the 2001 imagery. The other buffer widths show negligible conversions over the 2001-2006 period. Most recently, additional clearing and battlefield restoration was conducted on 16 ha between the Kentucky Memorial and the Texas monument (V. DuBowy personal communication). The U-index calculated for the park boundary was moderately low (0.29), while U-indices for the 3 km and 30 km buffers were respectively 0.65 and 0.44. The high conversion ratio at the 3 km buffer width is due mainly to the capture of the urban center of Vicksburg, MS, while at the larger 30 km scale due to the large-scale area of agricultural production in the Louisiana alluvial valley. Compared to proportion of natural landcover in other park units, VICK appears close to or slightly below the median among all park units (Figure 44). Natural landcover proportions show an overall negative skew.

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

General Category	NLCD classes
	land; Perennial ice/snow; Woody wetlands; Emergent herbaceous wetlands; Open water

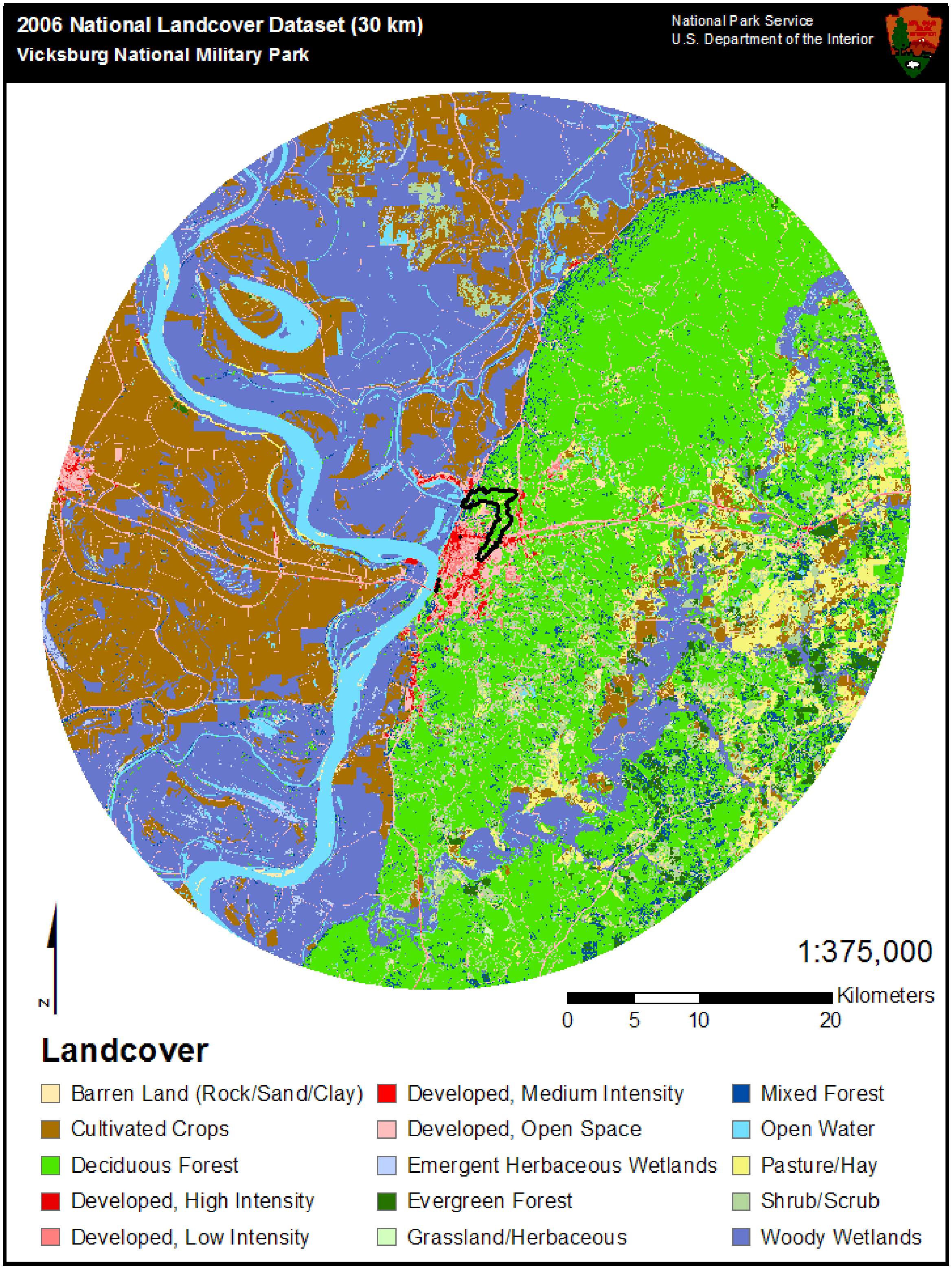

Figure 42. NPScape landcover product showing 2006 NLCD classification for Vicksburg NMP with 30 km buffer.

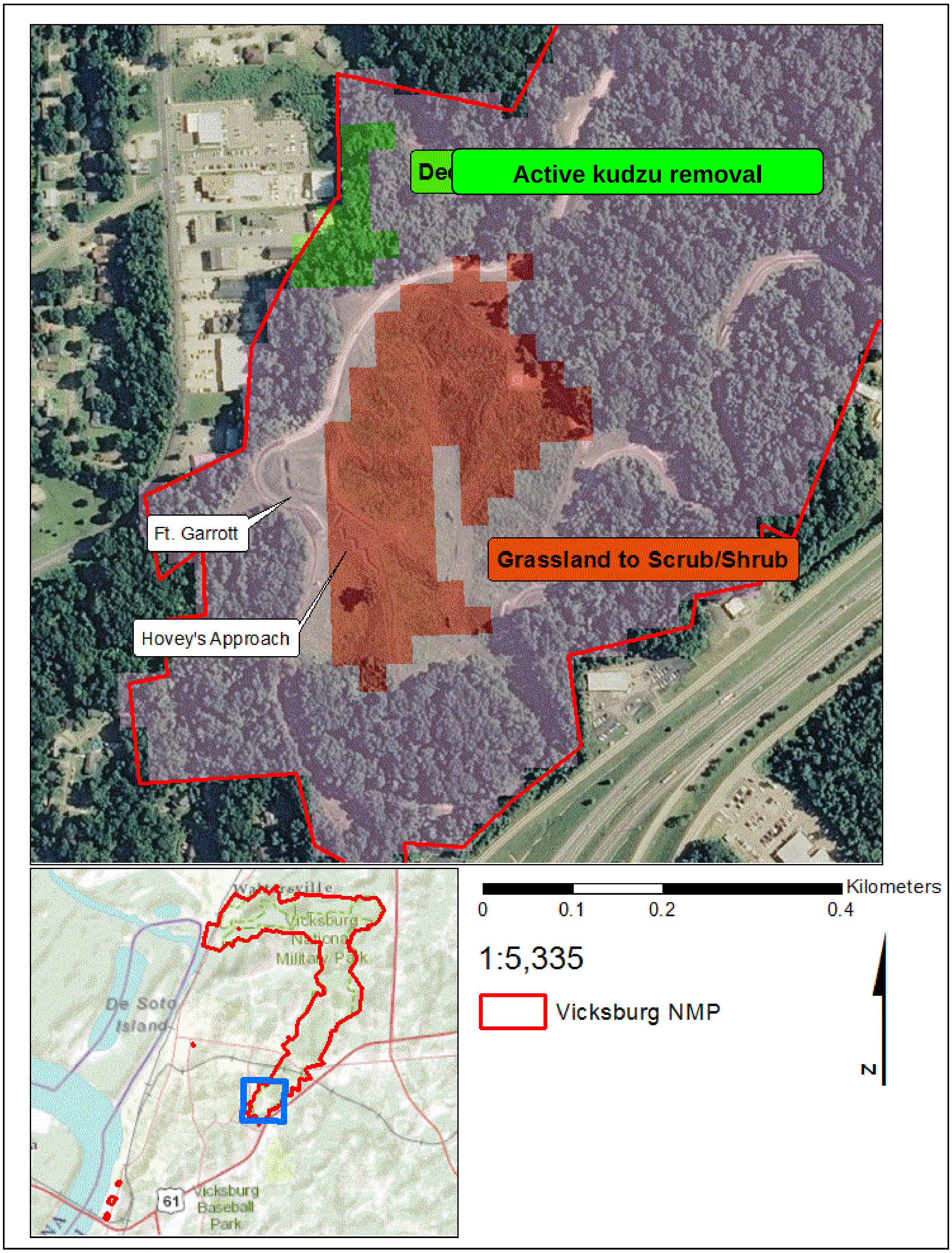

Figure 43. Two sections in southern VICK indicated a change in landcover between 2001 and 2006 according to the NLCD change product. Shown here with 2010 imagery, the northern section likely reflects active kudzu removal, while the southern portion shows a grassland to scrub/shrub conversion. This is likely indicative of some succession or merely different periods of elapsed time since mowing between photo periods.

Table 37. Landcover area and proportions of VICK 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	188.9	5.4	11.3	9.9	<0.1	0.1
Developed Open Space	143.6	4.1	20.7	18.0	1.2	17.4
Developed Low Intensity	22.1	0.6	9.7	8.5	0.1	1.6
Developed Medium Intensity	8.4	0.2	5.4	4.7	<0.1	0.2
Developed High Intensity	3.0	0.1	2.1	1.8	<0.1	<0.1
Barren Land	7.5	0.2	0.2	0.2	0	0
Deciduous Forest	959.1	27.3	33.9	29.6	4.5	63.5
Evergreen Forest	40.4	1.2	0.5	0.4	0.2	3.5
Mixed Forest	89.6	2.6	4.3	3.7	0.5	6.9
Scrub/Shrub	143.5	4.1	3.3	2.9	0.1	0.9
Grassland/Herbaceous	0.5	<0.1	<0.1	9.4	0	0
Pasture/Hay	150.9	4.3	2.2	1.9	0.3	3.8
Cultivated Agriculture	803.1	22.9	5.3	4.7	<0.1	0.5
Woody Wetlands	921.4	26.3	15.3	13.4	0.1	1.7
Emergent Herbaceous Wetlands	26.2	0.7	0.3	0.2	0	0
NLCD 2006						
Open Water	189.3	5.4	11.2	9.8	<0.1	<0.1
Developed Open Space	144.4	4.1	21.0	18.4	1.3	17.6
Developed Low Intensity	22.5	0.6	9.9	8.6	0.1	1.5
Developed Medium Intensity	9.0	0.3	5.8	5.1	<0.1	0.3
Developed High Intensity	3.1	0.1	2.2	1.9	<0.1	<0.1
Barren Land	6.2	0.2	0.3	0.3	0	0
Deciduous Forest	967.8	27.6	34.1	29.8	4.6	64.0
Evergreen Forest	48.2	1.4	0.5	0.4	0.2	3.4
Mixed Forest	86.2	2.5	4.0	3.5	0.5	6.6
Scrub/Shrub	177.0	5.0	3.5	3.0	0.1	1.8
Grassland/Herbaceous	5.6	0.2	0.1	0.1	0	0
Pasture/Hay	136.3	3.9	1.8	1.5	0.2	3.0
Cultivated Agriculture	752.0	21.4	4.6	4.0	0	0
Woody Wetlands	933.5	26.6	15.4	13.4	0.1	1.7
Emergent Herbaceous Wetlands	26.8	0.8	0.3	0.2	0	0
NLCD Change (2001-2006)						
--Overall--						
Converted	1067.2	30.4	45.2	39.5	1.6	22.9
Natural	2441.6	69.6	69.3	60.5	5.5	77.1
--Changed--						
Natural to Agriculture	0.8	<0.1	0	0	0	0
Natural to Urban	1.3	<0.1	0.6	0.5	<0.1	0.2
Agriculture to Urban	0.4	<0.1	0.4	<0.1	0	0
Converted to Natural	53.3	1.5	0.2	<0.1	0.1	1.1
U-Index	**0.44**		**0.65**		**0.29**	

