National Park Service
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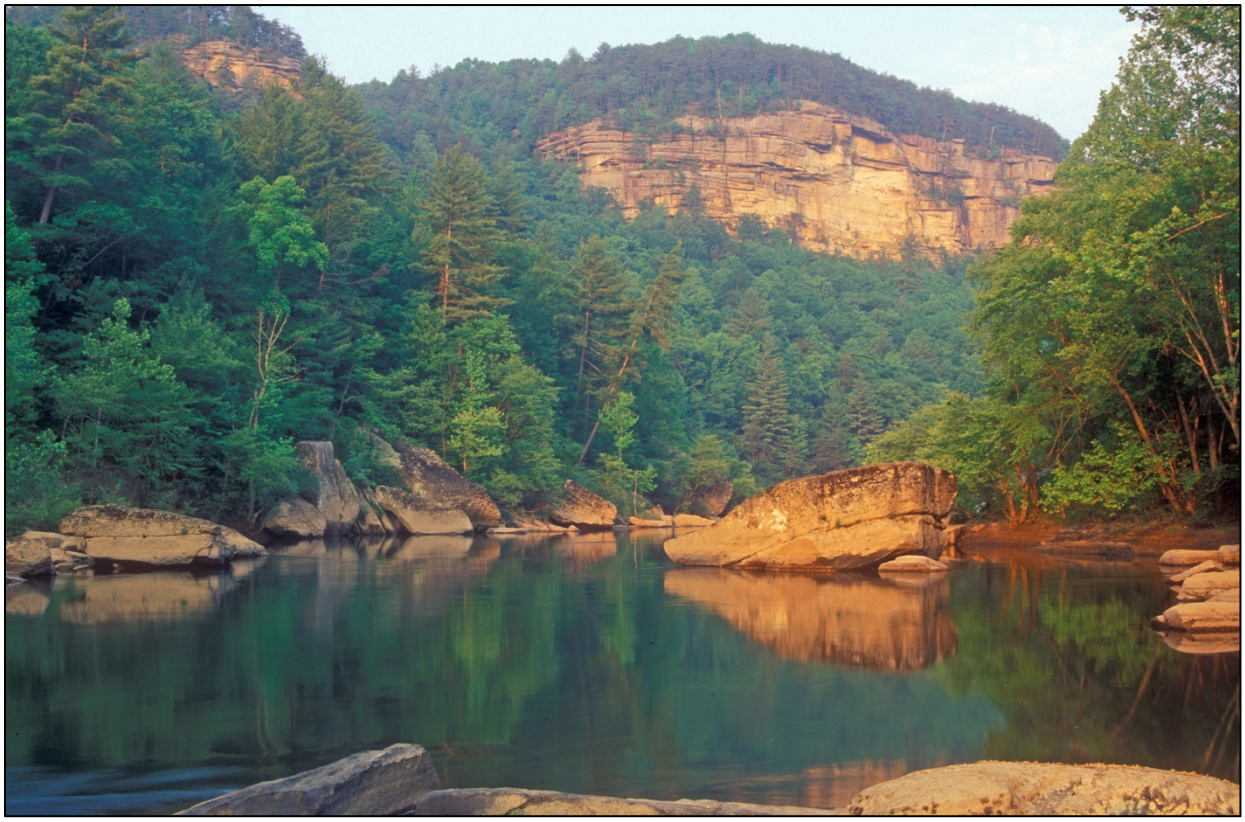
Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Big South Fork National River and Recreation Area

Natural Resource Report NPS/BISO/NRR—2013/619



ON THE COVER
Big South Fork River
Photograph by: C. Summers

Natural Resource Condition Assessment for Big South Fork National River and Recreation Area

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Luke Worsham, Gary Sundin, Nathan P. Nibbelink, Michael T. Mengak, Gary Grossman

Warnell School of Forestry and Natural Resources
University of Georgia
180 E. Green St.
Athens, GA 30602

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Executive Summary

This report provides a comprehensive assessment of the state of natural resources at Big South Fork National River and Recreation Area (BISO). It also addresses sets of stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Appalachian Highlands Inventory and Monitoring (I&M) Network (APHN), as well as on attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air quality, atmospheric deposition, weather and climate, water quality, vegetation, animal communities, and landscape dynamics.

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

Big South Fork National River and Recreation Area is a remote region of natural splendor. The area encompasses over 50,000 ha and includes a number of stream systems, all of which are tributaries of the Big South Fork Cumberland River (BSF). Park boundaries contain over 760 km of free flowing streams and rivers ranging from first to seventh order, and protect the entire length of the naturally free-flowing BSF. The BSF flows north through a deep gorge to join the Cumberland River in the artificially impounded Lake Cumberland. This impoundment physically affects the riverine habitat within BISO, creating a more lentic habitat in the northern reaches of the river within the park.

BISO protects habitats that support rich assemblages of vertebrate and invertebrate animals and plants. The Big South Fork River is a globally-important hotspot of freshwater mussel diversity, and protects a number of federally-listed mussel species. Around 40 mussel species may exist in the park, including 13 species threatened or endangered at the state or federal level. A recent comprehensive inventory of aquatic macroinvertebrates reported at least 414 taxa, including two species not previously described. The Cumberland River drainage supports diverse assemblages of native fishes, and BISO contains around 90 fish species including two federally-listed species and other species of concern. BISO bird assemblages consist largely of native species of neotropical migrants specializing in mature forest habitat. Recent researchers have reliably reported 147 bird species, including a number of species of concern. At least 173 bird species have been historically reported from the park. A recent inventory reported 47 mammal species, including a federally listed bat. The park supports a population of black bears and provides habitat for elk. Both species require relatively large tracts of naturalistic habitat. Recent inventory efforts reported 57 species of reptiles and amphibians, including state-listed species and species of conservation concern. A total of 1100 vascular plants have been documented in the park and rare vegetation types such as river scour prairies and clifftop sandstone and rockhouse communities host a variety of sensitive plant species.

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

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

Atmospheric pollutants – Although deposition near BISO is slightly less than average for the eastern US, it is still high enough to cause damage to terrestrial and aquatic systems. Elevated levels of particulate matter can indicate health dangers and result in degraded visibility.

Decreased water quality – This is possibly the most pertinent natural resource issue at BISO. The Cumberland Plateau is an area rich in oil, gas, and coal deposits. The BSF watershed has a long history of resource extraction, particularly coal mining. Coal, gas, and oil are currently extracted in watersheds that drain into the park. These processes result in pollution of streams through sedimentation, acid mine drainage, and brine loading, all of which contribute to the debilitation of water quality and aquatic habitat. Fishes, freshwater mussels, and aquatic insects are vulnerable to this pollution, and assemblages of these aquatic species have been negatively impacted in the park. However, evidence suggests that aquatic vertebrate and invertebrate assemblages are improving from historical conditions in some park watersheds. A notable feature of this issue is the close proximity of heavily mined areas to unpolluted stream systems of high quality. The watershed central to BISO is highly impacted in some areas, resulting in contaminated streams such as Bear Creek and Roaring Paunch Creek that have been repeatedly included on the Environmental Protection Agency's list of 303(d) impaired waters. In the same watershed, streams like Station Camp Creek and No Business Creek flow undisturbed into Big South Fork. Even after extractive operations have ceased, residual influences such as refuse piles can result in acid mine drainage for many years. Rock Creek, one of the most severely polluted systems as the result of mining in its lower reaches, has undergone major reclamation but still shows signs of impairment. The park has worked to close many abandoned mines, though oil and gas extraction permits are still granted in upland areas of BISO. Mineral extraction is also permitted under certain circumstances. However, the most serious threats to the aquatic resources in the park are from extraction activities occurring just at its periphery. Although for the most part these areas are out of control of the park, close monitoring of impacted systems will help target areas for reclamation and protection.

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. This is a particular issue in rare community types such as cobble bars.

Exotic/range-expanding/parasitic animal species – The presence and proliferation of exotic animal species, species outside of their native range, and range-expanding parasitic species can cause loss of native animal and plant diversity. Non-native fishes, birds, mammals, and freshwater mussels were reported from BISO in recent inventory efforts. However, park animal assemblages examined in this report are dominated by native species.

Animal disease – Several threats or potential threats to vertebrate populations are recognized for the park. The chytrid fungus *Batrachochytrium dendrobatidis* and viruses of the genus *Ranavirus* are known to infect amphibian populations in the southeast with results ranging from sub-clinical infection to local population failure. Neither of these had been discovered in BISO

at the time of publication. White-nosed syndrome (WNS), a disease of hibernating bats caused by the *Geomyces destructans* fungus, is an emerging threat in the region, causing catastrophic declines in some hibernating populations. Although it had not been reported from BISO at the time of publication, it affects at least seven species of bat reported from the park, and the threat to park bats is acute. Several species present in BISO may become federally listed as a result of the threat from this disease.

Insect pests – Insect pests can cause loss of native plant diversity and negatively impact ecosystems and wildlife habitat. Presently, hemlock woolly adelgid has been identified in the northern portion of the park.

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

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

Fourteen ecological attributes were assessed for this report. Three of the aquatic attributes—water quality, fish assemblages, and aquatic macroinvertebrate assemblages—were spatially subdivided, assessed, and reported in 14 small areas based on USGS hydrological boundaries. Based on the number of rankings falling within each condition category (for attributes assessed at the park level), and the proportion of rankings in each category (for attributes assessed by reporting area), the overall summary of natural resource condition assessments is as follows: 48% good, 39% fair, 3% poor, and 10% not ranked. None of the attributes assessed for the entire park area received a poor condition rating. Assessment method and data quality were both highly variable among assessed attributes, and therefore condition rankings are not necessarily directly comparable. Additional protocols are currently underway for landscape dynamics monitoring (e.g. NPScape), which will aid future condition assessment efforts within APHN parks.

Acknowledgements

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Acronyms and Abbreviations

ANC - Acid Neutralizing Capacity
APHN – Appalachian Highlands Network
ARD - Air Resources Division (NPS)
AVIP - Avian Conservation Implementation Plan
BBS - Breeding Bird Survey
BCI - Bird Community Index
BI – Biotic Index
BISO – Big South Fork National River and Recreation Area
BOD - Biochemical Oxygen Demand
BSF – Big South Fork of the Cumberland River
CAA – Clean Air Act
CASTNET - Clean Air Status and Trends Network
COOP - Cooperative Observer Program
CRI – Conservation Risk Index
CRMS - Center for Remote Sensing and Mapping Science (UGA Department of Geography)
CUGA - Cumberland Gap National Historical Park
CUPN – Cumberland Piedmont Monitoring Network
CWCS – Comprehensive Wildlife Conservation Strategies
DAQ – Division of Air Quality
DO - Dissolved Oxygen
DWS – Domestic Water Supply
EMF - Ecological Monitoring Framework
EPA - Environmental Protection Agency
EPT – Ephemeroptera, Plecoptera, Trichoptera
EVT – Existing Vegetation Type
GRSM - Great Smoky Mountains National Park
HUC - Hydrologic Unit Code
HWA – Hemlock Woolly Adelgid
IBI – Index of Biotic Integrity
IMPROVE – Interagency Monitoring of Protected Visual Environments
I&M - Inventory and Monitoring
IUCN – International Union for Conservation of Nature
KDFWR – Kentucky Department of Fish and Wildlife Resources
KIBI – Kentucky Index of Biotic Integrity
MDN – Mercury Deposition Network
MRDS – Mineral Resources Data System
MRLC - Multi-Resolution Land Characteristics Consortium
MSPA – Morphological Spatial Pattern Analysis
NAAQS - National Ambient Air Quality Standards
NADP – National Atmospheric Deposition Program
NHP – National Historical Park
NLCD - National Landcover Dataset
NPS - National Park Service
NRCA - Natural Resource Condition Assessment

NRCS - Natural Resource Conservation Service
NRRA – National River and Recreation Area
NTU - Nephelometric Turbidity Unit
NWS - National Weather Service
OBED – Obed Wild and Scenic River
ONRW – Outstanding Natural Resource Water
PAD – Protected Areas Database
PIF - Partners in Flight
POMS - Portable Ozone Monitoring Station
PPM - Parts per million
RAWS - Remote Automated Weather Station
RNA – Research Natural Area
SDI – Simpson's Diversity Index
SNA – State Natural Area
TDEC – Tennessee Department of Environment and Conservation
TMDL – Total Maximum Daily Load
TWC – The Weather Channel
UGA - University of Georgia
USACE – US Army Corps of Engineers
USFWS – US Fish and Wildlife Service
USGS - United States Geological Survey
VOC - Volatile Organic Compounds
WAQ – Warm Water Aquatic Habitat
WMA – Wildlife Management Area
WNS – White-nose syndrome

Chapter 1 NRCA Background Information

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

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

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

NRCAs Strive to Provide…

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

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

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

[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.

beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

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

Important NRCA Success Factors

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

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

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

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

[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.

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.

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

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

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

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

[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

Big South Fork National River and Recreation Area was designated in 1974 as the first park unit to contain both a National River and a National Recreation Area designation. The unit serves primarily to preserve the region associated with the Big South Fork of the Cumberland River and its associated tributaries. This goal of the park is outlined as follows by the enabling legislation:

> [Big South Fork NRRA is established] *for the purposes of conserving and interpreting an area containing unique cultural, historic, geologic, fish and wildlife, archeologic, scenic, and recreational values, preserving as a natural, free-flowing stream the Big South Fork of the Cumberland River, major portions of its Clear Fork and New River stems, and portions of their various tributaries for the benefit and enjoyment of present and future generations, the preservation of the natural integrity of the scenic gorges and valleys, and the development of the area's potential for healthful outdoor recreation.*

As a recreational area, Big South Fork is one of the few NPS units that allow hunting, fishing, and trapping in accordance with the laws of the respective state in which they are located. The park also maintains over 480 km (300 miles) of trails, designated for multiple uses including biking, hiking, or horseback riding (NPS 2008a).

2.1.2 Geographic Setting

Big South Fork National River and Recreation Area (BISO) is located on the border of Tennessee (TN) and Kentucky (KY), approximately 64 km (40 miles) northeast of Knoxville and west of Cumberland Gap National Historical Park (NHP). Encompassing over 50,000 hectares, the park centerpiece is the Big South Fork of the Cumberland River, a prominent recreation destination known for its fishing and whitewater opportunities. Several of its tributaries are also included in the protected area, a few of which, like Rock Creek, are also recognized regionally for exceptional water quality (Figure 1). The Big South Fork is also designated as Outstanding National Resource Water by the state of Tennessee.

The park unit stretches 53 km (33 miles) long north to south and 31 km (19 miles) wide east to west; its width tapers towards the northern and southern extremes. The park unit overlaps Fentress, Scott, Pickett, and Morgan counties in Tennessee, and McCreary County in Kentucky. Interstate-75 is about 24 km (15 miles) east of the park, while US Hwy-27 and State Hwy-154 traverse near the east and west boundaries of the park, respectively. The park unit also abuts Pickett State Park and Forest on its western boundary in Tennessee, which together comprise 7680 ha (18980 acres) and completely contain the 1,200 ha (2965 acres) Scott State Forest in the south-central portion—mostly used for white pine tree improvement studies. The northern Kentucky section of Big South Fork NRRA is located adjacent to the half-million hectare Daniel Boone National Forest (NF), which stretches approximately 225 km (140 miles) north from the BISO boundary, ending some 24 km short of the Ohio border. In addition, there are two state natural areas (SNA) designated by the Tennessee Department of Environment and Conservation but located in the park unit. The first, Twin Arches SNA, is about 600 ha (1,483 acres) and located around the headwaters of Middle Creek near Pickett State Park. It contains the Twin

Arches formation—a unique natural bridge formation that is one of the largest of its kind (Figure 2). The other, Honey Creek SNA, is 44 ha (109 acres) and located in the southern part of Big South Fork.

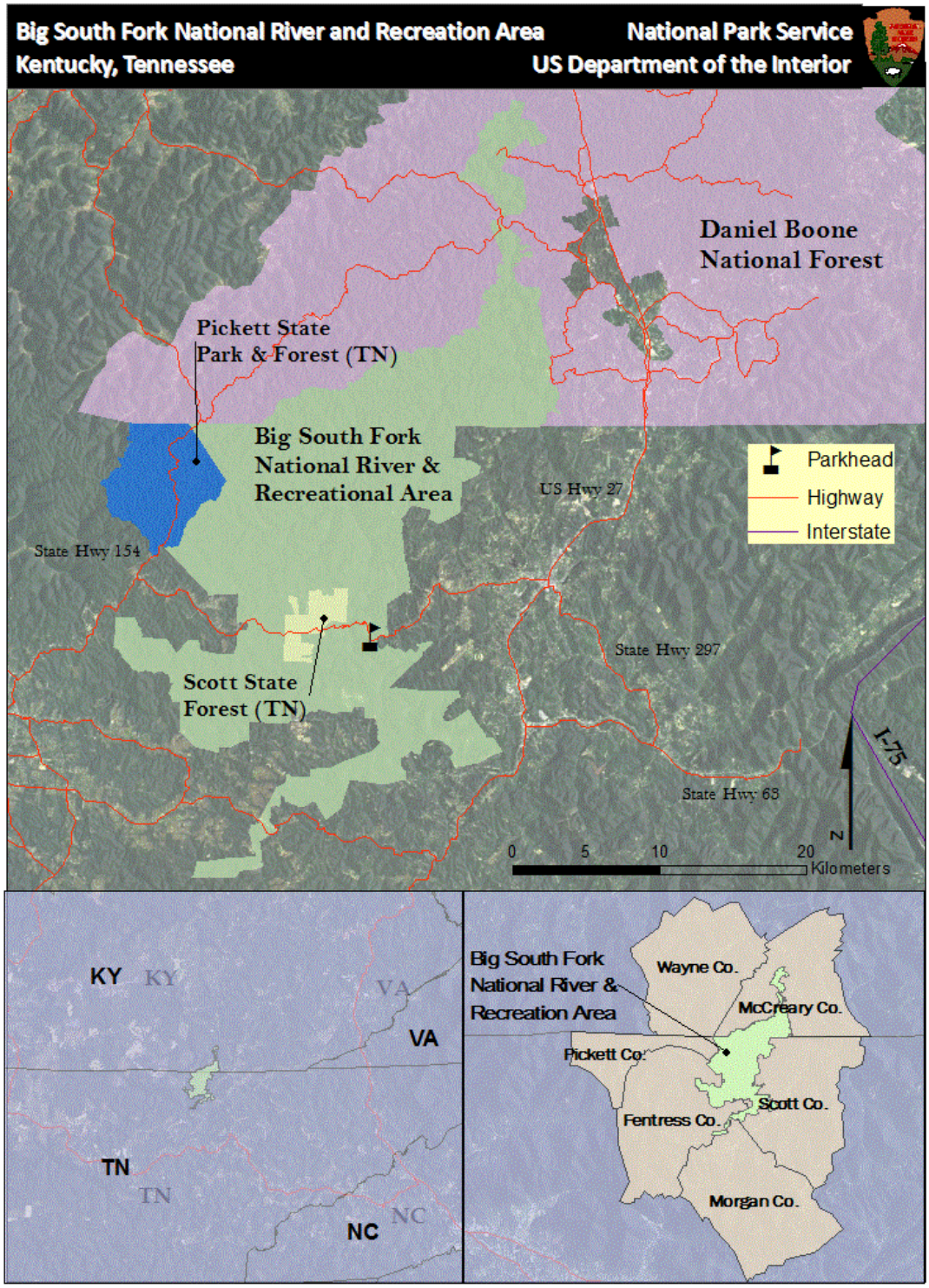

Figure 1. Big South Fork NRRA, encompassing 50,586 ha (125,000 acres) and 5 separate counties, is located on the border of Kentucky and Tennessee.

Figure 2. The North Arch, one of the Twin Arches, is 19 m (62 ft) tall and spans 28 m (92 ft).

2.1.3 Park History

Big South Fork has a rich historical record of human habitation and use stretching back to Paleo-Indian inhabitants of the area. In fact, the park contains over 1,500 identified archaeological sites, which are estimated to be only 20% of all the sites within the park (NPS 2008a). Many of the early inhabitants were drawn to the Cumberland Plateau area by the diverse flora and fauna and used the numerous rockshelters as homes or shelter. As a result, the rockshelters often harbor relics of these populations that offer insight into their diet, habits, and culture. By 1000 AD, several of the game animal populations had decreased in numbers, and the Native Americans began to travel and settle in more fertile river bottoms, such as those of the Tennessee and Cumberland. During the 18th century, Euro-American settlers from Virginia and North

Carolina began to farm much of the area along the Big South Fork, though much of the land was difficult to cultivate (NPS 2008a).

Nitre mining was also frequent in the area, evidence of which is still apparent today in the rockshelters. During the first part of the 20th century, logging and coal-mining practices spread through the region and paved the way for many new homesteads and isolated towns. Many of these settlements were abandoned after World War II. One of these abandoned populations, the Blue Heron mining community, still operates as a visitor destination in the park. Some of the land within the park is still tapped for oil and gas resources (NPS undated).

2.1.4 Climate, Soils, and Geology

Weather in the Big South Fork region is typically hot and humid during the summers, and cold and damp during the winters. Although annual precipitation varies widely throughout the park, the area regularly receives a high amount of rain. May is typically the wettest month and October the driest, with an annual average precipitation of 56 cm. Average temperatures range from -4 °C (25 °F) in January to 29 °C (84 °F) in July (TWC 2008).

Like the Cumberland Gap region, many of the popular features of Big South Fork NRRA are related to its geologic history. Big South Fork NRRA lies on the Cumberland Plateau region of eastern Kentucky and Tennessee, where much of the rock is comprised of quartz-rich and resistant sandstone of the Rockcastle Conglomerate. Underlying this is the Fentress Formation, which contains siltstone, shale, and coal (Miller 2006). Most of the coal extracted in Tennessee and Kentucky is from the Cumberland Plateau, and the erosion of the less resistant features beneath the conglomerate has resulted in several unique geologic formations throughout the park including mesas, chimneys (stone pillars), natural arches, cliffs, and rockshelters (NPS undated). In fact, this region contains the highest concentration of natural arches in the eastern US, the largest of which are the Twin Arches, which occur on the ridge of a major drainage divide (Figure 2). The river valleys occur in narrow gorges, often surrounded by steep talus slopes and sheer bluffs. Elevation within the park ranges from 240 to 550m, while cliff heights can vary dramatically (NPS 2008a).

Below the overlying conglomerate and sandstone layers is an older stratum of limestone that contains several rich deposits of oil and gas. In the 1970s and 1980s as a result of this discovery, a drilling boom spread throughout Scott County, and eventually over 300 wells were located inside the park, some of which are still active (Spradlin 2008).

Soil maps from the NRCS show that Gilpin soils and complexes are most common throughout the park unit, covering almost 25,000 ha, or about half the park. Gilpin complexes, which comprise over 25,000 ha or 50% of the park, primarily occupy the lower floodplain areas around the main river channels. Gilpin soils are moderately deep and well-drained, and formed in residuum of interbedded shale, siltstone, or sandstone (NRCS 2010). Lily soils, another predominant complex, are typically moderately deep and well-drained from weathered sandstone, often occurring on hillsides or ridgetops. Specifically, most of the park soils are in the Gilpin – Bouldin complex, though there is also a Lily – Gilpin complex. A detailed description of soils at BISO is provided in Appendix B.

2.1.5 Hydrology

Big South Fork NRRA falls completely within the South Fork Cumberland cataloging unit (HUC 05130104), which in turn is part of the Upper Cumberland accounting unit (HUC 051301) (Figure 3). The main river, and also the main feature of the park, is the Big South Fork of the Cumberland River, which starts in the southeastern section of the park at the confluence of the Clear Fork and New River and stretches to the northern tip of the park—a river-length distance of about 130 km (80 miles). Around two-thirds of the park falls within the Big South Fork drainage basin, which altogether comprises 82,000 ha. The remainder occurs inside the drainages of the Laurel Fork (17%; 22,700 ha total area), Clear Fork (7%; 46,700 ha total area), Lake Cumberland (4%; 47,200 ha total area), and New River (3%, 102,600 ha total area) watersheds.

Both Tennessee and Kentucky have monitoring programs in effect for stream water quality via anti- and non-degradation policies, and each state includes Big South Fork River in the Outstanding Natural Resource Waters (ONRW) protection category (NPS 2005). Unfortunately, many of the streams do not meet state criteria for suitable aquatic habitat, including three 303(d) listed streams within the park itself, largely because of mine drainage or sedimentation issues (NPS 2008a). Coal particulates and acidic drainage from mining practices are threatening some of the sensitive ecosystems associated with the river system, because older mining spoils and acid mine drainage from old deep mines were discharged into surrounding dumps before current levels of regulation. As a result, many tributaries of the Big Fork River are acidic and have high concentrations of heavy metals such as zinc, aluminum, iron, and manganese. Brine discharge from oil and gas extraction also negatively affects water quality within the park (NPS 2008a).

The future ecological status of these streams is uncertain because additional mining areas are still being proposed within the Big South Fork drainage. Furthermore, the majority of past coal mining in Tennessee occurred within the Big South Fork drainage, as do most of the mines found today in Tennessee. Mining activity is associated with numerous effects on species diversity due to acid mine drainage, heavy metals, and total suspended and dissolved solids (Koryak 1972, Bonta 2000, Tiwary 2001), and even without additional mining activity, Big South Fork River contains twice the amount of dissolved and suspended solids and 2.5 times the sulfate yield of a similar river basin without mining (NPS 2005).

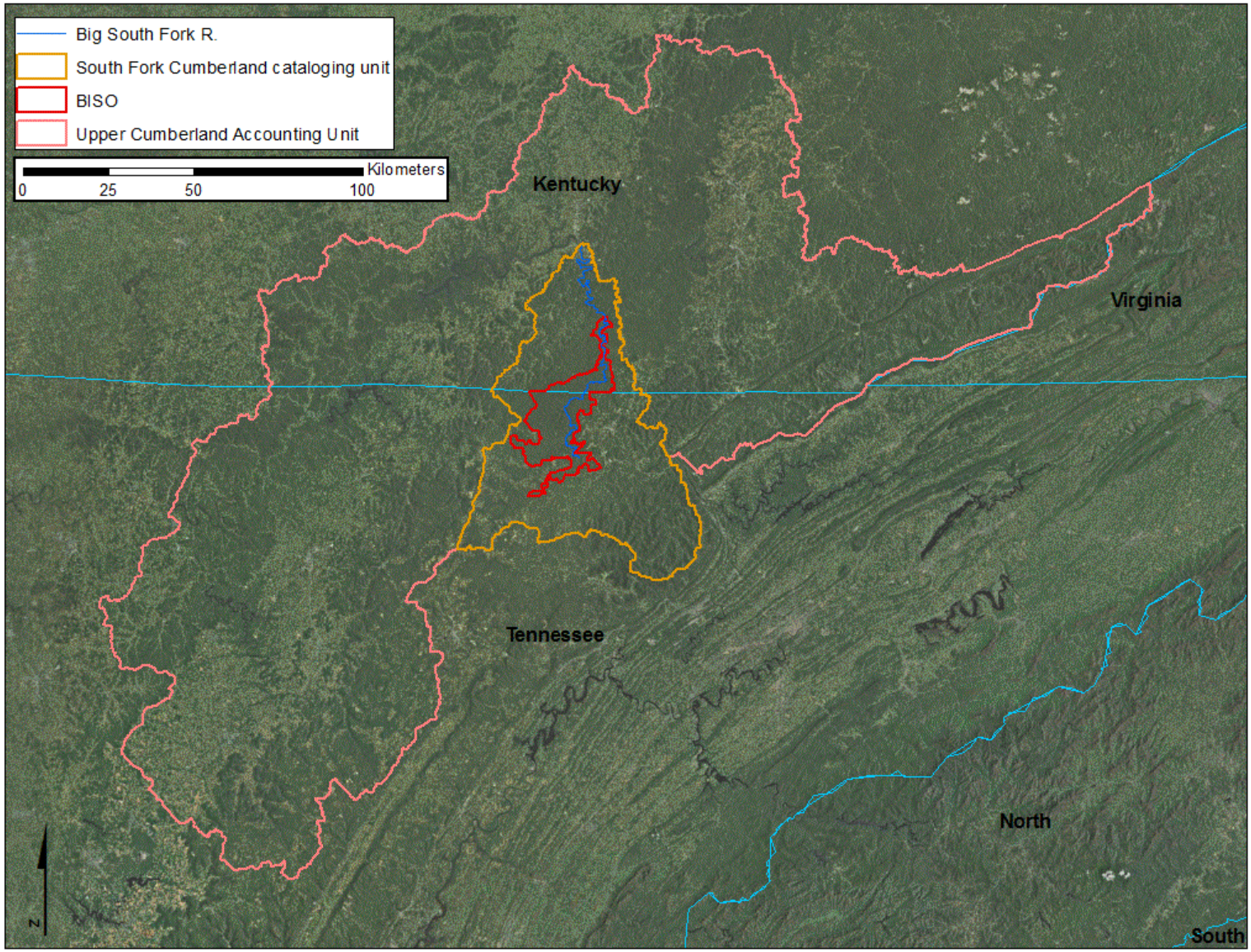

Figure 3. BISO is located completely within the South Fork Cumberland cataloging unit (HUC8), which drains into the larger Upper Cumberland accounting unit (HUC6).

2.1.6 Visitation Statistics

Data for annual number of visitors at BISO is available starting in 1988, after which visitation steadily increased to a peak of 920,000 in 2001(NPS 2012; Figure 4). After that, visitation began a slow decline until 2006 when it reached 623,000, the lowest since 1988. Visitation has been steadily climbing after that point. The overall mean visitors per year is 770,000.

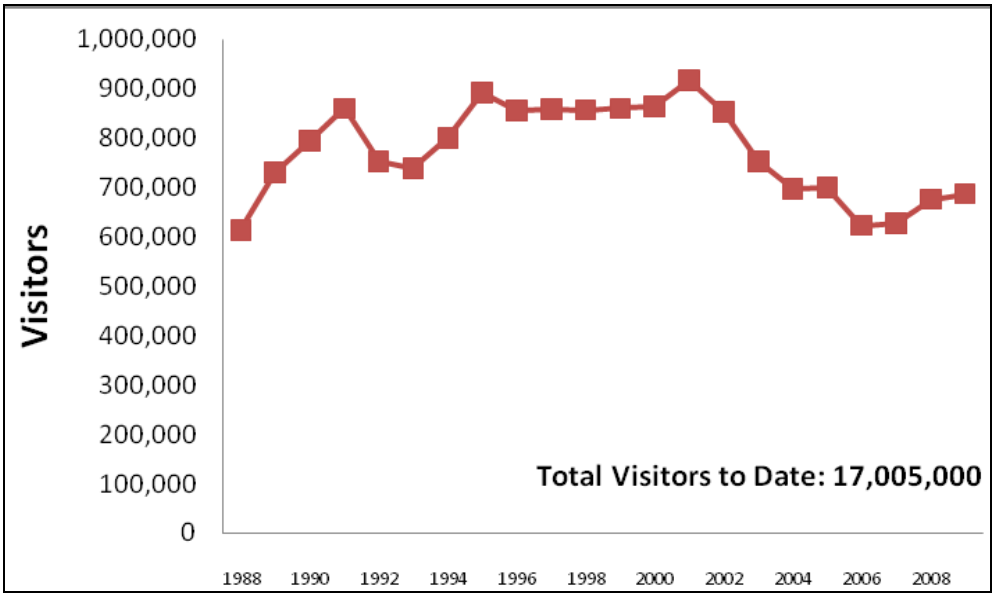

Figure 4. Visitor data for BISO since from 1988 to 2009.

2.2 Natural Resources

2.2.1 Resource Descriptions

<u>Sensitive Plant Species</u>

Big South Fork NRRA supports a wide variety of ecosystems and is home to various plants and animals, many of which are threatened or endangered. A recent survey documented 216 woody plant species, of which 186 are native (Shaw 2003). Recently completed vascular plant surveys at BISO have inventoried 1,100 species, representing an additional 125 species from pre-survey levels (Murdock and Emmott 2007). This level of plant richness is exceptional and represents a higher familial diversity than the Great Smoky Mountains National Park (52 vs. 48), which covers over four times the area of BISO. In all, one federally-endangered plant species , Cumberland sandwort (*Minuartia cumberlandensis*), and two federally-threatened plants, Cumberland rosemary (*Conradina verticillata*) and Virginia spirea (*Spiraea virginiana*), have been documented at BISO, all of which are endemic to the Cumberland River side Scour Prairie vegetation type (Nordman 2011, Blount 2003). White fringeless orchid (*Platanthera integrilabia*), also found at the park, is listed as a candidate species. Cumberland sandwort is a near-endemic species of the Big South Fork watershed. It was added to the endangered species list in 1988 and is susceptible to trampling due to its growth in loose sandy soils under frequently visited rockhouse areas. Park management installed several fences and barriers to prevent access to habitat sites for Cumberland sandwort and Lucy Braun's white snakeroot (*Ageratina luciae-brauniae*), another rare species.

Invasive Plants (APHN Vital Sign)

Invasive and exotic plants are only specifically identified as a vital sign of concern for the Blue Ridge Parkway, though they remain a matter of concern for Big South Fork NRRA as well. Invasive species were present in 25 of the 114 survey plots established for vegetation monitoring within the park. In addition, several homesteads in the gorge area resulted in the introduction of nonnative plant species such as peach (*Prunus persica*), though more noxious species like Japanese stilt grass (*Microstegium vimineum*), garlic mustard (*Alliaria petiolata*), and many others (Shaw 2003) had likely been introduced by other means. Many of these invasive species are also present in the floodplain forest communities, and park staff is currently involved with efforts to remove them (NPS 2008a). Management of these species within old agricultural and homestead fields is addressed in a field management plan for Big South Fork NRRA. Overall, there are 102 field units encompassing 300 ha, of which 10 units are officially designated as significant cultural landscapes. Most of these old fields are dominated by non-native fescue grass (*Festuca* spp.), though other species originally planted as animal fodder are still present, such as lespedeza (*Sericea* spp.) and red clover (*Trifolium pratense*). The Field Management Plan outlines the conversion and maintenance of each of these units to one of five vegetation types, the majority of which are forest and native warm-season grasses (mainly bluestem, *Andropogon* and *Schizachyrium* spp.), while the remainder are tall fescue, turf, and grassy woodland communities (NPS 2006).

Fishes (APHN Vital Sign: Rare Fish)

Fish are among the most important natural resources in BISO, and the park protects a rich fauna within a region noted for high richness and endemism. The BISO contains over 760 km of surface flowing streams and rivers, ranging in size from tiny headwater streams to large rivers. The park protects the entire section of the Big South Fork Cumberland River remaining in a free-flowing state. The northern, downstream reaches of the river in BISO have been changed to more lentic habitat by the impoundment of Lake Cumberland in the early 1950s. Around 90 species of fish, including four nonnatives, have been reported from the Big South Fork drainage within the park and upstream of park boundaries. Recent sampling by Scott (2010) reported around 80 species currently present within the park. Species present included the federally endangered tuxedo darter (*Etheostoma lemniscatum)*, and the federally threatened blackside dace (*Phoxinus cumberlandensis*). Four additional species were listed as threatened or endangered by Kentucky and/or Tennessee, and four species were listed as deemed in need of management by Tennessee.

Birds

Big South Fork National River and Recreation Area protects a moderately diverse avian fauna dominated by neotropical migrants and forest specialist species. At least 173 species have been reported from the park since its creation, with 147 species reported from reliable standardized surveys since 1994 (Stedman and Stedman 2007, Stedman 2011). No federally threatened or endangered birds have been reported from the park, although a number of species of conservation concern occur. Of the 147 species reported since 1994, nine were listed as threatened or endangered by Kentucky and/or Tennessee, nine were state listed as special concern or in need of management, and an additional 16 were identified as high priority breeders, or of high conservation concern by Partners in Flight (PIF) ranks (Nuttle et al. 2003, Watson 2005).

Mammals

A recent mammal inventory documented 47 mammal species in the park, including 42 native and five nonnative species (Britzke 2007). Species of concern reported from the park included the federally endangered gray bat (*Myotis grisescens*) and the candidate species the Allegheny woodrat (*Neotoma magister*). An additional seven species reported from the inventory were listed at the state level as species of concern or species in need of management. The mammal fauna of BISO includes large mammals such as the elk (*Cervus elaphus*) and the black bear (*Ursus americanus*) that typically exist in the region only in relatively large, protected areas.

Reptiles and Amphibians

The park supports a rich assemblage of regionally-typical reptiles and amphibians. A baseline inventory of herpetofauna conducted from February 2004 to June 2007 reported 57 species from BISO (Stephens et al. 2008). No federally threatened or endangered species were found in the park. One species, eastern slender glass lizard (*Ophisaurus attenuatus longicaudus*) was listed as threatened in Kentucky and four additional species were listed as special concern or in need of management by either Kentucky or Tennessee.

Freshwater Mussels (APHN Vital Sign)

Freshwater mussels are among the most imperiled taxonomic groups in the U.S., and represent one of BISO's most important natural resources. The mussel assemblages of southeastern U.S. river basins are the richest and most diverse on earth (Williams et al. 1993, Neves et al. 1997). The Cumberland drainage historically supported a rich and highly endemic mussel fauna of over 90 species, including at least 11 species now presumed extinct and many other species which have experienced local extirpations (Gordon and Layzer 1989, Williams et al. 1993). The mussel fauna of the Big South Fork River had been reduced by at least 30% and possibly by over 60% between 1910 and 2002 (Biggins et al. 2001, Ahlstedt et al. 2003). Despite great losses in mussel richness, BISO has been recognized as having one of the best extant mussel assemblages in the region, and as representing a significant opportunity for restoration within the region. Mussel restoration activities have been ongoing in BISO since 2002 and have included both propagation and translocation of mussels.

At least 40 species of mussels are currently or recently present in BISO as evidenced by recent inventories and management activities. Recent inventories in the Big South Fork drainage reported 27 species present from natural persistence, of which 26 occurred within the park (Ahlstedt et al. 2003, Ahlstedt et al. 2008). Of these, six were listed as federally endangered (Table 1) and an additional two were listed as threatened or endangered at the state level. An additional 14 species, not otherwise reported, have been translocated into BISO since 2008. Of these, three were federally listed as endangered and two were candidate or proposed species.

Table 1. Six species of freshwater mussels naturally persisting in BISO were federally listed as endangered.

Species		IUCN Status
Cumberland elktoe	*Alasmidonta atropurpurea*	EN
Cumberlandian combshell	*Epioblasma brevidens*	CR
Cumberland bean pearlymussel	*Villosa trabalis*	CR
Oyster mussel	*Epioblasma capsaeformis*	CR
Tan riffleshell	*Epioblasma florentina walkeri*	EN
Littlewing pearlymussel	*Pegias fabula*	CR

Aquatic Macroinvertebrates

A recent comprehensive inventory of aquatic macroinvertebrate insects reported at least 414 distinct taxa from BISO, including two new undescribed species (Parker 2003). Of the 414 distinct taxa, 205 were identified to the species level. Richness of individual samples ranged from 18 to 80 taxa, and total sample size ranged from 54 to 635 individuals (Parker 2003).

Insect Pests

Hemlock wooly adelgid (*Adelges tsugae*) was first identified at Blue Heron in 2010. Though this non-native pest is not yet thoroughly established throughout the park, the implications of its discovery are extensive. Hemlocks (*Tsuga* spp.) typically grow along stream corridors and help maintain suitable conditions for aquatic species. Hemlock functions as a keystone species in these communities, meaning that its role in the community is essential to their function. Numerous studies predicted a multitude of effects on the structure and function of hemlock riparian and cove hardwood communities due to adelgid-induced decline, including transpiration rates, carbon cycling, vegetation dynamics, structural complexity, wildlife, and potential spread of exotic species (Daley et al. 2007, Eschtruth et al. 2007, Ford and Vose 2007, Cleavitt et al. 2008, Nuckolls et al. 2009). While the park continually monitors infestation rates and health of trees throughout the park, it is especially important that treatments reach hemlocks in the uncommon communities where they serve such a vital function. Large-scale application of pesticides would not be feasible for the park, and the efficacy of bio-control projects is still being tested throughout the Southern Appalachians. As of this writing, 12 locations in BISO have documented HWA infestations ranging from Yahoo Falls in the northern section to Brewster Bridge in TN.

Another species, the Asian lady beetle (*Harmonia axyridis*), is present throughout the park as a result of release during the 1960s and 1990s to control agricultural pests (NPS 2008a). In addition, the park is also continually monitoring for outbreaks of the emerald ash borer (*Agrilus planipennis*).

Water Quality

Water quality is perhaps one of the most important natural resource issues at BISO because it affects a suite of network vital signs including rare fish, aquatic macroinvertebrates, freshwater mussels, and cobble bar/scour communities. The main threat to these vital signs is contamination of soil, air and water via coal mining and oil and gas extraction. These threats are most significant along the Big South Fork River and the New River. The impact of these activities on the park and its resources is not slight. More coal is mined in the New River

watershed than any other in Tennessee, and intensive rates of timber harvest can exacerbate erosion that contributes to high contaminant loading (NPS 2008b). In addition, high water demand and discharge from municipal sources, as well as erosion from development outside the park place significant stress on water resources within the Big South Fork River. As a result of mining-related siltation and drainage contamination, three reaches within BISO have been classified as 303(d) impaired waters, based on 2010 and 2012 data.

Currently, a park-level Water Quality Monitoring Protocol has been submitted for peer review by the Appalachian Highlands Network. This protocol includes sampling and analytical procedures, as well as locations for core and transient monitoring locations. Long-term monitoring within the park seeks to link information about water quality parameters (e.g. bacterial concentrations, sedimentation, nutrients, trace metals, flow characteristics, and other core measurements) with the condition of other aquatic resources and associated vital signs (NPS 2008b). The water quality parameters selected for monitoring are intended to detect possible impacts at each park unit, which in the case of Big South Fork NRRA include oil and gas extraction, coal mining, agricultural development, industrial pollution, and sewage effluent.

2.2.2 Ecological Units

Vegetation in the Big South Fork area may generally be divided into the region within the gorge and the surrounding upland forest. Upland forests are typically mixed-oak or dry oak-pine communities depending on soil and moisture conditions, with the dry pine-dominated sites adapted to a fire disturbance regime. Recent suppression of this natural fire cycle has resulted in changes in forest composition, though the park started prescribing fires in certain affected areas in 2005. With the disappearance of this habitat, fire-adapted plant and animal species have also become less frequent, including federally endangered American chaffseed (*Schwalbea americana*) a plant generally found on sandstone knobs and inland plains, as well as the vulnerable red-cockaded woodpecker (*Picoides borealis*; NPS 2006). Soils within the river gorge area are richer and generally support mixed-deciduous forest, though other unique zones such as hemlock ravine forest, floodplain forest, and sandstone rockhouse communities also are present (NPS 2008a). Seepage forest is also associated with some of the stream-head areas, where populations of white fringeless orchid (*Platanthera integrilabia*) have recently been found during inventories. This rare species is a Federal Candidate species and is listed with a state conservation rank of critically imperiled in KY and in TN is listed as endangered and imperiled. Currently, it is thought to have been extirpated from two of its original eight states.

<u>River Scour Prairie Communities</u>

Cobble bar plant communities, also known as river scour prairies, are a unique vegetation type that occurs along frequently flooded areas of bedrock, cobble, or gravel along rivers. These areas share attributes with the tallgrass prairies of the Midwest, most notably in that they are populated by grasses and wildflowers and are dependent on cycles of disturbance for reproduction and survival. Instead of a disturbance regime based on fires, however, these communities are adapted to frequent flooding events which limit the number of woody species. Instead, the hydrologic regime facilitates mainly riparian species such as herbs, grasses, shrubs, and forbs. Many of the plant species of special concern for BISO are found within these communities, including the federally-listed Virginia meadowsweet, Cumberland rosemary, Cumberland sandgrass (*Calamovilfa arcuata*, endangered in Tennessee), Mountain Witch-Alder

(*Fothergilla major*), and large-flowered Barbara's buttons (*Marshallia grandiflora*,endangered in Tennessee and Kentucky) (Schapansky 2007, Nordman 2011).

At BISO, 22 cobble bar communities have been located, though it is estimated fewer than 500 total acres of this community remain, much of which occurs within BISO and the Obed Wild and Scenic River Area. As a result, the Nature Conservancy includes river scour prairies/cobble bar communities in its list of Globally Imperiled (G2) vegetation communities, and APHN has established several permanent plots within these areas to monitor vegetation structure and substrate (Murdock et al. 2011). Through this monitoring, NPS staff will be able to assess the effect of changes in water quality or flood cycles on succession and natural community composition on cobble bars (Murdock et al. 2011).

2.2.3 Resource Issues Overview

In addition to the specific resources outlined above, there are other factors that actively affect natural resources in the park unit and deserve continued monitoring and management attention. Fire management is an effective management practice that can result in several ecological benefits. In addition, the area around BISO is especially sensitive to air quality factors due to high elevation and proximity of polluting industrial activity. On a larger temporal scale, weather and climate as well as landscape change represent significant factors that can fundamentally alter the nature of the park unit. The last three are additionally listed as network vital signs and accordingly are the object of regular data collection and analysis.

Fire Management

Currently, BISO is divided into two fire management units. The first unit, totaling 7,700 acres, focuses on areas with more difficult control requirements. It includes the northern portion of the park around the Blue Heron community and the southern area around the New River, in addition to developed areas within the park. This unit also contains a higher concentration of oil and gas wells. The southern boundary of the unit is surrounded by several pine plantations that were impacted by infestations of southern pine beetle (*Dendroctonus frontalis*) in 2000, and thus high fuel loading in this area adds to the difficulty of prescribed burns. The second fire management unit comprises the remaining 90,500 acres and focuses on undeveloped, natural areas.

The four primary objectives of the fire management plan (FMP) at BISO include (1) the reduction of hazardous fuel accumulations, (2) maintenance of cultural landscapes, (3) restoration of habitat for wildlife and plant communities, and (4) controlling exotic species (NPS, 2004a). The report notes that several species of plants and animals benefit from a natural fire regime, the suppression of which often becomes the reason plants become federally-listed. Dependent on a fire regime consisting of frequent fires, chaffseed is generally considered extirpated from the BISO area, because no specimens have been found within BISO or its vicinity since 1935 (NPS 2004b). In their ecological rationale for the fire management plan, Campbell et al. (2001) argue that careful fire management can certainly enhance biodiversity. In addition, fire can help control several exotic plant species such as fescue (*Festuca* spp.), garlic mustard (*Alliaria petiolata*), Japanese spirea (*Spiraea japonica*), multiflora rose (*Rosa multiflora*), and Japanese honeysuckle (*Lonicera japonica*; Campbell et al. 2001). Previously, fire suppression was the general policy of the USDA Forest Service until several catastrophic wildland fires highlighted the importance of a natural fire regime. This natural fire regime is

especially important for oak (*Quercus* spp.) and pine (*Pinus* spp.) forests of the eastern US (NPS 2004a).

During the period from 1991-1996, BISO conducted initial prescribed burns at 12 sites totaling 658 acres (NPS 2004a). These burns were conducted in part to encourage red-cockaded woodpecker (*Picoides borealis*) habitat, in addition to reducing fuel loads. A main consideration when conducting burns or managing wildfires at BISO are the numerous gas and oil well sites. Oil and gas transport lines run from wellheads to holding tanks. These holding tanks are at risk of explosion, and the wellheads themselves can vent flammable gas. The FMP points out that fireline plowing for controlled burns is a particularly risky procedure that can rupture pipelines and complicate burning efforts.

The current prescribed fire plan is intended to facilitate a natural ecological succession for plant communities. The treatment areas of concern mainly include old agricultural fields, native grasslands, sub-xeric mixed-hardwood forests, and xeric pine woodlands (NPS 2004a). These vegetation types will be used to direct simulated fire regimes that include mixed-severity fires for understory-only burns. Understory burns are the primary type of burn used, though in some cases, such as subxeric mixed-hardwood or xeric pine woodlands, mixed severity fires may be prescribed, in which case more extensive changes may result. For example, areas dominated by Virginia pine (*Pinus virginiana*) often undergo complete replacement (NPS 2004a). Areas with more shortleaf pine (*Pinus echinata*) and mixed hardwood would likely experience greater changes in vegetation, while grasslands are burned to eliminate all standing growth. This would also help control non-native grasses in field areas, as well as shrubs such as multiflora rose (*Rosa multiflora*).

Besides encouraging vegetation diversity and controlling exotic species, prescribed burns can also provide other benefits. Spores that transmit oak wilt fungus (*Ceratocytisis fagacearum*), a major affliction of red oaks, for instance, are controlled by burning, whereas bird species like wild turkey (*Meleagris gallopavo*) and ruffed grouse (*Bonasa umbellus*) benefit from open areas created by fires, as do other wildlife (NPS 2004b).

Landscape Dynamics

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

NPS created a series of landscape dynamics data products called NPScape, whose goal was to create an organized protocol for landscape scale assessment for all park units in the US. To achieve that goal, NPScape divided the landscape assessment 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 data source 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.

Weather and Climate

The purpose of weather monitoring within the park is to develop a long-term record of local meteorological data, which may in turn be used to track changes in local weather station patterns, inform atmospheric models, advise visitors on park conditions, and help understand changes in plant and animal communities or other natural resources (NPS 2008b). BISO contains a weather monitoring station in the Remote Automated Weather Station Network (RAWS) which is administered by the US Forest Service and provides several hourly meteorological measurements. The RAWS began collecting continuous weather observations in 2000. There are also 3 stations within 30 km of the park in the National Weather Service (NWS) Cooperative Observer Program (COOP) that began collecting almost continuous data in 1928, 1936, and 1952 (Davey et al. 2007).

Air Quality

Due to their height and physical location, the Southern Appalachians are subjected to high levels of atmospheric pollutants due to prevailing winds from industrial areas. Pollutants include sulfur dioxide and nitrous oxide, whether in the form of acid rain, dry deposition, or cloud vapor. Extensive monitoring in the Great Smoky Mountains National Park (GRSM) has shown that high-elevation nitrogen saturation can limit plant growth, as well as mobilize toxic metals such as aluminum. Monitoring stations throughout the Appalachian Highlands Network also record rates of nitrogen and sulfur deposition, ozone concentration, visibility, and airborne particulates. Although these issues are mainly threats for GRSM and BLRI, some data is available for areas like BISO on the Cumberland Plateau. Fortunately, monitoring has indicated that acidification resulting from atmospheric deposition is not an issue for surface waters in the park (Emmott et al. 2005).

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Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

During June 2010, an initial scoping meeting was held to discuss natural resource issues at BISO (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 APHN 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 while minimizing summary of existing reports and assessments.

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 2). 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 3 indicates the main sources of data used for the assessment, summarized by category.

Table 2. NPS Ecological Monitoring Framework used to organize and identify natural resource areas of interest at BISO (Fancy et al. 2009). Blue highlights indicate areas of interest identified at BISO during initial scoping meeting using APHN vital signs as guidance.

Ecological Monitoring Framework—BISO			
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	Wet & dry sulfate and nitrate deposition, concentration of nitrates
		Visibility and Particulate Matter	IMPROVE station data, change in visibility
		Air Contaminants	Hg
	Weather and Climate	Weather and Climate	Precipitation, temperature, wind speed/direction,
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	Siltation
		Marine Hydrology	
	Water Quality	Water Chemistry	Temperature, specific conductivity, pH, DO, ANC
		Nutrient Dynamics	Heavy metals
		Toxics	Acid mine drainage, coal
		Microorganisms	Fecal coliform, fecal strep
		Aquatic Macroinvertebrates and Algae	*S*, *H'*, stream macroinvertebrate IBI, relative abundance

Table 2. (continued)

Ecological Monitoring Framework—BISO			
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	Hemlock wooly adelgid
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	Streamhead bogs (white-fringeless orchid)
		Riparian Communities	Cumberlandian cobblebar communities (G2)
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	Pseudo-cavelike sandstone rockhouse communities
		Desert Communities	
		Grassland/Herbaceous Communities	
		Shrubland Communities	
		Forest/Woodland Communities	
		Marine Invertebrates	
		Freshwater Invertebrates	Freshwater mussel species composition, abundance, age structure
		Terrestrial Invertebrates	
		Fishes	
		Amphibians and Reptiles	
		Birds	Distribution, abundance, breeding success
		Mammals	Black bear (reintroduced), elk (reintroduced), bats
		Vegetation Complex (use sparingly)	
		Terrestrial Complex (use sparingly)	
	At-risk Biota	T&E Species and Communities	Plants (Cumberland rosemary, Virginia meadowsweet, Cumberland sandwort, Cumberland sandgrass, American chaffseed); Mammals (gray bat, blackside dace, tuxedo darter); Macroinvertebrates (13 endangered mussel species)

Table 2. (continued)

Ecological Monitoring Framework—BISO			
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	Prescribed fire management in upland pine-oak forests
	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 3. Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Big South Fork National River and Recreation Area. See Table 2 for the level of each attribute.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	Portable Ozone Monitoring System (POMS) in BISO	Hourly measurements of ozone concentration within BISO	May-September, 2003-2005
		KY Division of Air Quality Ozone Monitoring Station in Somerset	Measurements of ozone concentrations near BISO	2000-2003 continuous
	Foliar injury risk predictions (3-metric index)	NPS report for the Cumberland Piedmont Monitoring Network (NPS ARD 2004)	Kriged predictions extracted from US-wide ozone models	1995-2003
Atmospheric Deposition	Wet Deposition	Oak Ridge Laboratory and Speedwell monitoring stations in EPA Clean Air Status and Trends Network (CASTNET)	Wet deposition nitrate and sulfate concentrations	1980-2008 (Oak Ridge Laboratory); 1999-2008 (Speedwell)
	Dry Deposition	Edgar Evins CASTNET monitoring station	Dry deposition nitric acid, ammonium, nitrate, sulfur dioxide, and sulfate concentrations	1990-2007
	Mercury Deposition	National Atmospheric Deposition Program (NADP) Mercury Deposition Program (MDP) stations at Mammoth Cave National Park (MACA) and Great Smoky Mountains National Park (GRSM)	Mercury deposition	2002-Present
Visibility	National Ambient Air Quality Standards (NAAQS) for particulate matter	Interagency Monitoring of Protected Visual Environments Program (IMPROVE) sites at MACA and GRSM	Fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter concentrations	1991-2004 (GRSM); 1988-2004 (MACA)

Table 3. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Weather and Climate	Deviation from normal conditions and frequency of extreme weather events	Remote Automated Weather Station (RAWS) in BISO	Temperature, precipitation, wind speed/direction	2000-Present
		Three Cooperative Observer Program (COOP) sites in Allardt, Stearns, and Oneida	*Same as above*	1928-Present (Allardt); 1936-Present (Stearns); 1952-Present (Oneida)
		Flaherty (2010) climate summary for BISO	Assessment of temperature, precipitation, and wind trends for 2007 using RAWS, Allardt, and Stearns	2007
Water Chemistry	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), ANC (mean)	EPA Storet data for BISO cataloging unit	Raw water quality monitoring data from sampling at stations within South Fork Cumberland cataloging unit	2001-2010
		USGS Historical Water Quality Summary for BISO cataloging unit (Johnson 2003)	Summarized water quality data for South Fork Cumberland cataloging unit by watershed and subwatershed	1982-2001
		Rikard et al. (1986) Water Quality Report	Water quality summary report for major streams in BISO with attention to acid mine drainage and other disturbances	1982-1984
		Carew et al. (2003) Rock Creek Abatement Project	Description of drainage management and treatment to mitigate acid mine drainage effects in the lower Rock Creek watershed	1998-2000
		O'Bara et al. (1982) Survey of Water Quality	General water quality description including macroinvertebrate and fish sampling	1981
Microorganisms	*E. coli* (mean colonies/100mL), fecal	*Same sources as Water Chemistry*	--	--

Table 3. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Vegetation Communities	Exotic species, rare species, river scour prairies, rare vegetation communities	NatureServe (2007) draft vegetation communities report	Description of major vegetation communities mapped at BISO, as well as disturbance notes at each plot	2003-2004
		Nordman (2011) plant inventory/classification report	Discussion of exotics, rare species, and rare communities	2002-2005
		Murdock et al. (2011)	Cobble bar community monitoring protocol	2006-2010
Fish Assemblages	IBI, diversity indices, species of concern	Scott (2010) fish inventory	Narrative report and database of fish sampling results	2003-2006
		O'Bara et al. (1982) water, fish, and macroinvert inventory	Narrative report including fish sampling efforts in 16 tributaries	1981
		Carew (2002) report on Rock Creek mitigation	Narrative report including fish sampling in Rock Creek before/after mitigation efforts	1999-2001
Bird Assemblages	Bird community index (BCI), diversity indices, conservation value index, species of concern	Stedman (2011) BISO bird data website	Data on numbers/species of birds reported during annual sampling in BISO	1994-2006
		Stedman and Stedman (2007) bird inventory	Narrative report and accompanying electronic spreadsheets of data from sampling for an official BISO bird inventory	2003-2005
		Stedman (1998) publication	Peer-reviewed publication on three years of standardized BBS sampling in BISO	1994-1996
Mammal Assemblages	Reported vs. expected diversity, comparison studies	Britzke (2007) mammal inventory	Narrative report of BISO mammal inventory and GIS layer of trapping locations	2003-2004
Reptile and Amphibian Assemblages	Reported vs. expected, diversity, comparison studies	Stephens et al. (2008) herpetofauna inventory	Narrative report of BISO reptile /amphibian inventory and GIS layer of encounter locations	2004-2007
Freshwater Mussel Assemblages	Reported vs. expected, diversity	Ahlstedt et al. (2003) BISO mussel inventory	Narrative report of BISO mussel inventory	1999-2002
		Ahlstedt et al. (2008) New River mussel inventory	Narrative report of New River mussel inventory	2006-2008
Aquatic Macroinvertebrate Assemblages	IBIs, EPT bioclassification, diversity indices	Parker (2003) macroinvertebrate inventory	Narrative report and accompanying appendices and electronic spreadsheets of results of insect macroinvertebrate sampling in BISO	1998-2001

Table 3 (continued)

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
		Center for Remote Sensing and Mapping Sciences (CRMS) vegetation classification (2009)	Vegetation community map for BISO	2003

3.2.3 General Approach and Methods

Condition and Trend Status Ranking Methodology

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

We used this hierarchical framework to choose assessment attributes and to organize the presentation of results. We developed a list of ecological attributes suitable for condition assessment using 1) level-three category attributes from the adapted EPA framework described above, 2) the inventory and monitoring goals for the Appalachian Highlands Network (APHN; Emmott et al. 2005), and 3) input from NPS staff. We assessed the condition of each attribute using standard methods and reference criteria. When appropriate, we performed statistical comparisons using $a = 0.05$. We represented the condition of each attribute as a colored circle where color indicates condition (dark green = excellent, etc.;Table 5). 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 pass-fail categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al.'s (2008) NRCA report for Fort Pulaski National Monument (Table 4). The first category, thematic, refers to the adequacy of the data used to make the assessment, such as whether a certain water quality parameter is measured directly or inferred from a secondary variable. The spatial category assesses whether the data are spatially explicit, and inside the park unit. As in the ozone example, ozone concentration may be available from direct measurements (meeting the thematic requirement), but the monitoring station may not be inside the park boundary, therefore conditions at the park unit are inferred or interpolated. In such cases, the spatial requirement is not met. The third data quality category, temporal, is fulfilled if the data are five years old or less. To give an overall rank to the data quality, the number of requirements met are summed and translated into a good (3), fair (2), or poor (1) ranking and reported alongside the overall condition assessment (Table 5). Data that fulfill none of the three ranking categories are not used to assess vital sign conditions.

Because monitoring is relatively new for many aspects of natural resources in park units, several categories are missing criteria for data quality. However, as continued monitoring adds to the available data for future condition assessments, it is likely that these data quality rankings will

improve. In addition, implementation and refinement of monitoring protocols for the various natural resource categories is still underway. Data collection methods will likely also change as monitoring needs are fine-tuned to specific metrics and aspects of vital signs at each park unit.

Table 4. Data quality ranking criteria.

Data Category	Criteria
Thematic	Are data adequate? Are data reliable for attribute?
Spatial	Are data spatially explicit?
Temporal	Are data ≤5 years old?

3.2.4 Reporting Areas

Conditions were assessed and reported at the scale of the entire park or at smaller spatial scales. Water quality, fish assemblages, and aquatic macroinvertebrate assemblages were assessed for 14 or 15 small reporting areas corresponding to USGS HUC 10 or HUC 12 drainages. For water quality, an overall ranking for the park unit also is provided. Water quality parameters are also individually summarized on a park-wide basis, and 303d-listed streams are described separately. Other natural resource attributes were reported at the park level, although data and analyses from larger spatial scales were important for some assessments. Because air quality and weather vary at large spatial scales, the assessments of these attributes involved assessing data from stations outside of the park and Big South Fork watershed. The exotic plants section lends itself to division by habitat unit, though a park-wide summary is also given. Lastly, the landscape dynamics section incorporates data from the entire region, defined as a 30-km buffer around the park boundary. The condition status for this section is intended to reflect the influence of several large-scale factors on the park unit.

Table 5. Example condition assessments. Attribute condition is as follows: dark green=excellent, light green = good, yellow = fair, red = poor, blue = no condition assigned. Condition trend is indicated by the arrow within the circle. Pointing up=improving condition, pointing right=stable condition, pointing down=declining/deteriorating condition, no arrow=no trend assigned. Checkmarks indicate whether data were appropriately thematic, spatial, or temporal for assessments, as described in the text. Colored bar indicates data quality score. Green = 3 of 3 possible checks, yellow = 2 of 3 possible checks, red = 1 of 3 possible checks. An "*" indicates that although the condition of an attribute was ranked to be good, some caution is warranted because at least one data quality check was missing.

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

3.3 Literature Cited

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Chapter 4 Natural Resource Conditions

4.1 Air Quality

As one of the recognized vital signs of the APHN, air quality is a major consideration at BISO. Air quality is federally protected from degradation by the Clean Air Act (CAA) through a series of National Ambient Air Quality Standards (NAAQS), which are guidelines for certain airborne pollutants. There are six airborne pollutants for which NAAQS exist, and BISO has previously monitored ozone, particulate matter, and lead. The CAA classifies all park units into two air quality classes which determine the level of focus on air quality as a natural resource. Throughout the US, there are 158 park units classified as Class I, meaning they are accountable to stringent air quality requirements. Most park units, however, fall into Class II, which allows higher levels of pollutants before they are considered an issue. These more lenient standards are mainly intended to allow for some development. An even more lenient Class-III designation exists, though no park units are currently classified with this category (NPS 2010b).

In addition to the three air pollutants covered by NAAQS, there are other air quality related factors important at BISO, including potential rates of foliar injury caused by ozone concentrations, atmospheric deposition, and visibility. In a report on visibility in units managed by NPS, the National Resource Council (1993) indicated that average visibility in the eastern US is about 30 km due to air pollution, whereas the natural extent of visibility is approximately five times that distance.

4.1.1 Ozone

Ozone is an atmospheric constituent produced from reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs). In humans, exposure to high levels of ozone may contribute to respiratory problems, inhibit lung capacity, and result in overall impairment of the immune system. High ozone levels are harmful to plants, and may inhibit natural plant communities as well as agricultural production (NPS 2008b).

There was a single Portable Ozone Monitoring Station (POMS) located within BISO that monitored continuously during the ozone season (April – October) from 2003 – 2005. In addition to this station, the Somerset Kentucky Division of Air Quality (DAQ) ozone station in Pulaski Co. is located approximately 30 km north of the park. This station collected data from 2000 – 2003.

The NAAQS set by the EPA include two thresholds for primary and secondary pollutant limits. For ozone, the NAAQS lowered primary and secondary standard concentrations in May 2008 from 0.080 ppm to 0.075 ppm. As a result, a violation is incurred when 3-year averages of the 4th highest daily maximum 8-hour average ozone concentration (4th Hi Max 8-hr) exceed 0.075 ppm (NPS 2006a).

Of the three years of collection at the POMS in BISO, the respective annual 4th Hi max 8-hr ozone values were 0.064, 0.064, and 0.066 ppm, whereas average daily means were 0.033, 0.033, and 0.028 ppm, respectively (Figure 5). The three year average, constituting the official metric, is 0.065 ppm. Another measure of ozone used to give an idea of variability is the 2nd highest 1-

hr concentration, which for the monitoring years at BISO were 0.081, 0.073, and 0.073 ppm, respectively. For the period 2000 – 2003, Kentucky DAQ yielded respective annual 4th Hi Max 8-hr values of 0.087, 0.077, 0.081, and 0.075 ppm. Three-year averages are calculable for 2002 and 2003, which respectively are 0.082 ppm and 0.078 ppm. Finally, the NPS Air Resources Division (ARD) estimated average 4th Hi Max 8-hr metrics at BISO based on national interpolation datasets for the five-year periods 1995-1999, 1999-2003, and 2003-2007 of 0.088, 0.086, and 0.076 ppm, respectively.

Overall, ozone data from the three sources form an intermittent record from 1995 – 2007, though ARD estimates are single estimates that cover a 5-yr span. Between the ARD estimate for 1995-1999 and the KY DAQ station estimate in 2000, there is a small drop in the 4th Hi Max 8-hr value (0.088 to 0.087 ppm). However, there is a large difference between sources in 2003; the KY DAQ station showed a 4th Hi Max 8-hr value of 0.075 ppm, whereas data from the POMS at BISO reported a value of 0.066 ppm. This discrepancy is likely due to the large distance between the monitoring locations (~70 km), where local pollution sources in Somerset, KY may result in higher ozone values. In fact, the EPA's 2005 database of criteria air pollutant emitters in Pulaski Co., KY show 37 major pollution sources within 20 km of the KY DAQ in Somerset, most of which are closer than 6 km. Compared to the BISO POMS measurements during 2003-2005, the 2003-2007 NPS ARD estimate of 0.076 ppm is higher and is similar to KY DAQ values observed during 2000-2003. This could be the result of NPS ARD interpolations originating from areas with higher ozone measurements, like the station in Somerset. Overall, it is difficult to compare the 5-yr NPS ARD ozone concentrations with the finer-scale data, though it is worth noting that the interpolated value decreases for BISO over each subsequent time period.

Currently, the most recent data for ozone concentration at BISO show that values are low and relatively stable, although more up-to-date measurements would ensure the accuracy of this conclusion. But because of the correspondence of the NPS ARD estimates with the KY DAQ values, rather than the POMS station, these estimates may suggest a higher ozone risk than actually occurs within the park. Therefore, based mainly on the POMS monitoring from 2003-2005 which was below the updated (2008) EPA 4th Hi Max 8-hr metric, the ozone is assigned a good condition status (Table 6). When the POMS data is combined with earlier data from the KY DAQ station, a decreasing trend appears, though as described earlier, this decrease is likely due to the overall higher ozone values from industrial sources in Somerset, KY, rather than an actual decrease in ozone concentrations over that period. It is difficult, however, to discern one reason over the other, and thus no trend is assigned to the condition status.

Table 6. The condition status for ozone concentration at BISO was good and no trend was assigned. The data quality was also good.

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

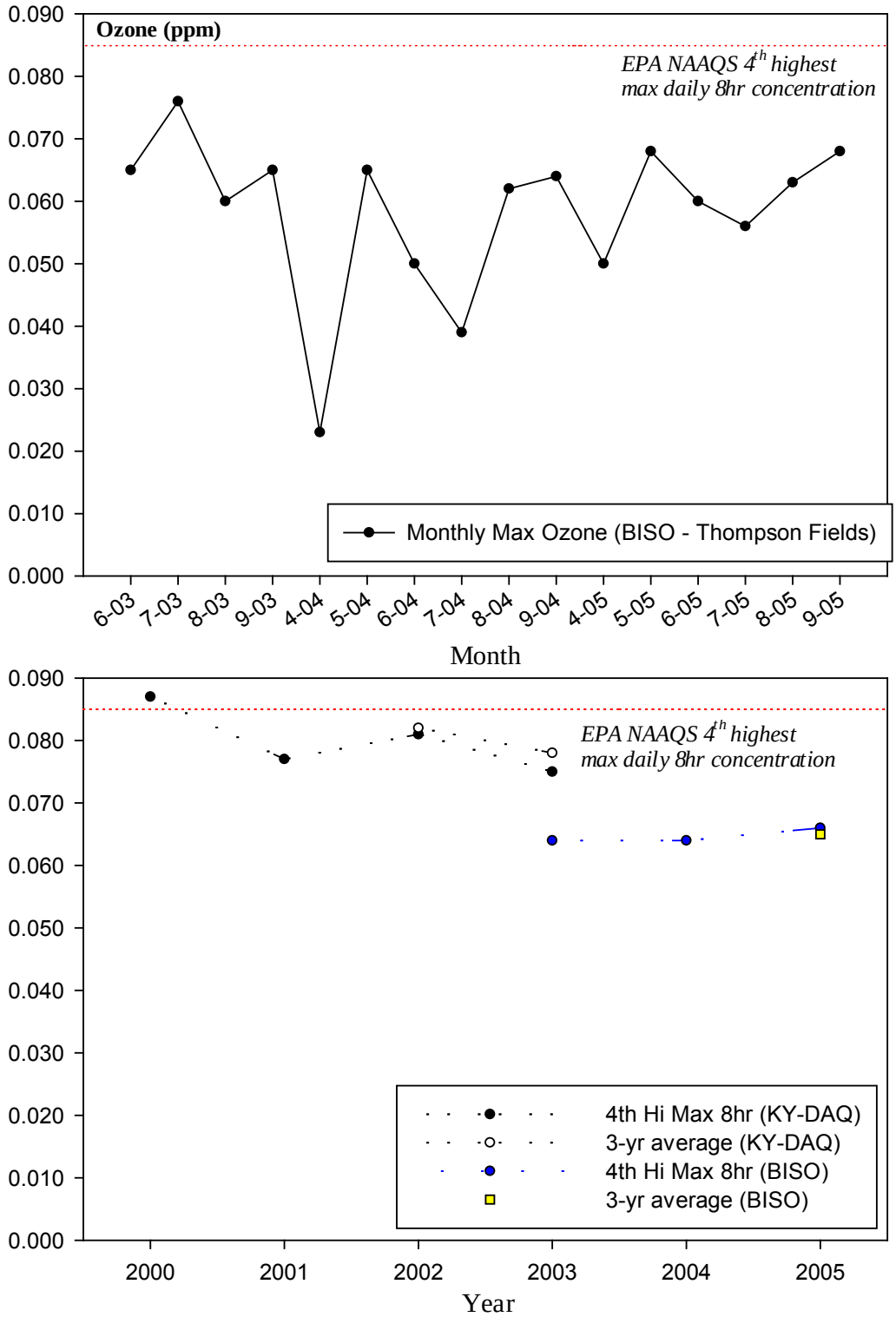

Figure 5. Continuous ozone monitoring was conducted at BISO using the Portable Ozone Monitoring Station (POMS) during the ozone season (April – October) from 2003 – 2005. Monthly concentrations are shown (top), along with annual 4th highest daily maximum 8-hr concentrations (4th Hi Max 8-hr) for the POMS and at the ozone monitoring station in nearby Somerset, KY (bottom).

4.1.2 Foliar Injury

Ozone concentrations have been linked with deleterious growth and physiological effects in sensitive plant species (Lefohn and Runeckles 1987, Ollinger et al. 1997). In a 2004 assessment of overall foliar injury risk, the ARD assigned BISO a high rating based on susceptible species lists, soil moisture patterns, and ozone concentrations. The NPS ARD also developed foliar injury metric prediction maps to predict potential harm to vegetation in each I&M park unit. The metrics for BISO are not measurements, but are actually kriged predictions extracted from ozone models for the entire US. These metrics are available as yearly predictions from 1995-1999 as part of the 2004 foliar injury assessment report for the APHN (Table 7).

Sum06

In order to describe potential foliar injury in park units, three biological indices with injury thresholds based on ozone concentrations were selected and applied to a representative group of ozone-susceptible plant species (NPS 2004a). The first metric, Sum06, is an index representing the cumulative sum of ozone concentrations ≥ 0.060 ppm between 8 AM and 8 PM over a moving 90-day period. The collection period usually occurs during the summer, when ozone concentrations are highest. The NPS ARD classifies 8 cumulative ppm-hours as the threshold for foliar injury, with the potential for growth reduction starting at 10 cumulative ppm-hr (NPS 2004a). At BISO, Sum06 prediction values averaged 30 cumulative hours > 0.060 ppm during the five-year prediction period, which is well past the threshold for foliar injury, despite low concentrations of ozone compared to EPA standards (Table 5).

W126

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

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

where W_i is the weighing factor for concentration C_i in ppm, and M and A are constants representing 4403 and 126 ppm, respectively. The constant A represents the ozone concentration of maximum weighting, and lends itself to the naming of the index. By using this index, higher ozone concentrations are weighted disproportionately greater since they present more of a threat for foliar injury (LeFohn and Runeckles 1987). For W126, highly-sensitive species are affected beginning at 5.9 cumulative ppm-hr, and moderately sensitive at 23.8 ppm-hr. Predictions at BISO for this metric averaged 45.9 for 1995-1999, which place it between the threshold affecting moderately and marginally sensitive species (Table 5).

N100

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

cumulative hrs. The average predicted N100 index during the five-year period was 19 cumulative hrs, which falls into the region affecting highly sensitive species only (Table 7).

Sensitive Species

It is also possible to predict the severity of foliar injury risk in the park unit based on the species composition in the park. The NPS and the US Fish and Wildlife developed a list of ozone sensitive plant species, defined as species that "exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar symptoms…have been documented." In addition, a subset of bioindicator species was developed, defined as a subset of sensitive species that best serve as indicators of ozone injury, due to easy identification of both the species and injury symptoms (Porter 2003). From that overall list, 24 sensitive and bioindicator species are recognized at BISO (Table 8).

Table 7. Set of foliar injury indices for BISO (NPS 2004a).

BISO Ozone Foliar Injury Indices					
	Sum06	W126	N60	N80	N100
	--ppm-hr--		--hrs--		
1995	26	38.4	695	120	17
1996	21	34.1	616	101	8
1997	26	39.2	709	116	10
1998	37	56.6	1004	226	34
1999	41	61.3	1112	249	24
1995-1999 Mean	**30**	**45.9**	**827**	**162**	**19**

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

Table 8. Twenty-four species at BISO were identified as bioindicators of ozone based on ease of identification of both species and injury symptoms (Porter2003).

Species		Family
Ailanthus altissima	Tree-of-heaven	Simaroubaceae
Asclepias exaltata	Tall milkweed	Asclepiadaceae
Asclepias syriaca	Common milkweed	Asclepiadaceae
Aster macrophyllus	Big-leaf aster	Asteraceae
Aster umbellatus	Flat-topped aster	Asteraceae
Cercis canadensis	Redbud	Fabaceae
Fraxinus americana	White ash	Oleaceae
Fraxinus pennsylvanica	Green ash	Oleaceae
Liquidambar styraciflua	Sweetgum	Hamamelidaceae
Liriodendron tulipifera	Tulip-poplar	Magnoliaceae
Parthenocissus quinquefolia	Virginia creeper	Vitaceae
Pinus rigida	Pitch pine	Pinaceae
Pinus virginiana	Virginia pine	Pinaceae
Platanus occidentalis	Sycamore	Platanaceae
Prunus serotina	Black cherry	Rosaceae
Rhus copallina	Winged sumac	Anacardiaceae
Robinia pseudoacacia	Black locust	Fabaceae
Rubus allegheniensis	Allegheny blackberry	Rosaceae
Rudbeckia laciniata	Cutleaf coneflower	Asteraceae
Sambucus canadensis	American elder	Caprifoliaceae
Sassafras albidum	Sassafras	Lauraceae
Verbesina occidentalis	Crownbeard	Asteraceae
Vitis labrusca	Northern fox grape	Vitaceae

Soil Moisture

In addition to these exposure indices, soil moisture conditions play a large role in mitigating or exacerbating potential for foliar injury. During periods of lower soil moisture, injury risk is reduced as leaf stomates close, thus reducing ozone uptake (Kohut 2007). Often, ozone damage is reduced naturally by weather conditions, because environmental conditions that facilitate the production of ozone such as a clear sky, high temperatures, and high UV levels also tend to reduce atmospheric gas exchange in plants, thus minimizing ozone uptake. The Palmer Z index (Palmer 1965) attempts to describe soil moisture and its departure from long-term averages for a given month and location by assigning a number in the range ±4.0 based on temperature, precipitation, and available soil water content, with ±0.9 representing the typical range for soil moisture (Wager 2003, NPS 2004a,). This method was used to calculate drought indices for the same time periods used to calculate both the Sum06 and W126 metrics (
Table 9, Table 10) from 1995-1999.

As the 2004 foliar injury report for the APHN points out, there is little association between the Sum06 metric and levels of soil moisture at BISO. The only year without drought conditions during the Sum06 assessment period—1996—demonstrated the lowest Sum06 metric, while the years with the highest metrics—1998 and 1999—showed both drought and wet months. Soil moisture conditions over the W126 period were generally wet, and in most years (1995-1998), there were more wet months than drought months. Although the driest year (1999) corresponded with the highest W126 metric, thus reducing the potential of foliar ozone uptake, W126 metrics for the other years were possibly high enough to present an injury risk given the overall wet conditions.

Summary

Overall, the NPS ARD estimates for 1995-1999 provide very little on which to base an assessment. Each of the three prediction metrics (Sum06, W126, N100) consistently fell into the same respective threshold region of risk to foliar injury for each year of the 5-yr prediction period. Because each of the three thresholds regions were covered by the metrics (low, medium, and high), the overall foliar injury risk appears moderate and is assigned a fair condition status (Table 11). Although foliar injury metrics are the result of kriged estimates, values for W126 support an increase of 6.8 ppm-hrs yr^{-1} (p = 0.044) and less significantly for Sum06 of 4.8 ppm-hrs yr^{-1} (p = 0.059). As a result, a trend of degrading is assigned. More recent data, especially those based on measurements at BISO, would qualify or refute this finding. Currently, data for foliar injury precedes the period for ozone concentration, possible reflecting a period of even higher ozone concentrations. Additional data collection by the POMS at Thompson Fields would help inform foliar injury risk in addition to ozone-related air quality compliance. Palmer Z indices would also help qualify foliar injury risk.

Table 9. Palmer Z indices for Sum06 at BISO (NPS ARD 2004).

Sum06	Month 1	Month 2	Month 3
1995	1.05	-1.28	-0.50
1996	-0.16	0.98	0.82
1997	-3.06	-0.75	0.66
1998	0.23	0.33	-2.51
1999	3.52	0.07	-1.87

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

Table 10. Palmer Z indices for W126 at BISO (NPS ARD 2004).

W126	A	M	J	J	A	S	O
1995	-1.05	2.31	1.05	-1.28	0.50	0.81	3.77
1996	0.28	0.46	-0.16	0.98	0.82	2.45	-0.93
1997	0.06	2.10	5.90	-3.06	-0.75	0.66	0.25
1998	4.35	-0.31	6.93	0.23	0.33	-2.51	-1.30
1999	-1.14	0.18	3.52	0.07	-1.87	-2.48	-1.25

Palmer Z drought index: -1.00 to -1.99 (mild), -2.00 to -2.99 (moderate), -3.00 and below (severe)
1.0 to 1.99 (low wetness), 2.0 to 2.99 (mid wetness), 3.0 and above (high wetness)

Table 11. The condition status for foliar injury at BISO was fair. The trend of foliar injury condition was declining. The data quality was poor, receiving a check only for thematic quality.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Foliar Injury	⇩	✓		
		1 of 3: Poor		

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4.2 Atmospheric Deposition

In addition to ozone exposure and foliar injury, another issue of air quality relevant to BISO is atmospheric deposition. 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) is particularly an issue at higher elevations. In particular, anthropogenic sources of sulfur dioxide and nitrogen oxides are issues

in the Southern Appalachian region, where they become trapped by the physical structure of the mountains (NPS 2010a). 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.

4.2.1 Sulfur Dioxide

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 US 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 US decreased by 17 and 34 percent, respectively (MACTEC 2008). Sulfur dioxide emissions at reference sites in the east dropped by 40% over the same 18-yr period. A large portion of the sulfur reduction included sulfur dioxide emissions from coal-fired power plants in the Ohio River Valley Region, which includes BISO. 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 ($PM_{2.5}$). Despite considerable reductions in sulfur dioxide emissions since 1990, the Ohio River Valley Region north of BISO still emits, by far, the highest concentrations in the US (MACTEC 2008).

4.2.3 Sulfate

Particulate sulfate (SO_4^{2-}) is a resultant product of sulfur dioxide that often takes the form of ammonium sulfate [$(NH_4)_2SO_4$]. Patterns of sulfate distribution in the US closely match those of sulfur dioxide, albeit with a more southerly skew. Like sulfur dioxide, sulfate concentrations are greatly elevated in the Ohio River Valley Region, and concentrations of sulfate at the eastern reference sites show a 26% decline during the period from 1990 to 2007 (MACTEC 2008).

4.2.4 Nitrogen Oxides

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^+). Total nitrate ($NO_3^- + HNO_3$) was highest in 2007 in the Great Lakes Region and southern California, though concentrations were moderately high (~2-3 $\mu g/m^3$) in the BISO region. Figure 6 shows a hierarchical format of atmospheric deposition and its constituents.

<u>Ecosystem effects of Nitrogen & Sulfur</u>

The mobilization of N and S plays a large role in determining the impacts of deposition on an ecosystem. In particular, large soil inputs of both nitrogen and sulfur can lead to eventual saturation and acidification, wherein nutrient limitations and cycling disruptions can inhibit plant growth or contribute to the mobilization of toxic cations like Al^+ (NPS 2010a). Mobile aluminum can damage plants via root uptake or create health problems for aquatic biota upon entering surface waters (Lovett et al. 2009). Deposition of N and S can also acidify surface waters, which can kill or displace sensitive aquatic biota, including freshwater mussels (Lovett et al. 2009, see section *Water Quality*). Continued buildup of these elements may contribute to prolonged damage, even though deposition rates may decrease over time.

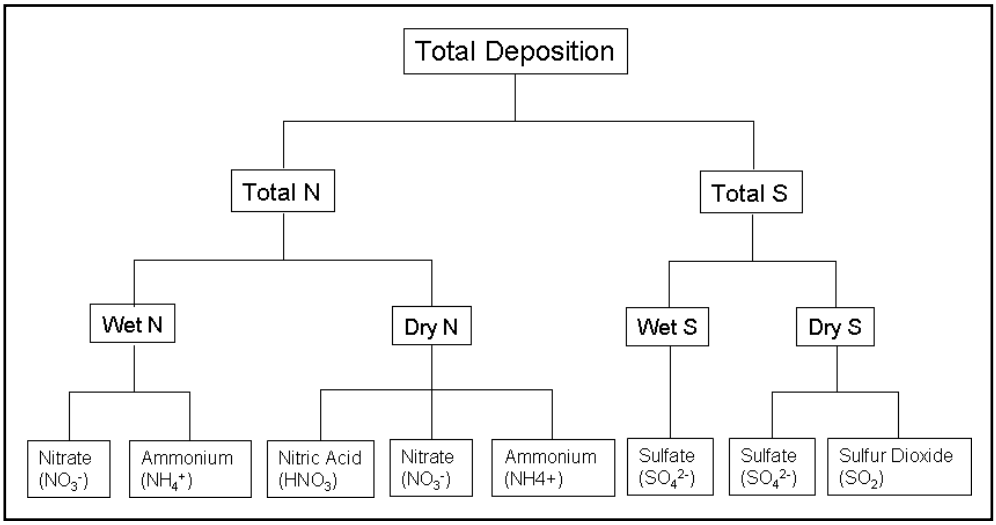

Figure 6. Total deposition is typically divided into nitrogen (N) and sulfur (S) portions, each with wet and dry means of deposition.

Leaching of anion versions of N (primarily NO_3^-) are a primary contributor to deposition-related soil acidification. This process often results in less hospitable conditions for plants, and may lead to an eventual shift in species composition towards N-adapted species (Lovett et al. 2009). As soil continually becomes N-saturated, this can also increase the emission rate of nitrogenous greenhouse gases from the soil itself (Fenn et al. 1998). Soil microorganism communities are also susceptible to increases in N. Carreiro et al. (2000) showed that added N can slow decomposition rates in hardwood litter with high-lignin content.