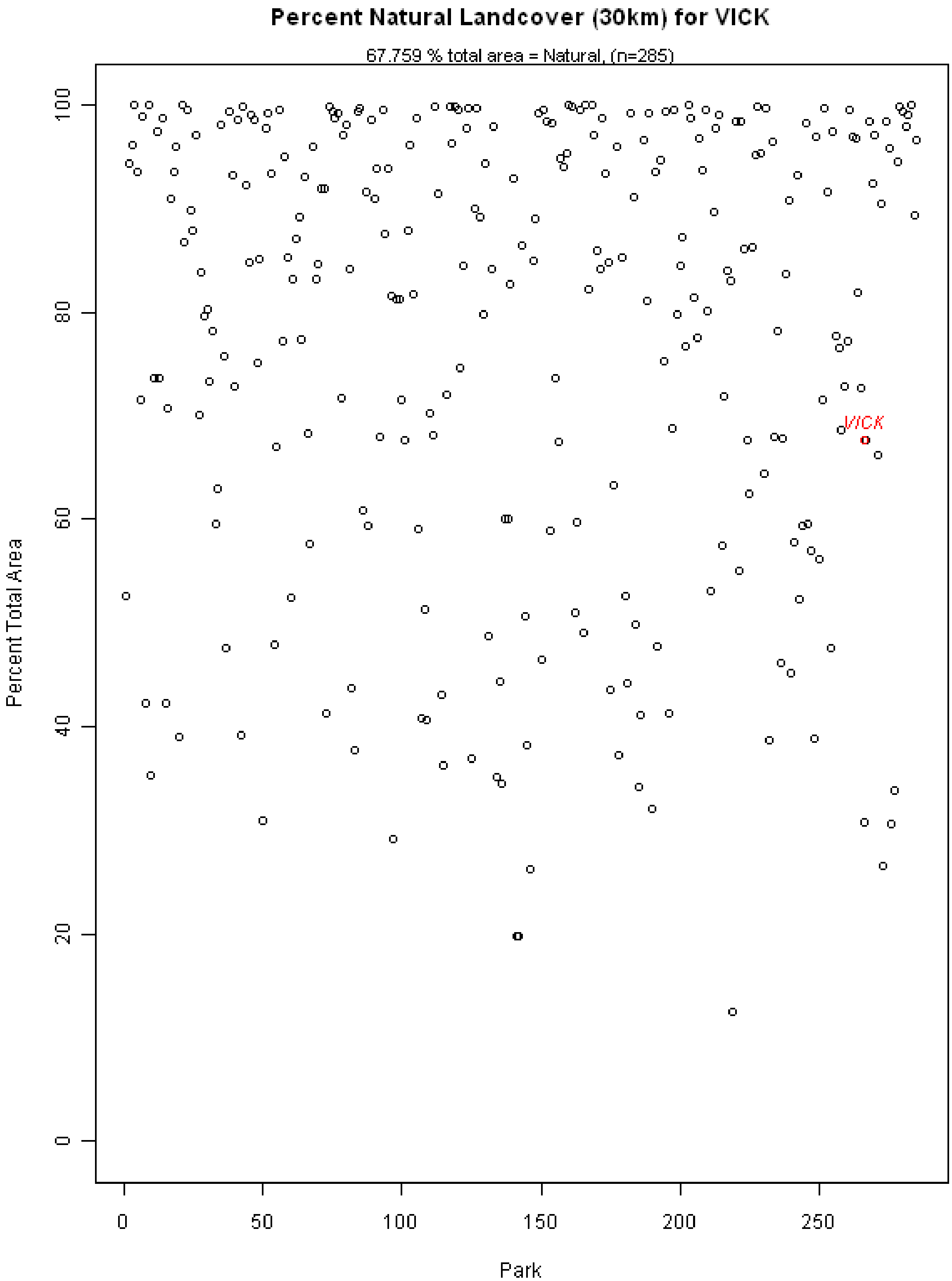

Figure 44. NPScape product showing proportion natural landcover within VICK landscape. The x-axis is a placeholder index for each park unit.

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 most recent version of the EVT dataset maps landcover using imagery over the period 1999 to 2008, with a focus on capturing changes during that time due to wildfire (LANDFIRE 2012). The landcover map is based on mid-scale ecological system classifications outlined by Comer et al. (2003). This LANDFIRE dataset is classified at a 30 m resolution and is mainly intended at a large landscape-scale, such as at a state or sub-regional level. Table 38 shows the amount and proportions of 30 landcover classes at VICK with 3 km and 30 km buffer widths. Figure 45 depicts the LANDFIRE classification for the 30 km buffer at VICK. At the 30 km buffer width, the most abundant vegetation class is the general riparian/swamp system (25.7%), followed by agricultural land (21.9%) and tree plantations (12.1%). Loess bluff forest is the most abundant class in the 3 km (21.4%) and no buffer classes (48.0%). Surprisingly, the tree plantation class reappears within the park boundary classification as an abundant class, though this likely represents a classification error. Roads (10.8%) are the third most predominant class within the park unit. Respective U-indices for the park boundary, 3 km, and 30 km buffers are 0.93, 1.13, and 0.88 (Table 38). Although U-indices for LANDFIRE classes show an identical pattern as those for NLCD among scales, overall proportions of converted land area are much higher for LANDFIRE data. An apparent reason for this is the surprisingly large area classified as managed plantations, especially the large portion (24.7%) classified within the park unit. Much of this classification is actually comprised of the cherrybark – water oak and sweetgum – pecan – water oak associations outlined by Rangoonwala and Ramsey (2007). Story et al. (unpublished) cautioned, however, that LANDFIRE data tends to focus on the predominant fuel type in an area, possibly resulting in an overestimation of that type of landcover. This may have to do with the higher U-indices, as may the finer division of classes.

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

	-30 km buffer-		**-3 km buffer-**		**-no buffer-**	
LANDFIRE	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	196.2	5.6	11.4	10.0	<0.1	<0.1
Developed Upland Vegetation*	68.7	2.0	18.8	16.4	0.6	7.8
Developed-Medium Intensity*	5.5	0.2	3.5	3.0	<0.1	0.1
Developed-High Intensity*	2.3	0.1	1.6	1.4	<0.1	<0.1
Developed-Roads*	101.5	2.9	13.8	12.1	0.8	10.8
Barren	6.8	0.2	0.2	0.2	0	0
Quarries-Strip Mines-Gravel Pits*	2.1	0.1	0.4	0.3	0	0
Herbaceous wetlands-Semi-wet/dry	24.6	0.7	0.3	0.2	0	0
Agriculture-Pasture and Hay*	253.8	7.2	3.0	2.6	0.3	3.9
Agriculture-Cultivated Crops and Irrigated Agriculture*	767.4	21.9	5.1	4.4	<0.1	0.7
Introduced Upland Vegetation—Grass/Forb*	14.2	0.4	0.4	0.3	<0.1	0.2
Transitional Herbaceous	<0.1	<0.1	0	0	0	0
Transitional Mixed Forest	57.5	1.6	1.0	0.9	0.1	1.6
East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	1.0	<0.1	<0.1	<0.1	<0.1	<0.1
East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	0.5	<0.1	0	0	0	0
East Gulf Coastal Plain Loess Bluff Forest	429.3	12.2	24.5	21.4	3.4	48.0
Southern Coastal Plain Limestone Forest	0.1	<0.1	0	0	0	0
Southern Coastal Plain Dry Upland Hardwood Forest	130.9	3.7	0.1	0.1	<0.1	0.2
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	2.6	0.1	0.1	0.1	<0.1	0.1
Southern Coastal Plain Mesic Slope Forest	96.4	2.7	0.1	0.1	<0.1	0.1
West Gulf Coastal Plain Pine-Hardwood Forest	0.2	<0.1	<0.1	<0.1	0	0
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	14.1	0.4	0.2	0.1	<0.1	0.6
West Gulf Coastal Plain Southern Calcareous Prairie	0.8	<0.1	0.1	0.1	0	0
East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	<0.1	<0.1	0	0	0	0
Gulf and Atlantic Coastal Plain Riparian and Swamp Systems	902.9	25.7	15.3	13.3	0.1	1.2
Lower Mississippi River Flatwoods	2.5	0.1	0.1	0.1	0	0
Managed Tree Plantation-Southeast Conifer and Hardwood Plantation*	425.7	12.1	14.7	12.9	1.8	24.7
Conifer Woodlands	0.6	<0.1	0	0	0	0
U-Index	**0.88**		**1.13**		**0.93**	