Increased N concentrations have also been shown to predispose some plants to certain insect pests. Pontius et al. (2006), for example, showed that N concentration of eastern hemlock (*Tsuga canadensis*) stands correlated with infestation of hemlock woolly adelgid (HWA) (*Adelges tsugae*), leading to more severe dieback symptoms. McClure (1991) tested hemlock response to N-fertilization in Connecticut and found a fivefold increase in the number of HWA per area and over a twofold increase in survival and fecundity. In addition, results showed that residual effects on HWA populations persisted even 6 months after initial fertilization. A later study by McClure (1992) comments that the "degree to which adelgid performance was enhanced by fertilization is remarkable…," and combined analysis showed that fertilization in the presence of pesticide application enhanced survival of HWA.

Sulfur is the other main constituent of total deposition, and can also affect forest ecosystems in several ways. Sulfur differs from nitrogen in that it is not a biologically-limiting element, and concentrations of S from deposition can persist in soil for long periods of time. Sullivan et al. (2008) points out that over time, soils can reach adsorption capacity such that additional S can be leached into surface waters as SO_4^{2-}, even if sulfuric atmospheric deposition rates decrease. In areas with low base-cation concentrations, sulfate leaching can lead to depletions of calcium (Ca^{2+}) and magnesium (Mg^{2+}), which can in turn inhibit hardwoods such as sugar maple (*Acer*

saccharum), white ash (*Fraxinus americana*), basswood (*Tilia americana*), and dogwood (*Cornus florida*;Lovett et al. 2009).

Wet Deposition

As part of the National Atmospheric Deposition Program (NADP), two sites within the Clean Air Status and Trends Network (CASTNET) collect wet deposition data: Oak Ridge National Laboratory in TN (~60 km SE) and in Speedwell, TN (~60 km E). The latest NADP map for NO_3^- shows that wet deposition rates at the Oak Ridge and Speedwell sites are comparable to other nearby sites in TN and KY (Figure 9), though values for SO_4^{2-} are slightly elevated from the surrounding region at the Oak Ridge site.

At Oak Ridge Laboratory, monitoring data for both wet nitrate (NO_3^-) and sulfate (SO_4^{2-}) support the reduction in annual deposition rates from the Clean Air Act starting about 1990 (Figure 7 and Figure 8), though SO_4^{2-} reductions are more definitive. Linear regression on seasonal data yields a significantly decreasing trend of 800 mg ha^{-1} yr^{-1} in sulfate deposition ($p = 0.001$) at the Oak Ridge Site (Figure 7, *lower left*). Data records for sulfate deposition at the Speedwell, TN NADP collection site begin in 1998 and show a similar decrease, though not significant ($p = 0.29$) (Figure 7, *lower right*). For nitrate, neither of the decreasing concentrations at Oak Ridge ($p = 0.28$) or Speedwell ($p = 0.06$) were significant (Figure 7, *upper left and right*).

Like the ozone estimates used to approximate values for individual park units, the NPS ARD also created total deposition estimates for N and S over the 2003-2007 period. Respectively, these amounts for BISO were 5.13 kg ha^{-1} yr^{-1} and 6.62 kg ha^{-1} yr^{-1} for total N and S from wet deposition. The NPS ARD also outlined an approach for assessing these values, noting that background wet deposition loading in the eastern US is roughly 0.25 kg ha^{-1} yr^{-1} for both N and S. To gauge condition, wet deposition for either N or S greater than 3 kg ha^{-1} yr^{-1} conveys significant concern, while deposition above 1 kg ha^{-1} yr^{-1} is considered moderate.

Dry Deposition

In the eastern United States, dry deposition is usually a small proportion of total deposition. Between 2003 and 2006, sulfur dry deposition averaged between 11% and 60% of total deposition in the eastern US (EPA 2007). Dry deposition is measured at Environmental Protection Agency (EPA) Clean Air Status and Trends Network (CASTNET) stations, the nearest to BISO of which is at Edgar Evins Park approximately 110 km SW of the site.

Dry N deposition values measured at the Edgar Evins CASTNET station include nitric acid (HNO_3), ammonium (NH_4^+), and nitrate (NO_3^-), while dry S deposition values include sulfur dioxide (SO_2) and sulfate. The dry deposition portions of both N and S comprise only a small proportion of total deposition rates during the three year period (Figure 9). For the years between 1990 and 2007 with complete datasets, linear regression of total dry deposition for N shows a decrease of 42 g ha^{-1} yr^{-1} ($p = 0.0005$), while dry deposition for S shows a decrease of 110 g ha^{-1} yr^{-1} ($p < 0.0001$) (Figure 10).

Total Deposition

Although it is encouraging that wet and dry deposition rates are decreasing, there are no official criteria available to place these values within a normal range of deposition. Measurements for

total deposition at the Edgar Evins CASTNET station (Figure 11) averaged 6.10 kg ha^{-1} yr^{-1} and 7.76 kg ha^{-1} yr^{-1} for total N and S, respectively, over the period 1990 to 2008. Over that period, linear regression also shows a negative trend for both parameters—0.04 kg ha^{-1} yr^{-1} ($p < 0.001$) for N and -0.11 kg ha^{-1} yr^{-1} ($p < 0.001$) for S. In the EPA's 2008 Report on the Environment, monitoring of total N and S deposition at several stations in the eastern US showed approximately 7 kg ha^{-1} yr^{-1} for N and 10 kg ha^{-1} yr^{-1} for S between 2003 and 2005. These values are higher than those observed at Edgar Evins, especially for S. Lastly, the NPS ARD offers estimates for natural levels of background deposition, which are roughly 0.50 kg ha^{-1} yr^{-1} in the eastern US.

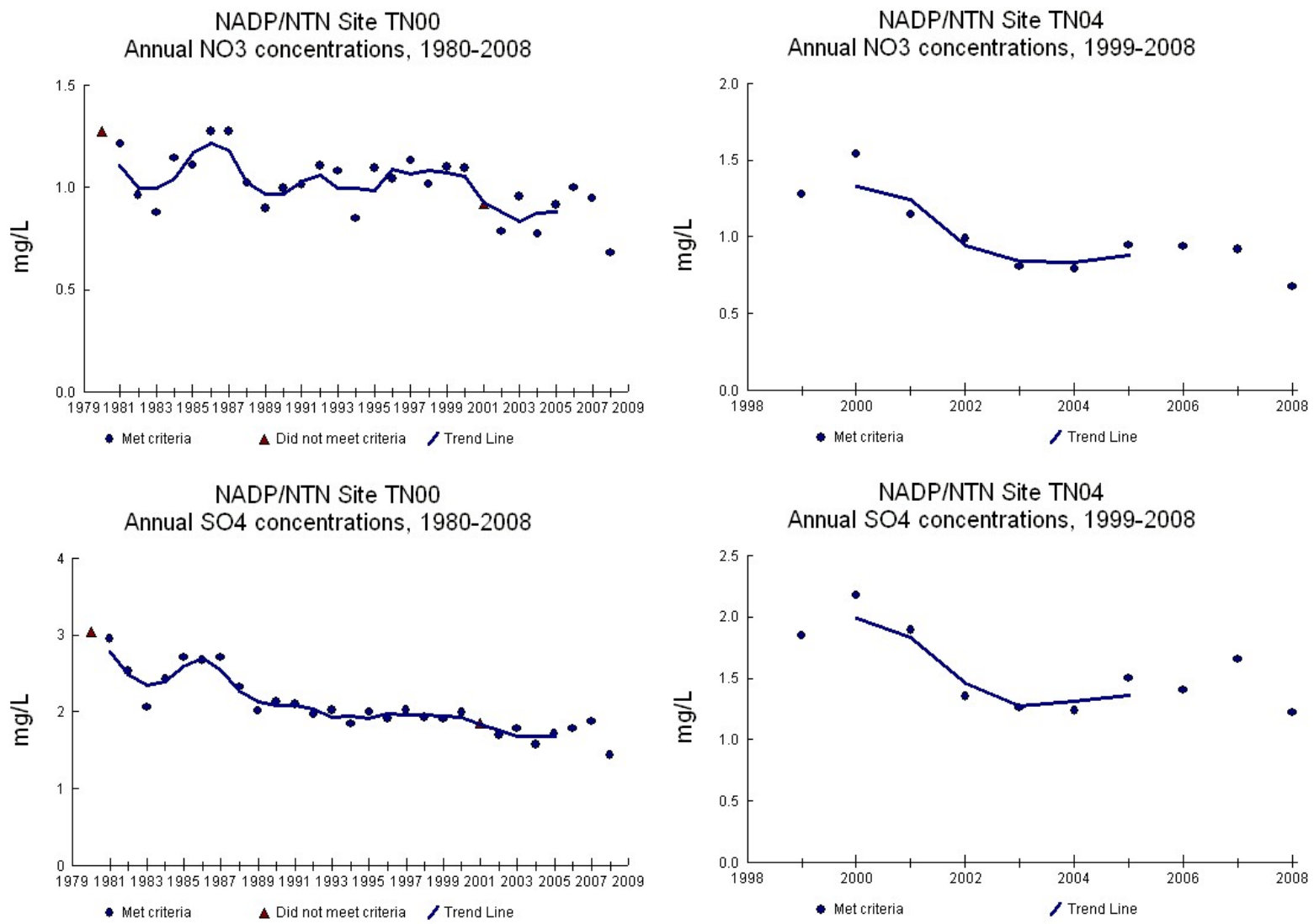

Figure 7. Average annual values for nitrate (NO_3^-) and sulfate (SO_4^{2-}) at Oak Ridge Laboratory (1980-2008; left) and Speedwell, TN (1999-2008; right). Points are precipitation-weighted annual means and are divided into years which do and do not meet NADP data completion criteria. The trend line shows centered 3-yr weighted mean values for periods where data completion criteria were met [Source: http://nadp.sws.uiuc.edu/].

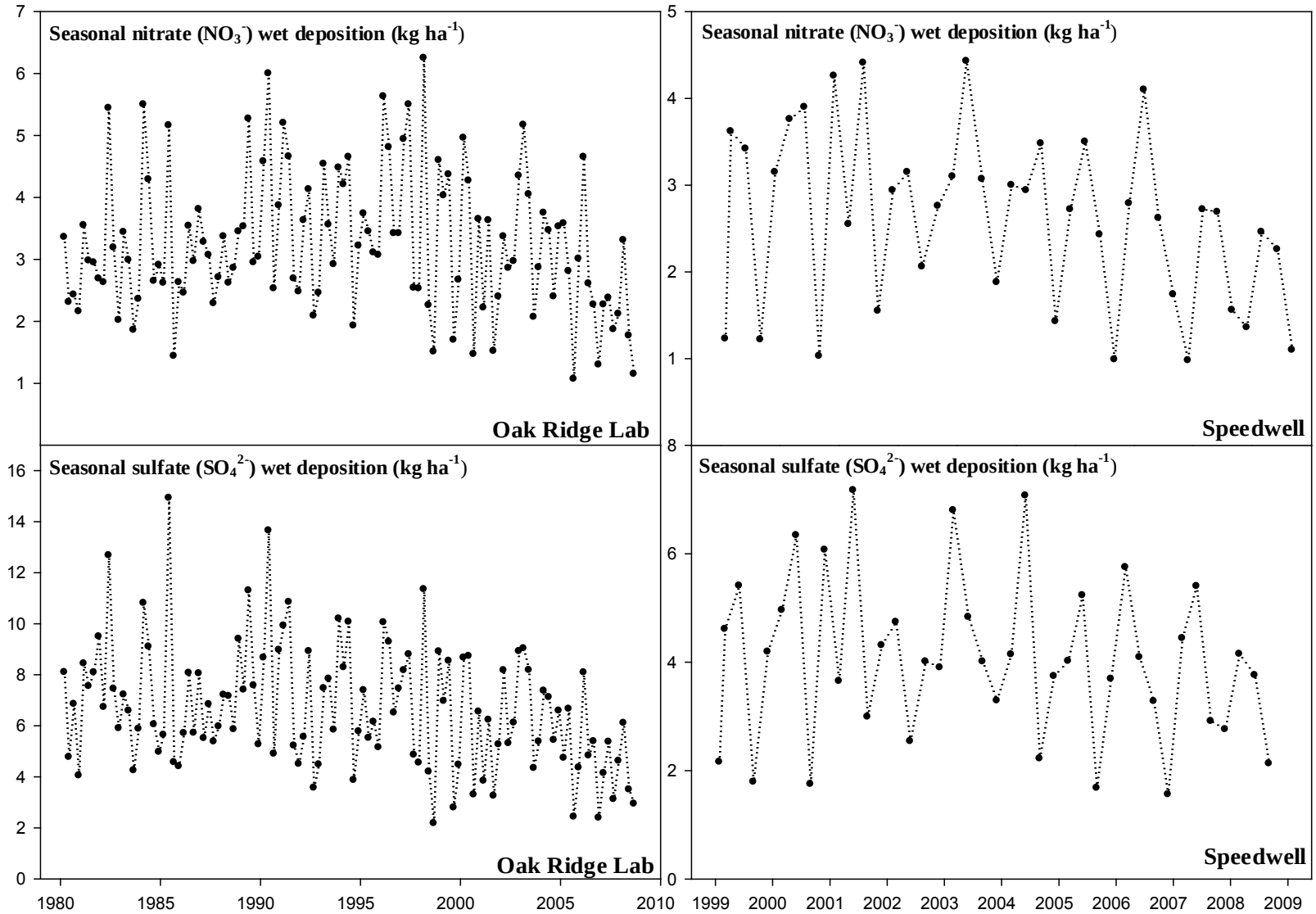

Figure 8. Seasonal wet deposition rates for nitrate (NO_3^-) and sulfate (SO_4^{2-}) at Oak Ridge Laboratory (1980-2008; left) and Speedwell (1999-2008; right) Clean Air Status and Trends Network (CASTNET) stations [Source: http://nadp.sws.uiuc.edu/].

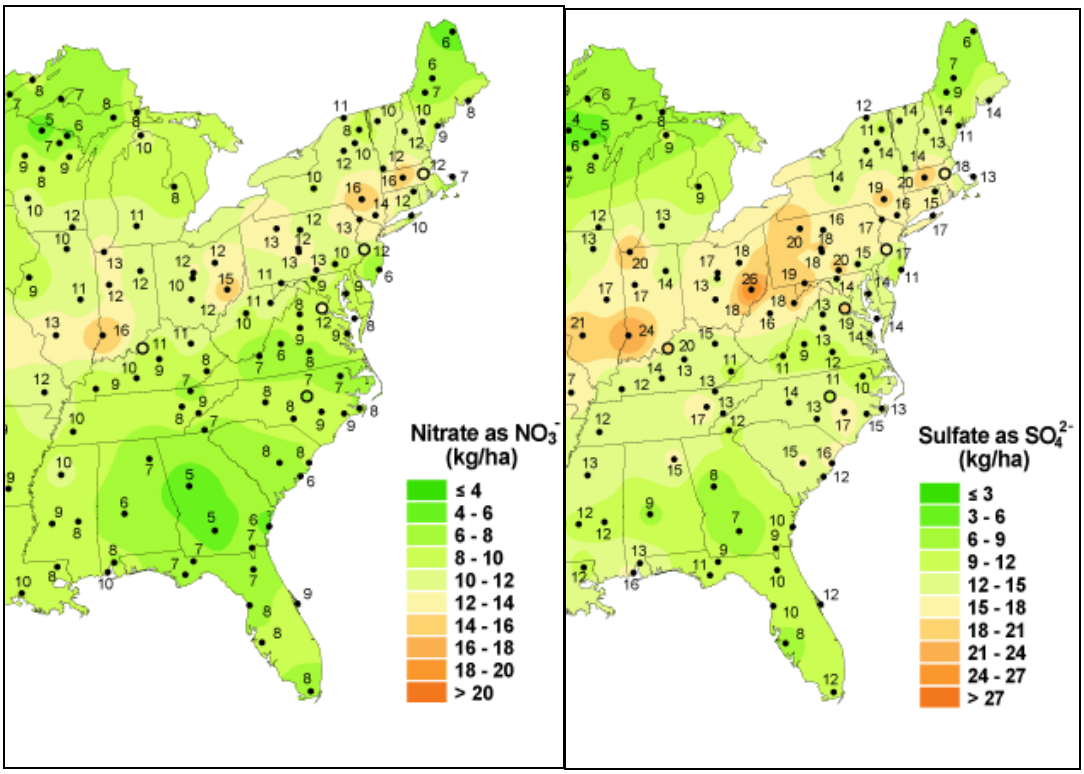

Figure 9. Eastern US nitrate (left) and sulfate (right) wet deposition for 2008 [Source: http://nadp.sws.uiuc.edu/].

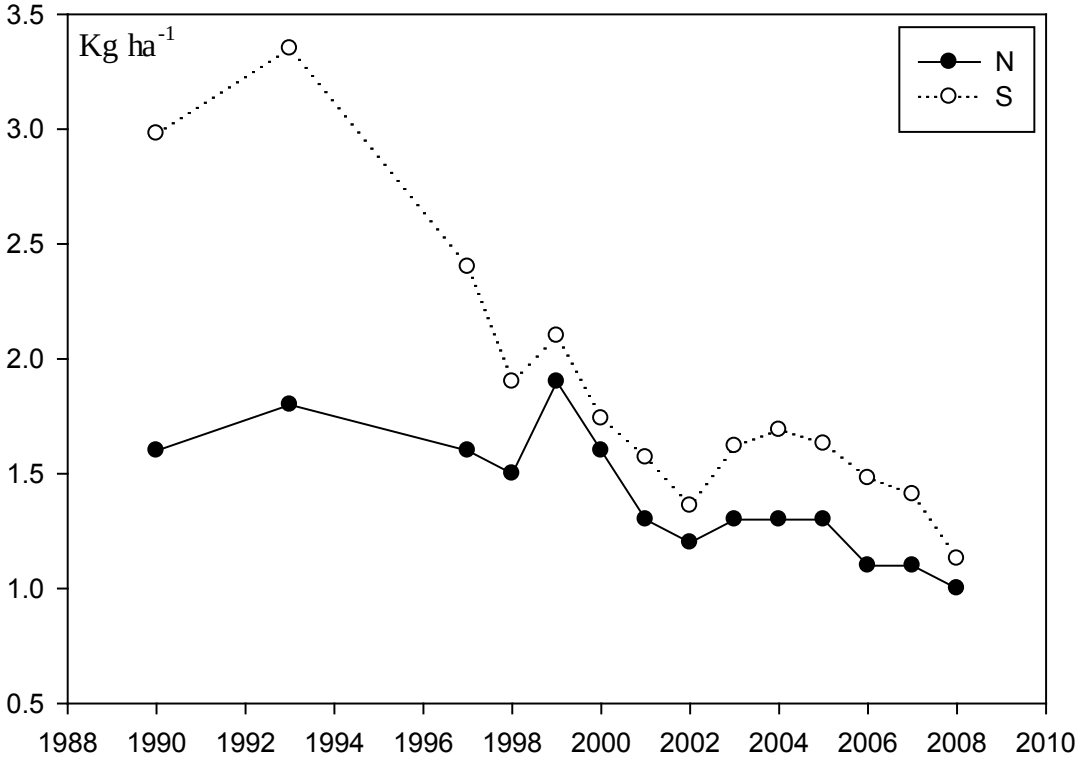

Figure 10. Annual dry N and S deposition values measured at Edgar Evins CASTNET station.

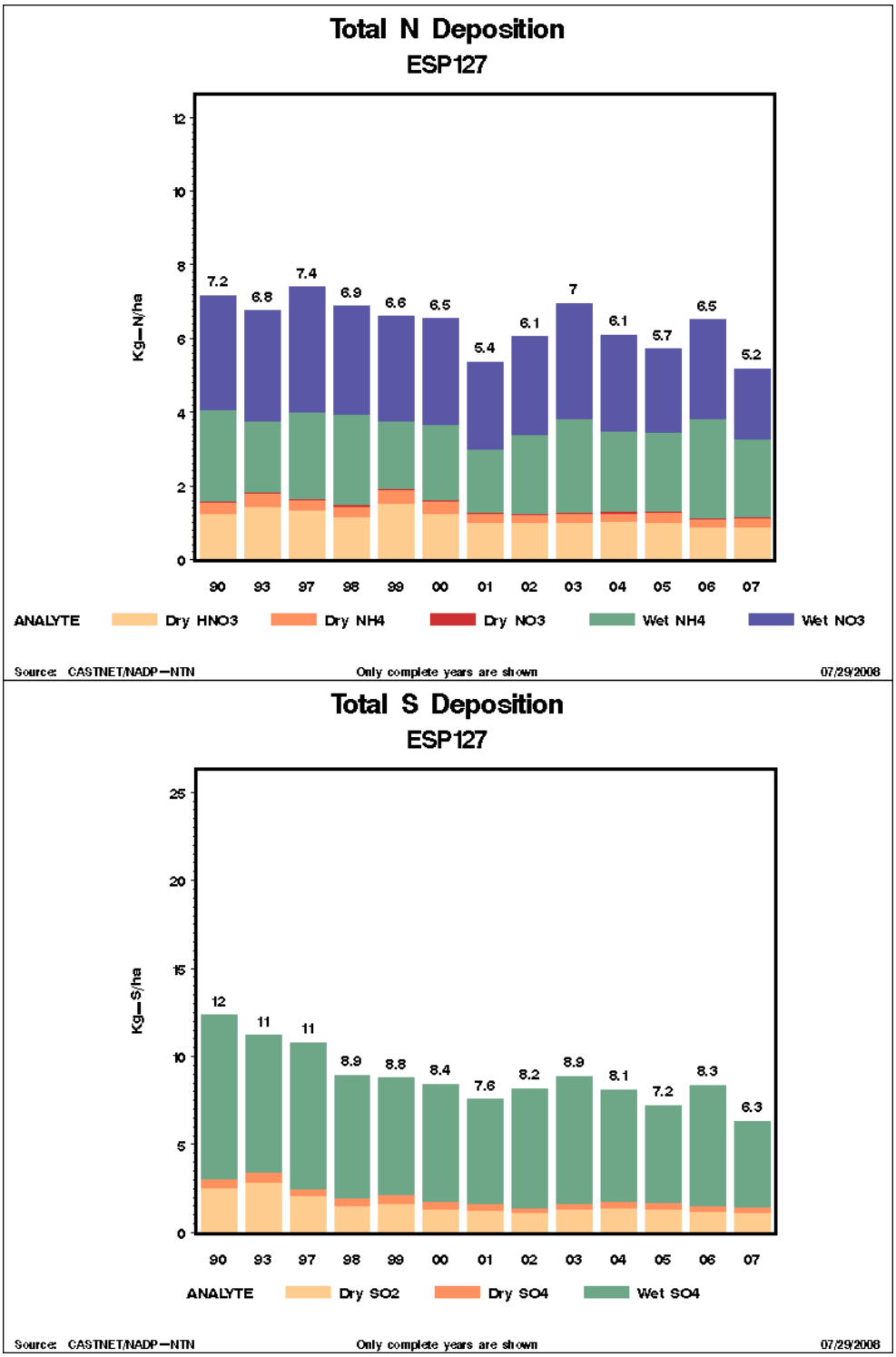

Figure 11. Total N (top) and S (bottom) deposition measured at the Edgar Evins Clean Air Status and Trends Network (CASTNET) site during the period between 1990 and 2007. Data for every year is unavailable [Source: http://nadp.sws.uiuc.edu/].

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 2010). Deposition of Hg is particularly a problem in forested areas, because forest canopies can act as a filter that trap 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 that which is 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 ($[CH_3Hg]^+$). This type of biotic accumulation, known as bioaccumulation, is particularly relevant in aquatic ecosystems, where organisms higher in the food chain (e.g. fish) can develop relatively high concentrations of mercury (NADP 2010). Fortunately, effects of Hg deposition on vegetation are minimal because most plants do not uptake Hg, thereby limiting a similar bioaccumulative terrestrial pathway (EPA 1997a).

The NADP Mercury Deposition Network (MDN) monitors stations throughout the US that collect weekly measurements of total mercury deposition (Figure 12). There are two MDN stations near BISO: one within the Great Smoky Mountains National Park (GRSM), and one at Mammoth Cave National Park (MACA), both of which are approximately 140 km from BISO. The station at GRSM (640 m elevation) is located in Elkmont, TN and began collecting data in January 2002; Mammoth Cave (236 m elevation) began collecting in August 2002. Figure 13 depicts weekly measurements at both sites, for which measurements at MACA are overall a bit higher. Over the period 2002 to mid-2009, average annual Hg deposition was 13.9 $\mu g\ m^{-2}$ at GRSM and 11.4 $\mu g\ m^{-2}$ at MACA. Although no trend appears visible at either site, linear regression yields significantly decreasing deposition on the order of 2.40 $ng\ L^{-1}\ yr^{-1}$ ($p = 0.01$). There are no federal or state standards for ambient concentrations and deposition of Hg, although EPA ambient surface water criteria limits Hg concentrations to 0.012 µg/L (EPA 1997b, see sec. *Water Quality*). It is important to note that although datasets are complete and extensive from the nearby MDN monitoring sites at GRSM and MACA, these distances do not completely eliminate the possibility that regional variation and sources may produce a different Hg depositional pattern at BISO. Direct monitoring at BISO would ensure that park-specific Hg depositional patterns do not go undetected.

High rates of mercury deposition can produce deleterious effects by facilitating bioaccumulation in wildlife populations. Fish, birds, and mammals have been shown to experience reduced reproductive success and hormonal changes in response to high blood levels of mercury (Driscoll et al. 2007). Because of the multiple mercury transfer pathways that can create variable concentrations in different portions of the ecosystem, it is difficult to draw direct connections between levels of atmospheric deposition and adverse health effects. However, the Mercury Study Report to Congress (1997), reports on numerous case studies of methylmercury poisoning resulting in paresthesia in and other nervous system developmental impairments in children.

In a 3-yr study from 2001-2003, Harris et al. (2003) conducted a watershed-scale study to determine effects of increasing mercury deposition on methylmercury concentrations in fish. Using enriched stable mercury isotopes to distinguish from ambient concentrations, they found that methylmercury concentrations in fish rapidly increased after application, and were still increasing after 3 years of observation. Most of the increase was due to the distinct isotope. The target application rate of 22 µg m^{-2} yr^{-1} used in the experiment was roughly double the annual wet deposition rates observed at MACA (11.4 µg m^{-2}) and GRSM (13.9 µg m^{-2}). Though lower, these observed deposition rates may still be resulting in aquatic bioaccumulation that could be influencing mercury consumption in humans.

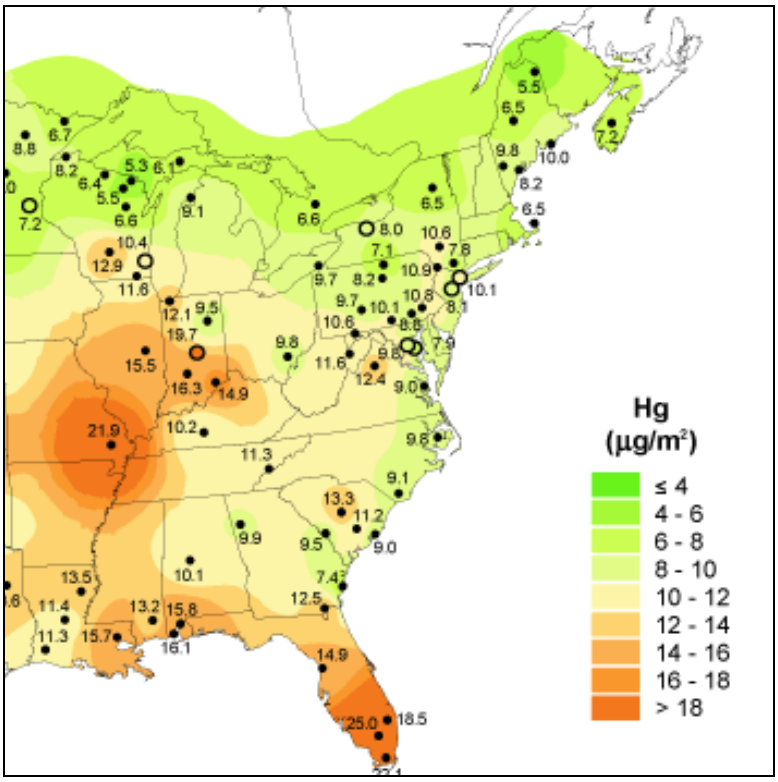

Figure 12. Eastern US mercury wet deposition in 2008.

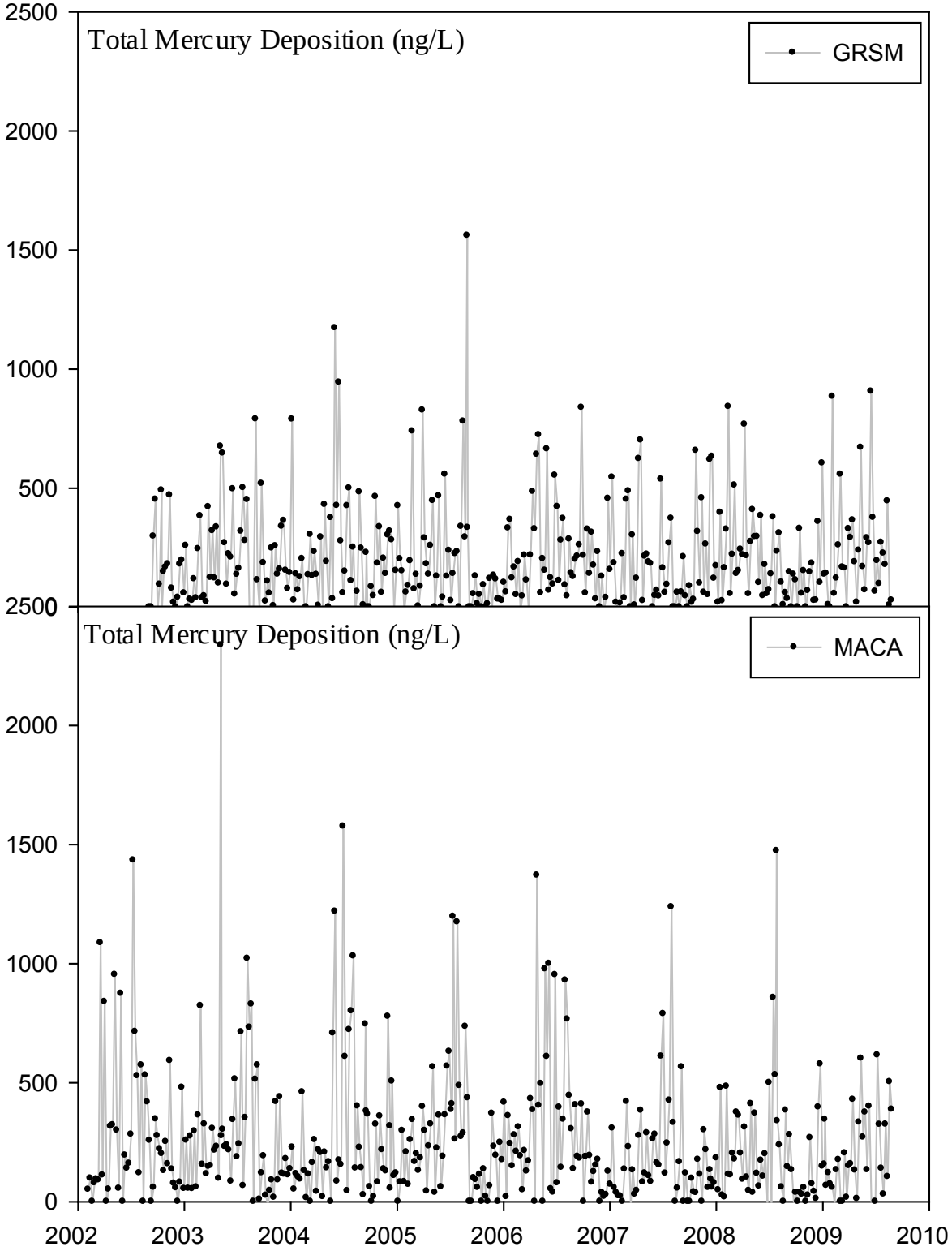

Figure 13. Total Mercury weekly deposition collected at Great Smoky Mountains National Park (top) and Mammoth Cave National Park (bottom), each of which are located ~140km from BISO.

Condition and Trend

Overall, the EPA CASTNET stations provide a continuous and relatively complete data source for deposition throughout the region, although they are not ideally located at the park. Wet, dry, total, and mercury deposition rates generally show decreasing trends over monitoring periods, and total deposition rates at the Edgar Evins CASTNET site were lower than mean values for the eastern US, according to the EPA's 2008 Report on the Environment. Estimates by the NPS ARD for wet N and S deposition at BISO, however, were well over the limit for ecosystem harm and placed the condition of atmospheric deposition in the park at significant concern. Because of these factors, BISO is assigned a condition status of fair for atmospheric deposition with an improving trend (Table 12). However, because components of the depositional data came from several different stations, none of which were located inside the park, the spatial aspect of the data quality is not fulfilled.

Table 12. The condition status for atmospheric deposition at BISO was fair. The trend of atmospheric deposition condition was improving. The data quality was fair, receiving two out of three data quality checks.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Atmospheric Deposition	⇧	✓		✓
		2 of 3: Fair		

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4.3 Visibility and Particulate Matter

4.3.1 Visibility

Throughout the southern Appalachians, anthropogenic sources of pollution have greatly impaired visibility (Figure 14). In eastern national parks, average visibility ranges have decreased from an unimpacted 150 km miles to ~30 km, and in some places, sunlight in the presence of airborne particles and humid conditions can reduce visibility even more (National Research Council 1993). To monitor atmospheric constituents that may inhibit visibility, the Interagency Monitoring of Protected Visual Environments Program (IMPROVE) was formed in 1985, which established monitoring stations in 156 national parks and wilderness areas. Generally, particulates finer than 2.5 µm ($PM_{2.5}$) are the main cause of visibility issues, but they are also important to regulate because they contribute to human respiratory problems (Emmott et al.

2005). Most particles form via atmospheric chemical reactions involving sulfur dioxides and nitrogen oxides.

There are two IMPROVE stations close to BISO at GRSM and MACA. Monitoring data for particulate matter and other airborne constituents is available for each site respectively from 1991-2004 and 1988-2004. The EPA regulates airborne particulate matter concentrations in two separate size classes. Particles between 2.5 and 10 µm are considered coarse particles (PM_{10}), for which the EPA poses a 24-hr primary standard of 150 µg/m^3, not to average more than one exceedance per year over the course of three years. At GRSM, PM_{10} levels did not violate the NAAQS metric for any 3-yr period, though a single day in 1989 recorded a concentration of 409 µg/m^3, which is likely an anomaly or error. At MACA, PM_{10} levels were also within NAAQS limits. For particles finer than 2.5 µm ($PM_{2.5}$), as opposed to the number of exceedances, NAAQS limits stipulate the 3-yr average of the weighted annual mean concentrations must not exceed 15 µg/m^3. According to this standard, neither GRSM nor MACA were in violation, though daily readings were frequently recorded above 15 µg/m^3. Figure 15 shows recorded values for both particulate sizes, with 3-yr averages for $PM_{2.5}$. Each particulate type showed a decreasing trend: GRSM $PM_{2.5}$ of -0.19 µg m^{-3} yr^{-1} (p = 0.01), GRSM PM_{10} of -0.36 µg m^{-3} yr^{-1} (p = 0.005), MACA $PM_{2.5}$ of -0.28 µg m^{-3} yr^{-1} (p = 0.005), and MACA PM_{10} of -0.40 µg m^{-3} yr^{-1} (p = 0.004).

4.3.2 Particulate Matter

In addition to the particulate matter measurements collected at GRSM and MACA, the NPS ARD modeled levels of visibility at parks across the US. Visibility is rated using a number called Group50, calculated as the mean of visibility between 40th and 60th percentile values. For a particular location, this mean is calculated for ambient conditions and estimated for natural conditions, the difference of which is the visibility rating used to assess condition. At BISO, the interpolated Group50 value was 13.89 deciviews (dv) over the period 2003-2007, which places the park unit well within the range of significant concern for visibility conditions (> 8 dv).

Figure 14. Airborne constituents photos at the GRSM IMPROVE site showing decreased visibility range from 300 km (left), to 40 km (middle), to 13 km (right).

4.3.3 Other Particulates

Lead (Pb) particulate is also monitored at both IMPROVE stations near BISO (MACA and GRSM). The EPA NAAQS for lead limits concentrations to 0.15 µg/m^3 Pb for rolling 3-month averages, though the maximum concentration between both sites over their monitoring periods was 0.03 µg m^{-3}, recorded at GRSM.

4.3.4 Condition and Trend

Overall, there is little data on which to base a condition assessment for visibility at BISO, and no data that was collected from within the park itself. As a result, this attribute does not receive a ranking for spatial data quality. Because of the monitoring data from GRSM and MACA and the NPS ARD visibility estimate, BISO receives a condition ranking of fair for visibility and particulate matter (Table 13). An improving condition is also assigned based on the decreasing trend observed in each of the particulate matter datasets for GRSM and MACA.

Table 13. The condition status for visibility and particulate matter at BISO was fair. The trend of visibility and particulate matter condition was improving. The data quality was fair, receiving two out of three data quality checks.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Visibility and Particulate Matter	⇧	✓		✓
		2 of 3: Fair		

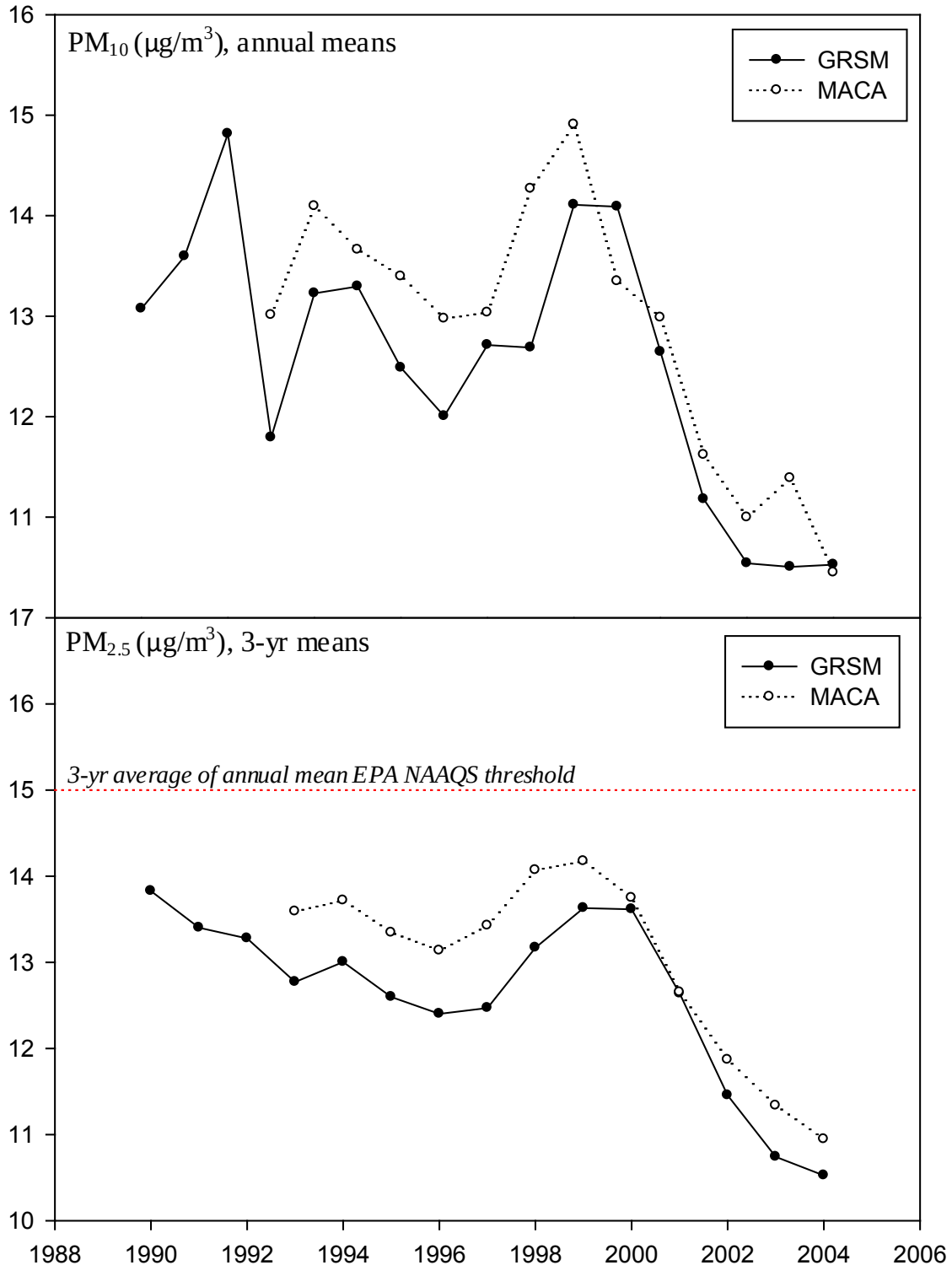

Figure 15. Particulate matter concentration measurements recorded at IMPROVE stations in GRSM and MACA, each approximately 140 km from BISO. PM10 is depicted as annual means based on 24-hr measurements (top). PM2.5 is based on 3-yr means of annual 24-hr averages (bottom).

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Interagency Monitoring of Protected Visual Environments (IMPROVE) 2009. Cooperative Institute for Research in the Atmosphere. Colorado State University. Fort Collins, CO Available at http://vista.cira.colostate.edu/improve/ (accessed 29 October 2012).

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4.4 Weather & Climate

The I&M Program monitors long-term weather and climate patterns to help identify patterns, trends, and deviations for certain characteristics. Certain patterns can provide insight into natural resource phenomenon, such as the reproduction of certain species, forest insect pest and pathogen outbreaks, and spread and invasion of exotic species (Davey et al. 2007). 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. Throughout the APHN, climate is closely tied to the presence of the Southern Appalachians. Precipitation varies with elevation, whereas temperature patterns depend on more localized topography. Both of these attributes can occur within quickly-changing gradients, resulting in unique microclimate areas over just short distances.

At BISO, there is a single monitoring station administered through the Remote Automated Weather Station (RAWS) Network that began collecting data in the fall of 2000. This station collects hourly measurements of temperature, precipitation, wind, and humidity, among other observations. In addition, there are three nearby weather stations in the National Weather Service (NWS) Cooperative Observer Program (COOP), all of which have extensive monitoring records. These stations collect minimum and maximum temperatures, precipitation, and snowfall, in addition to other selected parameters. The first of these stations is in Allardt, TN—7 km SW of BISO. It began collecting data in 1928. Of the three weather stations, Allardt has the most complete and extensive dataset. Stearns, the second station, is located 3 km NE of the park and began monitoring in 1936. This station is missing considerable data from observations during the 1940s, 1950s, and 1970s. Finally, Oneida is approximately 10 km east of the park and began collecting data in 1952 (Figure 18). Oneida's data record is fairly complete, though some observations are missing from the 1980s and 1990s. Because all three of these COOP sites are close to the park, their data provide a valuable resource for long-term comparisons.

4.4.1 Precipitation

The Southern Appalachian region generally receives the highest rates of precipitation in the eastern US. Precipitation is one of the most influential drivers for many ecosystem processes, through which it can affect fire regimes, primary production, stream flow, and pollutant deposition. In the Weather and Climate Inventory Report for APHN, Davey et al. (2007) point

out that, over the last century, precipitation has increased in some places in the APHN. The most recent climate summary for BISO in 2007 indicates that precipitation was well below average for that year (Flaherty 2010). Only 35.8 inches were recorded at the station, whereas the mean annual precipitation over the life of the station (2001-2006) was 54.5 inches. In Allardt and Stearns, precipitation was respectively 46.9 and 41.7 inches, representing 6-year mean departures of -9.5 and -7.6 inches (Flaherty 2010). The report further acknowledges the possibility of sensor malfunction at the RAWS station in BISO, because precipitation measurements were much lower than the two COOP stations after maintenance in September. Flaherty (2010) also points out that, with little exception, each of the three stations recorded below-average monthly precipitation in 2007, even when compared to 30-yr means at Allardt and Stearns.

Figure 16 shows annual precipitation levels at all three COOP monitoring stations, plus the Big South RAWS station in the park. Data is shown for the complete history at each station, with missing data points for years with one or more months of absent data. Linear regression for each COOP station shows no significant trends. Since the latest APHN climate summary in 2007 (Flaherty 2010), which reported unseasonably low rainfall for BISO and the surrounding region, precipitation amounts increased in both 2008 and 2009.

Figure 17 shows, for each station, the number of days in each year of monitoring that recorded a maximum rainfall over the entire period of record. When plotted over time, the Stearns and Oneida stations show a significant increase in number of days with maximum rainfalls. This might suggest an increase in the number of storm events over the period of these monitoring stations, and as a result could have significant impacts on resources in the park.

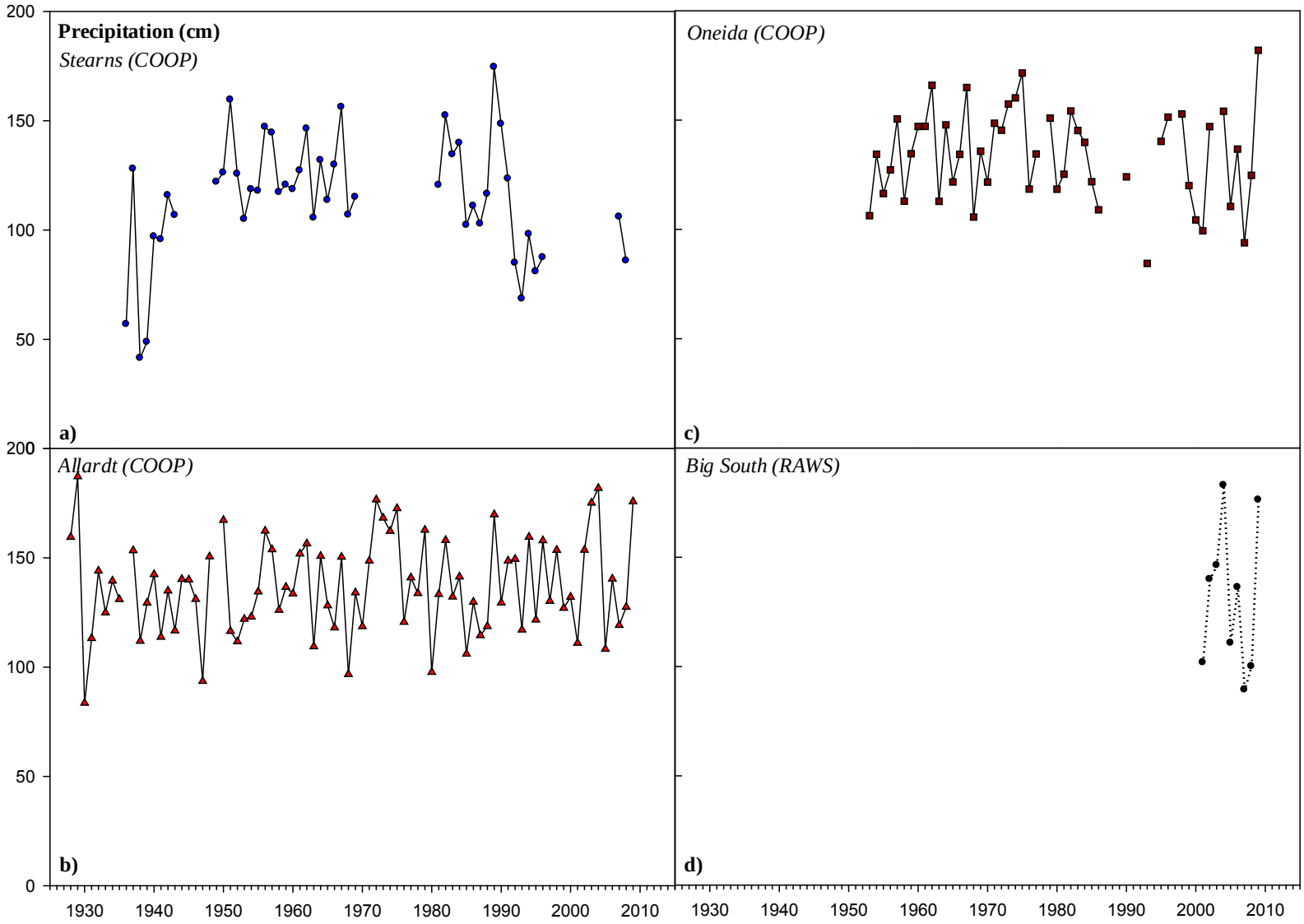

Figure 16. Annual precipitation at Stearns (a), Allardt (b), Oneida (c), and Big South stations (d). Years with at least one month of missing data are not included.

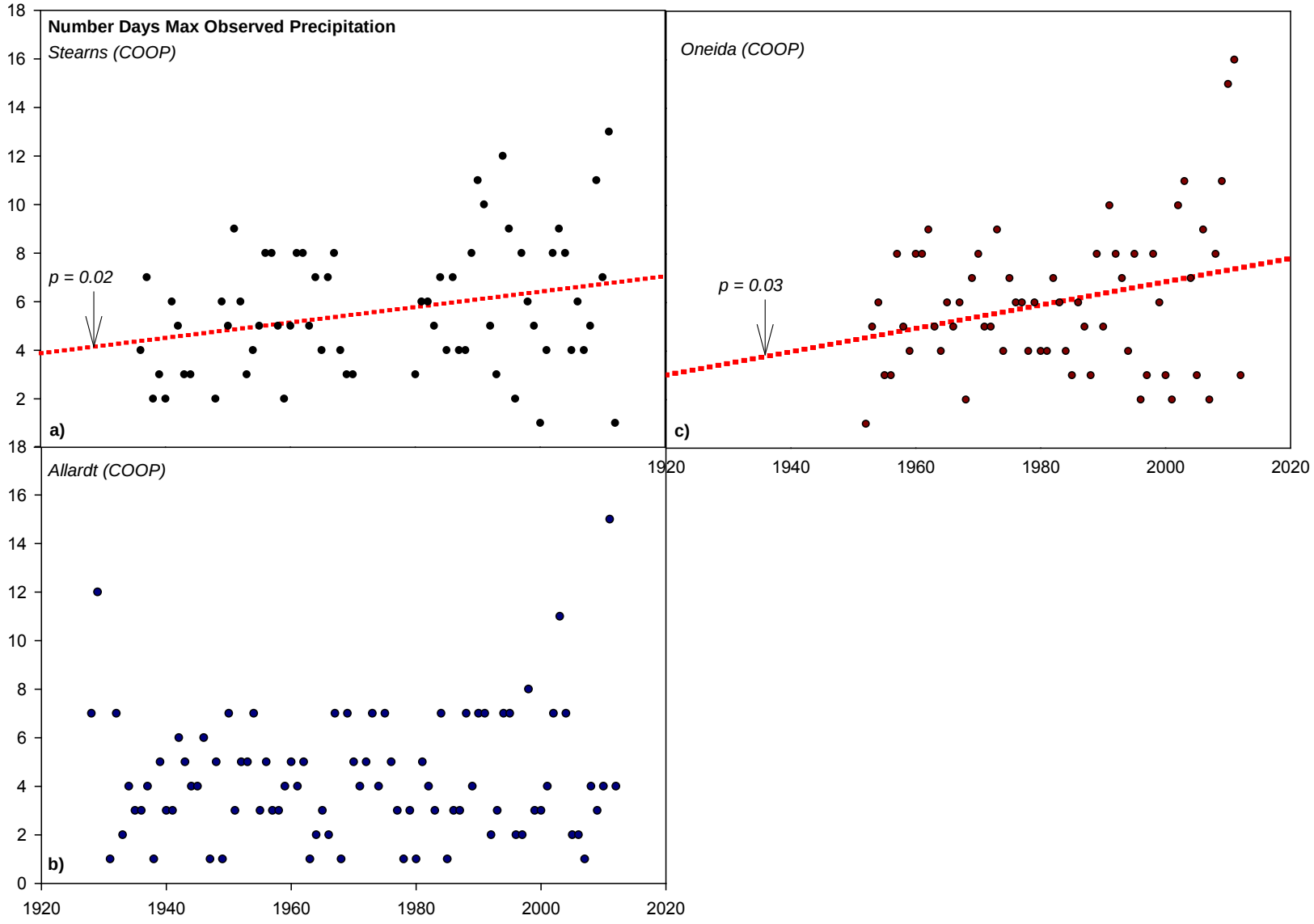

Figure 17. Number of days for each year that represent the maximum precipitation over the period of record for Stearns (a), Allardt (b), and Oneida (c) stations.

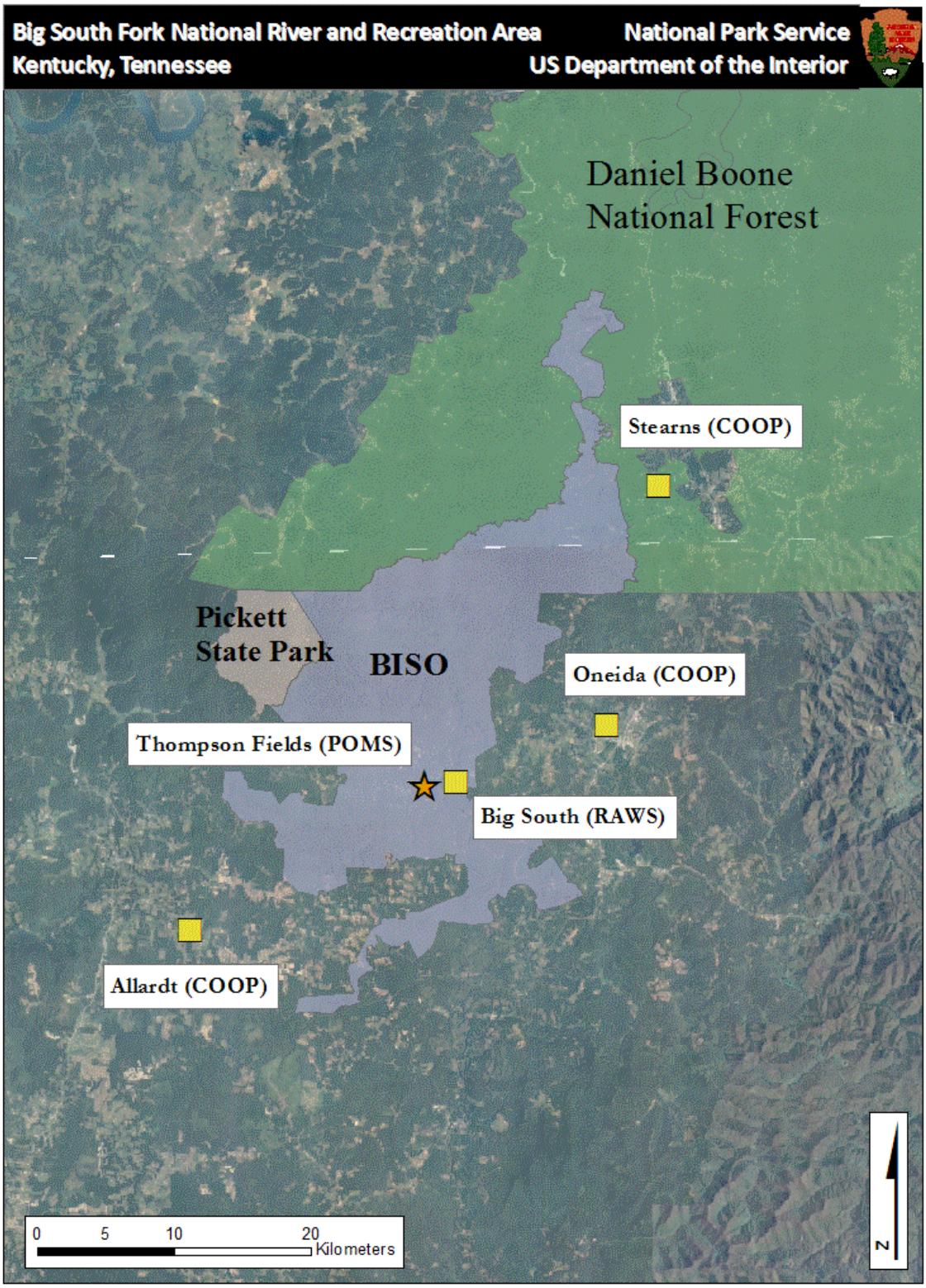

Figure 18. Along with the RAWS station within BISO, there are three COOP stations located in towns near the park. The POMS was located near the Big South RAWS.

4.4.2 Temperature

Long-term temperature monitoring in the APHN also has 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 also may have ecosystem-level effects such as altered fire regimes and increased susceptibility to invasive species (Davey et al. 2007). The APHN Weather and Climate Inventory Report points out that temperatures were warmest during the 1940s and 1950s, but became suddenly cooler in the 1960s. Following that decade, temperatures began to show a warming trend that continues to the present (Davey et al. 2007). Figure 19 shows average daily, maximum, and minimum annual temperatures at the three COOP stations and the Big South RAWS monitor. Allardt is the only station with data during the 1940s and 50s, which is consistent with the description of Davey et al. (2007). Linear regression for each of these data series shows significant trends. Although none of the daily mean temperatures demonstrated a trend, mean annual minimum temperatures showed an increasing trend at Oneida (0.03 °C yr^{-1}, $p = 0.009$) and Allardt (0.02 °C yr^{-1}, $p < 0.0001$). Despite much missing data, Stearns showed a decreasing trend for mean annual minimum temperature (-0.03 °C yr^{-1}, $p = 0.008$). At Allardt, mean annual maximum temperatures also showed a decreasing trend (-0.02 °C yr^{-1}, $p < 0.0001$). It is important to note, however, that just as many temperature records among the stations showed no significant linear trend.

Flaherty (2010) points out that 2007 was an exceptionally warm year for BISO, with a recorded mean temperature that was 1.1 °F warmer than the mean for the previous 6 years of records at the station. Annual means at Allardt and Stearns were also 2.6 °F and 1.4 °F warmer, respectively, when compared to annual means from 1971-2000.

Lastly, it is possible to track seasonal changes in temperature using the annual number of growing degree days (GDD) as a metric. Most simply, growing degree days correspond to the amount of time the temperature is above a certain baseline number of degrees. Often, 40 ˚F is used as a baseline, and temperatures above that threshold represent time plants can grow towards maturation. After Dorr et al. (2009), we used monthly temperature means from each of the COOP stations to calculate GDD according to the following equation:

$$GDD = (T_m - B)*D_m \qquad \text{(Eq. 2)}$$

where GDD is number of growing degree days, T_m is the monthly mean temperature, B is the baseline temperature (40 °C in this case), and D_m is number of days in the current month. Results of this calculation for each of the three stations are shown in Figure 20. Linear regression shows no trend at Allardt. Stearns and Oneida, both with shorter monitoring periods, respectively showed negative (-9.87 GDD yr^{-1}, $p = 0.009$) and positive (7.69 GDD yr^{-1}, $p = 0.02$) trends.

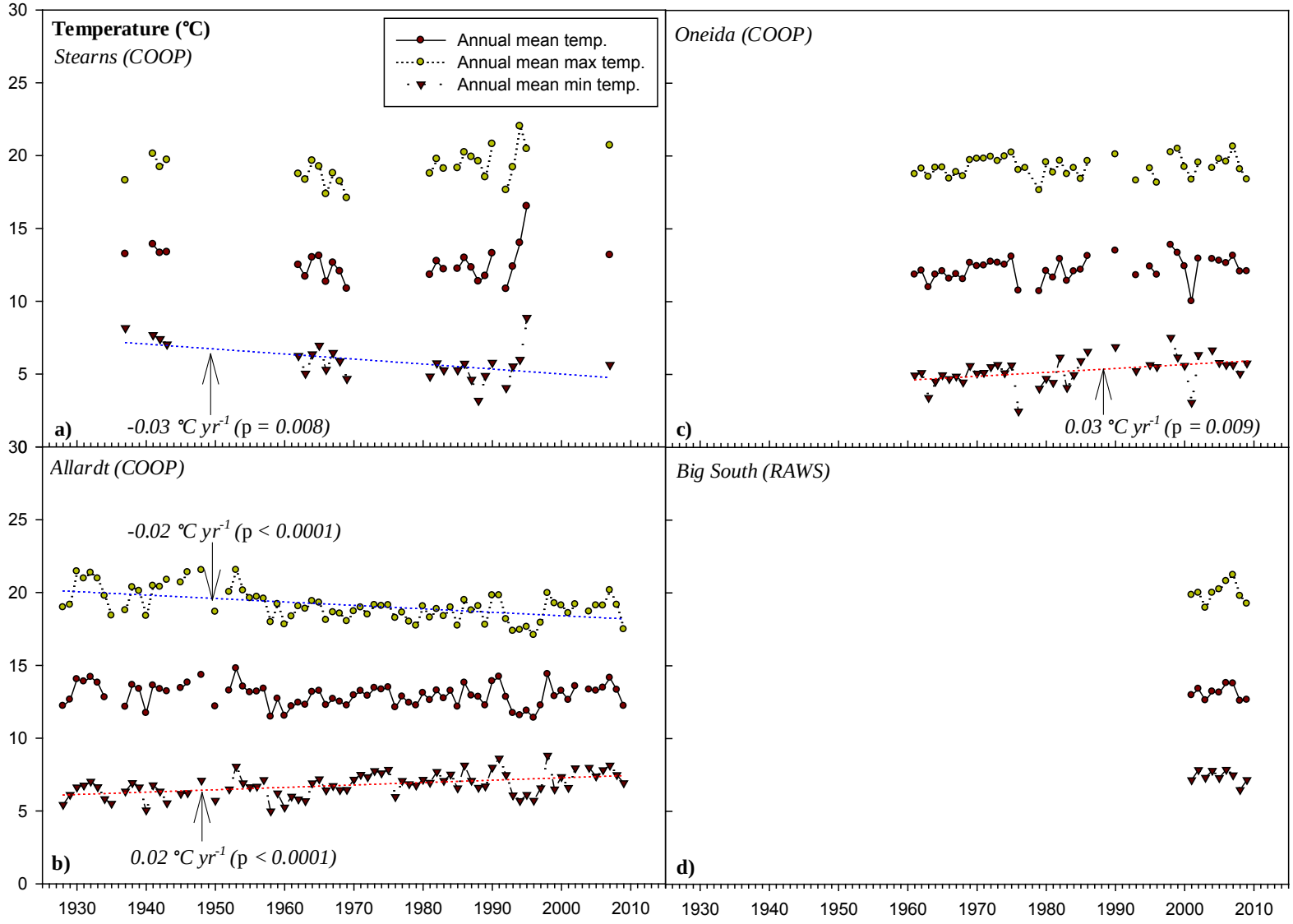

Figure 19. Average annual temperature (°C) at Stearns (a), Allardt (b), Oneida (c), and Big South (d). Only years with monitoring data for all 12 months are shown. Lines show significant trends for increasing (red) or decreasing (blue) temperatures.

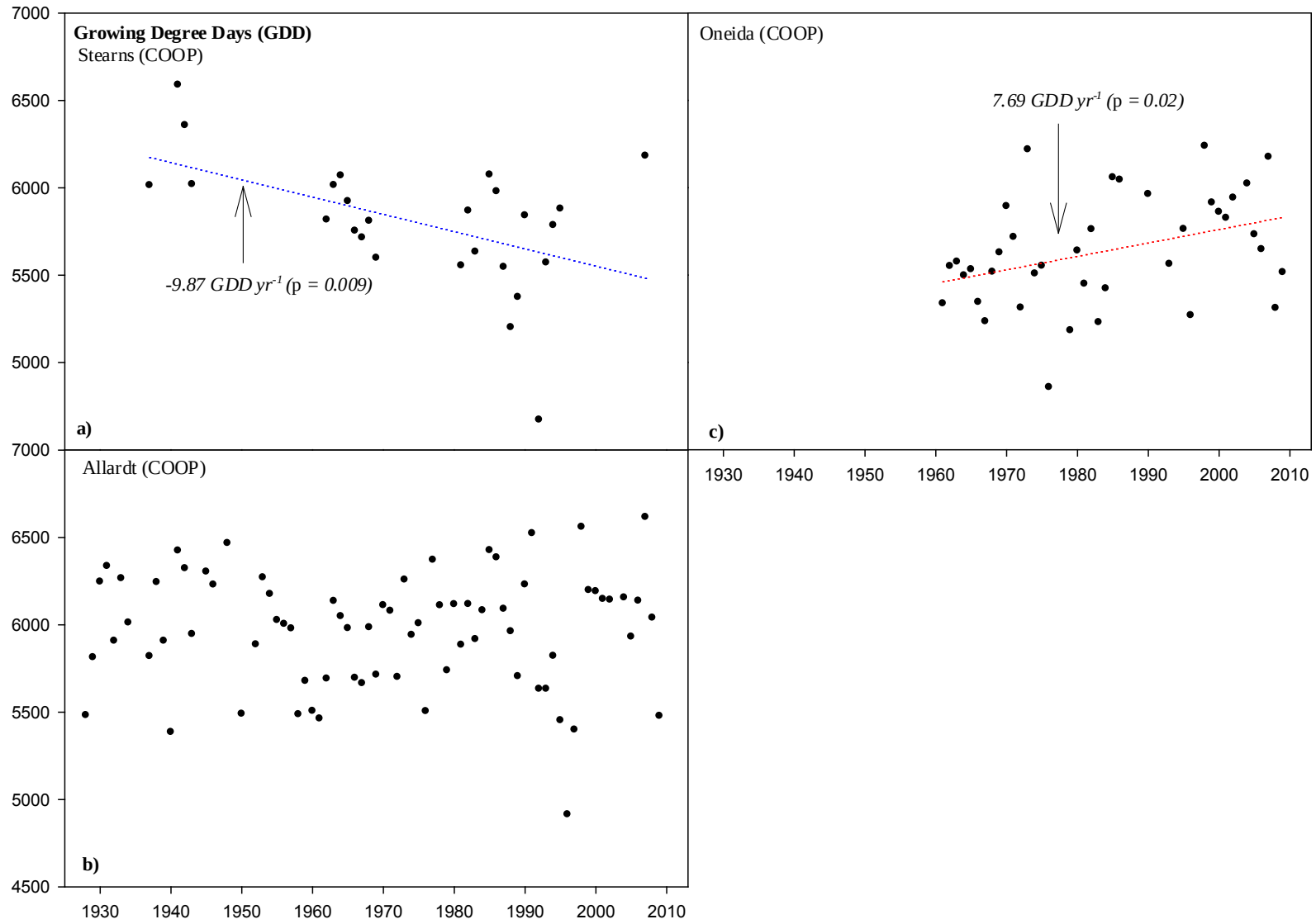

Figure 20. Mean monthly growing degree days (GDD), by year, for Stearns (a), Allardt (b), and Oneida (c). Only years with monitoring data for all 12 months are shown. Lines show significant trends for increasing (red) or decreasing (blue) temperatures.

4.4.3 Wind Speed and Direction

The RAWS at Big South also monitors wind speed and direction. Figure 21 shows a 16-point wind rose depicting cumulative wind speed and direction over the history of the monitoring station. Throughout that period, winds were calm (<1.3 mph) approximately half the time, and predominant directions of wind origin were SSW-SW. Speeds were typically below 3.6 m/s, and only occasionally exceeded that threshold.

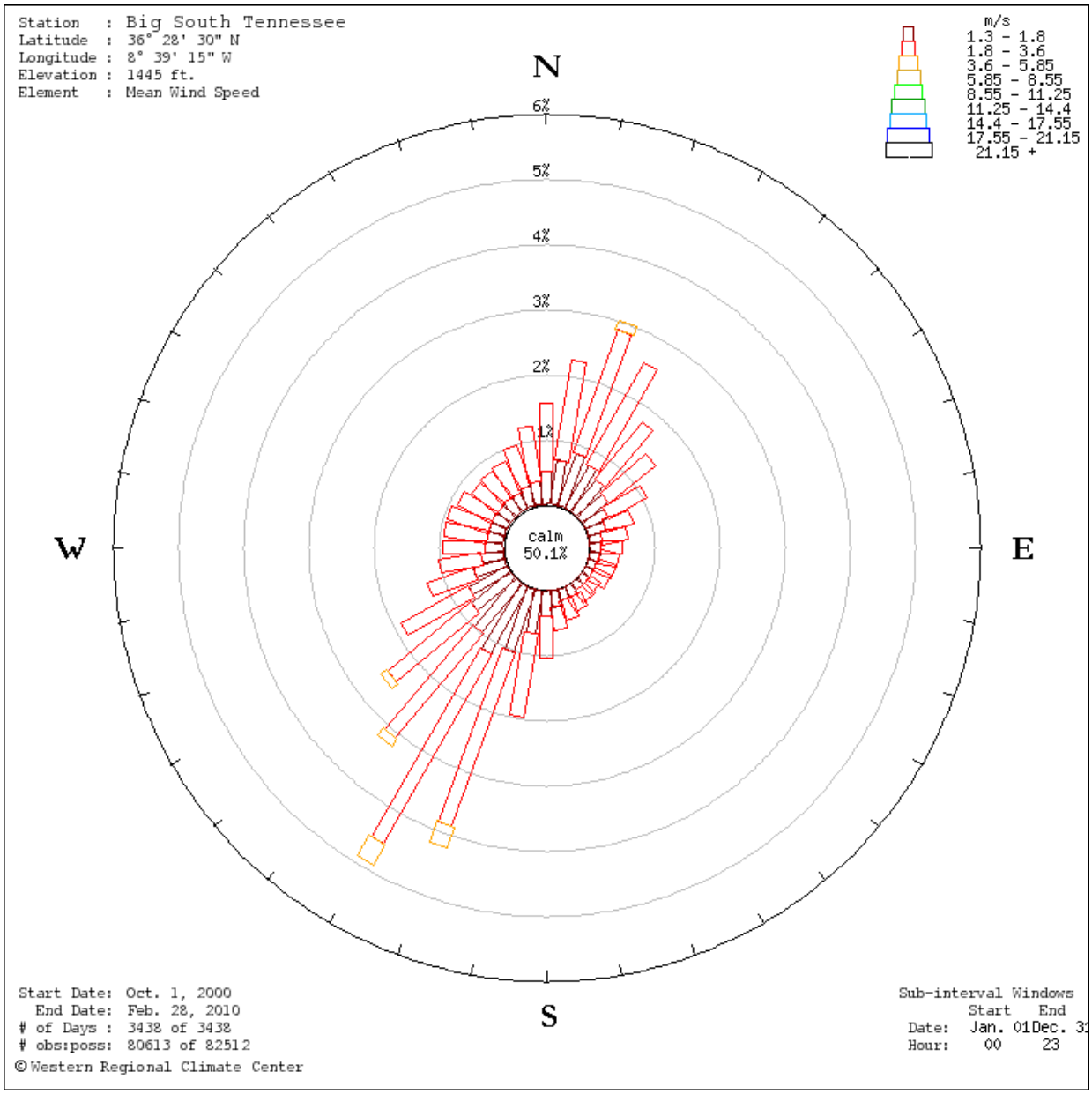

Figure 21. Directional wind rose for Big South RAWS for the data period Oct. 2000 through Feb. 2010. Colors represent wind speed, and lengths of individual colored bars represent proportion of wind in a given direction.

Summary
Overall, there are several data sources with reliable monitoring periods from which to make observations related to weather and climate. Because there is a RAWS located in BISO, the spatial quality criterion of the data quality for weather and climate is fulfilled. Although several trends are apparent in the number of growing degree days and temperature, they are conflicting and lead to no definitive assessment of changes over the period of available data. The increasing number of daily precipitation maximums for Stearns and Oneida may suggest an increase in the frequency of storm events, especially because the overall amount of precipitation has not changed over the same time span. Many time series sets, however, show an unchanging, or stable trend. As a result, the condition status for weather and climate at BISO is assigned a stable trend (Table 14). A condition, however, is not suited to this attribute, and thus none is assigned.

Table 14. The condition status for weather and climate at BISO was not ranked, though a steady trend was assigned. The data quality for this attribute is good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Weather and Climate	⇨	✓	✓	✓
		3 of 3: Good		

4.4.4 Literature Cited

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Dorr, J., S. Klopfer, K. Convery, R. Schnieder, L. Marr, and J. Galbraith. 2009. Natural Resource Condition Assessment with addendum, Fort Pulaski National Monument, Georgia, National Park Service, Blacksburg, VA.

4.5 Hydrology and Water Quality

The aquatic resources at BISO are perhaps the most vital and unique attributes of the park unit. The Big South Fork of the Cumberland River is the park centerpiece, portions of which are classified in Tennessee and Kentucky as Outstanding National Resource Waters. BISO contains less than 14% of the South Fork Cumberland cataloging unit and is influenced by a large area of upstream activities (Rikard et al. 1986). The Big South Fork is formed from the confluence of Clear Fork and the New River in the southeastern portion of the park. From there, it flows north roughly 73 km and then exits the Park. Altogether, there are ~800 km of small and medium streams and rivers inside the park; streams in the western portion of the park generally are

cleaner and in better condition than eastern and southern portions, because the latter areas are close to mine drainages (Emmott et al. 2005).

Aquatic resources in the park are jeopardized because of historical economic dependence of upstream regions on mineral extraction. The majority of coal mining in Tennessee occurs in the South Fork Cumberland watershed, most of which is in the New River drainage; a recent assessment counted over 3,000 active and inactive coal mine sites within the watershed (Guyot 2005). Parker and Carey (1980) also provide an overall summary of water quality issues in the New River and Clear Fork basins. In the park enabling legislation, the New River is highlighted as a specific area in need of restoration from effects of acid mine drainage and siltation, so much so that it is mandated toenhance water quality in this region . Even Big South Fork has shown evidence of acid mine drainage impacts, including elevated dissolved/suspended solids and sulfates (Hamilton and Smith 1997).

Gas and oil extraction can also represent a threat to freshwater mussels via chloride contamination. Picket, Fentress, and Scott counties in TN, all of which include southern portions of BISO, collectively accounted for roughly 30% of oil production in Tennessee in 2010. Scott County produced roughly 16% of natural gas in TN during the same year (Zurawski 2011). In the Big South Fork cataloging unit, Guyot (2005) reported over 1,400 oil and gas wells, most of which were located in the drainages of Clear Fork and North White Oak Creek (Guyot 2005).

At BISO, extraction regulations according to the enabling legislation differ for the gorge area, where no extraction is allowed, and within the “adjacent area” (i.e. upland), where oil and gas extraction is permitted. In these upland areas, mineral extraction is also permitted provided that “entrances” are outside the park boundary.

4.5.1 Acid Mine Drainage

Because the rivers in BISO are near the center of the South Fork Cumberland watershed, they are susceptible to runoff from various upstream activities. Runoff from active or abandoned coal mines, in particular, can contribute to loading from various contaminants. Sulfuric acid and ferric hydroxide ($Fe[OH_3]$) are two common and deleterious products that enter streams via runoff and erosion caused by extraction processes. Generally, this occurs when pyrite (FeS_2) generated from mining is oxidized to produce ferrous iron (Fe^{2+}), sulfate (SO_4^{2-}), and acidic hydronium ions (H^+) that lower water pH. Neutralization by water contributes to the production of ferric hydroxide—a solid called “yellow boy” that can discolor water and coat natural substrata (Figure 22; O’Bara et al. 1982). This coating inhibits benthic photosynthesis, which in turn disrupts the trophic foundation for aquatic invertebrates and fish (Koryak et al. 1972). In addition to this acidifying process, other common toxicants arising from acid mine runoff include aluminum, cadmium, cobalt, copper, iron, magnesium, manganese, and zinc. Consequently, some streams in BISO are severely impacted habitats with limited ability to support aquatic life (Emmott et al. 2005). O’Bara et al. (1982) outlined several water quality parameter thresholds indicative of acid mine drainage (Table 15).

Figure 22. Ferric hydroxide byproducts shown at a coal mine at BISO. Known colloquially as yellow-boy, ferric hydroxide is a byproduct of acid mine drainage that can inhibit benthic production. [Source: NPS Photo]

Table 15. Water quality parameter thresholds indicative of acid mine drainage. [Source: O'Bara et al. (1982)]

Parameter	Value
pH	< 6.0
Alkalinity (mg L^{-1} $CaCO_3$)	< Acidity
Iron (mg L^{-1})	> 0.5
Sulfate (mg L^{-1})	> 75.0
Aluminum (mg L^{-1})	> 0.3
Hardness (mg L^{-1})	> 150
Turbidity (mg L^{-1})	> 200

4.5.2 303(d) Streams

Under the Clean Water Act, states are required to provide a list of impaired waters violating water quality standards to the EPA every other year, referred to as the 303(d) list. For each impaired water, states are required to develop a recovery plan that includes specification of a Total Maximum Daily Load (TMDL) for pollutants found to be the cause of degraded water quality (Tennessee Department of Environment and Conservation 2010). Assignment of waters on the list helps each state prioritize water quality improvement efforts. As of this writing, 2010 is the latest available version of impaired waters. There are three listed stream segments that fall within BISO, totaling approximately 10 km in both states. A total of nine segments with associated tributaries are listed throughout the South Fork Cumberland cataloging unit (Figure 23).

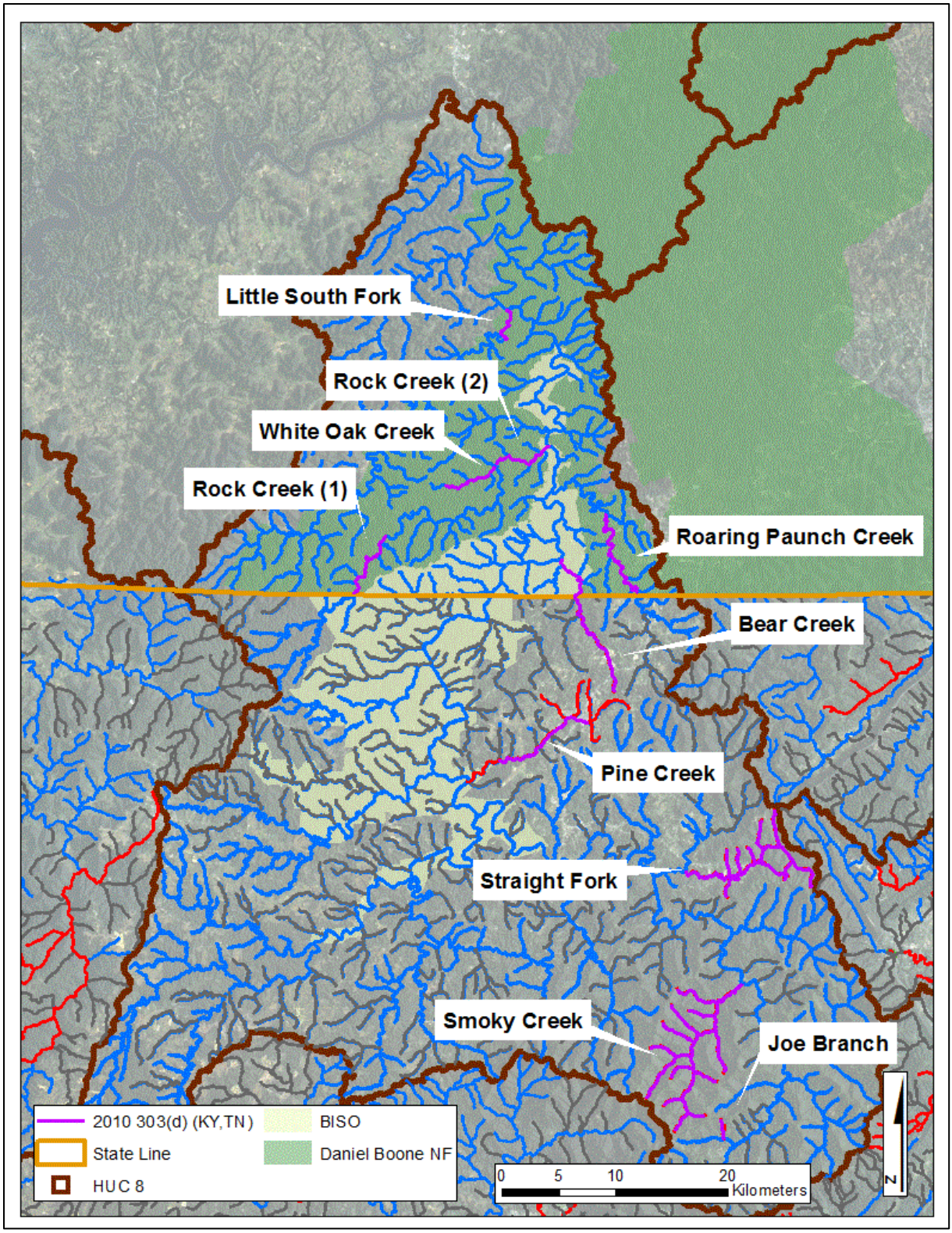

Figure 23. Three stream segments in BISO are included in the latest 2010 list of impaired waters: Rock Creek, Bear Creek, and Pine Creek. In the South Fork Cumberland cataloging unit overall (HUC 05130104), nine stream systems are included on the list. Streams shown in red are ones with completed TMDLs for pollutants. TN streams shown in gray were not assessed for attainment.

Rock Creek

Rock Creek is unique in that it represents one of the highest quality watersheds in Kentucky, though it is simultaneously threatened by acid mine drainage and industrial activity (Figure 24). Rock Creek begins in Pickett State Park in Tennessee and enters Kentucky where it flows through the Daniel Boone NF. From here, it is classified as a Kentucky Wild River and high quality water until its confluence with White Oak Creek. Despite its generally good condition, two sections of Rock Creek in Kentucky were included on the latest 2010 303(d) list of impaired streams (Figure 23). The northernmost listed section of Rock Creek stretches about 6.6 km, though only about 0.8 km flows inside the park boundary before converging with the Big South Fork. This section of Rock Creek, below its confluence with White Oak Creek in the Daniel Boone NF, was also included on the 303(d) list in 2002 and 2004 because of acidic conditions (Figure 23; *Rock Creek 2*). In 2008 and 2010, this section of Rock Creek was considered impaired for its designated use as warm water aquatic habitat, though it met the water quality standards for primary and secondary contact recreation waters (EPA 2010).

Figure 24. Rock Creek [Source: Kentucky Division of Water]

A separate stretch of Rock Creek southwest of the one previously described was also included on the KY 303(d) list for fish consumption impairment in 2002, 2004, 2006, and 2010 due to methyl-mercury contamination (Figure 23; *Rock Creek 1*). This surprisingly includes a portion of the same section classified as a Kentucky Wild River and high quality water. This listed section begins at the park/state boundary and continues approximately 2.1 km past its confluence with Turkey Branch. This section of 303(d) assignment does not pass through the park. Each year of listing, this stream segment met the water quality standards for cold water aquatic habitat. Although there is not a trout waters designation for Kentucky, Rock Creek is considered a trout stream due to heavy stocking.

A 1982 survey of water quality by O'Bara et al. detected high concentrations of aluminum and iron in its lower section and measured pH values as low as 3.0 SU at drainage locations in the upper sections around Watts Branch. O'Bara et al. (1982) also attributed logging activity in Pickett State Park to loading of aluminum, iron, and silt in the headwaters region of Rock Creek. Rikard et al. (1986) found elevated concentrations of iron, manganese, and sulfate, as well as visible iron hydroxide depositions.

Most recently, Carew et al. (2003) reported 40 coal mine portals and eight pyrite-rich refuse dumps below the White Oak Creek confluence that have severely degraded water quality in that section of the creek (Figure 25). As a result of these impacts, a group of federal and state agencies formed the Rock Creek Taskforce, which began a series of treatments in spring 2000 to reduce the acidic loading of tributaries along Rock Creek and White Oak Creek. These treatments included deliberate limestone particle loading into the creeks, in addition to treatment and relocation of the refuse site at Water Tank Hollow near the confluence with Big South Fork. As a result, acidic loading decreased dramatically—loading at the mouth of Rock Creek into Big South Fork decreased from 110 metric tons $CaCO_3$ eq to 0.063 metric tons $CaCO_3$ eq after treatment. Revegetation efforts have also led to decreased erosion along tributaries, and subsequent fish surveys have shown increasing species diversity and presence of certain sensitive fish species (Carew et al. 2003).