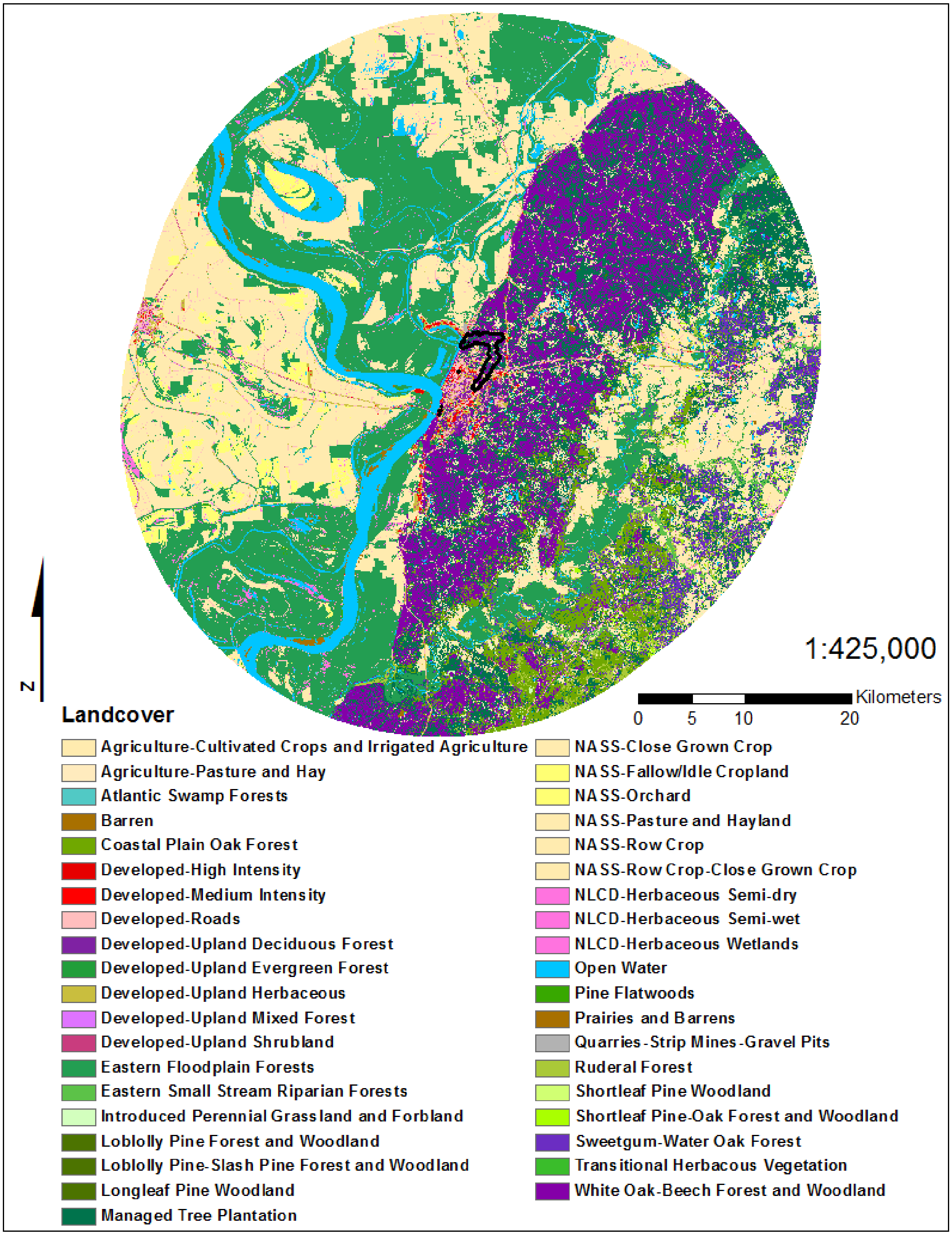

Figure 45. LANDFIRE landcover classification for VICK shown at the 30 km buffer width.

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" (USGS 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 VICK by buffer class. Because GAP classifications were created separately for the area including Louisiana and that of Mississippi, there is mismatch between class types. As a result, classifications from each state are shown separately in Table 39. For each buffer class, the most predominant single landcover class is the East Gulf Coastal Plain Loess Bluff Forest (Figure 46). At the 30 km, 3 km, and park boundary extents, this class represents 22.3, 31.0, and 71.9%, respectively. When combined across separate classifications, however, agricultural land represents a slightly larger proportion in the 30 km buffer (26.8%). At the 3 km and park boundary scales, developed open space is the second most common class, representing 16.5 and 15.9%, respectively. Overall, about 72.4% of VICK is forested, according to GAP data, with subsequent buffer classes of 39.9% (3 km) and 54.6% (30 km). Calculated U-Indices for GAP data are respectively 0.93, 1.13, and 0.88 for respective increasing extents. With the exception of the park itself, these ratios are similar to those of LANDFIRE. The park U-Index is likely higher for the LANDFIRE data because of the influential misclassification of managed backfields within the park unit.

U-Indices
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 supports even lower thresholds (Andrén 1994, With and Crist 1995). 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 depict a highly altered landscape at both the 3 km and 30 km buffer extents. Respectively, the 30 km buffer, 3 km buffer, and no buffer classes average U-Indices plus or minus standard error of 0.65 ± 0.12, 0.95 ± 0.15, and 0.53 ± 0.20.

These U-indices are conservative when compared to the above critical habitat threshold because they represent a ratio and not proportion of habitat. In contrast, because U-Indices include multiple vegetation classes, individual areas of natural habitat likely demonstrate less connectivity from the perspective of wildlife utilization than would a U-Index reflecting preferred habitat type. In other words, habitat specialists would not perceive all natural areas as suitable habitat, and therefore experience a lower connectivity than suggested by these indices.

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

Gap Analysis Program (GAP) Landcover	-30 km buffer- Area (km^2)	-30 km buffer- % Area	-3 km buffer- Area (km^2)	-3 km buffer- % Area	-no buffer- Area (km^2)	-no buffer- % Area
Mississippi						
Developed Open Space*	97.4	2.8	18.9	16.5	1.1	15.9
Low Intensity Developed*	23.2	0.7	9.9	8.7	0.1	1.4
Medium Intensity Developed*	8.3	0.2	5.4	4.7	<0.1	0.4
High Intensity Developed*	2.4	0.1	1.8	1.6	0	0
Quarries, Mines, Gravel Pits, and Oil Wells*	0.2	<0.1	0	0	0	0
Cultivated Cropland*	318.2	9.1	6.6	5.7	0.1	1.2
Pasture/Hay*	156.0	4.4	2.2	2.0	0.4	5.4
Open Water (Fresh)	96.1	2.7	4.9	4.3	<0.1	0.1
Bare Soil	2.9	0.1	0.1	0.1	0	0
Unconsolidated River Shoreline	19.4	0.6	0.3	0.2	0	0
East Gulf Coastal Plain Loess Bluff Forest	781.5	22.3	35.5	31.0	5.1	71.9
Disturbed/Successional*	183.4	5.2	4.3	3.8	0.2	2.4
Managed Plantation (Harvested or Regrowth)*	83.3	2.4	2.0	1.8	<0.1	0.3
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	228.6	6.5	0	0	0	0
East Gulf Coastal Plain Mesic Forest	21.5	0.6	0	0	0	0
East Gulf Coastal Plain Stream, River, and Floodplain Forest	155.1	4.4	0.2	0.2	<0.1	0.1
Mississippi River Low Floodplain (Bottomland) Forest	566.5	16.1	6.3	5.5	<0.1	0.1
Mississippi River Riparian Forest	15.9	0.5	0.3	0.3	0	0
Louisiana						
Water	132.0	3.8	9.6	8.4	--	--
Deciduous Upland Forest	0.1	<0.1	0	0	--	--
Deciduous Wetland Forest	145.8	4.2	3.4	2.9	--	--
Deciduous Wetland Scrub/Shrub	10.3	0.3	0.5	0.4	--	--
Mixed Wetland Forest	0.4	<0.1	0	0	--	--
Agriculture – Cropland – Grassland	465.2	13.3	2.8	2.4	--	--
Vegetated Urban	3.3	0.1	0	0	--	--
U-Index	**0.62**		**1.05**		**0.37**	

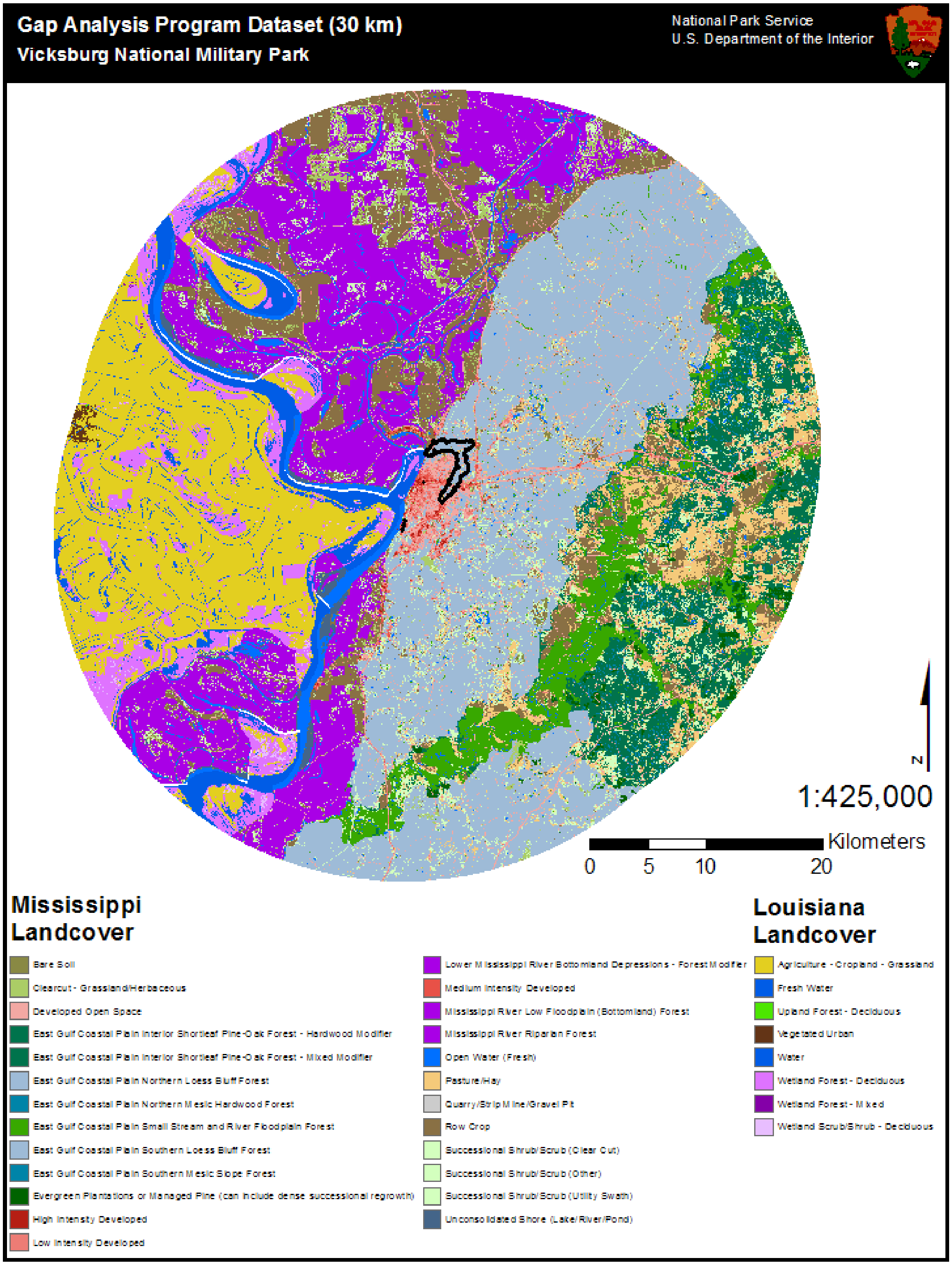

Figure 46. Gap Analysis Program (GAP) landcover shown for VICK with 3km and 30 km buffers.

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 (Harbor 1994, Arnold and Gibbons 1996). 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 proportions of 2% - 6%.

The 2006 NLCD version of impervious surface includes difference levels of development intensity in addition to developed open space. Using this classification, proportion of impervious area with each successive buffer class is 1.4% within the park boundary, 8.0% at the 3 km buffer, and 0.6% at the 30 km buffer width. Despite the predominance of the city of Vicksburg at the 3 km buffer width, 8.0% imperviousness is a relatively low value, influenced greatly by the adjacent Mississippi River and alluvial areas. At the larger 30 km extent, imperviousness is extremely low, reflecting a landscape of mainly agriculture. The park unit itself also shows a low level of imperviousness.

4.11.3 Roads

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 2000, Forman et al. 2002). 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

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. Using turtle movement models relevant at scales greater than 10 km^2, 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 U.S. where road densities are higher. This scale is most relevant to the area covered by the 3 km and 30 km buffers. Analysis of roads in the VICK vicinity reveals that combined road density within the park unit is 2.8 km km^{-2}, which increases to 4.5 km km^{-2} at the 3 km buffer width and decreases to 1.8 km km^{-}2 at the 30 km buffer width. Figure 47 shows the NPScape product for weighted road density within the 30 km buffer.