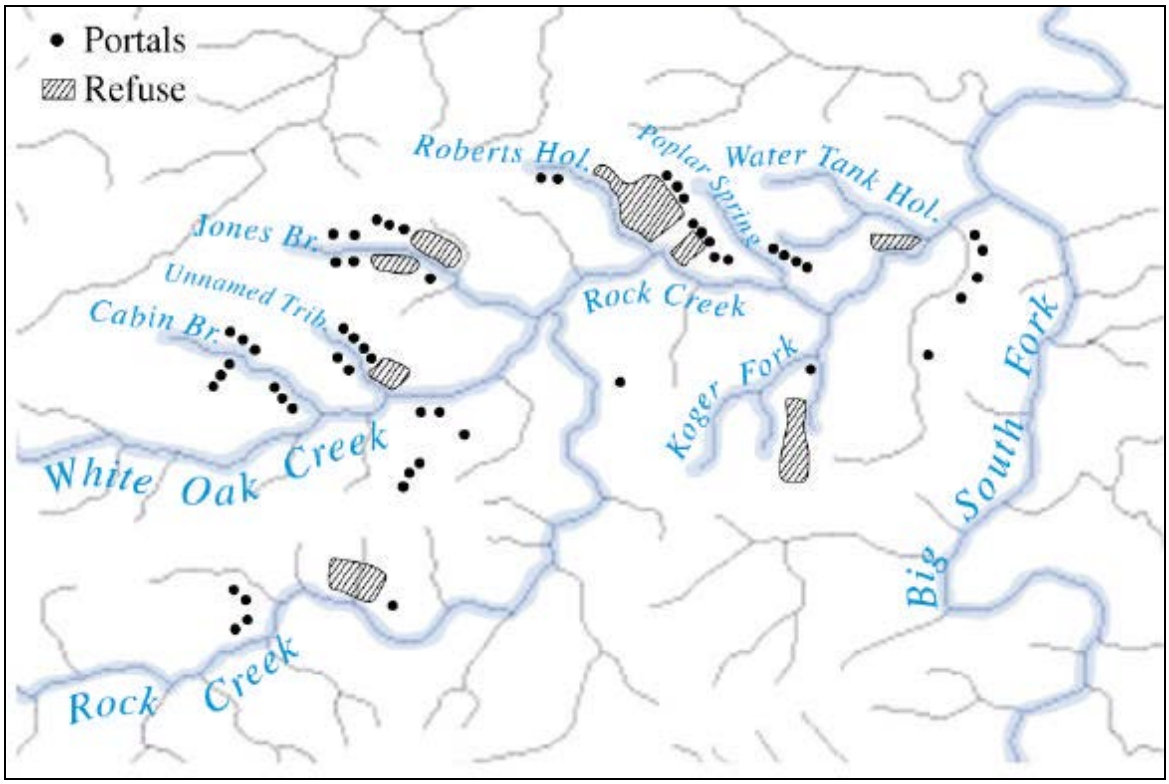

Figure 25. Rock Creek below its confluence with White Oak Creek was included on the most recent 2010 303(d) list of impaired streams. Several coal mine portals and resulting refuse piles have contributed to debilitated water quality conditions throughout the Rock Creek watershed. [Source: Carew et al. 2003]

The Mineral Resources Data System (MRDS) from the US Geological Survey (USGS) shows two prospective mine sites upstream of BISO, both of which occur in the Rock Creek subwatershed. The site closest to BISO is a proposed surface operation, indicated for clay, about 3.5 river km from the park boundary and situated approximately 180 m from Rock Creek. The other prospective site is indicated for silica and is located approximately 200 m from the headwaters to Rock Creek.

White Oak Creek

White Oak Creek has been listed in its entirety since 2006 from its headwaters to confluence with Jones Branch, just 0.2 km from the northern listed portion of Rock Creek. Originally, this section was listed as impaired due to low pH, iron contamination, and general habitat alteration. Impaired uses included recreation and warm water aquatic habitat. In 2008, the low pH impairment was dropped and the recreational use restored, and in 2010 the habitat modification impairment was also dropped. Coal mining was listed as the reason for low pH and metal contamination (EPA 2012).

Roaring Paunch Creek

Roaring Paunch Creek is another 303(d) stream that flows through the park unit for 1.6 km before it enters the Big South Fork approximately 4 km above Rock Creek. The portion of stream listed as impaired, however, begins near the state boundary and stretches 12 km to its confluence with Smith Fork roughly 10.5 km upstream from where it enters the park boundary. This portion of stream was included on the 303(d) list in 2008 and 2010 due to low pH (Figure 23). In 2008, impairment was attributed to acid mine drainage and shoreline habitat degradation from recreational boating. In 2010, impairment was attributed to acid mine drainage and legacy coal extraction (EPA 2012).

Rikard et al. (1986) also found highly polluted conditions which included high levels of specific conductivity, sulfate, iron, manganese, and chloride. Rikard et al. (1986) and O'Bara et al. (1982) offered different opinions on the impact of pollution on aquatic life. Rikard et al. (1986) noted that aquatic diversity in the stream was fairly high, though the Big South Fork crayfish (*Cambarus bouchardi*) remains fairly vulnerable due to its endemism to Roaring Paunch Creek and its tributaries.

Bear Creek

Bear Creek is a long section of impaired water, listed from its headwaters to its confluence with Big South Fork 11 km downstream. The stream enters the park boundary at the TN/KY border and flows through the park for 5.5 km. Both KY and TN have independently included the stream on their 303(d) lists for all even years between 2002 and 2010, except for the portion in KY, which was excluded in 2008. In the TN portion that flows into BISO, the impaired section of Bear Creek is divided into two parts: downstream and upstream from the confluence with West Branch Bear Creek, where it becomes East Branch Bear Creek. On the east branch, reasons for impairment include sedimentation/siltation, low pH, and iron contamination, all of which were attributed to impacts from abandoned mine lands. TMDLs have been developed for iron and pH, but not sedimentation/siltation (EPA 2012).

The shorter main stem of Bear Creek includes the section below the confluence of the two branches to the state boundary—a distance of 4.2 km. Reasons for listing this section include sedimentation/siltation and low pH, but not iron contamination. The KY section from river km 0 to 5.1 was classified as impaired due to low pH, which was attributed to surface/subsurface mining and sand/gravel/rock mining or quarries.

O'Bara et al. (1982) and Rikard et al. (1986) both identified Bear Creek as the most degraded system in the park unit. O'Bara et al. (1982) noted the surrounding Bear Creek watershed was particularly high in aluminum, which proved highly toxic to macroinvertebrate populations in the

stream. Rikard et al. (1986) found low buffering capacity and values of pH as low as 4.2 in headwater areas of the stream. Aquatic macroinvertebrate species were also severely inhibited. Within the park unit, these conditions showed noticeable improvement.

Pine Creek

Data from TDEC show several tributaries to Pine Creek that were listed in 2010 and 2012, in addition to the main stem, which was additionally listed in 2002 through 2008. The section below Mill Branch that flows into BISO was also listed in 2010 and 2012. In 2008, the main branch above Mill Branch was classified as impaired for fish/aquatic life and recreation, though it met the standards for irrigation and livestock watering and wildlife. Causes for impairment were numerous. They included: (1) alteration in stream-side or littoral vegetative cover due to channelization, (2) creosote deposition, (3) depressed dissolved oxygen (DO) concentrations, (4) elevated *Escherichia coli* concentrations due to municipal discharge and sewage, (5) nitrate/nitrite loading, and (6) sedimentation/siltation. Listing of tributaries stemmed from elevated *E. coli* concentrations from municipal point sources and septic systems around Oneida, TN, a point Rikard et al. (1986) made two decades earlier. Rikard et al. (1986) also identified Pine Creek as moderately polluted based on sampling from 1982 to 1984, but recognized general improvement in water quality after the flow enters the park.

4.5.3 Water Classification and Use

Kentucky and Tennessee both classify waters into “use” categories, with separate water quality criteria. In Tennessee, the classes include: (1) domestic water supply, (2) industrial water supply, (3) fish and aquatic life, (4) trout stream, (5) naturally reproducing trout stream, (6) recreation, , (8) livestock watering and wildlife, (9) irrigation, and (10) navigation (TDEC, 2008b). Kentucky water use classifications include: (1) warm water aquatic habitat, (2) cold water aquatic habitat, (3) primary contact recreation, (4) secondary contact recreation, (5) domestic water supply, and (6) outstanding state resource water (Kentucky Division of Water undated). Streams may be classified for multiple uses. Each state also assigns a set of anti-degradation criteria for waters not meeting a designated use, wherein waters will not receive additional sources of pollutants and degradation already occurring does not become permanent (Hamilton and Smith 1997). Table 16 and Table 17 show use classifications of streams in BISO in Tennessee and Kentucky, respectively.

Table 16. Stream use classifications for BISO waters in Tennessee. Length of waterway within BISO given in parentheses. '*' denotes streams not fully contained inside BISO boundaries.

Stream	DOM	IWS	FAL	REC	LWW	IRR	TS
Big South Fork Cumberland River (from KY-TN line to origin (35 km)	✓	✓	✓	✓	✓	✓	✓
No Business Creek (6 km)			✓	✓	✓	✓	✓
Parch Corn Creek (2 km)			✓	✓	✓	✓	✓
Station Camp Creek (8 km)			✓	✓	✓	✓	✓
Laurel Fork Creek (18 km)*			✓	✓	✓	✓	✓
North White Oak Creek (21 km)*			✓	✓	✓	✓	✓
Williams Creek (7 km)*			✓	✓	✓	✓	✓
Pine Creek (4 km)*			✓	✓	✓	✓	
New River (13 km)*			✓	✓	✓	✓	
Clear Fork River (32 km)*			✓	✓	✓	✓	
All other Streams			✓	✓	✓	✓	

DOM = Domestic Water Supply, IWS = Industrial Water Supply, FAL = Fish and Aquatic Life, REC = Recreation, LWW = Livestock Watering and Wildlife, IRR = Irrigation, TS = Trout Stream

Table 17. Stream use classifications for BISO waters in Kentucky. Length of waterway within BISO given in parentheses. '*' denotes streams not fully contained inside BISO boundaries.

Stream	WAH	CAH	PCR	SCR	DWS
Big South Fork Cumberland River (from KY-TN line to river mile 44.3; 17 km)*	✓		✓	✓	
Difficulty Creek (6 km)		✓	✓	✓	
Troublesome Creek (6 km)		✓	✓	✓	
All other Streams	✓		✓	✓	✓

WAH = Warm Water Aquatic Habitat, CAH = Cold Water Aquatic Habitat, PCR = Primary Contact Recreation, SCR = Secondary Contact Recreation, DWS = Domestic Water Supply

In addition to the categories above, both states include special categories relating to waters of exceptional quality or those that average conditions well above the standards for aquatic life (TDEC 2008b, Kentucky Division of Water undated). Currently, the Big South Fork of the Cumberland River is designated as an Outstanding National Resource Water (ONRW) in both states within the BISO boundary. In Tennessee, this listing is in conjunction with designation by the US Fish and Wildlife Service (USFWS) as critical habitat for Cumberland Elktoe (*Alasmidonta atropurpurea*), oyster mussel (*Epioblasma capsaeformis*), and Cumberlandian combshell (*Epioblasma brevidens*). All streams in BISO are listed as exceptional in Tennessee, and many streams provide habitat for sensitive plants or aquatic species. These streams are listed in Table 18. In Kentucky, the Big South Fork of the Cumberland is also designated as a state Wild River, which affords protection from most kinds of development along the river corridor.

Table 18. Exceptional Tennessee waterbodies in BISO.

Waterbody	Reason for listing
Wolf Branch	Virginia spirea (*Spiraea virginiana*); endangered-TN
Puncheoncamp Fork	Cumberlandian combshell (*Epioblasma brevidens*); endangered-federal Ashy darter (*Etheostoma cinereum*); threatened-TN
Williams Creek	Ashy darter; threatened-TN
White Oak Creek	Cumberland elktoe (*Alasmidonta atropurpurea*); USFWS critical habitat Purple bean (*Villosa perpurpurea*); endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat Oyster mussel (*Epioblasma capsaeformis*); endangered-TN & federal, USFWS critical habitat Cumberland rosemary (*Conradina verticillata*); threatened-TN & federal Virginia spirea; endangered-TN
Still Camp Branch	Virginia spirea; endangered-TN
Station Camp Creek	Ashy darter; threatened-TN
Slavens Branch	Cumberland bean (*Villosa trabalis*); endangered-TN & federal
Rough Shoals Branch	Cumberland rosemary; threatened-TN & federal Cumberland elktoe; endangered-TN & federal, USFWS critical habitat Purple bean; endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat
Rock Creek	Exceptional biological diversity TN Water Pollution Control (WPC) Ecoregion reference stream for Cumberland Plateau (Arnwine et al. 2000)
Roaring Paunch Creek	Big South Fork crayfish (*Cambarus bouchardi*); endangered-TN
North White Oak Creek	Cumberland elktoe; endangered-TN & federal, USFWS critical habitat Purple bean; endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat Oyster mussel; endangered-TN & federal, USFWS critical habitat Cumberland rosemary; threatened-TN & federal Ashy darter; threatened-TN
No Business Creek	Ashy darter; threatened-TN Tuxedo darter; endangered-federal Cumberland bean; endangered-TN & federal Cumberland elktoe; endangered-TN & federal Cumberlandian combshell; endangered-TN & federal Tan riffleshell (*Epioblasma walkeri*); endangered-TN & federal Littlewing pearlymussel (*Pegias fabula*); endangered-TN & federal

Table 20. Exceptional Tennessee waterbodies in BISO (continued).

Waterbody	Reason for listing
New River	Cumberland elktoe; endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat Oyster mussel; endangered-TN & federal, USFWS critical habitat Virginia spirea; endangered-TN Cumberland rosemary; threatened-TN & federal Ashy darter; threatened-TN
Laurel Fork of Station	Ashy darter; threatened-TN
Camp Creek	Exceptional biological diversity TN Water Pollution Control (WPC) Ecoregion reference stream for Cumberland Plateau (Arnwine et al. 2000) Naturally reproducing trout stream (upper 3 km)
Joe Branch	Virginia spirea; endangered-TN Cumberland elktoe; endangered-TN & federal
Clear Fork River	Cumberland elktoe; endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat Oyster mussel; endangered-TN & federal, USFWS critical habitat Virginia spirea; endangered-TN Cumberland rosemary; threatened-TN & federal Large-flowered Barbara's buttons (*Marsallia grandiflora*); endangered-TN Sticky Goldenrod (*Solidago simplex* ssp. *randii*); threatened-TN
Black House Creek	Tawny cotton-grass (*Eriophorum virginicum*); threatened-TN
Black Creek	Cumberland rosemary; threatened-TN & federal Cumberland sandgrass (*Calamovilfa arcuata*); endangered-TN
Bill Branch	Large-flowered Barbara's buttons; endangered-TN
Big South Fork Cumberland River	Cumberland elktoe; endangered-federal, USFWS critical habitat Purple Bean; endangered-TN & federal, USFWS critical habitat Cumberlandian combshell; endangered-TN & federal, USFWS critical habitat Oyster mussel; endangered-TN & federal, USFWS critical habitat Tan riffleshell; endangered-TN & federal Tuxedo darter; endangered-federal Littlewing pearlymussel; endangered-TN & federal Cumberland bean; endangered-TN & federal Virginia spirea; endangered-TN Cumberland rosemary; threatened-TN & federal Sweet-fern (*Comptonia peregrina*); endangered-TN Large-flowered Barbara's buttons; endangered-TN Ashy darter; threatened-TN Tennessee pondweed (*Potamogeton tenneeseensis*); threatened-TN Mountain witch-alder (*Fothergilla major*); threatened-TN Rockcastle aster (*Aster saxicastelli*); threatened-TN Sticky goldenrod; threatened-TN

Table 20. Exceptional Tennessee waterbodies in BISO (continued).

Waterbody	Reason for listing
Bandy Creek	Cumberland rosemary; threatened-TN & federal Sticky goldenrod; threatened-TN

4.5.4 Historical Water Quality Monitoring

Park-wide, BISO began regular water quality monitoring in 1982 at 19 sites. Monitoring locations and regularity were variable after that, but Johnson (2003) aggregated several sources of water quality monitoring efforts into a summary of the park, organized by watershed and subwatershed. Johnson (2003) used data from multiple sources, the most substantial of which was the EPA Storet database, which included observations through September 2001 at 167 unique sampling stations.

In general, Johnson's (2003) summary reflected water quality conditions consistent with mine contamination in many areas. Highlights from his summary for each parameter are as follows:

- Values for pH between 1982 and 1998, for example, were particularly low (< 6) in Laurel Fork of North White Oak Creek and North White Oak Creek itself. Acidic values were also observed on Long Branch southwest of the park and Bear Creek throughout 1982-1998. Johnson (2003) reported that the USGS observed overall low pH values throughout the Rock Creek and White Oak Creek subwatersheds for the period 4/99 and 9/01—six of the 22 sampling locations demonstrated median pH values less than 4 over that span.

- Elevated levels of chloride above 50 mg/L were sampled between 1980 and 1993 at two sites within the Roaring Paunch subwatershed.

- Johnson (2003) summarized iron (Fe) sampling data from several sites, of which a few had repeated observations that exceeded the KY warm water aquatic habitat and EPA freshwater aquatic life criteria of 1000 µg/L (EPA 1986). In particular, these included (1) three stations in the New River watershed (HUC0513010403) over the period 1965-1998, (2) two stations in the Clear Fork watershed (HUC0513010402) over the period 1975-1981, (3) one station at the mouth of North White Oak Creek over the period 1982-1998, and (4) three stations in a subwatershed of the Big South Fork (HUC0513010405) over the period 1982-2000. However, some of the highest concentrations of iron were found within nine sites in the lower Big South Fork and the Rock Creek subwatershed. Some of the samples in this area collected over the period 1995-1997 approached 100 mg/L (100,000 µg/L). These stations included Worley Creek, Devils Creek, Nancy Graves Creek, Blair Creek, and Laurel Branch.

- High values of manganese were collected at one site in the New River watershed over the period 1975-1981 and at three sites in the Clear Fork Basin over approximately the same period. Slightly higher repeat samples, in the range of 2000 – 4000 µg/L, were collected over the period 1983-1998 at two stations on Bear Creek, and at Puncheon Camp Creek and Roaring Paunch Creek. Almost all sites in the Lower Big South Fork subwatershed showed elevated levels of manganese during the years 1995-1997. There are no state

standards for manganese, but the EPA Goldbook (1986) discusses a minimum threshold of 1.5 mg/L for toxicity effects on freshwater aquatic life.

- Copper values at numerous sites in the South Fork Cumberland cataloging unit were frequently above the TN fish and aquatic life maximum for both acute (13 µg/L) and continuous (9 µg/L) concentrations (TDEC 2008b).

- Like copper, values for lead were also high at several sampling stations throughout the cataloging unit, often exceeding both the TN acute (65 µg/L) and continuous (2.5 µg/L) concentration criteria for fish and aquatic life (TDEC 2008b). Highest concentrations of dissolved copper were observed in the Big South Fork at the Blue Heron community over the period 1975-1995.

- Zinc was also found in high concentrations at sampling stations throughout the park, often exceeding the TN lethal limit of 120 µg/L for fish and aquatic life. Highest concentrations for this metal were consistently detected in the New River watershed.

- Values for dissolved aluminum were also high throughout the cataloging unit, especially at sites in the New River watershed and along the lower portion of Big South Fork. With the exception of stations in the White Oak Creek subwatershed, stations in these regions often to mostly had values that exceeded the TN max continuous concentration criteria of 87 µg/L. Stations in the New River watershed and along the lower Big South Fork observed values that sometimes exceeded the max acute concentration criteria of 750 µg/L.

Parent Material

Generally, water quality is better in the western portion of the park than the south and eastern areas due to their proximity to coal-mining, forestry, and urban runoff (Hamilton and Smith 1997). In addition, the geological characteristics of an area strongly influence the natural range of stream water quality parameters. At BISO, streams are typically divided into those with sandstone or limestone parent material (Table 19); Rikard et al. (1986) offers a comparison of parameter ranges and how they are affected by this difference in geology (Table 19).

Table 19. Examples of unimpacted streams and their geology (Hamilton and Smith 1997) and their typical range of parameters (Rikard et al. 1986).

Stream	Sandstone Parent Material	Limestone Parent Material
Bandy Creek	✓	
Grassy Fork of Williams Creek	✓	
Laurel Fork of Station Camp Creek	✓	
Upper Rock Creek	✓	
No Business Creek		✓
Station Camp Creek		✓
Parameter		
Conductivity (μS cm^{-1})	≤ 30	≤ 60
pH	5.5 – 7.0	6.0 – 7.5
Chloride (mg L^{-1})	-- ≤ 5.0 --	
Iron (mg L^{-1})	-- ≤ 0.2 --	
Manganese (mg L^{-1})	-- ≤ 0.5 --	
Sulfates (mg L^{-1})	-- ≤ 10 --	
Alkalinity (mg L^{-1})	< 5.0	most > 10
Hardness (mg L^{-1})	< 20	20 - 30
Turbidity (NTUs)	-- < 10 --	
Temperature (°C)	-- 0 – 25 --	
Dissolved Oxygen (mg L^{-1})	-- ≥ 5.0 --	
Fecal Coliform (colonies 100 mL^{-1})	-- < 100 --	

4.5.5 Water Quality Recent Efforts

Figure 26 depicts multi-agency sampling results from the EPA Storet water quality database immediately following Johnson's (2003) effort, which summarized data through September 2001. Data after that date from EPA Storet was available through the end of 2007 and included records from three agencies—Tennessee Department of Environment and Conservation (TDEC), Kentucky Division of Water, and the US Army Core of Engineers (USACE; Table 20). Additional data provided independently by TDEC contained additional records with samples dated as late as March 2010.

Stations represent regions throughout the Big South Fork cataloging unit, and separate agencies often conducted sampling at the same location. Figure 27 and Table 20 show sampling stations and the origin of their sampling data. Available data from all sources were sorted by individual station and grouped by sampling location in each watershed (HUC10) as shown in the results in Figure 26. An explanation of the sampling data for each parameter after September 2001 is also given, along with a summary and individual ranking of the new data within the context of previous analyses. Because of its particular relevance to BISO, the central watershed encompassing the largest portion of the park is divided and summarized at the subwatershed level (HUC12).

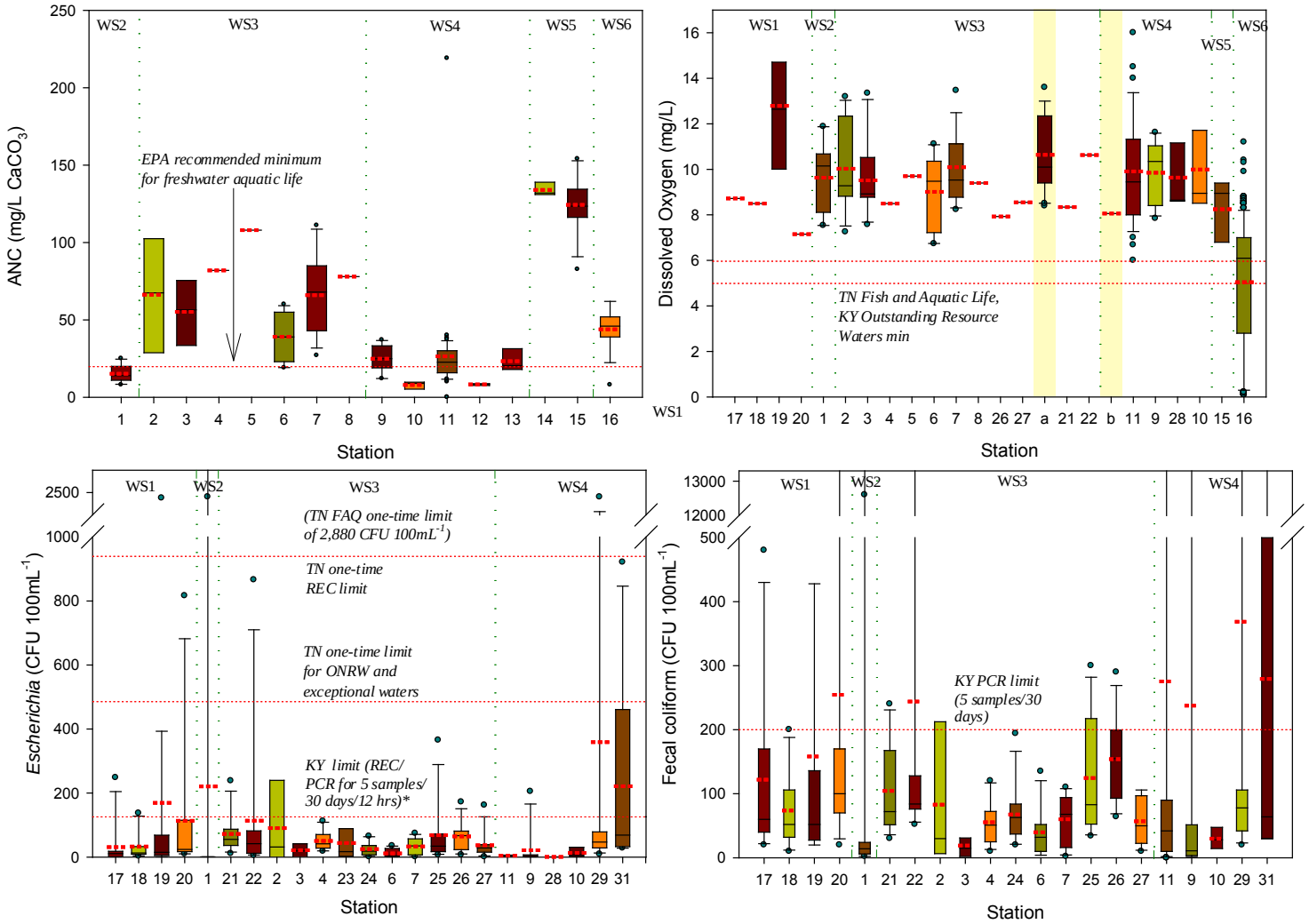

Figure 26. Box and whisker water quality summaries for stations in the Big South Fork sub-basin after September 2001, sorted by HUC10 watershed. Numbered stations correspond to repeat sampling locations, as indicated in Table 20 and Figure 27. Letters represent aggregations of non-repeat sampling locations by TDEC. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dotted lines are means.

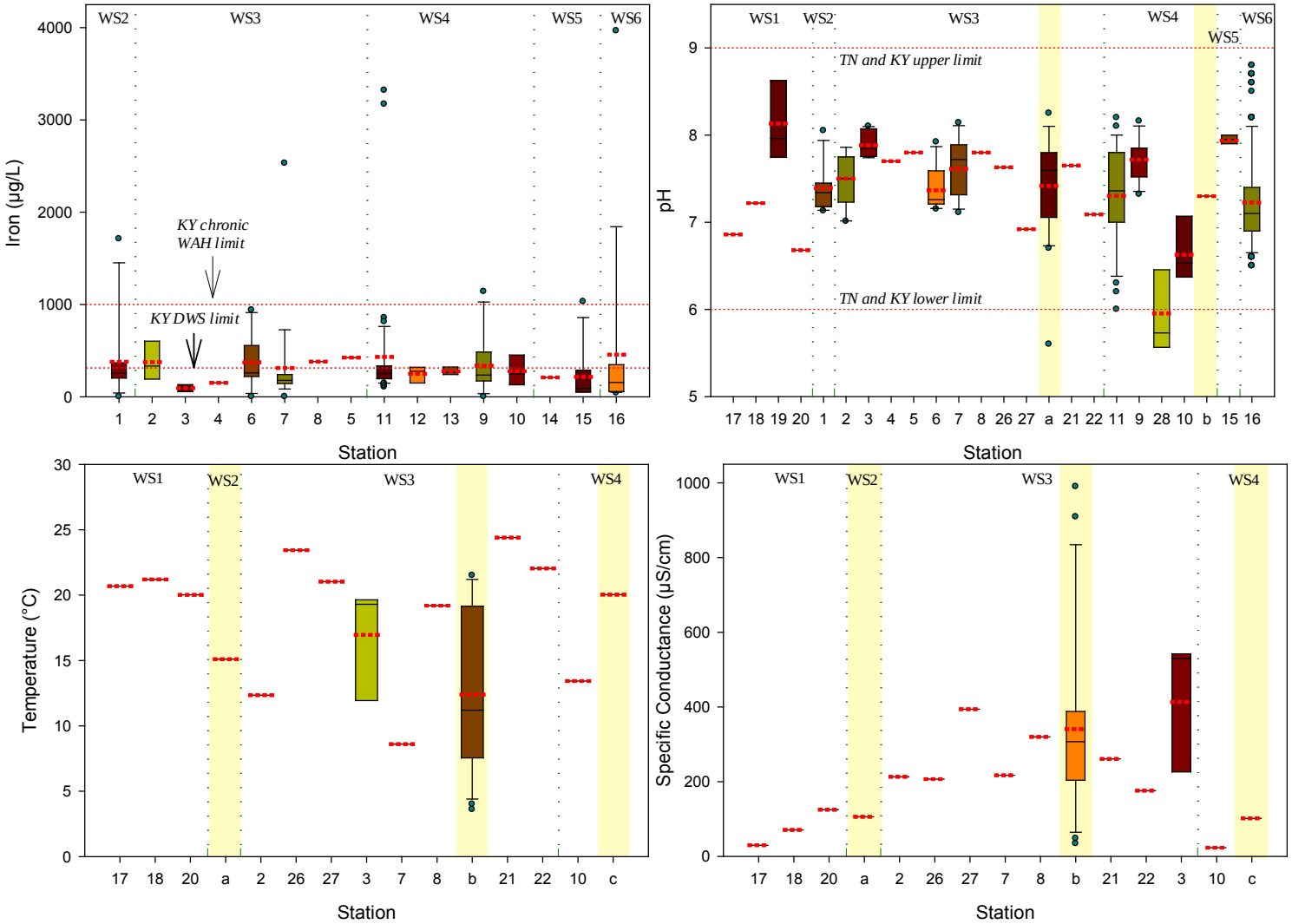

Figure 26. Box and whisker water quality summaries for stations in the Big South Fork sub-basin after September 2001, sorted by HUC10 watershed. Numbered stations correspond to repeat sampling locations, as indicated in Table 20 and Figure 27. Letters represent aggregations of non-repeat sampling locations by TDEC. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dotted lines are means (continued).

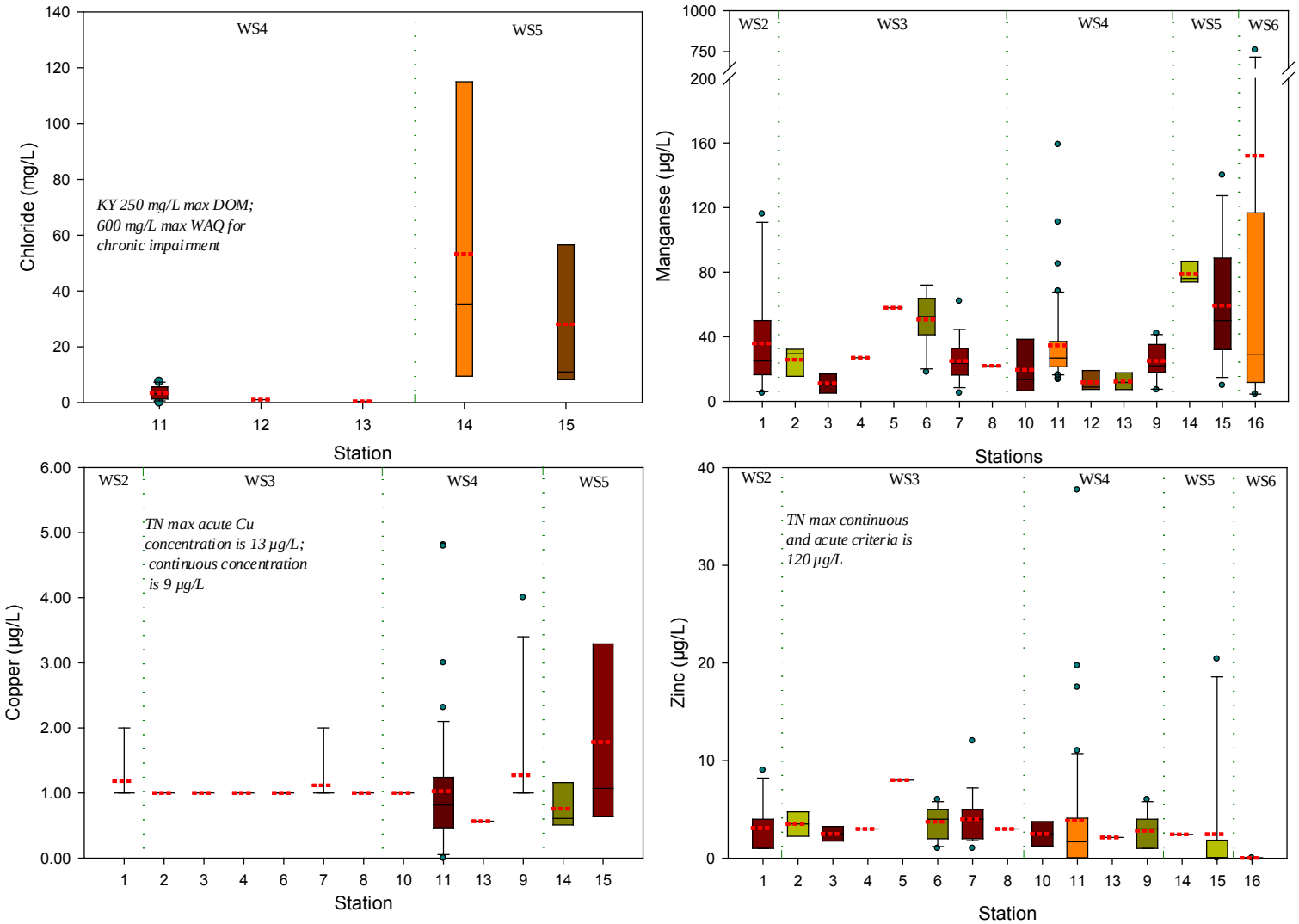

Figure 26. Box and whisker water quality summaries for stations in the Big South Fork sub-basin after September 2001, sorted by HUC10 watershed. Numbered stations correspond to repeat sampling locations, as indicated in Table 20 and Figure 27. Letters represent aggregations of non-repeat sampling locations by TDEC. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dotted lines are means (continued).

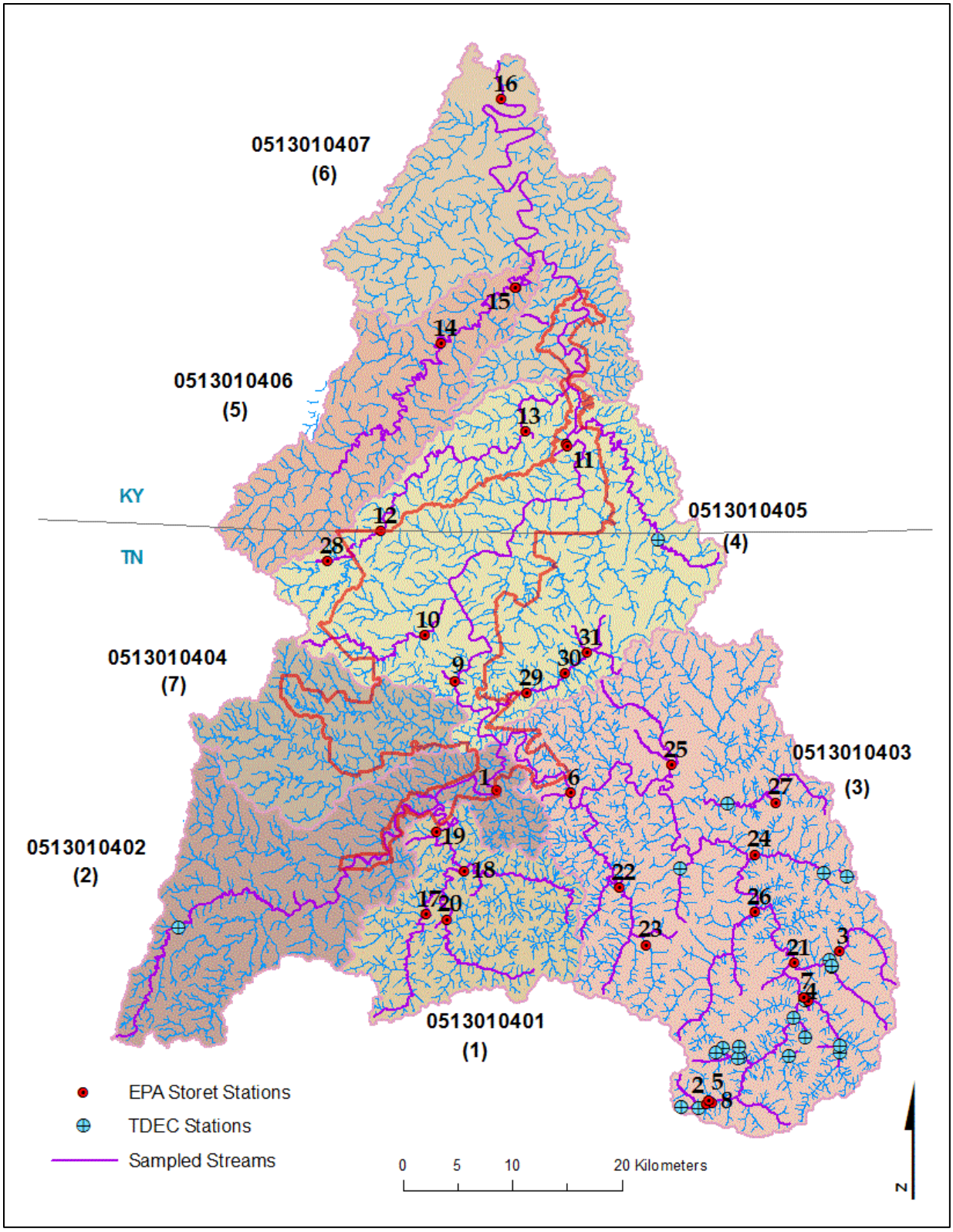

Figure 27. Water quality sampling summaries include data after 2001 from 33 EPA Storet stations and 22 TDEC stations. Sampling locations were grouped by watershed (HUC10) and divided into

subwatersheds (HUC12) for the central Big South Fork watershed. Streams represented by sampling locations are highlighted in purple.

Table 20. List of repeat sampling stations within the Big South Fork sub-basin.

Station ID	Organization	HUC10	Station Code
BCAMP002.2MG	Tennessee Department of Environment and Conservation	513010401	17
BWOLF000.1MG	|	|	18
WOAK005.7MG	|	|	19
WOAK015.7MG	|	|	20
CFORK003.8SC	|	513010402	1
ECO69D05	|	513010403	2
ECO69D06	|	|	3
LIGIA000.5AN	|	|	4
STALL000.1AN	|	|	5
NEW008.8SC	|	|	6
NEW045.0AN	|	|	7
NEW056.0AN	|	|	8
BEECH000.2CA	|	|	21
BRIMS009.2SC	|	|	22
MILL001.3SC	|	|	23
MONTG000.5SC	|	|	24
PROCK001.0SC	|	|	25
SMOKY000.8SC	|	|	26
STRAI001.9SC	|	|	27
BSFOR070.0SC	|	513010405	9
ECO68A03	|	|	10
ECO68A01	|	|	28
PINE003.6SC	|	|	29
PINE006.0SC	|	|	30
PRI008	Kentucky Division of Water	513010405	11
WRP010	|	|	12
WRP011	|	|	13
WRP004	|	513010406	14
WRP005	|	|	15
3WOL10029	US Army Corps of Engineers, Nashville District	513010405	32
3WOL10035	|	513010406	33
3WOL20007	|	513010407	16

Acid neutralizing capacity

Acid-neutralizing capacity (ANC) is measured to assess the relative ability of the water to buffer acidic loading resulting from precipitation or other sources. It is the most common measurement used to assess sensitivity to acid deposition, wherein lower ANC values generally correspond to higher levels of aluminum ion (Al^{n+}), as well as a greater level of toxicity to aquatic biota such as fish, invertebrates, and phytoplankton. Although calcium carbonate is used as an equivalent standard for ANC values, it reflects the concentration of all substances that would tend to raise the water pH above approximately 4.5 (EPA 1986). Higher values of ANC are particularly influenced by concentrations of carbonates (CO_3^{2-}), bicarbonates (HCO^{3-}), phosphates (PO_4^{3-}), and hydroxides (OH^-). When referring to calcium carbonate concentrations, units of mg L^{-1} are

used, while microequivalents per liter (μeq L^{-1}) are used to reflect concentrations of other compounds influencing alkalinity.

Samples for acid neutralizing capacity or alkalinity (mg/L $CaCO_3$) were collected at sixteen different stations within the cataloging unit. Although there are no state standards for this measure in either TN or KY, the EPA recommends a minimum of 20 mg/L to benefit freshwater aquatic life (EPA 1986). Rikard et al. (1986) point out that many unpolluted waters have natural levels of alkalinity lower than this, and suggests that levels below 5 mg/L might be typical for waters unaffected by limestone.

The Clear Fork station in watershed 2 (WS 2) averaged low alkalinity levels from 11 observations between 2004 and 2005. The New River watershed (WS 3) demonstrated consistently higher values for alkalinity at seven stations sampled between 2004 and 2007, all averaging above 20 mg/L. This was also the case for the two stations on the Little South Fork north of the park (WS 5) and on the Big South Fork near the northern drainage point of cataloging unit (WS 6), both of which were sampled from the period 2003-2005. In watershed 4, two of five stations showed low alkalinity at Laurel Fork of Station Camp Creek and Rock Creek at the state line. These streams occur in areas with sandstone parent material (Rikard et al. 1986), and therefore the low alkalinity levels reflect natural geology. The remaining stations on Big South Fork (central and northern) and further downstream Rock Creek showed higher means above 20 mg/L, all of which reflected the period 2001-2007.

Dissolved Oxygen (DO)

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

Dissolved oxygen measurements (mg/L) were available at 22 stations from the EPA Storet database. Additional data from TDEC included dissolved oxygen measurements in watershed units 3 and 4, though station visits for these records were for the most part not repeated. These collective measurements are represented by a single distribution for each watershed in Figure 26. In general, TN and KY stipulate minimum DO concentrations of 5.0 mg/L for instantaneous measurements. Tennessee further poses a minimum of 6.0 mg/L for trout streams. With the exception of the station at Lake Cumberland near the drainage point of the cataloging unit, all samples were above 6.0 mg/L DO. However, despite high concentrations, sampling records for watersheds one, two, and five were relatively sparse.

Microorganisms

Total coliform bacteria are a group of bacteria that live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated

viruses and pathogens. Total coliform counts themselves, however, do not necessarily represent a health risk. Fecal coliform are a subset of total coliform bacteria that exist only in warm-blooded organisms, and may often originate in streams via wildlife feces. At BISO, measurements of fecal coliform were collected at 21 stations in 4 watersheds, mostly in 2004, but also during the period 2005-2007. *Escherichia coli*, part of the fecal group of bacteria, was also collected at 23 stations in 4 watersheds over the same time period.

In Kentucky, primary recreation waters (i.e. those used for swimming) are subject to a limit of 200 colonies per 100 mL of water for fecal coliform and 130 colonies per 100 mL water for *E. coli* when "based on not less than five samples taken during a 30 day period" (Kentucky Division of Water 2009). Although samples collected in the park do not follow this scheme, these limits are still helpful as a baseline for comparison. Tennessee provides limits based on individual samples, stipulating a fish and aquatic life classification limit of 2,880 colonies for *E. coli* and a recreation limit of 941 colonies per 100 mL water. In addition, individual *E. coli* samples from ONRW or exceptional TN waters are limited to 487 colonies per 100 mL water. Tennessee does not provide a limit for fecal coliform measurements.

For *Escherichia* monitoring, none of the means from sampling stations exceeded either the 487 or 941 colonies per 100 mL water limit. With the exception of samples on White Oak Creek, none of the stations on exceptional TN waters or on the Big South Fork exceeded the standard. Two samples in 2004 demonstrated *Escherichia* concentrations in Pine Creek above the TN limit for recreational waters. Fecal coliform concentrations were often observed above the 200 colonies per 100 mL threshold at stations in all four watersheds sampled, though none of the sampling schedules for this parameter were intended to follow that stipulated by the KY limit. Two sampling stations on the White Oak Creek south of the park unit (tributary to Clear Fork) exceeded the threshold on three occasions. All four stations sampled in the southern White Oak Creek watershed experienced either the highest or second highest observation in August 2005, which likely suggests a period of particularly high flow. In watershed four, four of the five stations averaged fecal coliform concentrations greater than 200 colonies per 100 mL water—two each on Big South Fork and Pine Creek. The stations on Pine Creek shared the high concentrations observed in August 2005.

Iron

Sampling for iron was conducted at 17 stations, representing roughly the period between 2001 and 2007. Iron persists in different forms, but ferrous (Fe^{++}) iron is associated with low levels of dissolved oxygen, and often originates in areas of acid mine drainage (EPA 1997). KY places two limits on iron concentrations which include 300 µg/L for domestic water supply (DWS) and 1,000 µg/L for warm water aquatic habitat (WAQ). In watershed four, two stations on Big South Fork classified as domestic water supply frequently exceeded the 300 µg/L threshold, as did samples in Lake Cumberland in the northern portion of the cataloging unit. Otherwise, several stations demonstrated occasional samples over the 1,000 µg/L threshold, though none of them appeared to indicate chronic exceedances.

pH

Measurement of pH is an important water quality attribute, because it affects 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). Measurements of pH were collected at 22 regularly sampled stations throughout six cataloging units, though most were in the New River cataloging unit. In addition, several sporadic locations were sampled by TDEC. Both TN and KY require that pH be between 6 and 9 standard units for most use classifications. Samples were collected between 2001 and 2010, although most of the samples were collected between 2004 and 2006. Samples fell mostly within acceptable ranges throughout the six watersheds with the exception of a single 2005 sample on Joe Branch, a tributary to Indian Fork in the New River watershed. In addition, of the five samples collected near the Rock Creek headwaters in Pickett State Park during 2002/2004, four of the samples, collected within a two-week period, showed persistent levels of acidity. Unfortunately, no additional data was available for pH at lower stretches of Rock Creek.

Temperature

Data for temperature was sparser than other parameters, and only was repeatedly sampled at three stations out of the four watersheds within BISO. Sampling from TDEC also provided several records. Kentucky stipulates a limit of 31.7 °C for acceptable habitat for warm water species, although TN specifies a limit of 30.5 °C. All samples fell well below those limits, though some resident fish species could potentially benefit from much lower temperatures, which can affect their survival and growth rate (EPA 1997). The EPA Goldbook (1997) suggests weekly average temperature of 25 °C for sauger (*Sander canadensis*), for example, which was identified by Scott (2007) in a recent survey at BISO. Further comparison between temperature observations and fish habitat requirements could yield more relationships and identify potentially stressed areas.

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.

Like temperature, there were few observations for specific conductance, which gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Conductance is measured as the reciprocal of resistance and expressed in micro-Siemens/cm (µS/cm). Although no state standard exists for this parameter, the EPA (1997) sampling methods manual identifies an ideal range of 150 to 500 µS/cm for "inland fresh waters…supporting good mixed fisheries," and furthermore suggests that "conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates." In contrast, Rikard et al. (1986) observes that, much like acid-neutralizing capacity, conductivity values in the Cumberland Plateau area of BISO are often dictated by parent material, such that sandstone-derived waters have naturally lower levels of natural conductivity (< 30 µS/cm) than limestone-derived water (< 60 µS/cm), though both fall below the EPA recommended range. They suggest that waters with conductivity > 100 µS/cm are indicative of moderate pollution, while waters with conductivity > 150 µS/cm indicate signs of severe pollution.

Sampling locations in four watersheds were, for the most part, not revisited. Despite this, samples indicate some separation between watersheds. Watersheds one, two, and four were all sampled below the 150 µS/cm suggested range, while watershed three, the most thoroughly sampled, was above this range with the exception of three samples collected by TDEC. Rikard et al. (1986) also reports on the elevated conductivity levels in the New River, among other factors, that indicate the influence of mining upstream. Johnson's (2003) assessment also showed several high specific conductance values in the New River watershed, ranging from 200 to 600 µS/cm.

Chloride and Heavy Metals

Samples for chloride were only collected at five stations in two watersheds. Big South Fork was sampled several times between 2001 and 2007, while two other sites on Rock Creek were visited once each. Two sites on Little South Fork were sparsely sampled in 2003 and 2005. Only KY specifies a limit of 250 mg/L chloride for DOM waters and 600 mg/L for warm water aquatic habitat. However, none of the stations reported values close to these. Samples for manganese were collected at 16 sites in five watersheds, most of which were during the period 2004 – 2006. Samples collected on the Big South Fork at Blue Heron were the most extensive, spanning the period 2001 – 2007. Although there are no state standards for this parameter, the EPA Goldbook (1997) recommends a limit of 50 µg/L for waters classified as domestic water supply.

Concentrations of manganese below 1.5 mg/L are generally non-toxic to freshwater aquatic life. Samples collected within the BISO cataloging unit were all well below this threshold. Samples for copper were collected at 13 stations in four watersheds, though most stations were only visited once. Several samples were collected on the Big South Fork over the period 2001 – 2007, though most of the samples represent the period 2004 – 2006. Tennessee specifies maximum acute and chronic concentrations of copper at 13 µg/L and 9 µg/L respectively, though the highest concentrations observed on Big South Fork were below 5 µg/L. This parameter is difficult to compare to Johnson's (2003) summary due to the dearth of sampling data after 2001. However, Johnson (2003) reported several measurements of dissolved copper above thresholds for aquatic life at all watersheds sampled, which included all watersheds in the South Fork Cumberland except the Rock Creek, Little South Fork, and Sinking Creek sub-watersheds in the northern portion of the cataloging unit. Samples for zinc were collected at 15 stations in five watersheds. Like the other heavy metals, most samples were collected during the period 2004 – 2006, with the most extensive dataset from the Big South Fork, which includes the period 2003 – 2007. Tennessee stipulates maximum continuous and acute criteria thresholds of 120 µg/L for zinc concentrations. Most samples collected were less than 10 µg/L, however, with the highest value of 40 µg/L collected at Big South Fork.

Summary

Overall, available data suggest the persistence of some water quality issues at BISO (Johnson 2003). Heavy metal observations were low at the few sites sampled, and the five stations sampled for chloride did not exceed water standards. Samples on the Clear Fork River indicate low levels of alkalinity. Although such levels could be the result of neutral or acidic parent material, they could still exacerbate issues with acid mine drainage from the surrounding subwatershed. Rikard (1986) classified Clear Fork as a slightly polluted stream, owing to high

conductivity values and contamination from White Oak Creek. Johnson's (2003) assessment showed relatively low levels of conductivity, and although the few recent samples were elevated, no other parameters suggested water quality issues on Clear Fork.

Sites with elevated levels of bacterial contamination showed some congruity between *Escherichia* and fecal coliform sampling. Most notably, samples from 2004 on two stations in Pine Creek, a 303(d) listed stream, showed elevated values for both measures, resulting in exceedances of one-time limits for *Escherichia* concentrations. These sites, though in TN, also exceeded the KY limit for fecal coliform concentrations, which is averaged from at least 5 samples within a 30-day period. This sampling minimum was met over the short period observed, and both sites exceeded the limit of 200 colonies 100 mL^{-1}. Unfortunately, no post-2003 water quality data are available for Pine Creek (Johnson 2003), although Johnson (2003) found elevated specific conductance over the period 1982 – 1998, as well as slightly high levels of chloride. Data also showed several measurements of lead concentration that exceeded the EPA continuous concentration criteria for aquatic life. Taken together, this suggests that further sampling be devoted to Pine Creek either at the park boundary or near its confluence with Big South Fork.

Rock Creek, another 303(d) stream, showed relatively low levels of alkalinity from three paired visits to two sites in 2003 and 2005. The site located on the TN/KY state line is at the upstream tip of the length classified as 303(d) and showed low alkalinity values—lower than values at the downstream station near the confluence with White Oak Creek. This difference could be the result of efforts to reduce acidic loading in Rock Creek started in 2000 (Carew et al. 2003). A handful of samples close to the headwaters of Rock Creek in Pickett State Park showed acidic waters around the same period. Sampling data summarized by Johnson (2003) also reported acidity frequently at several sites along Rock Creek, in addition to iron and manganese. Taken together, high levels of acidity and low alkalinity can have debilitating effects on aquatic life and create special concern for the downstream portion, which is classified as a state exceptional water because of its biological diversity. It is important to note, however, that the upstream and downstream sections of Rock Creek are subject to different influences. While both sections demonstrate high acidity, the downstream section has been exposed to impacts from mining along White Oak Creek, leading to its impaired classification due to low pH. The upper section is listed as impaired for methyl-mercury contamination, but is also relatively unimpacted from mining, hence its classification as a state wild river.

Aside from Pine Creek and Rock Creek, no other monitoring data for 303(d) streams in the South Fork Cumberland cataloging unit is available during this latest period, which includes Roaring Paunch and Bear Creek in the park unit, and Copperas Fork and Straight Fork outside the boundary. Elevated levels of specific conductance, manganese, chloride, and acidity were reported on Roaring Paunch Creek and Bear Creek by Johnson (2003) in addition to elevated dissolved aluminum and sulfate on Bear Creek.

Most of the general observations stemming from analysis of water quality data are the result of an inadequate and sporadic dataset. Especially on the 303(d) streams where water quality is sensitive to inputs from oil, gas, and historic coal extraction activity, further sampling data is necessary to understand how water quality has changed since Johnson's (2003) thorough

summary assessment, as well as whether issues highlighted by the current assessment still persist.

4.5.6 Watershed Summary

HUC0513010401

O'Bara et al. (1982) and Rikard et al. (1986) both mention that timber operations and oil extraction have influenced this watershed in the past. Timber operations occurred specifically on Black Wolf Creek, Barger Branch, Gum Branch, and Stonecipher Branch, all of which flow directly into White Oak Creek and resulted in sedimentation issues. O'Bara et al. (1982) attributed observations of high conductivity levels to oil well activity throughout the White Oak Creek watershed and observed that Sunbright, TN in Morgan County was a source of domestic and industrial waste. Johnson (2003) observed somewhat elevated values for specific conductance in the White Oak Creek watershed over the history of monitoring from 1960 to 2000. These samples fell in the range indicative of moderate pollution according to Rikard et al. (1986).

Following Johnson (2003), data for the White Oak Creek watershed consists of sampling from four stations—two on White Oak Creek, and one each on Bone Camp Creek and Black Wolf Creek. Although the core parameters were represented in sampling, they were only available through 2006, and heavy metals were missing from the dataset. Microorganism sampling was well-represented in this watershed, which showed some high values for *Escherichia coli* in 2004 and 2005, possibly also the result of waste originating in Sunbright. Because White Oak Creek is included on the TN list of exceptional waters, this is of particular concern. In addition, fecal coliform means for both stations on White Oak Creek were higher than the other two stations.

It is difficult to trace the status of this watershed over each of the different analyses conducted by O'Bara et al. (1982), Rikard et al. (1986), Johnson (2003), in addition to the current data. Current data does show evidence of continued contamination from domestic and industrial discharge, and Johnson's (2003) recent summary could be indicative of polluted waters related to extractive processes in the watershed. Because of this, the overall status of water quality within the White Oak Creek watershed is assigned a fair and stable status ranking, though much additional data, such as metal concentrations, would be useful (Figure 28).

HUC0513010402

The Clear Fork River is the center of this watershed and is formed by the North and South Clear Fork prongs southwest of the park boundary. From there, it flows approximately 10 km to its confluence with Crooked Creek where it enters the park. Although O'Bara et al. (1982) did not sample on Clear Fork, Rikard et al. (1986) reported it as a slightly polluted stream, impacted by coal, oil and gas, and timber operations. Rikard et al. (1986) observed moderate conductivity levels and elevated sulfate at four sampling locations on Clear Fork, which increased after entering BISO. He attributed some of this to pollutive flow from White Oak Creek. Even later, Johnson (2003) sampled several stations along the Clear Fork with repeated specific conductance values greater than 100 µS/cm. Earlier sampling reported by Johnson (2003) showed elevated iron and manganese concentrations in tributaries to Clear Fork in the late 70's, as well as elevated copper and lead concentrations on Clear Fork through the 90's.

After Johnson's (2003) sampling summary, data was available mainly for the period 2004-2006. The Clear Fork watershed was infrequently sampled at one station on Clear Fork River near its junction with the New River. With the exception of chloride, there was at least one data point for each parameter. Several samples showed elevated conductivity values (> 100 µS/cm); these likely included some of the elevated values Rikard et al. (1986) reported. Acid neutralizing capacity was particularly low, though pH values were relatively invariable with a mean around 7.5. A single sample point in 2005 showed high values for both measures of microorganisms, though otherwise these measures were quite low. Elevated concentrations of iron were observed on two Clear Fork tributaries between 1975 and 1981. Based on the minimal data available for this watershed, it is difficult to tell how water quality has changed since earlier assessments. Additional conductivity samples would be helpful in determining continued effects, if any, on this watershed from resource extraction. Because available sampling does show issues related to resource extraction in the watershed, Clear Fork is assigned a fair status ranking without a trend (Figure 28).

HUC0513010403

The New River watershed is a system comprised of several major drainages, including the Smoky Fork, Buffalo Creek, and Brimstone Creek subwatersheds. Overall, the New River watershed is among the most heavily mined in the cataloging unit, with the highest concentration of mines occurring in the subwatershed that includes the New River headwaters (Johnson 2003). Rikard et al. (1986) offers the earliest report, classifying it as moderately polluted due to conductivity and sulfate levels associated with strip mining in the headwaters region. Elevated concentrations of suspended sediment were also reported in the basin. Johnson's (2003) assessment showed multiple water quality issues within the New River watershed:

- High values of conductivity for multiple sites in the watershed from as early as 1964 through 2001.
- Highest rates of sediment loading for the cataloging unit in the Smoky Creek subwatershed.
- High concentrations of iron and manganese in repeated samples on Indian Fork, a tributary to the New River.
- Elevated sulfate levels at multiple sites throughout the watershed.
- High concentrations of lead at multiple sites throughout the watershed.
- Elevated concentrations of zinc and aluminum at some sites in the watershed.

Following Johnson (2003), data is available over the period 2004-2010. The New River watershed was extensively sampled with 14 regularly sampled stations and several additional observations by TDEC. Datasets, however, were still remarkably sparse for temperature, conductance, and copper concentration. Most samples for conductance were above 200 µS/cm, with the highest mean being observed on Round Rock Creek. Sampling for iron, manganese, and zinc revealed much lower concentrations than Rikard (2003) observed, however, though this may be due to differences in sampling locations. Microorganism monitoring showed high concentrations for both *Escherichia* and fecal coliform on a single date in 2004. Values for pH fell within a normal range with the exception of a single TDEC observation on Joe Branch. Sampling at a single tributary to Straight Fork, which is currently listed as a 303(d) water in part due to acidity, did yield one of the lower pH values, though this value was near-neutral.

Although data appear to show somewhat improved water quality over previous analyses, especially in regards to metal concentrations, high rates of conductivity are still predominant in the watershed. O'Bara et al. (1986) indicates that, based on previous observations at BISO, conductivity and sulfate levels are reliable indicators of acid mine drainage in this system. In addition, Smoky Creek is listed as a 303(d) stream due to sedimentation issues, which is not addressed by the available data. Additional sedimentation and sulfate loading data would help inform how much of an effect mine drainage continues to have in this watershed. For now though, elevated conductivity rates indicate continued effects from acid mine drainage, and therefore the water quality of this watershed is assigned a status ranking of fair with an improving trend (Figure 28).

HUC0513010405

This watershed, central to the South Fork Cumberland cataloging unit, drains to Big South Fork and is the watershed comprising the largest portion of the park unit. This watershed is essentially divided into an eastern and western portion by the Big South Fork River. Major subwatersheds include those of Pine Creek, Laurel Fork, Bear Creek, Roaring Paunch Creek, and Rock Creek. Portions of Rock Creek and Roaring Paunch Creek are 303(d) listed in the latest 2010 data, while Pine Creek and Bear Creek are listed in their entirety in respective subwatersheds. Because of the complexity of this particular watershed, it is divided and ranked based on subwatersheds as follows.

Rock Creek Subwatershed

Rock Creek, as discussed earlier, was historically impacted by timber activities in its northern section, resulting in metal contamination and sedimentation (O'Bara et al. 1982). Rikard et al. (1986), on the other hand, classified this upper section as a clean, unimpacted stretch with naturally low conductivity levels. The lower section of Rock Creek, below its confluence with White Oak Creek, was one of those most heavily impacted river sections in the region. Numerous mine portals, as well as an old coal plant resulted in heavy input of acid mine drainage along this section, as well as high concentrations of iron, manganese, sulfate, and aluminum (O'Bara et al. 1982, Rikard et al. 1986). Rikard et al. (1986) went on to classify this lower section as one of the most heavily polluted streams in the Big South Fork region, also citing the presence of ferric hydroxide sediment buildup—a clear indication of acid mine drainage.

Johnson (2003) summarized substantial data in the Rock Creek subwatershed, especially in the polluted lower reach, including the lowest pH values observed for the cataloging unit. Mean values at some sites along Rock Creek and White Oak Creek were between 3 and 4 for sampling between 1999 and 2001. Fifteen sampling locations also reported extremely high conductance values—some in excess of 3,000 µS/cm. Readings this high likely indicate sources of direct industry discharge, such as brine (S. Bakaletz pers. comm.) Elevated iron concentrations were observed on Rock Creek above its confluence with White Oak Creek (1997-2000), as well as at the mouth of Rock Creek (1982 – 1998). Elevated manganese concentrations were observed at several locations on Rock and White Oak Creeks, some of the highest of which were observed at its mouth in BISO over the period 1982-1998. High sulfate levels were observed at 17 locations, including three stations within the subwatershed that sampled consistently above 1,000 mg/L as SO_4 between 1999 and 2001.

Following Johnson's (2003) assessment, the amount of data available for this subwatershed is somewhat sparse, but includes sampling stations in the upstream portion of Rock Creek in Pickett State Park and on the state boundary, in addition to sampling on Rock Creek just above the confluence with White Oak Creek over the period 2002 to 2005. Minimal sampling within the state park resulted in some low pH values from sampling in 2004, with a mean just below the state limit. Sampling for iron, chloride, manganese, zinc, and copper showed low values for available data. However, data for mercury concentrations—the reason this upper section of Rock Creek is 303(d) listed—is not available.

An assessment of this subwatershed would not be complete, however, without data from Rock Creek below its confluence with White Oak Creek. Unfortunately, no data is available from this section for this time period. Because of the extensive evidence of pollution associated with mine drainage shown by O'Bara et al. (1982), Rikard et al. (1986), and Johnson (2003), and also because of the recent recovery efforts on the lower section of Rock Creek described by Carew et al. (2003), an update on the condition of the Rock Creek subwatershed, specifically on the section below White Oak Creek, is the obvious next step in monitoring water quality in this area. The dearth of observations for this section represents a significant data gap. Based on the most recent assessment available, mine drainage is still a major issue in this subwatershed, and as a result, it receives a condition rating of poor (Figure 28). No trend is assigned based on insufficient recent data.

Williams Creek Subwatershed

The Williams Creek subwatershed, which contains a portion of the Big South Fork, also drains major tributaries such as Troublesome Creek, Difficulty Creek, Williams Creek, and Puncheoncamp Fork. O'Bara et al. (1986) reports that Williams Creek is affected by acid mine drainage and oil well runoff, while Troublesome Creek and Grassy Fork are relatively clean and unaffected, though Johnson (2003) did report low pH values at the latter during sampling between 1982 and 1984. Rikard et al. (1986) classifies Grassy Fork, a tributary to Williams Creek, as a stream of excellent water quality. O'Bara et al. (1982) attributes its pristine condition to inaccessibility due to its location in steep gorges. Williams Creek showed elevated iron concentrations and sedimentation, though O'Bara et al. (1986) refers to it as having overall good water quality, as do Rikard et al. (1986).

Puncheoncamp Fork is affected by mine drainage minimally at its headwaters, with elevated coliform values due to agricultural runoff. Rikard et al. (1986) refers to this stream as moderately polluted, citing elevated sulfate levels. Johnson (2003) reported elevated conductance, manganese, and iron concentrations over the period 1982 to 1998 on Puncheoncamp Fork. After Johnson (2003), no data is available in this subwatershed. Although streams seem to be relatively unaffected with the exception of Puncheoncamp Fork, additional sampling data is needed to confirm whether this is still the case. Because of the somewhat debilitated status of Puncheoncamp Fork among the other unaffected streams, this subwatershed receives a condition rating of fair (Figure 28). Due to the lack of current data, no trend is assigned.

No Business Creek Subwatershed
This subwatershed also contains a main section of Big South Fork, the main tributary to which is No Business Creek. O'Bara et al. (1982) refers to this section as undisturbed, a claim supported by Rikard et al. (1986), who indicates that its limestone parent material results in high buffering capacity. Johnson (2003) also reported no parameters indicative of pollution in this subwatershed. Like the Williams Creek subwatershed, no sampling data is available for this area following the assessment of Johnson (2003). Based on these previous analyses, however, it appears this subwatershed has a consistent history of intact water quality, and thus it receives a condition rating of good with a stable trend (Figure 28).

Station Camp Creek Subwatershed
Based on sampling on Laurel Fork and Station Camp Creek, O'Bara et al. (1986) determined that both Station Camp Creek and Laurel Fork were undisturbed. Rikard et al. (1986) also observed clean water quality, noting high dissolved oxygen and low metal concentrations. Station Camp Creek, Rikard et al. (1986) also observed, is predominantly forested and protected from harmful inputs, though he anticipated elevated bacterial concentrations due to the presence of Charit Creek Lodge along the creek. Sampling downstream of the hostel, however, did not show any effects. Johnson (2003) reported two elevated iron concentrations on Laurel Fork between 1997 and 1998, though the cause is unknown. Following Johnson (2003), data in the Station Camp Creek subwatershed was available from only a single regular sampling station on Laurel Fork over the period 2004-2006, where no water quality issues were apparent. Mean dissolved oxygen was around 10 mg/L, and bacterial sampling for both *E. coli* and fecal coliform showed low concentrations. Metals were also observed in low concentrations, and ANC was low and characteristic of the sandstone parent material. As Rikard et al. (1986) points out, there are several agricultural areas in the headwaters region of Laurel Fork, just outside the boundary of the park. These could pose noticeable water quality issues in the future, but so far, no problems are apparent in this subwatershed. As a result, it receives a condition rating of good with a stable trend (Figure *28*).

Bandy Creek Subwatershed
Immediately below the Station Camp Creek subwatershed is the Bandy Creek subwatershed. Bandy Creek is a major tributary to the Big South Fork, the latter of which begins at the top of this subwatershed at the confluence of Clear Fork and New River. Much of Bandy Creek flows through Scott State Forest. Other major tributaries include Bill Branch and Fall Branch. O'Bara et al. (1982) observed that a clearcut and road construction had caused siltation in the headwaters of Bandy Creek, negatively affecting aquatic habitat. Rikard et al. (1986) refer to Bandy Creek as a generally clean stream, though they cite the sedimentation effects from O'Bara et al.'s (1982) sampling. Rikard et al. (1986) also observed effects from construction of the Bandy Creek campground, which resulted in elevated iron concentrations. However, each of these disturbances is presumably temporary, and Johnson (2003) reported no abnormal parameters from his sampling summary.

Following Johnson's (2003) summary, data is available from a station on Big South Fork over the period 2004 to 2005, just below the Bandy Creek confluence. Though most parameters were normal, samples for *E. coli* and fecal coliform were elevated, as well as some iron concentrations. These possibly showed the influence of runoff and erosion from the Bandy Creek campground. Samples closer to the campground on Bandy Creek would clarify its

influence. At the very least, other stations along Big South Fork could help pinpoint effects from its multiple tributaries within the subwatershed. Because of the bacterial contamination and elevated iron concentrations, presumably from the Bandy Creek campground, the Bandy Creek subwatershed receives and condition rating of fair (Figure 28). Because of the temporary nature of past disturbances and unclear influence of current contamination, no trend is assigned.

Pine Creek Subwatershed

The Pine Creek subwatershed is located mostly outside of BISO, though a portion of it flows into the park before joining the Big South Fork. Pine Creek is listed as a 303(d) impaired water for its entire length throughout the subwatershed. Tributaries are fairly small in this watershed, but significant ones include Mill Branch, Thomas Branch, Nance Branch, and Niggs Branch. Pine Creek has a history of effects from many disturbances along its course, including mining and oil extraction, in addition to waste treatment discharge into Litton Fork from the town of Oneida, TN. O'Bara et al. (1982) and Rikard et al. (1986) observed elevated bacterial counts, in addition to channelization, high turbidity, and siltation resulting from activity around Oneida. All of these factors greatly reduced the amount of available stream habitat, which was evident in the debilitated aquatic life. Throughout the subwatershed, O'Bara et al. (1982) found elevated iron concentrations, which may have been due in part to a surface mine on Ails Branch. Rikard et al. (1986) found elevated chloride, sulfate, and conductivity, and referred to the stream overall as moderately polluted. Johnson (2003) also reported elevated conductivity and sulfate levels during monitoring between 1982 and 1998. Following Johnson's (2003) assessment, little data is available in this subwatershed. Two monitoring stations—one near Oneida and one near the park boundary—both showed elevated *E. coli* and fecal coliform concentrations in 2004. Finally, the most recent 303(d) listing cited several causes of impairment indicative of upstream disturbance, demonstrating that the issues identified by Rikard et al. (1986) and O'Bara et al. (1982) persist in this subwatershed. For these reasons, the Pine Creek subwatershed receives a condition rating of poor with a stable trend (Figure 28).

Bear Creek Subwatershed

Bear Creek is formed by the confluence of West Branch and East Branch Bear Creek, where it flows for approximately 2 km before entering BISO at the state boundary, and then another 5 km before joining Big South Fork. The whole section of Bear Creek, from the headwaters of East Branch to its confluence with Big South Fork, is listed as a 303(d) impaired stream. The only significant tributary in this subwatershed is Line Fork, which joins just upstream of the confluence with Big South Fork.

O'Bara et al. (1982) refers to Bear Creek as the most degraded system that enters BISO, due to very high iron and aluminum concentrations as the result of multiple mines in the upper reaches. The presence of aluminum, they attribute, has a disproportionately negative effect on aquatic life compared to iron. Aluminum disrupts ionoregulatory and respiratory processes in fish gills, the effects of which may be exaggerated by low pH, another result of acid mine drainage (Gensemer and Playle 1999). O'Bara et al. (1982) go on to recommend extensive reclamation, including removal of toxic soils and revegetation, and also efforts to target and eliminate sources of acidic drainage. Rikard et al. (1986), classifying the stream as one of the three most severely polluted in the BISO region, cites low pH, high sulfate and turbidity, and elevated concentrations of manganese and iron. Once inside BISO, they mention, Bear Creek improves in quality before

joining Big South Fork. Johnson's (2003) assessment confirmed continued impacts from mining along Bear Creek, with observations including:

- Low pH values (4-7 SU) and high conductance values on Bear Creek just downstream from the confluence of East and West Branch and at the confluence with Big South Fork over the period 1982 to 1998

- High manganese concentrations at the same two sampling locations over the period 1983 to 1998

- High sulfate concentrations at the same two sampling locations over the period 1982 to 1998

- Elevated dissolved aluminum and zinc at the mouth of Bear Creek over an unknown time period

Following Johnson's (2003) assessment, no regularly sampled stations provide data in the Bear Creek subwatershed. However, as mentioned previously, Bear Creek and East Branch Bear Creek have been included on the 303(d) stream list since 2002. Bear Creek outside BISO is listed for sedimentation, while East Branch Bear Creek is additionally listed for elevated iron concentrations. These sections, as well as the portion within BISO are all listed due to low pH. Mining is cited as the source of all of these impairments. Because Bear Creek is in a relatively small subwatershed, and Bear Creek continues to show impacts from acid mine drainage, it receives a condition rating of poor. Monitoring at the park boundary or at the confluence of Big South Fork is essential in order to detect the effects of mining in this subwatershed. Despite the long history of mining impacts to this system, it is unclear whether water quality has improved, and thus no trend is assigned (Figure 28).

Roaring Paunch Subwatershed

This subwatershed is the easternmost within the HUC10 watershed, and only a small portion falls within BISO. Headwaters of Roaring Paunch begin in the southeastern portion. Major tributaries include Jones Branch, Otter Creek, and Smith Fork. Roaring Paunch drains into Big South Fork between confluences with Rock Creek to the north and Bear Creek to the south. Many of the same mining issues are present in this subwatershed as Bear Creek, due in part to mining of the same coal seam, Poplar Creek. In addition to elevated iron, aluminum, and sulfate concentrations, O'Bara et al. (1982) reported abandoned coal and pyritic material in Barthell, KY contributing to drainage, which was perhaps the most significant problem along the stream. High bacterial concentrations were indicative of agricultural runoff in this subwatershed, and siltation was also predominant. Rikard et al. (1986) indicated Roaring Paunch a severely polluted stream for the same reason as O'Bara et al. (1982), though additionally citing elevated conductivity, manganese, and chloride measurements. Though O'Bara et al. (1982) stressed that aquatic life in Roaring Paunch was severely debilitated, Rikard et al. (1986) offered that some diversity remained, the most notable of which was the Big South Fork crayfish (*Cambarus bouchardi*).

Johnson's (2003) assessment of this subwatershed reported some of the most acidic values in the cataloging unit in a tributary to Jones Branch between 1977 and 1979. High conductance levels

were also consistently measured at two locations on Roaring Paunch from 1979 to 1998, and high chloride and manganese values were reported between 1980 and 1998. High sulfate levels were reported throughout the subwatershed. No regularly sampled stations are available for this watershed following Johnson's (2003) assessment.

Although the middle section of Roaring Paunch is currently listed as a 303(d) section, both the upper and lower reaches were previously listed but currently are not. The currently listed portion, from the state boundary to the Smith Fork confluence, is impaired due to low pH. Previously, sections had been listed for sedimentation and pH, so conditions in these upper and lower reaches may be improving. However, current data is needed to make this determination. Based on thorough evidence of acid mine drainage from the latest data available—Johnson (2003)—a condition rating of poor is assigned to this subwatershed.

Blair Creek Subwatershed

The smallest subwatershed, Big South Fork runs through this drainage which begins with the confluence with Bear Creek and extends downstream to its confluence with Rock Creek. Major named tributaries include Devils Creek, Laurel Crossing Branch, and Blair Creek. Neither O'Bara et al. (1982) or Rikard et al. (1986) sampled within this subwatershed. Sampling summarized by Johnson (2003) did include locations on Blair Creek, Devils Creek, and Worley Creek, as well as two locations on Big South Fork, all of which reported elevated iron concentrations between 1995 and 1997. Blair Creek and Devils Creek also reported elevated manganese concentrations during the same time period, and high lead concentrations were measured at Blue Heron on Big South Fork over the period 1979 to 1995. Finally, dissolved aluminum values were elevated during the period 1995 to 1997 on Blair Creek and Devils Creek.

Following Johnson (2003), several samples were available on Big South Fork around Blue Heron over the period 2001 to 2007. These measurements showed elevated fecal coliform concentrations from two samples in 2004, which may have been the result of flow following a rainfall event. Regular monitoring for both iron and manganese at this station showed overall elevated values over the period 2001 to 2007, though neither metal was found at concentrations reported by Johnson (2003). The remaining parameters for which there were data showed no values of concern. Although data for lead and aluminum concentrations were not available at this site, it appears that conditions at this location may be improving due to lower iron and manganese concentrations than those found by Johnson (2003). Based on available data, this subwatershed receives a condition rating of poor with an improving trend (Figure 28).

<u>HUC0513010407</u>

Also informed by very little data, the only regular station in this watershed is on Lake Cumberland at the terminus of Big South Fork. Lentic systems typically demonstrate different water quality properties than streams, such as slightly lower dissolved oxygen. Samples at this site, however, did show slightly elevated levels of iron and manganese based on recent monitoring over the period 2003 to 2005. This is likely due to loading to Big South Fork from tributaries affected by mine drainage. Though data for ANC, dissolved oxygen, pH, and zinc reflected overall normal values at this site, this watershed receives a condition status of fair due to the elevated iron and manganese concentrations (Figure 28). Insufficient information is available to assign a trend.

HUC0513010404

This watershed is comprised mainly of North White Oak Creek, which drains into Big South Fork. The main tributary, flowing in the north part of the watershed, is Laurel Fork. Mill Creek, another major tributary, joins North White Oak Creek from the southern portion. O'Bara et al. (1982) report that Laurel Fork is slightly polluted by runoff and erosion as well as sewage discharge from a campground around Sharp Place, TN near the headwaters, though elevated bacterial concentrations were not observed. North White Oak Creek, like Laurel Fork, is affected somewhat by agricultural runoff. Mill Creek showed signs of sedimentation, likely related to oil and gas activity (O'Bara et al. 1982). Rikard et al. (1986) reported on a slightly more affected watershed, citing the influence of mines along North White Oak Creek and erosion downstream of Mill Creek. Although samples showed low aluminum and sulfate concentrations, iron concentrations were slightly elevated in the upper section. On Laurel Fork, Rikard et al. (1986) noted high bacterial contamination in the headwaters due to agricultural runoff above Hwy 154, which affected aquatic life below that point. Runoff also resulted in elevated iron concentrations.

Johnson (2003) identified some low pH values between 1974 and 1982 on a tributary to Mill Creek, and elevated iron concentrations at the mouth of North White Oak Creek. Some high dissolved aluminum concentrations were also observed on Mill Creek, though the sample date is unknown (Johnson 2003). Following Johnson's (2003) assessment, no data was available after September 2001 for this watershed. However, the salient issues appear to be agricultural runoff and resulting bacterial contamination in the headwaters region of Laurel Fork, as well as negative effects of resource extraction along Mill Creek. Based on the available data, this watershed receives a condition rating of fair with a stable trend, though additional sampling in these areas, at least, would be beneficial (Figure 28).

Summary

O'Bara et al. (1982) and Rikard et al. (1986) provide comprehensive descriptions of the status of waters within the BISO region, including ones most significantly affected by mining and other forms of resource extraction. Water quality data was divided into watershed reporting with the exception of the central Big South Fork watershed, which was divided into nine HUC12 subwatersheds. This roughly matches the reporting units used by previous reports with some variation. Within this section, five subwatersheds were ranked as poor, two were ranked fair, and two were ranked good. Of the remaining six watersheds in the South Fork Cumberland cataloging unit, five were ranked fair, while one was ranked good. The vast majority of issues that arose among systems were related to mining, though in some areas, such as the Pine Creek subwatershed, activity from development has resulted in sedimentation and bacterial contamination issues. Laurel Fork has also shown signs of pollution from sewage discharge. Oil and gas extraction is also a source of pollution, mainly from brine discharge, which can raise conductivity levels. Most oil and gas wells in the cataloging unit are located in the Clear Fork and North White Oak Creek drainages.

Many streams represent pristine and high quality waters representative of the recreation area, including Laurel Fork of Station Camp Creek, No Business Creek, the middle section of Rock Creek, and Big South Fork. Other streams represent highly debilitated waters, such as the lower

section of Rock Creek, Roaring Paunch, Bear Creek, and Pine Creek. Monitoring on these areas in particular would help track their recovery.

Each of the four watersheds listed as poor water quality demonstrate a history of mining, and each also have a section listed as 303(d) waters related in part or in whole to mining activity. Mining pressure was particularly heavy in the downstream portion of the Rock Creek, below its confluence with White Oak Creek. Current data was not available on this section, but recent recovery and reclamation activities would likely show an improvement in this stretch of water. The Roaring Paunch subwatershed demonstrates a history of heavy mining, though this area represents particular importance because of the presence of the Big South Fork crayfish, which is endemic to the subwatershed. Bear Creek also represents a particular concern due to elevated aluminum concentrations, which can have a disproportionate effect on aquatic life. From Bear Creek to Yamacraw, there are numerous old mines (~100) that still discharge acid mine drainage into the main river. Overall, water quality within the South Fork Cumberland cataloging unit receives a fair condition status (Table 21). An assessment at this scale, however, is of limited use because water quality issues occur at a much finer scale.

Of the 15 watersheds and subwatershed included in this assessment, four are assigned trends of stable, while one is assigned trends of improving. No overall trend is provided.

Table 21. The overall water quality condition status for BISO was fair. No trend was assigned to this overall condition. The quality of the data used to make this assessment was good.

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

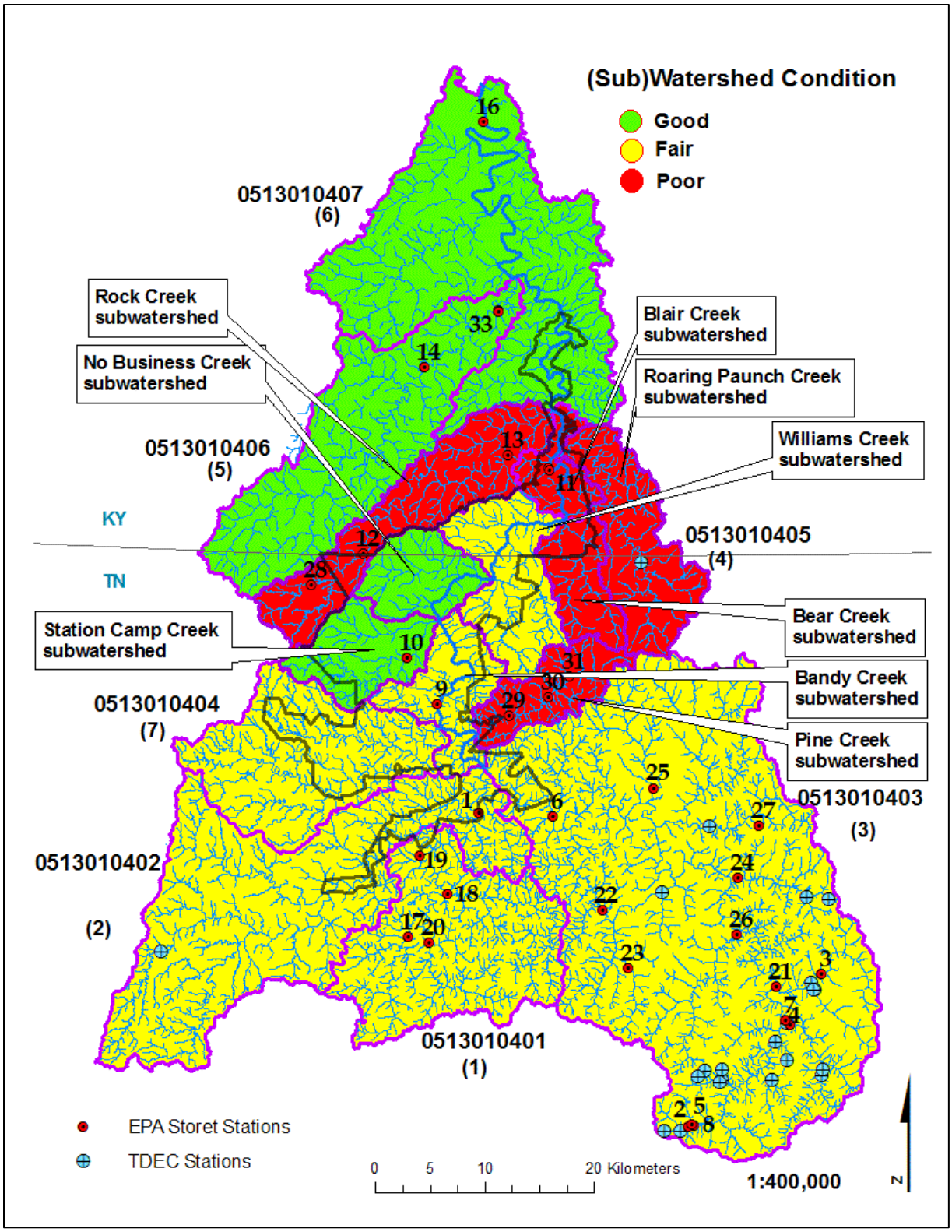

Figure 28. Individual watersheds and colored rankings within the South Fork Cumberland cataloging unit. Of the seven watersheds, three were ranked good, one fair, one poor, and one was not ranked.

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4.6 Vegetation

4.6.1 Community Classification

Nordman (2011) summarizes a comprehensive vegetation classification conducted at BISO by NatureServe and the Tennessee Natural Heritage Inventory Program beginning in 2004. This effort classified vegetation types at BISO into a total of 47 communities according to the National Vegetation Classification (Grossman et al. 1998). Of these, 38 were represented in plots, while the remaining nine were in small patches, represented aquatic vegetation, or were not captured for various reasons. In addition, 176 new plant taxa were documented, bringing the total to 1023 plant species in the park. Nordman (2011) pointed out five globally rare community types at the park that represent a disproportionate amount of biodiversity, shown in Table 22.