Distance to Nearest Road

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 (Forman and Alexander 1998). Exotic plant species 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 calculated as 72 m within the park unit, 210 m at the 3 km buffer, and 493 km at the 30 km buffer width.

Effective Mesh Size

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 the 30 km buffer, average roadless patch area is 3.1 km^2, while at 3 km, average patch size is 21.3 km^2, though this mean is due mainly to the presence of a single large roadless patch comprising De Soto Island immediately west of downtown Vicksburg. Because road density is so high surrounding and within the park unit, there are no roadless patches (>500 m) within it. Figure 48 shows the NPScape version of effective mesh size at the 30 km buffer scale. The two largest roadless patch areas at this scale surround Eagle Lake, an oxbow lake immediately northwest of the park unit. These areas are classified by NLCD as woody wetland and are as a result relatively protected from development.

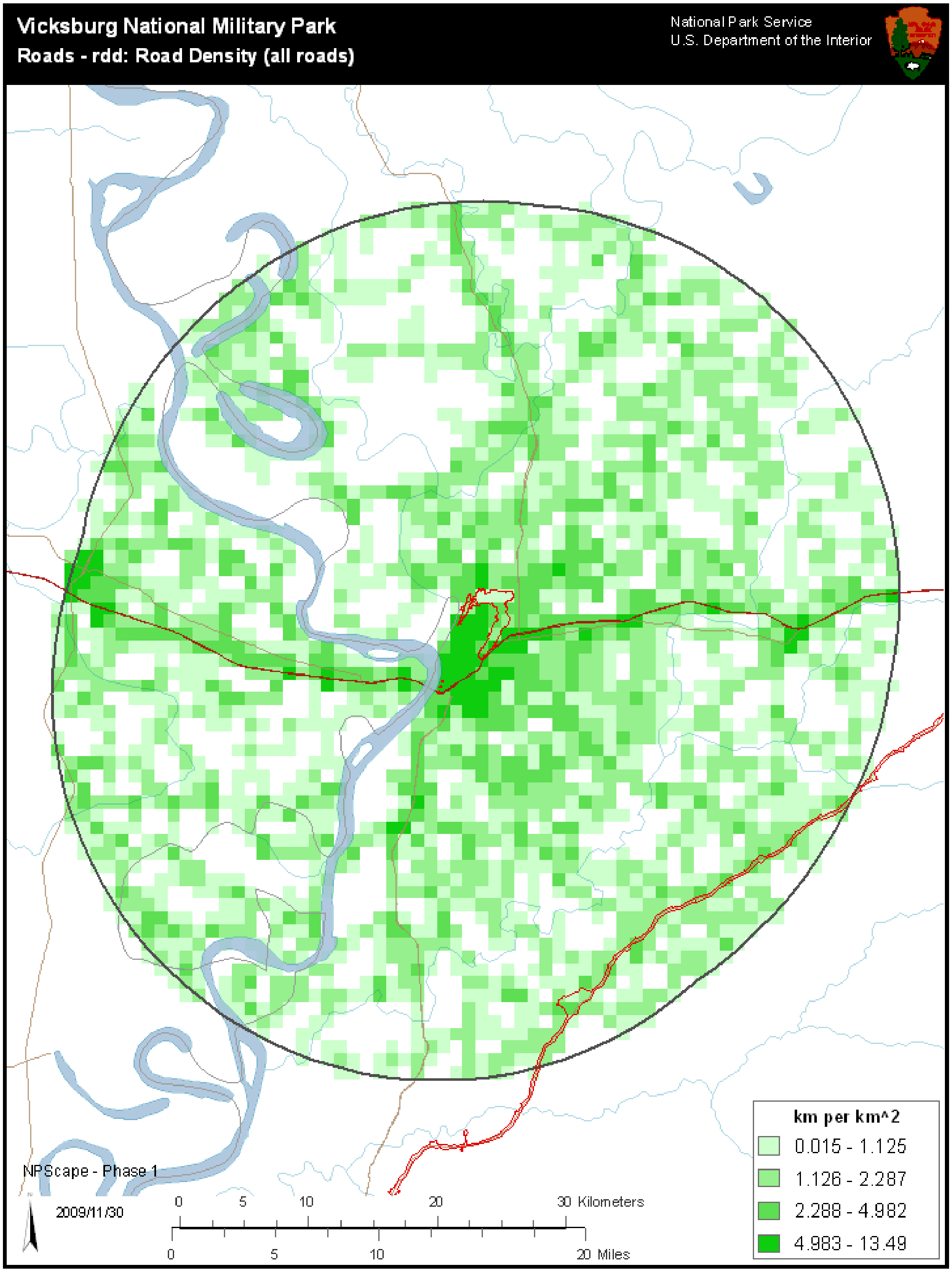

Figure 47. NPScape product (Gross et al. 2009) showing VICK with weighted road density at a 30 km buffer width.

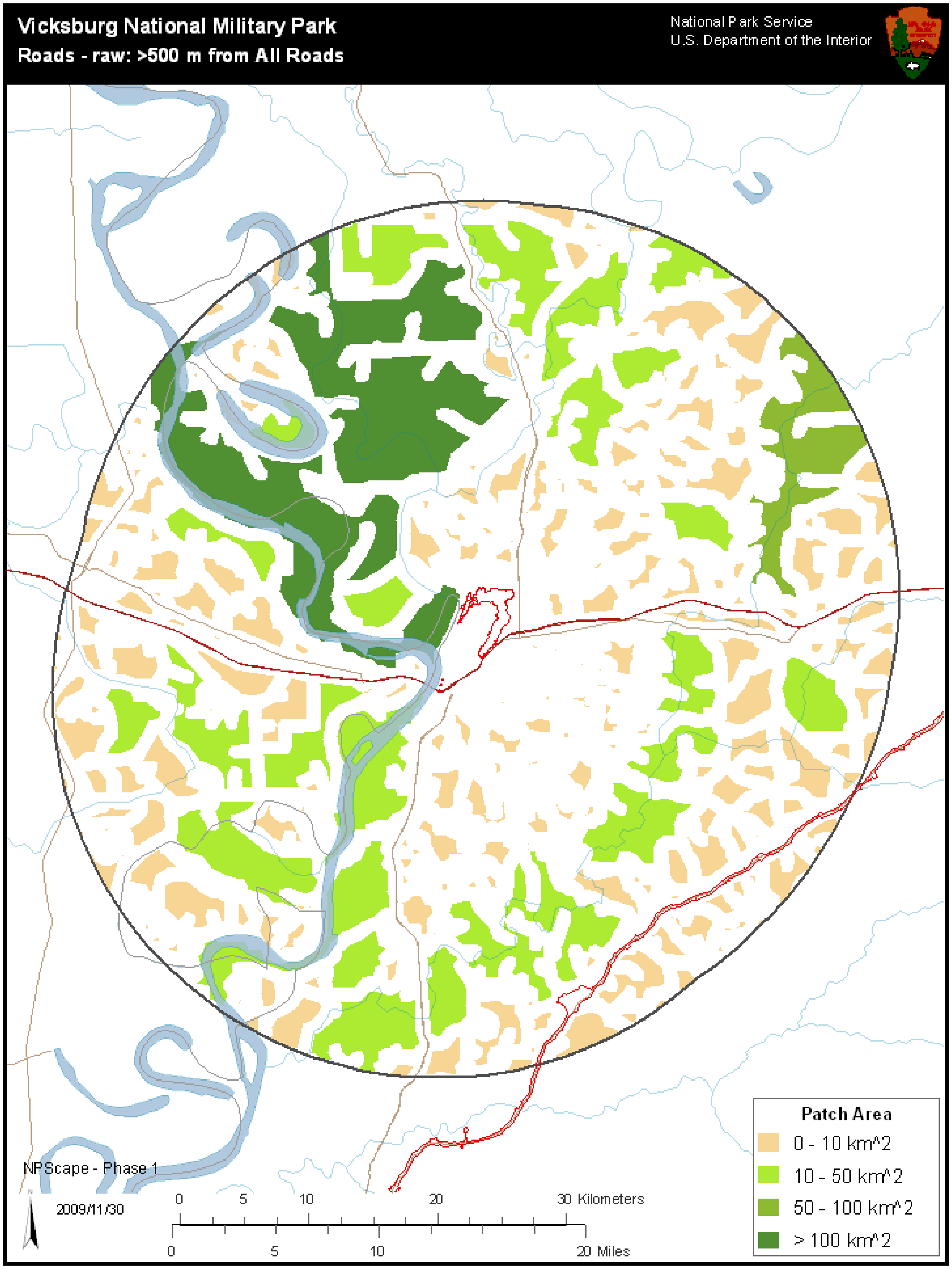

Figure 48. NPScape product (Gross et al. 2009) showing effective mesh size created by roads at a 30 km buffer width.

4.11.4 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 et al. 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 U.S. 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 areas into 13 development classes, plotted for six decades from 1950 and 2000. Figure 49 depicts the change in proportion represented by each housing density class within the 30 km buffer for VICK. There is a visible decrease in proportions of least density housing classes over this time period, though linear regression shows no significance. Regression does show a significant increase for all except the densest (>2470 units per km^2) 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 U.S. Population data for counties within the 30 km buffer show mostly steady increases during the period 1800 to 1990 (Figure 50), with an especially rapid increase in population growth beginning around 1920 in Hinds County, which includes the capital Jackson.

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Table 40 shows the breakdown of housing density classes in the 2010 prediction for each buffer size. Because VICK is located in an urban setting, the six greatest density classes representing exurban to urban development are present in higher proportions at the 3 km buffer scale. The commercial/industrial class is also much greater at the 3 km buffer width. At the 30 km buffer scale, the two lowest rural density classes represent almost two-thirds of the landscape. The overall lower proportion of developed area at the 30 km buffer width reflects the large area of undeveloped riverine wetlands and cropland on the west floodplain of the Mississippi River.

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 51), which shows that VICK falls among the lowest of overall population density classes in both 1990 (18.9 individuals km^{-2}) and 2000 (19.6 individuals km^{-2}) relative to other NPS units.

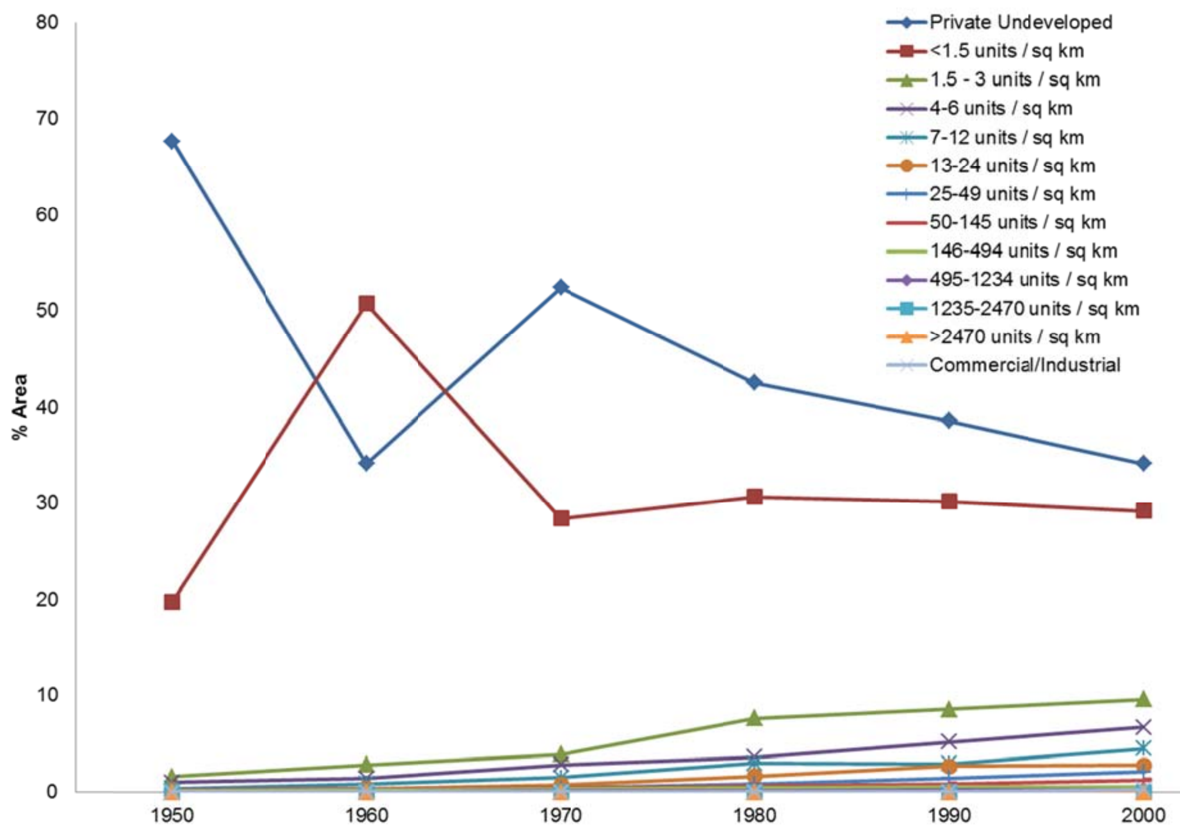


Figure 49. Historical NPScape data for housing density classes within the 30 km buffer over the period 1950 to 2000.

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

Density Class	**-30 km buffer-**	**-3 km buffer-**	**Development Class**
	-%-		
Private undeveloped	34.1	23.2	Rural
< 1.5 units / square km	29.2	5.4	|
1.5 - 3 units / square km	9.6	1.3	|
4 - 6 units / square km	6.7	4.6	↓
7 - 12 units / square km	4.4	3.3	Exurban
13 - 24 units / square km	2.9	8.2	|
25 - 49 units / square km	2.1	14.6	|
50 - 145 units / square km	1.2	14.2	↓
146 - 494 units / square km	0.6	12.4	Suburban
495 - 1,234 units / square km	0.2	5.5	Suburban/Urban
1,235 - 2,470 units / square km	<0.1	1.1	Urban
>2,470 units / square km	<0.1	0.2	|
Commercial/industrial	0.3	6.0	↓

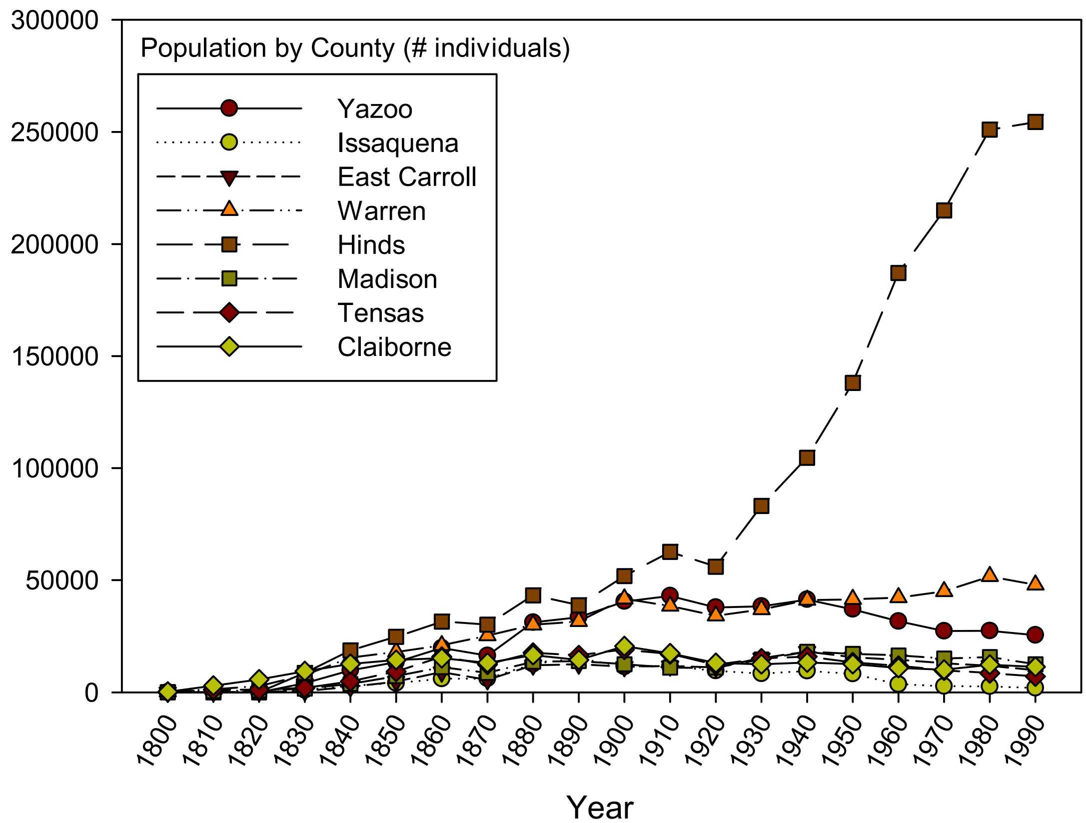
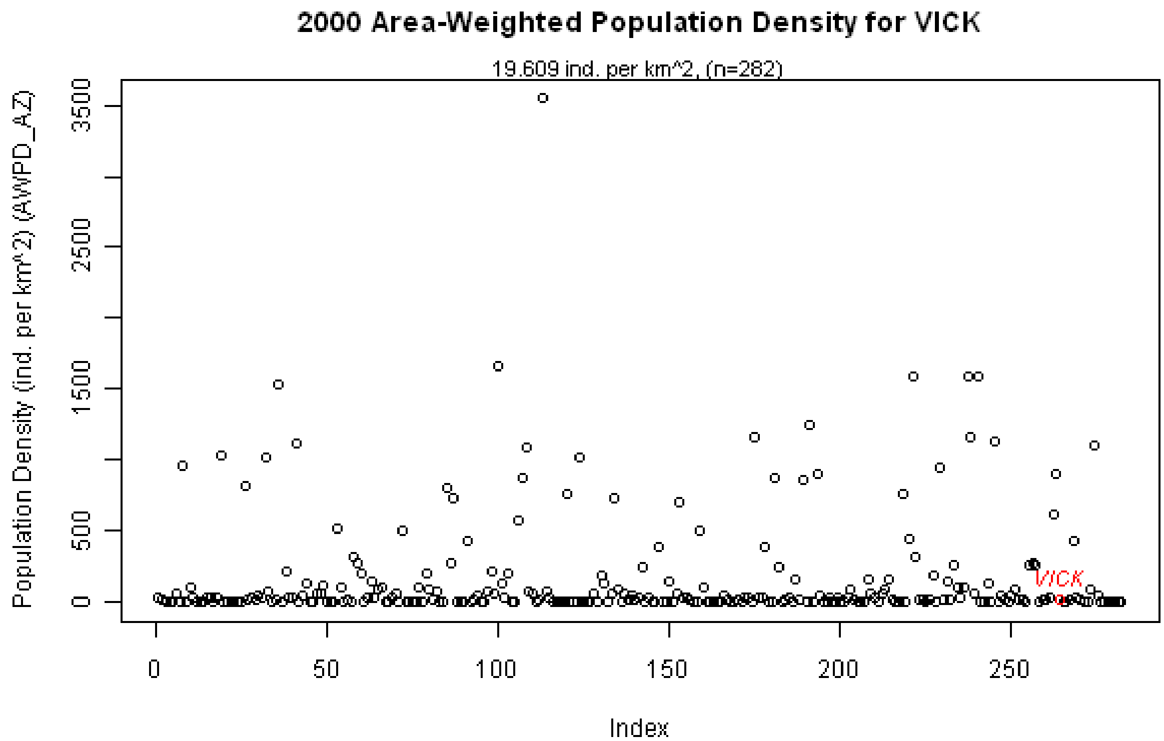


Figure 50. Population for counties within the VICK landscape for the period 1800 to 1990.



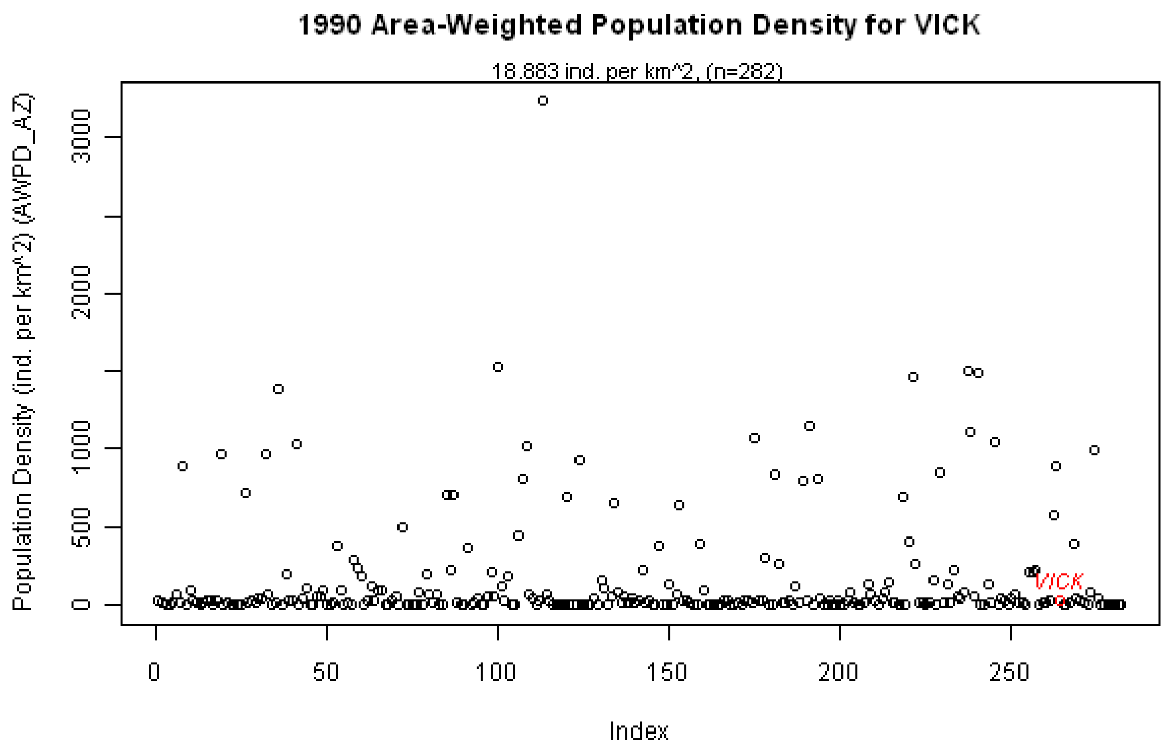


Figure 51. NPScape product showing population density of VICK in 1990 and 2000 relative to landscapes of other NPS units. The x-axis is an index placeholder representing other NPS units.