Table 22. List of globally rare vegetation communities at BISO identified by Nordman (2011).

Community Type	CEGL	Global Rank[1]
Cumberland Plateau Rockhouse*	4301	G2
Cumberland Riverside Scour Prairie	8471	G2?
Eastern Hemlock – (White Pine) Montane Alluvial Forest (Small River Type)	7143	G3
Mountain Laurel – Huckleberry Cumberland Sandstone Heath Glade	8470	G3
Cumberland Plateau Clifftop Sandstone Barren*	4061	G3

*Not mapped

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

4.6.2 Exotic Plants

A total of 86 non-native taxa were also documented at the park, ranging from relict plantings at homesites to highly aggressive invasives capable of exerting a negative ecological impact (Nordman 2011). Of the 97 plots used in the assessment, over half (52%) contained exotic species (Table 23), and had a history of disturbance (Figure 29). Nordman (2011) points out that the Cumberland Riverside Scour Prairie community is particularly susceptible to exotic invasion and should be managed protectively from this threat.

Table 23. Exotic species observed in NatureServe plots.

Community Type	CEGL	# Plots	Exotics Observed
Southern and C entral Appalachian/Piedmont Rich Cove/Mesic Slope Forest	008412	2	Japanese honeysuckle (*Lonicera japonica*)
Successional Black Walnut Forest	007879	1	Japanese kerria (*Kerria japonica*) Japanese honeysuckle Japanese stiltgrass (*Microstegium vimineum*)
Successional Sweetgum Forest	007216	1	Multiflora rose (*Rosa multiflora*)
Interior Mid- to Late-Successional Tuliptree – Hardwood Upland Forest (Acid Type)	007221	1	Japanese stiltgrass
Ridge and Valley Limestone Oak – Hickory Forest	004793	2	Crown vetch (*Coronilla varia*) Queen Anne's lace (*Daucus carota*) Sericea lespedeza (*Lespedeza cuneata*) Tall fescue (*Lolium arundinaceum*) Meadow fescue (*Lolium pratense*) Japanese honeysuckle Yellow sweetclover (*Melilotus officinalis*) Japanese stiltgrass Field clover (*Trifolium campestre*) Red clover (*Trifolium pratense*) White clover (*Trifolium repens*)
River Birch Levee Forest	007312	4	Tree-of-heaven (*Ailanthus altissima*) Mimosa (*Albizia julibrissin*) Hairy bittercress (*Cardamine hirsuta*) Sericea lespedeza Japanese stiltgrass Multiflora rose Ivyleaf speedwell (*Veronica hederifolia*)
Successional Sweetgum Floodplain Forest	007330	2	Japanese honeysuckle Multiflora rose
Cumberland Forested Acid Seep	007443	3	Indian strawberry (*Duchesnea indica*) Japanese stiltgrass
Cumberland Appalachian Hemlock – Hardwood Cove Forest	008407	7	Tree-of-heaven Sericea lespedeza Japanese stiltgrass Princesstree (*Paulownia tomentosa*) Multiflora rose
Blackberry – Greenbrier Successional Shrubland Thicket	004732	1	Sericea lespedeza
Central Interior Beech – White Oak Forest	007881	6	Crown vetch Ox-eye daisy (*Leucanthemum vulgare*) Tall fescue Japanese honeysuckle Japanese stiltgrass White clover
Cumberland Plateau Dry-Mesic White Oak Forest	008430	10	Japanese honeysuckle
Ridge- and Valley- Dry-Mesic White Oak – Hickory Forest	007240	4	Hairy bittercress Japanese honeysuckle Japanese stiltgrass

Table 23. Exotic species observed in NatureServe plots. (continued)

Community Type	CEGL	# Plots	Exotics Observed
Appalachian White Pine – Mesic Oak Forest	007517	5	Redtop (*Agrostis gigantea*) Ox-eye Japanese honeysuckle Japanese stiltgrass Red clover White clover
Cultivated Meadow	004048	1	Queen Anne's lace Japanese clover (*Kummerowia striata*) Sericea lespedeza Pearl millet (*Pennisetum glaucum*) Multiflora rose
Cumberland Riverside Scour Prairie	008471	2	Mimosa Sericea lespedeza Japanese stiltgrass Multiflora rose

I-Ranks

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics called the I-rank. The 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. Each I-rank has been recalculated to a number between zero and three for the exotic species identified in plots, with three representing the greatest threat to park resources. These rankings are shown in Table 24. Following this approach, of 16 species, Japanese honeysuckle, Tall fescue, Japanese stiltgrass, and sericea lespedeza possessed I-Ranks >2.00— the highest possible risk category. Eleven species displayed I values between one and two, and three species were ranked below one (i.e. minimal risk). I-Ranks were not available for the remaining seven species.

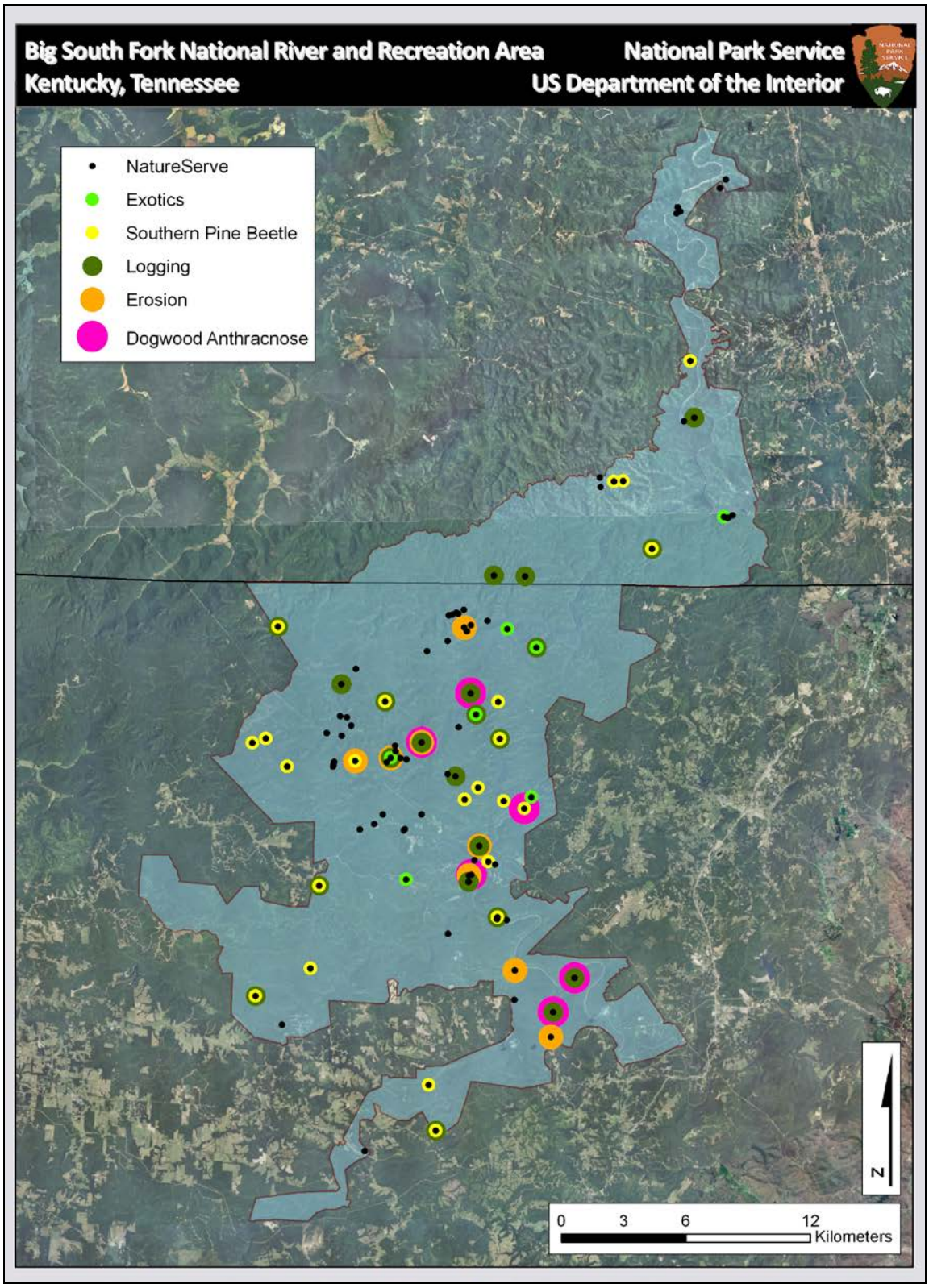

Figure 29. NatureServe plots indicating locations of exotic plants, among other disturbances.

Table 24. I-Ranks shown for 23 species of exotics observed in NatureServe plots.

Species	Common Name	Family	I-Rank*	Total Plots
Lonicera japonica	Japanese honeysuckle	Caprifoliaceae	2.33	10
Lolium arundinaceum	Tall fescue	Poaceae	2.17	2
Microstegium vimineum	Japanese stiltgrass	Poaceae	2.00	16
Lespedeza cuneata	Sericea lespedeza	Fabaceae	2.00	9
Lolium pratense	Meadow fescue	Poaceae	1.67	1
Albizia julibrissin	Mimosa	Fabaceae	1.67	3
Ailanthus altissima	Tree-of-heaven	Simaroubaceae	1.50	3
Leucanthemum vulgare	Ox-eye daisy	Asteraceae	1.50	2
Paulownia tomentosa	Princesstree	Bignoniaceae	1.33	1
Rosa multiflora	Multiflora rose	Rosaceae	1.17	13
Trifolium repens	White clover	Fabaceae	1.17	3
Agrostis gigantea	Redtop	Poaceae	1.17	1
Kummerowia striata	Japanese clover	Fabaceae	1.17	1
Duchesnea indica	Indian strawberry	Rosaceae	0.83	1
Trifolium pratense	Red clover	Fabaceae	0.50	2
Daucus carota	Queen Anne's lace	Apiaceae	0.33	2
Kerria japonica	Japanese kerria	Rosaceae	Not Ranked	1
Coronilla varia	Crown vetch	Fabaceae	Not Ranked	2
Melilatus officinalis	Yellow sweetclover	Fabaceae	Not Ranked	1
Trifolium campestre	Field clover	Fabaceae	Not Ranked	1
Cardamine hirsuta	Hairy bittercress	Brassicaceae	Not Ranked	2
Veronica hederifolia	Ivyleaf speedwell	Scrophulariaceae	Not Ranked	1
Pennisetum glaucum	Pearl millet	Poaceae	Not Ranked	1
Overall	**--**	**--**	**1.33†**	**52†**

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

4.6.3 Wetland Communities

In fall 2009, the Louis Berger Consulting Group conducted wetland delineations at No Business Creek and Oil Well Branch areas after the decision by BISO to close several oil and gas wells inside the park. Wetland areas were assessed separately using both Cowardin et al.'s (1979) wetland classification system as well as the US Army Corps of Engineers (USACE) wetland delineation manual (2009). The group identified 19 wetlands in the two areas, which together comprised 7.5 ha along approximately 3 km of stream length (Table 25). The three general requirements for wetland classification according to the USACE manual included hydric soils, wetland hydrology, and hydrophytic vegetation. Under NPS standards, any one of the three attributes is indicative of wetland area. As a result, ten wetlands at No Business Creek and four in the Oil Well Branch area met the USACE standards, while 3 and 2 wetlands, respectively, met only the NPS standards.

Table 25. Wetland types and location at No Business Creek and Oil Well Branch sites in BISO. [Taken from Louis Berger Group's 2009 assessment]

Site	Wetland/Stream Identification Criteria	Type	Location	Area (acres/ha)
No Business Creek	Wetland NBNA (USACE/NPS)	Palustrine, forested, broad-leaved deciduous, saturated (PFO1B)	Northern floodplain of No Business Creek, at the western site boundary	0.15/0.06
	Wetland NBNB (NPS)	Palustrine, forested, broad-leaved deciduous, saturated (PFO1B)	Northern floodplain of No Business Creek, approximately 120 feet east of the western site boundary	0.13/0.05
	Wetland NBNF (USACE/NPS)	Palustrine, forested, broad-leaved deciduous, saturated (PSS1B)	Northern floodplain of No Business Creek, approximately 550 feet east of the western site boundary	0.11/0.04
	Wetland NBNZ (USACE/NPS)	Palustrine, scrub-shrub, broad-leaved deciduous, saturated (PSS1B)	Northern floodplain of No Business Creek, near the center of the site	0.16/0.06
	Wetland ACB (USACE/NPS)	Palustrine, forested, broad-leaved deciduous, saturated (PFO1B)	Northern floodplain of No Business Creek, 250 feet west of the confluence with Anderson Cave Branch	<0.01/<0.01
	Wetland BSA (NPS)	Palustrine, forested, broad-leaved deciduous, saturated (PFO1B)	Southern floodplain of No Business Creek, directly abutting the creek near the center of the site	0.05/0.02
	No Business Creek (USACE/NPS)	Riverine, upper perennial, unconsolidated bed, permanently flooded (R3UBH)	Flows west to east through the center of the site	2.82/1.14, 4,030 linear feet
	Longfield Branch (USACE/NPS)	Riverine, upper perennial, unconsolidated bed, permanently flooded (R3UBH)	Flows north into No Business Creek near the eastern site boundary	0.15/0.06, 500 linear feet
	Anderson Cave Branch (USACE/NPS)	Riverine, upper perennial, unconsolidated bed, permanently flooded (R3UBH)	Flows north into No Business Creek near the center of the site	0.11/0.04, 406 linear feet
	Stream NBNS-1 (USACE/NPS)	Riverine, intermittent, unconsolidated bed, intermittently flooded (R4UBJ)	Flows southeast into No Business Creek, approximately 240 feet east of the western site boundary	0.03/0.01, 400 linear feet

Site	Wetland/Stream Identification Criteria	Type	Location	Area (acres/ha)
	Stream NBNS-2 (USACE/NPS)	Riverine, intermittent, unconsolidated bed, intermittently flooded (R4UBJ)	Flowing east from Wetland NBNZ into No Business Creek	<0.01/<0.01, 256 linear feet
	Stream ACA (NPS)	Riverine, ephemeral, unconsolidated bed, temporarily flooded (REUBA)	Southern floodplain of No Business Creek, approximately 20 feet upstream of the confluence with Anderson Cave Branch	<0.01/<0.01
	Stream NBNC (USACE/NPS)	Riverine, intermittent, unconsolidated bed, intermittently flooded (R4UBJ)	Flowing south into No Business Creek, approximately 420 feet east of the western site boundary	0.20/0.08, 585 linear feet
	Stream NBSA (USACE/NPS)	Riverine, intermittent, unconsolidated bed, intermittently flooded (R4UBJ)	Flowing east into No Business Creek near the center of the site	0.08/0.03, 475 linear feet
	Stream NBSB (USACE/NPS)	Riverine, intermittent, unconsolidated bed, intermittently flooded (R4UBJ)	Flowing east into NBSA near the center of the site	0.10/0.04, 292 linear feet
Oil Well Branch	Wetland OWA (NPS)	Palustrine, forested, broad-leaved, seasonally flooded/well drained (PFO1D)	Floodplain of the Big South Fork of the Cumberland River, east of Oil Well Branch	0.40/0.16
	Wetland OWB (NPS)	Palustrine, emergent, non-persistent, seasonally flooded/well drained (PEM2D)	Floodplain of the Big South Fork of the Cumberland River, west of Oil Well Branch	1.41/0.57
	Big South Fork of the Cumberland River (USACE/NPS)	Riverine, upper perennial, unconsolidated bottom, permanently flooded (R3UBH)	Southern boundary of the site	0.79/0.32, 910 linear feet
	Oil Well Branch (USACE/NPS)	Riverine, upper perennial, unconsolidated bottom, permanently flooded (R3UBH)	Flows south through the center of the site	0.80/0.32, 1,080 linear feet

4.6.4 Cobble Bars

Cumberlandian cobble bar habitats, also known as river scour prairies, are an exceptional type of vegetation community that only exists in the Cumberland Plateau region of KY and TN. These areas occur along rivers atop various sediment types or bedrock and are regularly flooded, or scoured, by flood-stage river waters that limit woody vegetation. Drought periods also play an important function (NatureServe 2007, NPS 2008). Vegetation is characterized by several species of grasses such as big bluestem (*Andropogon gerardii*.), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), as well as other herbaceous plants and woody shrubs. Psamments, the most common soil type in these areas, are sandy and characterized by an overall lack of pedogenic development. These well- to rapidly-drained soils are typically distributed patchily across the cobble bar habitat, often in protected crevices or among boulders (NRCS 1999, NatureServe 2007). These areas can resemble prairie expanses filled with grasses and forbs, and they also host a unique assemblage that includes several rare plants, such as the federally endangered Cumberland sandwort (Murdock et al. 2011). These communities are also an especially important habitat for the federally threatened Cumberland rosemary (Figure 30), for which BISO and the Obed Wild and Scenic River support most of the remaining population. NatureServe (2007) and Murdock et al. (2011) outline 19 rare plant species that are particularly valuable to these communities, many of which are completely endemic to these areas (Table 26).

Figure 30. Cumberland rosemary is a federally threatened species endemic to cobble bar communities.

Currently, fewer than 200 ha (500 acres) of cobble bar habitat remain, resulting in a Nature Conservancy classification of globally imperiled (G2). At BISO, 22 cobble bars have been identified over 77 river miles of on-the-ground surveys (NPS 2008), while the CRMS vegetation map of the park unit classified 106 ha of cobble bar community over 196 unique polygons, mostly along the Big South Fork. NatureServe (2007) surveyed two cobble bar plots in the park unit and recorded a total of 155 herbaceous species. Murdock et al. (2011) indicate that invasive plants are one of the most significant risks to cobble bar communities, in part because the frequent scouring leaves behind the type of disturbed habitat favored by many exotics. In the recent cobble bar monitoring protocol (Murdock et al. 2011), nine sites at BISO were identified for continued monitoring once every two years to detect changes in plant composition and threats from exotics.

4.6.5 Condition and Trend

Overall, BISO supports a variety of important vegetation types, not only including the river scour cobble bar communities, but also the Cumberland Plateau rockhouse and clifftop sandstone barren communities. These communities host a wide variety of plant species and represent

important targets for management attention. Currently, the biggest threat to communities such as these may be the invasion of exotic species, the most widely spread of which include Japanese honeysuckle, Japanese stiltgrass, multiflora rose, and sericea lespedeza. The new monitoring program in place for the cobble bar communities will ensure early detection of exotics. Regular monitoring at other sensitive communities will ensure these areas are also protected. Despite the threat of exotics, vegetation at BISO receives a current condition ranking of good due to the protection and monitoring of these communities (Table 27). As monitoring continues, sufficient information will be available to assign a trend.

Table 26. Rare plant species found within cobble bar community survey plots by Murdock et al. (2011).

Species		Ranking		
		TN[1]	KY[1]	Global[2]
False indigo	*Baptisia australis*	S3	S3	--
American barberry	*Berberis canadensis*	Special Concern/S2	Endangered/S1	G3
Cumberland sandreed*	*Calamovilfa arcuata*	Endangered/S2	S1	G2
Eastern sweetshrub	*Calycanthus floridus*	--	Threatened/S2	--
Whiteleaf leatherflower	*Clematis glaucophylla*	Endangered	S3	G4
Sweet-fern	*Comptonia peregrina*	Endangered/S1	Endangered/S1	G5
Cumberland rosemary	*Conradina verticillata*	Threatened/S3	Endangered/S1	G3
Star tickseed	*Coreopsis pubescens*	--	Special Concern/S2	--
Rockcastle aster*	*Eurybia saxicastellii*	Endangered/S1S2	Threatened/S1S2	G1G2
Mountain witch-alder	*Fothergilla major*	Threatened/S2	--	G3
Rough hawkweed	*Hieracium scabrum*	Threatened	S4	G5
Large Flowered Barbara's Buttons	*Marshallia grandiflora*	S2	S1	G2
Small evening primrose	*Oenothera perennis*		Endangered/S1	G5
Pitch pine	*Pinus strobus*	--	S3	--
Hairy snoutbean	*Rhynchosia tomentosa*	Endangered	S1	G5
Southern racemose goldenrod	*Solidago arenicola*	Threatened/S1	Special Concern	G2G3
Virginia spirea	*Spiraea virginiana*	Endangered/S2	Threatened/S2	G2
Leatherleaf meadowrue[¥]	*Thalictrum coriaceum*	Threatened	S4	G4
Northern white cedar	*Thuja occidentalis*	Special Concern/S3	Threatened/S2	G5

*Candidate species for federal listing
[¥]Historically present
[1]Rounded NatureServe conservation status of a species from a state/province perspective, characterizing the relative imperilment of the species. S1=Critically Imperiled, S2=Imperiled, S3=Vulnerable, S4=Apparently Secure, S5=Secure, SH = Possibly Extirpated, H = Historic; Refer to <http://www.natureserve.org/explorer/nsranks.htm> for additional information on ranks.
[2]Rounded NatureServe conservation status from a global (i.e. rangewide) perspective, characterizing the relative imperilment of the species. G1=Critically Imperiled, G2=Imperiled, G3=Vulnerable, G4=Apparently Secure, G5=Secure. Refer to <http://www.natureserve.org/explorer/ranking.htm> for additional information on ranks.

Table 27**.** The condition status for vegetation at BISO was good. No trend was assigned to vegetation condition. The data quality was good.

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

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4.7 Fish Assemblages

4.7.1 Relevance and Context

The Big South Fork National River and Recreation Area is organized around a riverine system, and protection of aquatic natural resources is an eminently important goal of the unit's mandate and management strategy (NPS 2010). The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000). The Cumberland River drainage is notable for its high number of endemic aquatic species. The watershed below Cumberland Falls, in which the Big South Fork (BSF) is included, contains one of the richest assemblages of native fishes among North American drainages (Sheldon 1988). The BISO contains over 760 km of surface flowing streams and rivers, providing habitat for a variety of fish species. The river is formed in the southeastern portion of the unit at the confluence of Clear Fork and the New River. It flows north through the unit and joins the main branch of the Cumberland River in the eastern reaches of 17,700-hectare Lake Cumberland, approximately 22 km north of the NPS boundary (Figure 31). During much of the summer, Lake Cumberland backs up the Big South Fork into BISO, creating reservoir habitat for approximately 28 km of the river's length in the unit (Scott 2010).

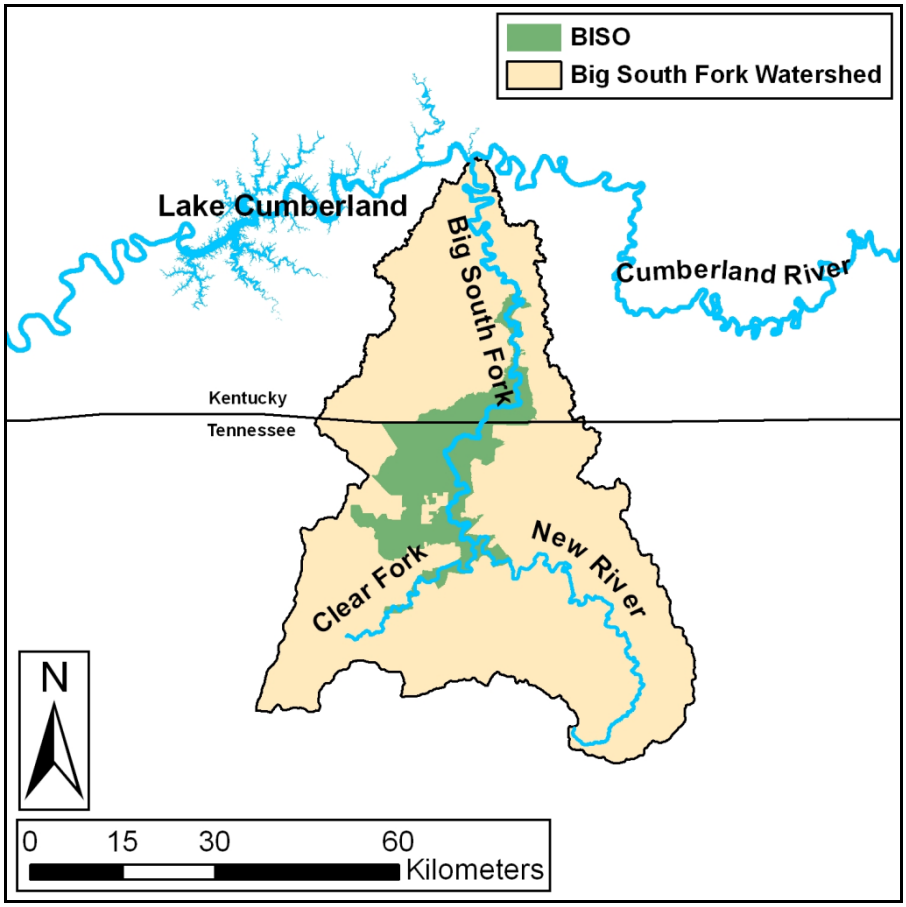

Figure 31. Overview of the Big South Fork National River and Recreation Area and the Big South Fork HUC 8 watershed area.

4.7.2 Threats and Stressors

Human activities, most importantly coal mining, have negatively impacted water quality and fish assemblages in the BSF drainage for over 100 years (Shoup 1940, Shoup and Peyton 1940, Comiskey and Etnier 1972, Brazinski 1979, O'Bara et al. 1982, Carew 2002, NPS 2010, Scott 2010). Mining has occurred in the watershed since the 1880s, and open pit strip mining has been the dominant method of extraction since the 1940s (Vaughan 1979, Hamilton and Turrini-Smith 1997). Though the amount of coal mining in the region has decreased from peak levels, many polluted abandoned mine sites remain, and active mining continues and has even increased in recent years within the BISO watershed (Hamilton and Turrini-Smith 1997, Carter et al. 2005, NPS 2010). The eastern tributaries of the BSF watershed have suffered more detrimental mining impacts than western tributaries have, and the most impacted stream segments are outside and hydrologically above NPS boundaries.

Several fish sampling efforts in the watershed have reported the adverse effects of mining. Shoup (1940) conducted water sampling throughout the BSF drainage, reporting that the vertebrate fauna of many tributaries, particularly of the New River, were severely affected by acid mine drainage. Shoup and Peyton (1940) reported that many tributaries of the upper BSF drainage were so polluted that they were "comparatively barren" in terms of biological

productivity. Comiskey and Etnier (1972) reported that the New River and lower Rock Creek were "badly polluted by strip mining activities and many portions of these streams lack a vertebrate or macro-invertebrate fauna". Vaughan (1979) reported that several small tributaries of the New River affected by strip mining had significantly lower richness, diversity, and catch per effort of fishes, relative to a nearby unaffected tributary of similar size. Brazinski (1979) sampled fishes in the New River watershed and found that streams more affected by acid mine drainage had lower abundance, diversity, and species richness relative to streams less affected by mining. Evans (1998) sampled fishes in the New River drainage and evaluated and compared his results with Brazinski's (1979) using diversity metrics and an index of biotic integrity (IBI). He found that 21 of 41 sites sampled were "poor" or "very poor" quality, but noted that his samples indicated improvement in quality relative to Brazinski's (1979) samples (Evans 1998). O'Bara et al. (1982) surveyed fish assemblages in 16 tributaries of the BSF. They reported that fish populations of 10 tributaries were negatively affected by coal mining or other anthropogenic impacts, and six were unaffected by anthropogenic sources (O'Bara et al. 1982; Figure 32). The BSF drainage contains several stream segments listed in 2010 under Clean Water Act guidelines as 303(d), non-supporting or partially-supporting of designated uses (Figure 23).

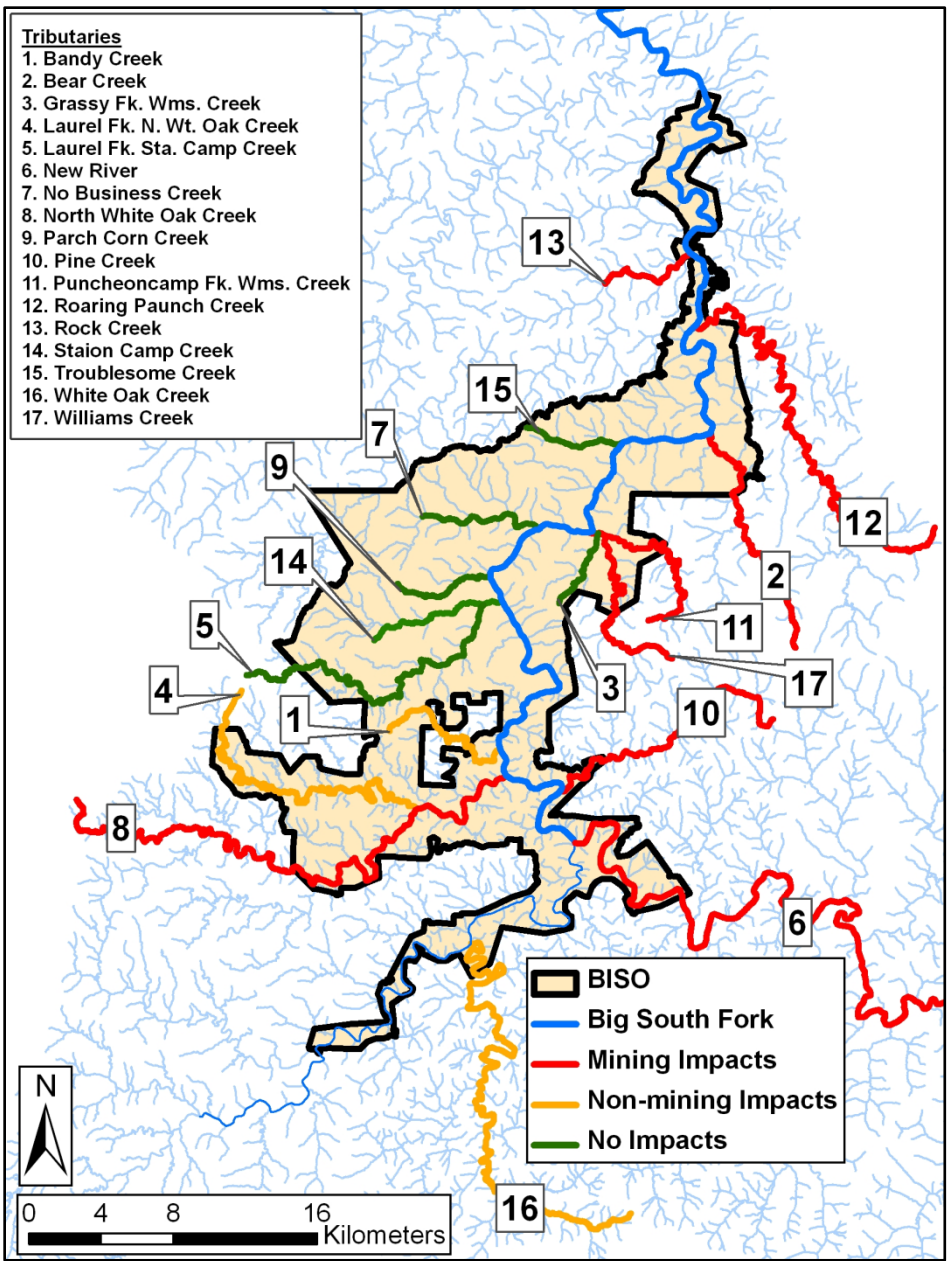

Figure 32. Major tributaries of the Big South Fork River in BISO showing types of anthropogenic impacts affecting fish assemblages in the early 1980s. Data on impact type taken from O'Bara et al. (1982).

4.7.3 Resource Knowledge

There have been a number of fish sampling efforts, dating to the 19th century, within the Big South Fork drainage. Because of the long history of mining, knowledge of the fish assemblages existing prior to impairment is incomplete. We examined the results from a number of available studies in an effort to understand the history and current condition of the resource as well as possible. Because BISO is located downstream of much of the BSF drainage, water quality and aquatic resources within the park are significantly affected by activities outside its boundaries. An understanding of park fish assemblages requires some knowledge of resources outside the

unit, and even efforts conducted under NPS contract have include sampling outside park boundaries (O'Bara et al. 1982; Scott 2010).

A number of efforts have sampled fishes in the BSF watershed within and upstream of park boundaries. Cope (1870) reported on four (possibly five) darter species from the system. Kirsch (1893) seined six flows and reported 24 species. Shoup and Peyton (1940) sampled fish in the BSF drainage, reporting 34 species from the BISO watershed. Comiskey and Etnier (1972) conducted surveys in the BSF drainage using seine nets, bag seines, gill nets, and piscicides, reporting 53 species from their own efforts in the BISO watershed. Brazinski (1979) sampled the New River watershed above park boundaries and reported 31 species. O'Bara et al. (1982) used backpack electroshocking and piscicides to sample 16 wadeable tributaries of the BSF and reported 44 species. Evans (1998) sampled the New River drainage and reported 41 species. Scott (2010), under the mandate of the NPS Inventory and Monitoring program, conducted the most recent and comprehensive survey of fishes in BISO and in the nearby upstream watersheds. This effort employed boat-mounted and backpack electroshocking, seines, dip nets, gill nets, minnow traps, and snorkeling (Scott 2010). It further reported selected results from sampling conducted by NPS-contracted entities and on efforts in conjunction with state agencies (Scott 2010). Scott (2010) reported 79 species.

Combined, the sources discussed above include 89 species (including four non-natives) that have been reported from the BSF drainage within and upstream of park boundaries (Appendix D). Among these species, Shoup and Peyton (1940) provided the sole report of brook trout (*Salvelinus fontinalis*) which occurred at a single location following hatchery introductions. The quillback (*Carpiodes cyprinus*) was unique to a single study and was reported from the New River above park boundaries (Brazinski 1979). The slender madtom (*Noturus exilis*) was also unique to a single study and was reported only from the New River drainage (Evans 1998). The lake sturgeon (*Acipenser fulvescens*) was reported only from the NPSpecies database, where notes indicated it had been reintroduced into park waters in 2008 in cooperation with the Kentucky Department of Fish and Wildlife Resources (KDFWR; NPSpecies 2010). The redtail chub (*Nocomis effusus*) was reported in unpublished data within the APHN fish database, and an occurrence in the park was also mentioned by Scott (2010) and attributed to sampling by KDFWR. Similarly, the pallid shiner (*Hybopsis amnis*) was reported by Scott (2010) as a species that had been sampled within BISO by KDFWR. The most recent BISO inventory reported 15 species that were unique among these studies (Scott 2010).

A further 18 species (including three non-natives) may potentially occur in the BSF watershed because they have been reported from the Little South Fork (LSF) watershed or are known from the broader region (Scott 2010). The LSF is part of the BSF watershed, but occurs outside and hydrologically below BISO boundaries. From the earliest samples available, observed LSF fish assemblages have included species not found elsewhere in the larger watershed. Moreover, the most recent inventories, including those directed by NPS, have not included sampling in the LSF. Therefore while the drainage provides a potential source of immigration for upstream portions of the BSF watershed, it is worthy of separate discussion. Comiskey and Etnier (1972) reported five unique species, including the federally endangered palezone shiner (*Notropis albizonatus*) from the LSF (Table 28). Scott (2010) lists a further 13 species that are likely to

occur in BSF, primarily because they are reservoir species known to occur in Lake Cumberland (Table 28).

Table 28. Species that could potentially occur in the Big South Fork drainage within or upstream of the park. The list includes species reported by Comiskey and Etnier (1972) from the Little South Fork (LSF), and species identified by Scott (2010) as species known from the region that could occur in the BSF.

Scientific Name	Common Name	Reported from LSF	Other Potential Species
*Alosa pseudoharengus**	alewife		X
*Carassius auratus**	goldfish		X
Carpiodes carpio	river carpsucker		X
Carpiodes velifer	highfin carpsucker		X
Cottus carolinae	banded sculpin	X	
Dorosoma petenense	threadfin shad		X
Erimystax insignis	blotched chub	X	
Etheostoma flabellare	fantail darter	X	
Etheostoma spectabile	orangethroat darter	X	
*Gambusia affinis**	western mosquitofish		X
Hiodon tergisus	Mooneye		X
Ictalurus furcatus	blue catfish		X
Notropis albizonatus	palezone shiner	X	
Notropis boops	bigeye shiner		X
Notropis buchanani	ghost shiner		X
Polyodon spathula	paddlefish		X
Pomoxis annularis	white crappie		X
Pomoxis nigromaculatus	black crappie		X

* Non-native species

Ten species historically known from the region are believed extirpated or are probably precluded from BISO by habitat changes following the impoundment of Lake Cumberland (Scott 2010, Table 29). Kirsch (1893) identified four species from the LSF drainage that have not been reported in recent years and are believed extirpated (Table 29). A single report of the crystal darter (*Crystallaria asprella*) may be attributable to Cope (1870), but has never been reported by others in the drainage (Comiskey and Etnier 1972, Scott 2010). A further five species of large-river fish historically known from the Cumberland River have probably been precluded from the BSF drainage by habitat changes following the impoundment of Lake Cumberland (Scott 2010; Table 29).

Reference condition

We created a park reference list from all species reported from the drainage (Appendix D) and from species potentially occurring (Table 28), excluding non-native species and species no longer expected (Table 29). This list included 100 species and was useful for understanding the modern potential of the park. Other reference conditions used in the exploration of park fish communities included those implied through the use of a regionally appropriate index of biotic integrity (Table 30).

Table 29. Ten fish species historically reported from the region are probably extirpated or are no longer present following the impoundment of Lake Cumberland. Data from Scott (2010).

Scientific Name	Common Name	Probably Extirpated	Precluded by Impoundment
Alosa chrysochloris	skipjack herring		X
Anguilla rostrata	American eel		X
Crystallaria asprella	crystal darter	X	
Cycleptus elongatus	blue sucker		X
Etheostoma simoterum	snubnose darter	X	
Hiodon alosoides	goldeye		X
Ictiobus cyprinellus	bigmouth buffalo		X
Moxostoma lacerum	harelip sucker	X	
Percina burtoni	blotchside logperch	X	
Percina macrocephala	longhead darter	X	

Table 30. Range of values and narrative interpretation for possible scores of the Kentucky Index of Biotic Integrity (Compton et al. 2003).

KIBI Interpretation	Value Range
Excellent	71-100
Good	59-70
Fair	39-58
Poor	19-38
Very Poor	0-18

4.7.4 Data

For our assessment of BISO fishes, we used data collected recently under park mandate. The results of the Scott (2010) survey, combined with a few unpublished NPS records of recent sampling in the park, provided the most current and comprehensive overview of BISO fishes available. These data included records of 16,820 individual fish of 78 species from 90 samples, where samples were efforts conducted on a single day in a single general location. All samples were collected from October, 2003 to November, 2006. Several samples represent long river reaches, for example in cases where sampling was conducted while floating by raft between access points on the Big South Fork. Sampling equipment and methods used included backpack electroshockers, boat electroshockers, seines, gillnets, dipnets, snorkeling, and minnow traps. This dataset was termed the analysis dataset. Excepting Rock Creek fish assemblage condition, all analyses and discussions of recent condition were based upon this dataset. For determining trend and for discussions of historical condition we also conducted analyses using the data presented in the narrative of O'Bara et al. (1982). These data included abundance and diversity for fishes collected in 16 BSF tributaries in 1981. For some analyses of Rock Creek fish assemblages we used data presented in the narrative report by Carew (2002) on the response of Rock Creek to acid mine drainage mitigation measures.

4.7.5 Reporting Areas

We reported BISO fish condition by 14 watershed areas (Figure 33). Reporting watersheds were either USGS HUC 10 or HUC 12 hydrologic boundaries that overlapped with park boundaries and had received fish sampling efforts in the recent fish survey. Watersheds on the park periphery were reported at the HUC 10 level and watersheds in the central park region were

reported at the HUC 12 level. These reporting unit boundaries match those used in water quality assessments in this report (Figure 28). Metrics and indices used to determine condition and trend were summarized for each of these reporting areas. Fish reporting areas varied greatly in size and in the amount of each area that was included within park boundaries (Table 31). Of 14 reporting units, five were comprised of greater than 50% BISO land and seven contained less than 10% BISO land (Table 31). Fish samples in the analysis dataset included samples collected both within and outside BISO boundaries. Most non-park samples were collected very close to park boundaries, with the exception of several samples in the New River reporting area. Samples were collected in the upper reaches of this watershed, relatively far from the park (Figure 33).