4.11.5 Pattern

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.

<u>Edge</u>

Edges are the boundary between two different patch types, and as certain landcover types are fragmented 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 increasing or decreasing 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 different organisms undergo increased rates of parasitism and predation along edge habitats and demonstrate greater rates of nest success in larger patches (Andrén and Angelstem 1988, Paton 1994, Donovan et al. 1997), though species responses to edge habitat may be positive, negative, or neutral and are highly variable (Ries and Sisk 2004, Gross et al. 2009).

<u>Patch Size</u>

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.

<u>Morphological Spatial Pattern Analysis (MSPA) at VICK</u>

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 52. 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 within the VICK landscape is highest within the park unit and decreases with 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 53 depicts proportion of core and edge area within the vicinity of VICK compared to other NPS units. Proportions of core forest (45.1%) and edge (7.8%) within the 30 km landscape both appear above average compared to other NPS units.

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

Pattern type	Definition	-30 km buffer- Area (km^2)	-30 km buffer- % Area	-3 km buffer- Area (km^2)	-3 km buffer- % Area	-No buffer- Area (km^2)	-No buffer- % Area
Core	Interior forest area not influenced by edge	1582.1	45.1	35.3	30.8	3.7	52.4
Islet	Patch too small to contain core area	17.3	0.5	1.2	1.0	0.1	1.0
Perforated	Edge (linear) internal to core forest type (30 km)	45.3	1.3	0.4	0.4	<0.1	0.1
Edge	Perimeter (linear) of forest patch (30 km)	272.7	7.8	13.1	11.5	1.3	18.3
Bridge	Non-core (linear) forest connecting disjunct core patches	42.5	1.2	1.5	1.3	0.1	2.0
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	46.1	1.3	2.4	2.1	0.1	1.7
Background	Non-forested area	1502.1	42.8	60.5	52.8	1.7	24.4

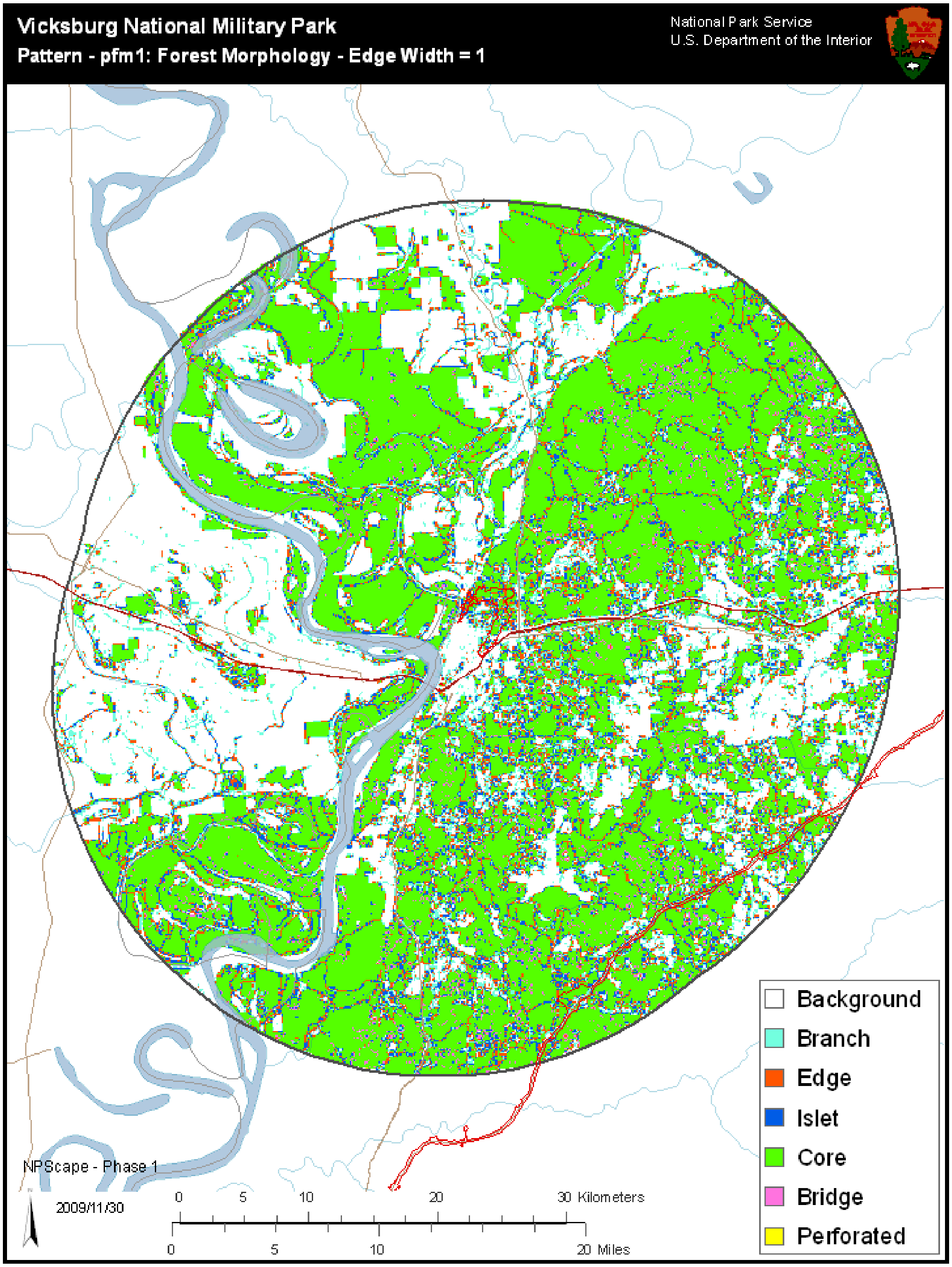
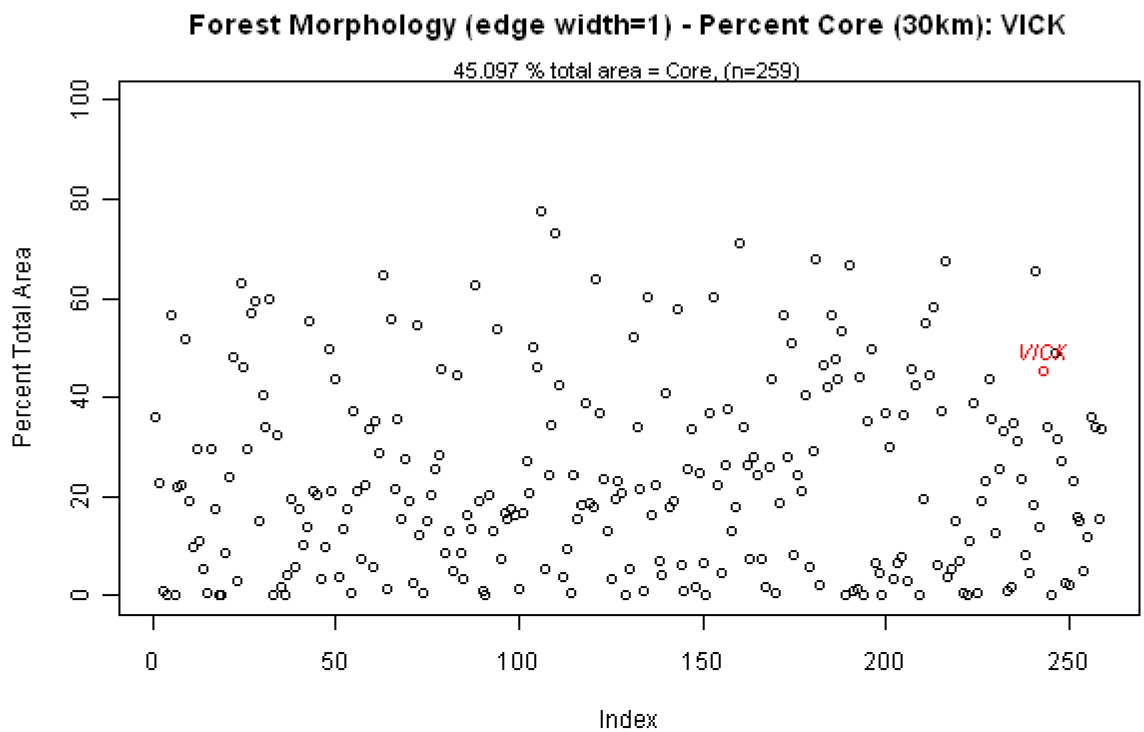


Figure 52. NPScape product showing forest morphology metrics for VICK with a 30 km buffer. Forest edge width is defined as 30 m.



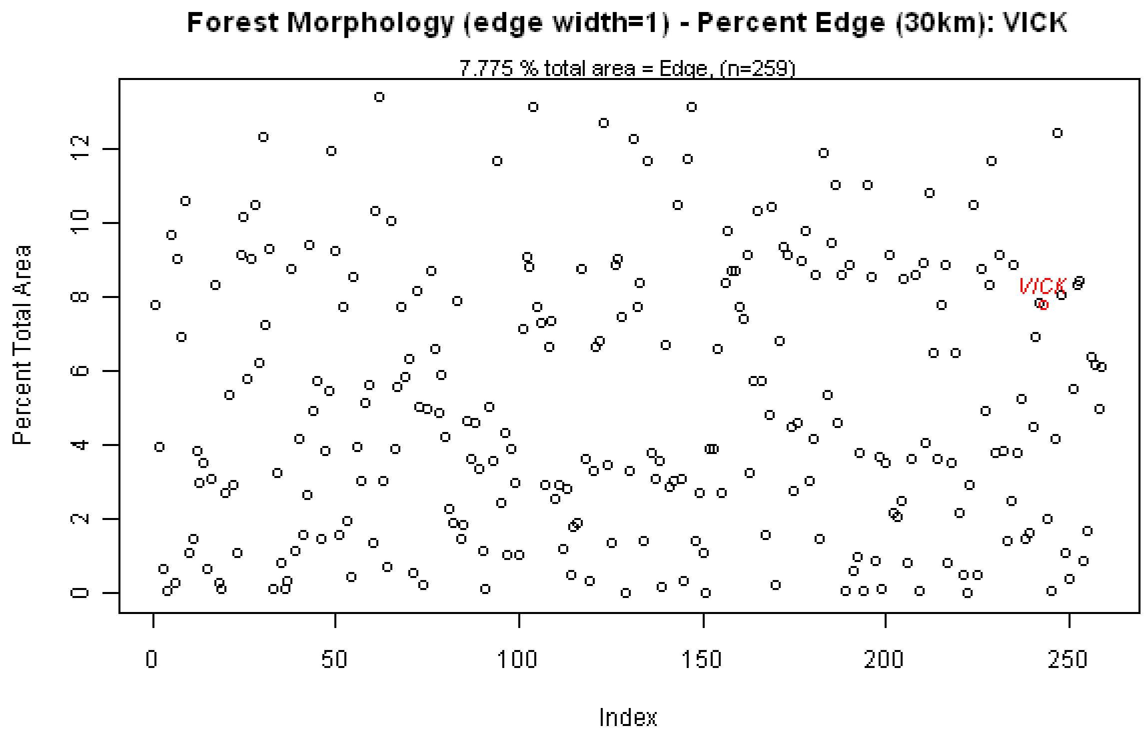


Figure 53. NPScape pattern product showing percent core (top) and percent edge (bottom) for VICK compared to other NPS units. The x-axis is a placeholder index representing other NPS units.

4.11.6 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 U.S., 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). GAP status levels 1 and 2 are commonly used to define protected areas, treating them separately from the 3 and 4 statuses that are typically reserved for "multiple-use" areas, such as those managed by the Bureau of Land Management (BLM) or the USFS.

Because there are no GAP status level 1 or 2 areas within the 30 km landscape, the NPScape product only shows areas classified as level 3. Other than VICK, these areas include the 53 km^2 Mahannah Wildlife Management Area (WMA) north of the park unit and a 10.5 km^2 section of the Natchez Trace Parkway to the southeast. Two tracts of private land totaling 33.3 km^2 are also classified as GAP status 3. Overall, there are 110 km^2 of class 3 protected area within the buffer representing approximately 3% of the landscape. Figure 54 shows land ownership within the vicinity of VICK, including the Mahannah WMA tract and Natchez Trace Parkway.

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).

<u>Conservation Risk Index</u>

Besides thresholds of protection, Gross et al. (2009) outline out a metric described by Hoekstra et al. (2005) called 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 converted area to protected area. 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,

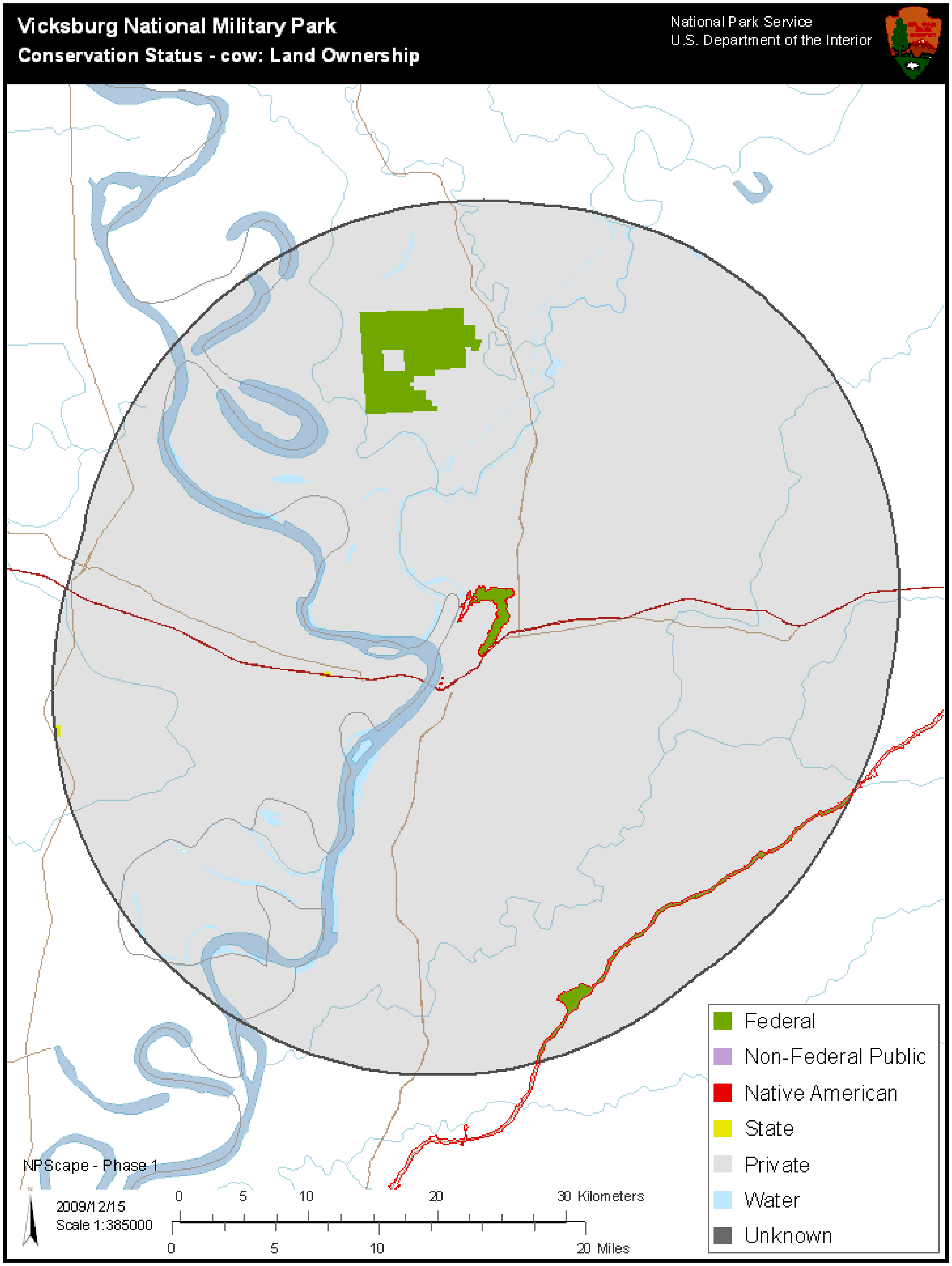


Figure 54. NPScape product depicting protected areas, as defined by the Gap Analysis Program (GAP), within a 30 km buffer of VICK (Gross et al. 2009). GAP-defined protected areas only include class 1 and 2 land units, and thus the classification of VICK as class 3 excludes it from the list of protected areas.

the CRI is still a useful reference for the VICK landscape, despite its much finer park-level scale of analysis.

According to Gross et al. (2009), the CRI is typically applied using GAP level-1 and 2 protected areas. In cases such as the VICK landscape where no areas are assigned level-1 and 2 protection, Gross et al. (2009) recommend assigning a low value as a placeholder for protected land, so in the case of VICK, the CRI would fall in the critically endangered class of greater than 25. According to NLCD (2006), LANDFIRE, and GAP data, respective proportions of converted land are 30.4%, 46.8%, and 35.0%. The mean conversion proportion is 37.4%, which would places it in the vulnerable class. Because of the disparity in class assignment due to differences in the CRI ratio and converted area proportions, a reasonable compromise would be to adopt the intermediate “endangered” classification. Including level-3 areas in the definition of protected lands, the CRI for the VICK landscape decreases to 11.9, which, taken alone, would place it in the “endangered” class. These class designations were originally developed by Hoekstra et al. (2005) to indicate conservation gaps in regional biomes where species and ecosystems are at risk. Although this analysis is presented at a much smaller scale, it is still relevant to indicate how vulnerable the landscape is to ecological decline.

4.11.7 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 conditions within individual park units. Because most of the park units lie within larger ecosystems and interact with 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 VICK 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 the 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	0.44	0.66	0.29
LANDFIRE	0.88	1.13	0.93
GAP	0.62	1.05	0.37
Average	**0.65**	**0.95**	**0.53**

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.

- Fortunately, average values of imperviousness at VICK are 1.4% within the park unit, which places it below the threshold for effects on stream quality. Due to the presence of highly erodible loess soils in the park, however, geomorphological are prevalent, especially around impervious areas. In fact, erosion remains one of the top management considerations for the park in areas with and without impervious structures.

- Imperviousness for successive buffer widths of 3 km and 30 km are respectively 8.0% and 0.6%. Both of these proportions are low, especially considering the high influence of the Vicksburg urban center at the 3 km extent (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 U.S. is 0.67 km km^{-2}.

- At VICK, road density increases from 2.8 km km^{-2} with no buffer, to 4.8 km km^{-2} at the 3 km buffer, and decreases to 1.8 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.

- Average distance to road measure is much lower within the park boundary—72 m—than for the 3 km (210 m) and 30 km (493 m) buffer widths.

- The effective mesh size (average roadless patch area) for VICK is 0 m, because there is no section of the park unit greater than 500 m from a road. The 3 km and 30 km buffer widths have respective roadless patch areas of 21.3 km^2 and 3.1 km^2.

- Although the distance to road and effective mesh size metrics suggest a significant road system within VICK, it is important to keep in mind that the park is a relatively small unit designed for slow driving tours. This metric is most useful for the buffer classes. Road density is the only metric that accounts for the size of the park unit, and thus indicates a result in between each of the buffer sizes. The distance to road metric is lowest for the park scale among the three scales of analyses, road density is in the middle, and average roadless patch is lowest for the park boundary scale. These metrics are highly influenced by the small area of the park unit.

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*).

- Along with the majority of NPS units, VICK falls within a very low population density class for the surrounding landscape (Figure 51). Within the 30 km buffer, average population density was 19.6 individuals per km^2 in 2000, which falls in the exurban development class outlined by Theobald (2005).

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

- Proportion developed area is overall higher at the 3 km buffer scale for all density classes at 13-24 units per km^2 and above. This is due to the dominance of the city of Vicksburg at that scale.

- Since 1950, private undeveloped land and the lowest density housing classes (<1.5 units km^{-2}) appear to show a decreasing trend within the 30 km buffer, although the trend is not significant. The remaining higher density classes, with the exception of the highest, do show significant increases over this time period.

Pattern

The NPScape product used the GUIDOS package to derive a set of eight metric classes for the landcover around VICK. 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, and highest at the 3 km scale, again reflecting the influence of the Vicksburg urban center.

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 VICK. 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 suggested minimum threshold of 41.6% ± 7.7 %.

An additional guideline for amount of 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.

- The PAD has assigned a rating of level-3 protection to VICK. This rating likely results from the primary purpose of the park as a historical and cultural memorial, and does not imply that natural resources are not a major park concern. The protected areas product created by NPScape only includes land units classified as either level-1 or level-2 protection, and thus they exclude VICK.

- No areas within the 30 km landscape are classified as level-1 or level-2 protection.

- There are 110 km^2 of level-3 protected area within the landscape, or roughly 3% of the landscape.

- The CRI ratio, according to Hoekstra et al. (2005), is incalculable due to the lack of level-1 or level-2 protected area within the landscape. As a result, the highest risk classification of critically endangered is assumed (Gross et al. 2009). The proportion of converted area, however, averages 37.4% among classifications, thereby placing it in the vulnerable CRI rating. The intermediate rating for CRI is endangered.

4.11.8 Landscape Conclusions

Adjacent land use for VICK was assessed using NPScape analysis products supplied by the National Park Service. NPScape analyses explored landscape changes and conditions that were expected to affect natural resources within VICK. These analyses were conducted within VICK's boundaries and at two broader scales (3 km and 30 km buffers around the park). Five general categories of NPScape analyses were used in this NRCA. These were: 1) landcover proportion, 2) roads, 3) population and housing, 4) landcover pattern and, 5) conservation status. Multiple metrics were presented and discussed within each of these categories. Combined, these findings provide an overall view of key landscape attributes of VICK and the immediately surrounding area. Several aspects of adjacent land use are considered capable of supporting a functioning ecosystem with high quality natural resources. Conversely, several landscape attributes indicate increasing pressures from urbanization and human development that are expected to negatively impact the park's natural resources. These points are discussed in more detail below.

Low impervious landcover in and around the park, relatively low population density in the surrounding area, and relatively high core forest area within the park were positive indicators of high quality landscape for VICK. Proportions of impervious landcover were very low within VICK and within the 30 km buffer around VICK. The proportion of impervious surface was greater within the 3 km buffer, due to the influence of the town of Vicksburg. However, proportion of impervious surface within the 3 km buffer was lower than published values at which the most severe negative impacts are expected to natural resources (Klein 1979, Wang et al. 2001). Human population density within the 30 km buffer assigned to a lower tier of development (Theobald 2005), mainly due to the presence of agricultural land and undeveloped riverine wetlands in the Mississippi floodplain. Although population density is best considered in combination with other ecologically relevant metrics, low densities within the 30 km buffer suggest that future negative impacts from development and urbanization may be low relative to other urban parks. VICK had a high proportion of core forest area relative to the proportion of core forest in the surrounding buffers. This suggests that the park may provide an important refuge in the region for organisms that require or prefer core forest habitat.

High levels of urbanization within the 3 km buffer, regional increases in higher density housing classes, and the relatively small proportion of protected land within the 30 km buffer were indicators of poor adjacent landscape quality for VICK. Close proximity to the town of Vicksburg has resulted in high proportions of developed land, high rates of conversion from natural to developed land, and high road density within the 3 km buffer around the park. These common indicators of urbanization have been shown to negatively affect ecosystem function and natural plant and animal assemblages. Although the human population density in the 30 km buffer region was low, high density housing in the exurban and suburban classes has significantly increased since 1950. This increase is generally consistent with findings throughout the U.S and is expected to negatively influence natural resources (Kerr and Curie 1995). Areas protected by legislation that promoted high biodiversity were rare within 30 km buffer of VICK and the most highly ranked classes of protected lands did not exist. While the absence of these protected land classes does not imply that protected land was non-existent in the VICK region, it does indicate a potentially high risk of biodiversity loss due to land conversion (Wilcove et al. 1998).

In summary, landscape metrics for the region within 30 km of the park's boundaries suggested both positive and negative effects to the quality of VICK's natural resources. The park is located in an urban area within a sparsely populated rural and agricultural region. Within its urban setting, VICK provides an important habitat refuge for a variety of flora and fauna. However, human density is increasing across the region, similarly to population increases throughout the country. Increasing human density is known to negatively impact natural communities and ecosystem function (e.g., Merenlender et al. 2009). Because a relatively small proportion of the surrounding landscape sustains strong legislative protection, the potential for biodiversity loss is significant.

Thus, 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). Although the overall lack of level-1 and level-2 protected area leaves the landscape susceptible to landscape conversion, the recent NLCD change layer indicates few shifts have occurred between the years 2001 and 2006. As a result, this condition is assigned a stable trend (Table 43).

The data quality is overall quite good (Table 43), fulfilling five of six data quality checks. The NPScape data products provide a comprehensive analysis at a landscape scale using a variety of relevant metrics. The NPScape program is divided into two phases. The first phase, on which this assessment is based, was completed in 2009 using the data sources listed in

Table 44. With the exception of two data sources—the U.S. Census TIGER Line Files and LANDFIRE vegetation landcover—both updated in 2008, the remaining data sources are from 2006 and earlier. The second phase of NPScape is scheduled for completion in the near future, and will likely update some or most of these data sources. For now, however, the temporal currency data quality check is withheld from the condition ranking.

Table 43. The condition status for landscape change at VICK was fair, qualified with a stable trend. The data quality for this ranking was good, attaining five out of six data quality checks.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Adjacent Land Use		Relevancy ✓	Proximity ✓	Currency
		Sufficiency ✓	Coverage ✓	Coverage ✓
		5 of 6: Good		

Table 44. List of NPScape metric categories and data source currency.

Category	Data Source	Year
Landcover	• National Landcover Dataset (NLCD) • Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) • Gap Analysis Program (GAP)	• 2001 and 2006 • 2008 • 1999-2001
Roads	• Tele Atlas streets Database • U.S. Census Topologically Integrated Geographic Encoding and Referencing (TIGER) Line Files	• 2003 • 2008
Population and Housing	• U.S. Census Bureau • Waisanen and Bliss • Spatially Explicit Regional Growth Model (SERGoM v 3) • SILVIS Model	• 2000 • 2002 • 2000 and 2006 • 1990 and 2000
Pattern	• National Landcover Dataset (NLCD)	• 2001
Conservation Status	• Protected Areas Database (PAD)	• 2006

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Chapter 5 Discussion

5.1 Summary

Vicksburg National Military Park supports a variety of valuable natural resources. VICK is a relatively small park surrounded by urban development, and historically experienced significant degradations to its natural environment. This history of degradation is not unique to the park, but is generally representative of the entire region. The setting and history of the park influence the current natural resource conditions. The high level of protection and management enjoyed by VICK has improved the natural resource setting in the park, and makes VICK an important refuge of biodiversity in the region.

Based on a review of available ecological information at VICK, we addressed the current condition of 11 natural resource attributes in the park. All attributes were assessed at the park level. Overall, natural resource conditions at VICK were ranked as 27.3% good, 36.3% fair, and 18.2% poor. The remaining 18.2% were not ranked.

Summarized into broad categories the percentages of condition rankings were:

Air and Climate (two attributes)—50% Fair, 50% Not ranked
Water (one attribute)—100% Good
Biological Integrity (seven attributes)—29% Good, 43% Fair, 14% Poor, 14% Not Ranked
Landscapes (one attribute)—100% Fair

We assigned trends to natural resource attribute conditions where appropriate. Because long-term data were relatively uncommon, trends were not assessed for most attributes. Overall, natural resource condition trends in VICK were 18% improving, and 18% stable. The remaining 64% were not assigned a trend.

Summarized into broad categories the condition trend assignments were:

Air and Climate (two attributes)—50% Improving, 50% Not ranked
Water (one attribute)—100% Stable
Biological Integrity (seven attributes)—14% Improving, 86% Not ranked
Landscapes (one attribute)—100% Stable

We also characterized the quality of data used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Data quality was assessed for all instances where data existed. Therefore, all individual condition assessments were assigned a data quality ranking, regardless of whether the attribute was assigned a condition rank. Overall, natural resource attribute data quality was ranked 36.3% very good, 27.3% good, 27.3% marginal, and 9.1% poor.

Summarized into broad categories the data quality rankings were:

Air and Climate (two attributes)—50% Very Good, 50% Good
Water (one attribute)—100% Very Good
Biological Integrity (seven attributes)—29% Very Good, 14% Good, 43% Marginal, 14% Poor

Landscapes (one attribute)—100% Good

5.2 Discussion by Category

This project represents the first iteration in the development of a comprehensive natural resource monitoring program at VICK. 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. Natural resources at VICK were chosen based on data availability, park-level importance, and vital sign status. The level of data completeness varied greatly among natural resource categories. Where appropriate, suggestions are offered to improve natural resource datasets.

5.2.1 Air and Climate

Atmospheric deposition is a regional concern, and sources of pollution exist near the park. Wet deposition of nitrogen oxides and sulfur dioxides was relatively high at regional monitoring stations, and mean values for the last five years were above the NPS ARD threshold for posing threats to ecosystem health. Data suggest that deposition rates are improving the region. Precipitation, temperature, and the occurrence of intense storm events were stable over a long time period for the VICK region. Managing regional air pollution sources and climate conditions are outside the scope of the park's management, although park management may work to mitigate the impacts of these large-scale forces. No major data gaps were identified for these resources, although wet deposition may vary at a relatively fine scale, suggesting that monitoring within the park may provide useful information not available from regional stations.

5.2.2 Water Quality

No major water quality problems were noted for the park during four years of sampling. Some elevated turbidity values not obviously associated with major rain events may have resulted from activities within the Durden Creek watershed. The current water quality monitoring efforts in the park provide excellent current data. It is recommended that water samples are collected at a consistent time of day to avoid unnecessary variability in pH.

5.2.3 Biological Integrity

The vegetation and vertebrate animal assemblages in VICK vary considerably in condition and in the quality of data available. The most important negative impacts to native species in VICK result primarily from non-native species. Exotic, invasive, and range-expanding plants and animals are relatively common in the park, and this situation is expected given park's urban setting and the prevalence of these species in the region. Generally, the park supports a number of native species and probably provides an important refuge for native plants and animals within the broad region. VICK enjoys a higher level of natural resource protection and active management than the surrounding landscape, and is thus likely to provide a positive regional example of biodiversity.

<u>Flora</u>

The park supports several examples of unique regional vegetation and vegetation assemblages. VICK's loess bluff hardwood forests are among the oldest and most relatively intact examples of this forest type. The imperiled prairie nymph is abundant in the park's grassland areas, and appears to flourish in park habitat. Exotic plants are a major management issue in VICK, and over 25% of the known plant species in the park are invasive. These species are a threat to native plant species and decrease the quality of wildlife habitats in the park. VICK has an active exotic plant management program, and has made significant positive impacts on floral communities in recent years. Although invasive plants cannot realistically be eliminated from the VICK landscape, the knowledge of park managers and the proactive approach to this issue suggests that VICK vegetation complexes will improve in coming years, especially relative to surrounding landscapes that do not benefit from this level of management. Generally, park data on vegetation is very good. The park would benefit from updated maps of exotic plant treatment areas for species other than kudzu. Another useful data product would be distributional maps of rare plant species other than the prairie nymph.

Fauna

VICK supports a regionally typical vertebrate animal fauna, and represents a refuge for animal assemblages in the region. The park is recognized as regionally outstanding bird habitat, providing habitat for many breeding and migrating species of conservation concern. The park provides a good example of regionally-expected bat diversity. As with plants, the most important threats to native animals appear to be non-native species. Invasive species of fish and feral hogs are known to impact native plant and animal assemblages and have been addressed through park management. As expected for an urban setting, feral or free-ranging domestic pets are relatively common in the park. Excellent data from ongoing monitoring are available for park birds, and the mammal inventory provided a comprehensive understanding of mammal diversity. Fish data were relatively old, and an updated inventory of fish assemblages following invasive species removals would greatly benefit park managers. An updated inventory of park reptiles and amphibians would greatly increase the understanding of park herpetofauna, although ongoing GULN monitoring efforts are adding significantly to the knowledge of these fauna in the park.

5.2.4 Landscape Dynamics

Because of the park's urban setting, the immediately surrounding landscapes are subjected to a variety of negative anthropogenic natural resource impacts. As such, VICK represents a large tract of mostly forested land, making it very unique within the nearby region. In this respect, the park is an outstanding resource. However, the increasing human impacts in the surrounding region inevitably cause some negative impacts on park natural resources. Most of these surrounding influences are beyond park control. The NPScape data products available for the park are very useful in providing information about the park's region. As newer products become available, changes and trends in landscape will be become more apparent.

Appendix A. List of Initial Scoping Meeting Attendees

Vicksburg National Military Park:

Michael Madell, Superintendent
Virginia DuBowy, Natural Resources Program Manager
Melissa Perez, Education Specialist

Gulf Coast Inventory and Monitoring Network:

Robert Woodman, Ecologist

University of Georgia:

Nathan Nibbelink, Principal Investigator
Michael 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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