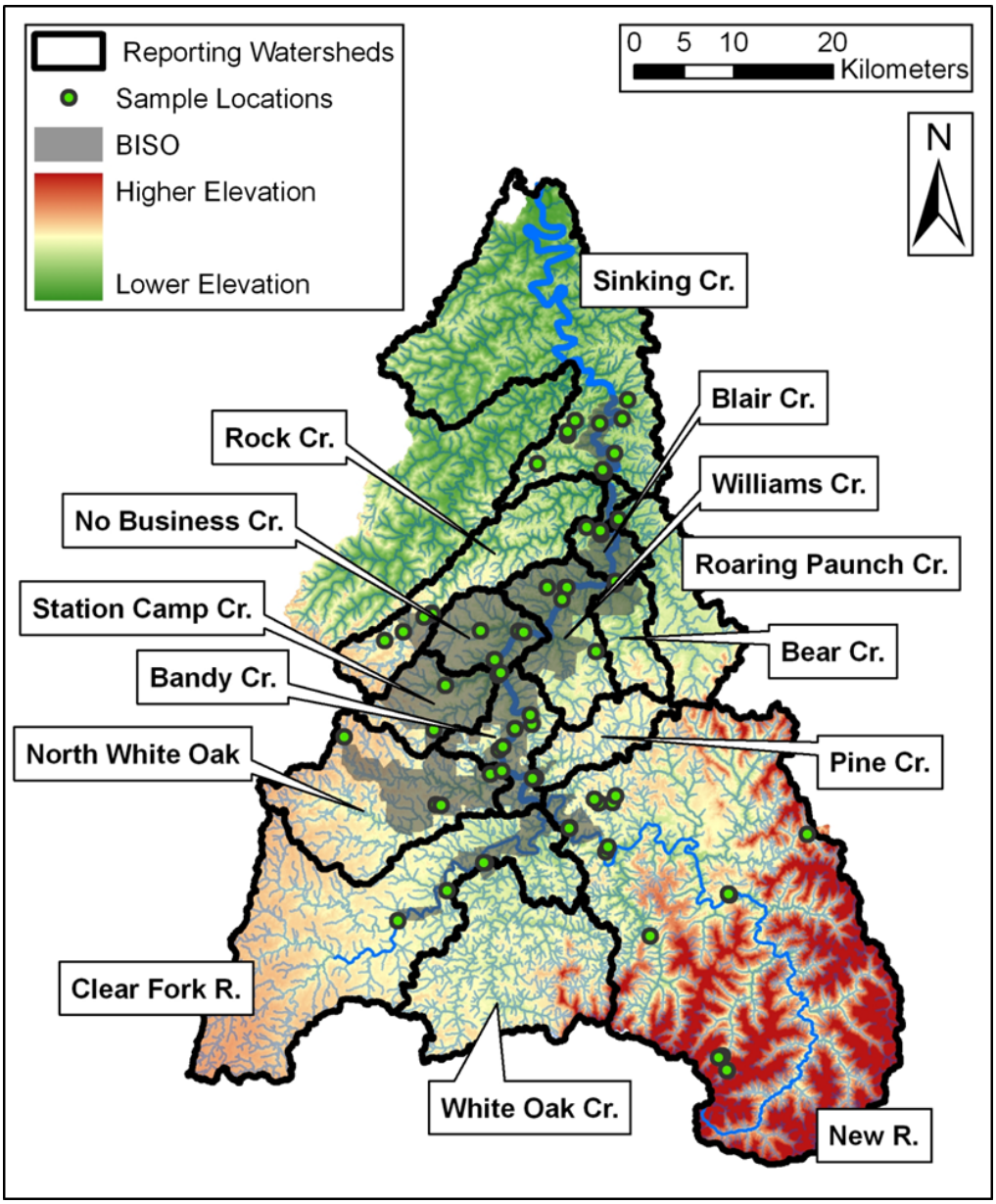

Figure 33. Fourteen watersheds, defined by USGS HUC 10 and HUC 12 boundaries, were used to report fish assemblage condition in Big South Fork National River and Recreation Area. Reporting areas are named by the major streams they drain. The locations of fish sampling efforts in the park are also shown.

Table 31. Name, HUC, and physical description areas used to report fish assemblage condition in Big South Fork National River and Recreation Area. Included for each reporting area are the surface area, percentage within park boundaries, total length of streams, and the total length of streams within park boundaries.

Name	HUC	Area (km^2)	% In BISO	Tot. Str. Length (km)	Park Str. Length (km)
White Oak Cr.	0512310401	267	1	499	6
Clear Fork R.	0513010402	467	7	703	76
New R.	0513010403	1026	2	1582	38
North White Oak Cr.	0513010404	227	35	354	146
Sinking Cr.	0513010407	472	5	553	32
Pine Cr.	051301040501	70	3	110	7
Station Camp Cr.	051301040502	83	82	105	88
Bandy Cr.	051301040503	84	74	138	103
No Business Cr.	051301040504	71	100	88	88
Williams Cr.	051301040505	117	62	155	102
Bear Cr.	051301040506	61	23	68	16
Roaring Paunch Cr.	051301040507	129	2	171	2
Rock Cr.	051301040508	162	7	214	16
Blair Cr.	051301040509	42	70	58	45

4.7.6 Methods

We used basic statistics and biodiversity indices to explore fish assemblages in BISO and surrounding watersheds. We examined the presence, abundance, and stability of species of management concern, and the relative abundance of native and "intolerant" species, where intolerant species were those identified as such in the Kentucky Index of Biotic Integrity. Various indices are commonly used to describe diversity of sampled populations. Simple metrics include species richness (number of different species in a sample) and evenness (equitability of relative abundance of each species within a sample). More complex diversity metrics are typically a combination of these two components (Huston 1994). Such parameters are useful indices of assemblage changes, or assemblage differences among standardized samples within a study, but their relationship to ecological function is not well-understood (Huston 1994, Kwak and Peterson 2007). Therefore, we report them here to assist in describing and comparing assemblages sampled from the park, and as baseline references for future work. Regardless of intent, several statistics emphasizing both richness and evenness should be reported when describing a community (Huston 1994, Kwak and Peterson 2007). We used species richness and Simpson's diversity index (SDI). Simpson's diversity index is based on the concept that diversity is inversely related to the probability that any two randomly sampled individuals from an assemblage will be the same species (Kwak and Peterson 2007). It emphasizes species evenness, and ranges from 0-1, with larger values representing more "diverse" assemblages (Huston 1994).

We calculated SDI as 1-D, using:

$$D=\sum_{i=1}^{s}(p_i^{\,2}) \qquad \text{(Eq. 3)}$$

where s = number of species in the sample, and p_i = proportion of the total individuals in the sample represented by the i_{th} species. For comparison purposes, we calculated the SDI only for samples collected by backpack electroshocking, seining, or a combination of these methods.

We also used an index of biotic integrity (IBI) to evaluate fish assemblages in and around BISO. Fish-based IBIs evaluate freshwater aquatic resources based upon relative density, diversity, and ecological attributes of sampled species (Karr 1981). Quality rankings are developed by analyzing assemblages from sites with known and independently-assessed levels of anthropogenic disturbance (Karr 1981). Generally, good conditions are indicated when communities contain a wide diversity of trophic specialists, and relatively high proportions of specialists and sensitive species. We used the Kentucky Index of Biotic Integrity (KIBI) which was developed for use in Kentucky's wadeable and headwater streams, including the streams of the Cumberland River drainage (Compton et al. 2003). To conform to recommended sampling methods, we only applied the KIBI to samples collected using backpack electroshocking, seining, or a combination of these methods (Compton et al. 2003). We delineated catchments above each KIBI sample location. We applied the KIBI to samples with catchments within the recommended size range of 5 - 777 km^2 (Compton et al. 2003). All samples collected from the Big South Fork River were excluded from KIBI analysis because of the large drainage size. Using KIBI protocol, samples with catchment areas less than 15.5 km^2 were calculated using methods for "headwater streams", and samples with catchment areas greater than 25.9 km^2 were calculated using methods for "wadeable streams" (Compton et al. 2003). Samples with catchments greater than 15.5 km^2 and smaller than 25.9 km^2 were designated as a "gray area" to be calculated based upon the experience of the observer (Compton et al. 2003). For consistency, we used the wadeable calculation method for the four samples in our dataset within this gray area. Possible scores for the KIBI range from 0-100 with 100 having an interpretation of "excellent" and 0 having an interpretation of "very poor" (Compton et al. 2003; Table 30).

To explore trend, we considered qualitative reports in the literature, and also compared metrics calculated from the analysis dataset to metrics calculated from data reported by O'Bara et al. (1982). We made comparisons of area-summarized data. Because O'Bara et al. (1982) did not collect samples from the main-stem BSF, we removed Scott's (2010) BSF samples for area-summarized comparisons. We also compared a set of single-sample pairs, where each pair was collected from the same location. O'Bara et al. (1982) collected single samples at each location, using block nets and two-pass electrofishing in most sites, and with ichthyacides in a few remote locations. We compared these to single samples collected by Scott (2010), using electrofishing and seining, from the same location. Where multiple samples by Scott (2010) existed for a location, we randomly chose a single sample for comparison purposes. O'Bara et al. (1982) did not sample in four of the 14 watershed reporting areas; therefore no comparisons were possible for those watersheds.

4.7.7 Condition and Trend

Full Area Summary

We used the analysis dataset described above to provide a summary of fish assemblage across the entire area of interest. Of the reference list of 100 potential species, 78 (78%) were reported from the area in the analysis dataset. Sixty one samples were suitable for calculating Simpson's

Diversity Index. The mean SDI for the area was 0.63 (SD±0.23). Forty six samples were suitable for analysis using the KIBI. The mean KIBI score for all samples was 54 (SD±17), corresponding to a narrative interpretation of fair. Nineteen samples (41%) ranked as good or excellent, 21 (46%) were fair, and 6 (13%) were ranked as poor or very poor. Of the 46 IBI samples, 30 were collected within park boundaries. The mean score of these samples was 57 (SD±18) corresponding to an interpretation of fair.

Thirteen fishes of particular conservation concern were reported from recent efforts in the BSF drainage (Table 32), including the federally endangered tuxedo darter (*Etheostoma lemniscatum*) and the federally threatened blackside dace. Tuxedo darters have been monitored by Conservation Fisheries, Inc. at five sites in the main BSF within NPS boundaries from 1993 or 1995 to 2005 (Scott 2010). Although highly variable at several sites, numbers have not shown notable declines or extirpation in the park (Scott 2010). A total of 35 blackside dace, from three sampling events, were reported by Scott (2010) from a western tributary of the BSF with a watershed primarily outside NPS boundaries, and from a small eastern tributary of the BSF. To our knowledge, these records represent the first report of this species from the watershed.

Table 32. Fishes of conservation concern reported from BISO and adjacent drainages, 2003-2006. Showing federal and state listed species and species listed by Tennessee and Kentucky as priority concern species in their Comprehensive Wildlife Conservation Strategies (CWCS). E=endangered, T=threatened, S=special concern, and D=deemed in need of management (analogous to special concern).

Scientific Name	Common Name	Fed List	KY List	TN List	Sate CWCS
*Acipenser fulvescens**	lake sturgeon		E	E	TN,KY
Erimystax dissimilis	streamline chub				TN
Etheostoma baileyi	emerald darter			D	TN,KY
Etheostoma cinereum	ashy darter		S	T	TN,KY
Etheostoma lemniscatum	tuxedo darter	E	E	E	TN,KY
Etheostoma sagitta	arrow darter			D	TN,KY
Etheostoma sanguifluum	bloodfin darter				KY
Etheostoma tippecanoe	Tippecanoe darter			D	TN
Ichthyomyzon greeleyi	mountain brook lamprey				KY
Notropis micropteryx	highland shiner			D	TN
Notropis sp. "sawfin shiner"	sawfin shiner		E		KY
Percina squamata	olive darter		E	D	TN,KY
Phoxinus cumberlandensis	blackside dace	T	T	T	TN,KY

* Did not occur in analysis database, but species was reintroduced to BISO in 2008 (NPSpecies 2010).

The most numerically common and widely occurring species in the analysis dataset were from the Cyprinidae family. The highland shiner (*Notropis micropteryx*) was the most numerous, representing about 19% of the total individuals captured (Table 33). The most widely occurring species was the largescale stoneroller (*Campostoma oligolepis*) which was reported from about 67% of the samples collected (Table 34). Scott (2010) stated that of the two species of stonerollers (largescale and central) expected in the drainage, central stonerollers (*C. anomalum*) should occur only in the New River drainage. However, because of the difficulty of differentiation, and because of reports of individuals out of their expected ranges, the distribution

of these species is "problematic" in the watershed (Scott 2010). Regardless, *Campostoma* spp. are the most ubiquitous species among the analysis samples.

Table 33. Ten most numerically common fish species sampled in BISO during efforts by Scott (2010) and others, 2003-2006, showing the total observed and the relative abundance in the total combined sample of 16,820 individuals.

Scientific Name	Common Name	Family	Total Observed	Sample Relative Abundance (%)
Notropis micropteryx	highland shiner	Cyprinidae	3141	18.7
Semotilus atromaculatus	creek chub	Cyprinidae	2625	15.6
Campostoma oligolepis	largescale stoneroller	Cyprinidae	1396	8.3
Notropis telescopus	telescope shiner	Cyprinidae	745	4.4
Etheostoma caeruleum	rainbow darter	Percidae	655	3.9
Notropis stramineus	sand shiner	Cyprinidae	623	3.7
Notropis volucellus	mimic shiner	Cyprinidae	616	3.7
Etheostoma blennioides	greenside darter	Percidae	577	3.4
Hypentelium nigricans	northern hog sucker	Catostomidae	506	3.0
Etheostoma camurum	bluebreast darter	Percidae	500	3.0

Table 34. Ten most commonly occurring fish species sampled in BISO during efforts by Scott (2010) and others, 2003-2006, showing the number of samples where species were present and the relative presence among a combined total of 90 samples.

Scientific Name	Common Name	Family	No. Samples Observed	Sample Relative Presence (%)
Campostoma oligolepis	largescale stoneroller	Cyprinidae	60	66.7
Semotilus atromaculatus	creek chub	Cyprinidae	55	61.1
Etheostoma blennioides	greenside darter	Percidae	51	56.7
Hypentelium nigricans	northern hog sucker	Catostomidae	50	55.6
Etheostoma caeruleum	rainbow darter	Percidae	44	48.9
Ambloplites rupestris	rock bass	Centrarchidae	42	46.7
Lepomis megalotis	longear sunfish	Centrarchidae	39	43.3
Cyprinella galactura	whitetail shiner	Cyprinidae	38	42.2
Etheostoma camurum	bluebreast darter	Percidae	37	41.1
Notropis micropteryx	highland shiner	Cyprinidae	36	40.0

0513010401—White Oak Creek

Summary

The White Oak Creek HUC 10 watershed lies in the southern BSF watershed (Figure 33). It drains an area of 267 km^2 and contains nearly 500 km of streams (Table 31). Only about one percent of the watershed lies within park boundaries. The analysis dataset contained two samples from White Oak Creek near the confluence with the Clear Fork River. Both were collected within park boundaries. Both samples were suitable for calculation of the Simpson's Diversity Index and KIBI scores. The number of samples per kilometer of stream was the lowest among the 14 reporting area watersheds. O'Bara et al. (1982) reported that White Oak Creek

was subject to sources of anthropogenic disturbance including domestic and agricultural pollution, and runoff from oil wells and forestry practices (Figure 32).

Condition

The combined watershed samples in the analysis dataset contained 103 individuals of 18 species, including one species of concern and one non-native species (Table 35). The samples were composed of 19% intolerant individuals and this value was the third lowest among the 14 reporting watersheds. The mean SDI score was 0.87, which was the highest among the reporting watersheds, suggesting that most of the species captured in the creek were captured relatively frequently. The mean KIBI score was 39, corresponding to an interpretation of fair. We did not assign a condition to fish assemblage for the White Oak Creek reporting area (Table 37). The data were not adequate to assess an area of this size.

Trend

O'Bara et al. (1982) collected three fish samples in the reporting area. Samples were qualitative and reported only the presence of captured species and not the number of individuals. O'Bara et al. (1982) reported 21 species from the area, which was greater than the more recent richness of 18 species (Table 36). Data were insufficient to establish a trend for the White Oak Creek reporting area (Table 37).

Data Quality

The quality of the data was fair (Table 37). The data were of an appropriate nature for assessing condition, and were recently collected within park boundaries. However, the samples were collected in a single location within a large area and are not necessarily representative of the entire watershed. Therefore, the data did not receive a spatial check. Because the samples were collected near the most downstream point in the reporting area, they were more representative of overall watershed conditions than samples collected a single location upstream within the watershed.

Table 35. Summary of fish sampling effort and selected assemblage metrics for 14 watershed reporting areas in Big South Fork National River and Recreation area. The number of samples, number of individuals (N), and species richness for each reporting area are shown separately for samples collected in the main stem of the Big South Fork (BSF) and for samples collected in tributaries (TR). Tributaries included the Clear Fork and New Rivers. Effort is also shown in number of samples per kilometer of stream in the watershed and in number of samples per kilometer of stream within park boundaries. Other assemblage metrics include the percentage of intolerant individuals in the total sample, the number of concern species (as identified in Table 32), the number of non-native species, the mean Simpsons Diversity Index value of individual samples, the mean KIBI score of individual samples, and the narrative interpretation of the mean KIBI score. Numbers in parentheses are standard deviations.

	Samples		N		Richness		Samp. Per Tot. Str. Length (#/km)	Samp. Per. Park Str. Length (#/km)	% Intol. Ind.	Conc. Spp.	Non-native Spp.	Mean Simp.	Mean KIBI	KIBI Interp.
Watershed	**BSF**	**TR**	**BSF**	**TR**	**BSF**	**TR**								
White Oak Cr.	0	2		103		18	0.004	0.333	19	1	1	0.87 (0.03)	39 (5)	Fair
Clear Fork R.	0	4		990		23	0.006	0.053	32	1	0	0.76 (0.18)	45 (6)	Fair
New R.	0	20		3844		42	0.013	0.526	34	4	2	0.67 (0.16)	52 (17)	Fair
North White Oak Cr.	0	6		1413		33	0.017	0.041	48	6	0	0.73 (0.22)	64 (7)	Good
Sinking Cr.	1	11	195	908	21	24	0.022	0.375	14	3	1	0.48 (0.23)	53 (9)	Fair
Pine Cr.	0	1		198		17	0.009	0.143	55	1	0	0.81	69	Good
Station Camp Cr.	0	5		1216		32	0.048	0.057	27	6	1	0.62 (0.26	60 (27)	Good
Bandy Cr.	6	2	1403	91	48	10	0.058	0.078	61	9	0	0.72 (0.11)	45 (8)	Fair
No Business Cr.	5	4	1421	1262	48	42	0.102	0.102	47	8	1	0.82 (0.06)	73 (10)	Exc.
Williams Cr.	5	4	955	1008	43	38	0.058	0.088	44	7	2	0.60 (0.28)	52 (17)	Fair
Bear Cr.	0	1		234		16	0.015	0.063	50	2	0	0.70	76	Exc.
Roaring Paunch Cr.	0	3		109		11	0.018	1.500	38	1	1	0.66 (0.25)	20 (16)	Poor
Rock Cr.	0	6		938		16	0.028	0.375	44	1	0	0.47 (0.27)	58 (11)	Fair
Blair Cr.	2	2	82	450	8	6	0.069	0.089	7	3	0	0.30 (0.36)	50 (4)	Fair

Table 36. Comparisons of total numbers of individuals, species richness, mean Simpson's Diversity Index value, mean KIBI score, and percentage of intolerant individuals reported by watershed from data collected in tributaries of the Big South Fork in 1981 by O'Bara et al. (1982) and during 2003 – 2006 by Scott (2010). Values of "-" indicate no data were collected for the watershed. Red font indicates comparisons where the more recent value was lower than the earlier value.

	N		Sp. Rich.		Mn. Simp.		Mn. KIBI		% Int. Inds.	
Watershed	**'81**	**'03-'06**	**'81**	**'03-'06**	**'81**	**'03-'06**	**'81**	**'03-'06**	**'81**	**'03-'06**
White Oak Cr.	N/A	103	**21**	**18**	N/A	0.87	N/A	39	N/A	19
Clear Fork R.	-	990	-	23	-	0.76	-	45	-	32
New R.	-	3844	-	42	-	0.67	-	52	-	34
North White Oak Cr.	301	1413	29	33	0.69	0.73	54	64	26	48
Sinking Cr.	-	908*	-	24*	-	0.36*	-	53	-	11*
Pine Cr.	152	198	13	17	0.54	0.81	42	69	5	55
Station Camp Cr.	554	1216	24	32	**0.72**	**0.62**	54	60	13	27
Bandy Cr.	**95**	**91***	6	10*	0.53	0.66*	N/A	45	3	23*
No Business Cr.	547	1262*	19	42*	0.66	0.85*	51	73	23	33*
Williams Cr.	614	1008*	28	38*	0.49	0.56*	37	52	13	35*
Bear Cr.	18	234	1	16	0	0.70	N/A	76	0	50
Roaring Paunch Cr.	94	109	9	11	**0.69**	**0.66**	3	20	17	38
Rock Cr.	371	938	**17**	**16**	**0.70**	**0.47**	16	58	25	43
Blair Cr.	-	450*	-	6*	-	0.30*	-	50	-	2*

* Indicates that samples from the BSF main-stem were excluded from the total sample for comparison purposes.

Table 37. The condition of fish assemblages in the 0513010401 (White Oak Creek) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
0513010401: Fish Assemblages		✓		✓
		2 of 3: Fair		

<u>0513010402—Clear Fork River</u>

Summary

The Clear Fork River HUC 10 watershed lies in the southwestern BSF watershed (Figure 33). It drains an area of 467 km^2 and contains over 700 km of streams (Table 31). About seven percent of the watershed lies within park boundaries. The analysis dataset contained four samples from this reporting area, collected at two locations on the Clear Fork River within BISO boundaries. All samples were suitable for calculation of the SDI, and two were appropriate for calculation of KIBI scores. Two samples were not used for KIBI calculation because they were collected using boats. The number of samples per kilometer of stream was the second lowest among the 14 reporting area watersheds. O'Bara et al. (1982) did not collect any samples within the reporting area.

Condition
We did not assign a condition to fish assemblage for the Clear Fork River reporting area (Table 38). The combined watershed samples in the analysis dataset contained 990 individuals of 23 species, including one species of concern and no non-native species (Table 35). The samples were composed of 32% intolerant individuals. The mean SDI score was 0.76. The mean KIBI score was 45, corresponding to an interpretation of fair. The number of samples was low relative to the length of streams in the reporting area, and samples were not well-distributed throughout the area. The amount of area in the watershed occurring in park boundaries was low, and the four samples collected were all within park boundaries. Therefore, the data suggest that the fish assemblages within park boundaries in the Clear Creek watershed could reasonably be ranked as fair.

Trend
No trend was assigned to Clear Creek watershed fish assemblage condition (Table 38). Neither qualitative nor quantitative historical baseline data were available

Data quality
The quality of the data was fair (Table 38). The data were of an appropriate nature for assessing condition, and were recently collected within park boundaries. However, the samples were collected at only two locations within a large area and are not necessarily representative of the entire watershed. Therefore, the data did not receive a spatial check.

Table 38. The condition of fish assemblages in the 0513010402 (Clear Fork River) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
0513010402: Fish Assemblages		✓		✓
		2 of 3: Fair		

<u>0513010403—New River</u>

Summary
The New River HUC 10 watershed lies in the southeastern BSF watershed (Figure 33). It drains an area of 1,026 km^2 and contains over 1,582 km of streams (Table 31). About two percent of the watershed lies within park boundaries. The analysis dataset contained 20 samples from this reporting area, of which three were collected in park boundaries. Of the twenty samples, 13 were suitable for calculation of SDI, and nine were appropriate for calculation of KIBI scores. Although it lies largely outside BISO, the New River watershed received a relatively large amount of effort in recent fish inventories. The drainage has a long and well-reported history of mining impacts to fauna. Because the New River is the largest tributary forming the BSF, the status of the watershed upstream of BISO is of particular interest to park managers. O'Bara et al. (1982) did not collect any samples within the reporting area.

Condition

We ranked the condition to fish assemblages for the New River reporting area as fair (Table 39). The combined watershed samples in the analysis dataset contained 3,844 individuals of 42 species, including four species of concern and two non-native species (Table 35). When main-stem BSF samples were excluded, the New River tied for the greatest observed richness among the 14 reporting watersheds. The samples were composed of 34% intolerant individuals. The mean SDI score was 0.67. The mean KIBI score was 52, corresponding to an interpretation of fair. This assessment was based primarily upon the mean KIBI score. We also qualitatively considered the observation that percent intolerant, number of concern species, and mean Simpson's for the New River were intermediate among the reporting areas. We acknowledge that the later comparison is suggestive at best.

Trend

We ranked the trend of New River fish assemblage condition as improving (Table 39). This was based primarily upon observations made in the literature showing improvements in fish assemblage quality over time. We also considered the general gist of the qualitative statements made by many researchers suggesting that the most severe anthropogenic mining impacts in the watershed have been abating over the last 30 years. The New River watershed has received both acid drainage and sediment from mining activities (Shoup1949, O'Bara et al. 1982, Carter et al. 2005). Shoup and Peyton (1940) and Comiskey and Etnier (1972) both noted that many of the tributaries of this river we veritably devoid of vertebrate life. Brazinski (1979) conducted a study of the drainage, analyzing fish samples with an IBI, and reported that the fish fauna of the drainage was less abundant, diverse, and of lower quality in the tributaries most affected by acid mine drainage. Evans (1998) studied the fish of the New River, in part to look for improvement following 20 years of mitigation, and to compare assemblages to those reported by Brazinski (1979). He found that IBI scores and species richness had increased for most sites, but noted the difficulty in comparing studies due to differences in effort (Evans 1998). Carter et al. (2005) conducted sampling at two locations in the New River, and calculated the same IBI as Evans (1998). He found that one site scored as poor, but that the score was slightly greater than the score calculated by Evans (1998) for the site. The second site, previously scored as poor by Evans (1998) scored as good (Carter et al. 2005).

Data Quality

The quality of the data used to make the assessment was good (Table 39). Although the watershed area is large and the number of samples per stream kilometer was not particularly high, the level of sampling was greater than for other large watersheds upstream of the park. Samples were distributed throughout the reporting area and were not limited to park boundaries. Samples were recent and were of an appropriate nature for assessing condition.

Table 39. The condition of fish assemblages in the 0513010403 (New River) reporting area was fair. The trend of fish assemblage condition was improving. The quality of the data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
0513010403: Fish Assemblages	⇧	✓	✓	✓
		3 of 3: Good		

0513010404—North White Oak Creek

Summary

The North White Oak Creek HUC 10 watershed lies in the southwestern BSF watershed (Figure 33). It drains an area of 227 km^2 and contains around 354 km of streams (Table 31). About 35% of the watershed lies within park boundaries. The analysis dataset contained six samples from five locations, of which five were collected inside park boundaries. Of the six samples, four were suitable for calculation of SDI, and three were appropriate for calculation of KIBI scores. O'Bara et al. (1982) collected six samples within the watershed, three in North White Oak, and three in its tributary Laurel Fork. O'Bara et al. (1982) reported that North White Oak and Laurel Fork suffered from acid mine drainage and other anthropogenic sources of impairment (Figure 32).

Condition

We ranked the condition to fish assemblages for the North White Oak Creek reporting area as good (Table 40). The combined watershed samples in the analysis dataset contained 1,413 individuals of 33 species, including six species of concern and no non-native species (Table 35). The samples were composed of 48% intolerant individuals. The mean SDI score was 0.73. The mean KIBI score was 64, corresponding to an interpretation of good. The assessment of good was based upon the high mean KIBI score and upon the fact that the samples lacked non-native species and had relatively high mean diversity scores and high percentages of intolerant species.

Table 40. The condition of fish assemblages in the 0513010404 (North White Oak Creek) reporting area was good. No trend was assigned to fish assemblage condition. The quality of the data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
0513010404: Fish Assemblages	●	✓	✓	✓
		3 of 3: Good		

Trend

We did not assign a trend to the condition of the North White Oak Creek reporting area fish assemblage (Table 40). O'Bara et al. (1982) collected six fish samples in the reporting area, and these were used to explore changes over time. Summarized at the reporting area level, all metrics were greater for the more recent sample relative to the older samples (Table 36). This comparison does not account for effort, although both combined samples included six individual samples. Two individual sample pairs, separated by the time of the studies, occurred at the same location and were suitable for more standardized comparisons. Simpson's was lower in the newer sample for both pairs, and the KIBI was greater in the new sample for the single suitable comparison pair (Table 41).

Table 41. Comparisons of total numbers of individuals, species richness, Simpson's Diversity Index value, and KIBI score for individual sample pairs collected in tributaries of the Big South Fork in 1981 by O'Bara et al. (1982) and during 2003 – 2006 by Scott (2010). Sample names are location names used by O'Bara et al. (1982). Name headings (bold font) indicate the watershed reporting area where samples were collected. Red font indicates comparisons where the more recent value was lower than the older value.

	N		Sp. Rich.		Simpson		KIBI	
Name	**'81**	**'03-'06**	**'81**	**'03-'06**	**'81**	**'03-'06**	**'81**	**'03-'06**
North White Oak Cr.								
LFNWOC III	39	154	**4**	**3**	**0.56**	**0.41**	N/A	
NWOC II	68	337	14	26	**0.86**	**0.77**	54	59.5
Pine Cr.								
PC I	120	198	11	17	0.71	0.81	42	69
Station Camp Cr.								
LFSCC II	96	119	**5**	**4**	**0.41**	**0.16**	**38**	**22**
SCC I	72	402	12	28	**0.80**	**0.77**	44	98
SCC II	111	216	**18**	**15**	0.76	0.76	**79**	**59**
No Business Cr.								
NBC I	96	188	13	20	0.78	0.80	57	75
NBC III	174	431	11	13	0.80	0.82	63	63
PCC I	30	175	10	36	0.82	0.84	34	82
Williams Cr.								
PCF III	80	162	1	4	0	0.16	N/A	
TC I	28	270	7	14	0.69	0.77	23	70
TC III	80	91	2	2	0.29	0.34	47	47
Bear Cr.								
BC I	0	234	0	16	N/A		N/A	
Roaring Paunch Cr.								
RPC I	13	26	4	11	0.66	0.84	3	20
Rock Cr.								
RC III	31	121	3	7	0.63	0.66	16	57

Data Quality

The quality of the data used to make the assessment was good (Table 40). Samples were recent and were of an appropriate nature for assessing condition. The number of samples per stream kilometer was relatively low and samples were collected in or near park boundaries. However, sampling occurred at multiple locations in each of the two major tributaries in the watershed.

0513010407—Sinking Creek

Summary

The Sinking Creek HUC 10 watershed is the northernmost BSF watershed (Figure 33). It drains an area of 472 km^2 and contains 553 km of streams (Table 31). About five percent of the watershed lies within park boundaries. The Sinking Creek reporting area includes the most downstream 65-km of the BSF and all its tributaries in this reach except the Little South Fork Cumberland River. As a result of the impoundment of Lake Cumberland, the entire section of the BSF in this reporting area is subject to continuous or periodic alteration into lentic habitat. The analysis dataset contained 12 samples from 10 locations in this reporting area; six samples were collected within the park and six were collected outside park boundaries. A single sample was collected in the BSF and the remaining 11 were taken from tributaries. Eight samples were appropriate for calculating Simpson's Diversity Index, and seven were suitable for KIBI calculation.

Condition

We ranked the condition to fish assemblages for the Sinking Creek reporting area as fair (Table 42). The combined samples in the analysis dataset contained 1,103 individuals of 38 species, including three species of concern and a single non-native species (Table 35). The single BSF sample contained 21 species and the 11 combined tributary samples included 24 species. The combined sample was composed of 14% intolerant individuals. The mean SDI score was 0.48. The mean KIBI score was 53, corresponding to an interpretation of fair. Although species richness for the reporting area was intermediate, the mean Simpson's Diversity Index and the percent intolerant individuals were both low relative to most other reporting areas.

Table 42. The condition of fish assemblages in the 0513010407 (Sinking Creek) reporting area was fair. No trend was assigned to fish assemblage condition. The quality of the data used to make the assessment was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
0513010407: Fish Assemblages		✓	✓	✓
		3 of 3: Good		

Trend

We did not assign a trend to the condition of the Sinking Creek reporting area fish assemblage (Table 42). O'Bara et al. (1982) did not collect within this reporting area and there are few historical data available.

Data Quality

The quality of the data used to make the assessment was good (Table 42). Samples were recent and were of an appropriate nature for assessing condition. The number of samples per stream kilometer was intermediate relative to the value found in other reporting areas. Sampling did not

occur in the northern portion of the reporting area, downstream of park boundaries. The lack of well-distributed sampling effort would be of greater concern in other reporting areas. However, the un-sampled area is downstream of the park and the BSF in the un-sampled reach consists of lentic habitat. Therefore, the un-sampled area is relatively independent of samples collected in the southern reaches of the reporting area.

<u>051301040501—Pine Creek</u>

Summary

The Pine Creek HUC 12 watershed is in the central BSF watershed (Figure 33). It is the catchment of Pine Creek, an eastern tributary of the BSF. It has an area of 70 km^2 and contains 110 km of streams (Table 31). About three percent of the watershed lies within park boundaries. The analysis dataset contained a single sample from this reporting area. The sample was collected in Pine Creek near its confluence with the BSF. This sample was suitable for calculation of SDI and KIBI score. O'Bara et al. (1982) collected three samples from the reporting area, including a sample collected at the approximately same location as the Scott (2010) sample in the analysis dataset. O'Bara et al. (1982) reported that Pine Creek had been highly channelized, received treated municipal wastewater, and suffered from acid mine drainage (Figure 32).

Condition

We did not assign a condition to fish assemblage for the Pine Creek reporting area (Table 43). The single sample in the analysis dataset contained 198 individuals of 17 species, including one species of concern and no non-native species (Table 35). The sample was composed of 55% intolerant individuals. The Simpson's Diversity Index was 0.81. The mean KIBI score was 69, corresponding to an interpretation of good. The data indicate a reasonably diverse and healthy fish assemblage near the mouth of Pine Creek. However, we believe a single sample is insufficient to determine the condition of the entire reporting area.

Table 43. The condition of fish assemblages in the 051301040501 (Pine Creek) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040501: Fish Assemblages		✓		✓
		2 of 3: Fair		

Trend

No trend was assigned to the condition of fish assemblages in Pine Creek (Table 43). O'Bara et al. (1982) reported multiple anthropogenic impacts to the stream, but found 13 species of fish in three samples collected in the creek (Table 36). Scott (2010) reported 17 species from a single sample collected near the confluence of the BSF. The SDI value, KIBI score, and percent intolerants were all greater for the recent sample compared to the combined historical sample (Table 36) and to a single comparable historical sample (Table 41). A reach of Pine Creek

upstream of BISO boundaries remained listed as impaired 303(d) non-attainment) in 2010 (Figure 23). We believe limited evidence supports the theory that Pine Creek fish assemblage condition has improved since the early 1980s. However, a single recent sample is insufficient to fully support an increasing trend.

Data Quality

The quality of the data was fair (Table 43). The data were of an appropriate nature for assessing condition, and were recently collected within park boundaries. However, only a single recent sample collected at near the confluence is available for analysis. This single sample is insufficient to represent the entire reporting area.

<u>51301040502—Station Camp Creek</u>

Summary

The Station Camp Creek HUC 12 watershed is in the central western BSF watershed (Figure 33). It is the catchment of Station Camp Creek, a western tributary of the BSF. It has an area of 83 km^2 and contains 105 km of streams (Table 31). About 82% of the watershed lies within park boundaries. The analysis dataset contained five samples from this watershed, collected at three locations. All samples were collected from Station Camp and tributaries within park boundaries. All five samples were suitable for calculation of SDI and KIBI scores. O'Bara et al. (1982) collected six samples from the watershed, and reported that Station Camp Creek did not suffer from negative anthropogenic impacts.

Condition

We ranked the condition to fish assemblages for the Station Camp Creek reporting area as good (Table 44). The combined watershed samples in the analysis dataset contained 1,216 individuals of 32 species, including six species of concern and one non-native species (Table 35). The samples were composed of 27% intolerant individuals. The mean SDI score was 0.62. The mean KIBI score was 60, corresponding to an interpretation of good. The assessment of good was based upon the high mean KIBI score and upon the fact that the samples had relatively high mean diversity.

Table 44. The condition of fish assemblages in the 051301040502 (Station Camp Creek) reporting area was good. No trend was assigned to fish assemblage condition. The quality of the data was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040502: Fish Assemblages		✓	✓	✓
		3 of 3: Good		

Trend
No trend was assigned to the Station Camp Creek fish assemblage condition (Table 44). Indices comparing historical and recent fish assemblage data differed among locations and at different levels of summation. Summarized at the reporting area level, recent samples from the analysis dataset showed greater species richness, KIBI scores, and percentage of intolerant individuals relative to historic samples (Table 36). The mean SDI was lower for recent samples (Table 36). Individual sample pair comparisons at three locations showed an increase in some indices and a decrease in others between the historical and recent samples (Table 41). Because of this variability, we did not assign a trend to the data.

Data Quality
The quality of the data used to make the assessment was good (Table 44). Samples were recent and were of an appropriate nature for assessing condition. Samples were collected at several locations in Station Camp Creek and its main tributary and locations included both upstream and downstream locations in the watershed.

<u>051301040503—Bandy Creek</u>

Summary
The Bandy Creek reporting area lies in the central BSF watershed (Figure 33). It drains an area of 84 km^2 and contains around 138 km of streams (Table 31). About 74% of the reporting area lies within park boundaries. Some of the reporting area not included within park boundaries is in the Scott State Forest. The Bandy Creek reporting area is bisected by the main-stem of the BSF and includes a 23-km long section of the BSF as well as multiple small eastern and western tributaries. The analysis dataset contained eight samples from seven locations, all occurring inside BISO. Six of the samples were collected on the main-stem of the BSF, and two were collected in eastern tributaries near the confluence with the BSF. Two of the provided sample locations occurred near the three-way boundary of the Bandy Creek, Station Camp Creek, and Troublesome Creek reporting areas. Notes in the APHN fish database indicated that these were snorkel samples collected from the mouth of Station Camp and upstream. For that reason, these samples were included in the Bandy Creek reporting area, although the position recorded for the samples was ambiguous. Three samples were suitable for calculation of SDI, and two were appropriate for calculation of KIBI scores. O'Bara et al. (1982) collected three samples from Bandy Creek, a western tributary in the reporting area, and reported that the creek suffered from sedimentation related to clearcuts and road construction (Figure 32).

Condition
We did not assign a condition to fish assemblage for the Bandy Creek reporting area (Table 45). Most of the samples collected in the reporting area were collected in the main BSF. Therefore the tributaries in the area are poorly represented in the samples. The combined sample for the area contained 1,494 individuals of 50 species; 48 species occurred in the BSF and 10 were reported from tributaries (Table 35). Nine species of concern and no non-native species were reported. The sample was composed of 61% intolerant individuals. The mean SDI was 0.72. The mean KIBI score was 45, corresponding to an interpretation of fair. The Bandy Creek reporting area is largely characterized by the main-stem BSF. The size of this river precludes assessment with the KIBI. The data indicate that the BSF in this section includes a diverse fish

assemblage with many species of concern and a high relative abundance of intolerant individuals. The condition of the many tributaries in the section is poorly understood, though KIBI scores from two tributaries indicated fair condition. However, the largest tributary in the section, Bandy Creek, was not sampled in the recent inventory. Therefore, although the area received a relatively large amount of recent sampling effort, we believe available data is insufficient to assess the general reporting area.

Table 45. The fish assemblage in the 051301040503 (Bandy Creek) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040503: Fish Assemblages		✓		✓
		2 of 3: Fair		

Trend
No trend was assigned to Bandy Creek reporting area fish assemblage condition (Table 45). O'Bara et al. (1982) collected three samples from Bandy Creek, but none were collected in the stream during recent inventory efforts. Therefore, comparisons of tributary summaries between historical and recent samples must be interpreted with caution (Table 36). We believe the lack of overlap in the location of the samples precludes any assessment of trend.

Data Quality
The data used to assess Bandy Creek reporting area fish assemblage quality was fair (Table 36). Data were collected recently within park boundaries using appropriate standardized methods. However, because many tributaries in the reporting area were not sampled, and because no data were collected from Bandy Creek, the data did not receive a spatial checkmark.

<u>051301040504—No Business Creek</u>

Summary
The No Business Creek reporting area lies in the central BSF watershed (Figure 33). It drains an area of 71 km^2 and contains 88 km of streams (Table 31). The entire reporting area lies within park boundaries. This level of complete protection within BISO boundaries is unique among the 14 fish reporting areas. The No Business Creek reporting area is bisected by the main-stem of the BSF and includes over 8 km of the river within its boundaries. Two main tributaries, Parch Corn Creek and No Business Creek, enter the river from the west in this area. The analysis dataset contained nine samples from this reporting area; five were collected from the main-stem BSF, and four were collected from No Business Creek and Parch Corn Creeks. Two of the BSF samples were collected during float trips that sampled over large sections of the river. Five samples were suitable for calculation of SDI, and three were appropriate for calculation of KIBI scores. O'Bara et al. (1982) collected six samples from the area, three each from Parch Corn and No Business Creeks, and reported that neither stream suffered from negative anthropogenic impacts.

Condition
The condition of the fish assemblage of the No Business Creek reporting area was good (Table 46). The combined samples in the analysis dataset contained 2,683 individuals of 51 species; 48 species from the BSF and 42 species from tributaries (Table 35). Eight species of concern and one non-native species were reported (Table 35). The sample was composed of 47% intolerant individuals. The mean SDI was 0.82. The mean KIBI score was 73, corresponding to an interpretation of excellent. The data indicate that the BSF and its major tributaries in this reporting area both contain diverse fish assemblages and support relatively high abundances of intolerant species and species of concern. The data suggest that No Business and Parch Corn Creeks are in good condition, and are among the best extant examples of potential fish diversity for small BSF tributaries in BISO.

Table 46. The condition of the fish assemblage in 051301040504 (No Business Creek) reporting area was good. The trend of fish assemblage condition was stable. The quality of the data was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040504: Fish Assemblages	⇨	✓	✓	✓
		3 of 3: Good		

Trend
We ranked the trend of No Business Creek reporting area fish assemblage condition as stable (Table 46). O'Bara et al. (1982) collected six samples in Parch Corn and No Business Creeks, providing a relatively rich dataset for comparison with recent samples. When summarized for the reporting area, indices from recent collections in these tributaries were equal to or greater than indices from the historical dataset, for all indices examined (Table 36). Similarly, individual pair comparisons showed greater recent values for pairs examined (Table 41). Given the universally greater values of recent indices relative to historical indices, it could be argued that fish assemblage quality is increasing or has increased in this reporting area. However, apparent increases could result, in part, from more efficient sampling in recent efforts. Furthermore, no explicit historical data on main-stem BSF fish assemblages were available from this area. The major tributaries on which the trend is based were qualitatively described by O'Bara et al. (1982) as being free from anthropogenic impacts, suggesting a relatively good historical condition for these streams. Therefore, lacking qualitative reports explaining specific improvements in the area, we believe a stable trend is the best-supported designation.

Data Quality
The quality of the fish assemblage data for the No Business Creek reporting area was good (Table 46). The data were collected recently using appropriate methods within park boundaries. Furthermore, samples were collected throughout the reporting area in both the BSF and in major tributaries.

051301040505—Williams Creek

Summary

The Williams Creek reporting area lies in the central BSF watershed (Figure 33). It drains an area of 117 km^2 and contains 155 km of streams (Table 31). About 62% of the reporting area lies within park boundaries. The Williams Creek reporting area is bisected by the main-stem of the BSF and includes over 11 km of the river within its boundaries. Within the reporting area, Troublesome Creek enters the BSF from the west, and Williams Creek enters the BSF from the east. The Troublesome Creek drainage lies entirely within BISO. Williams Creek has a drainage area of 62 km^2, of which 22 km^2 (35%) lies within park boundaries. It is the largest watershed area within park boundaries draining to a single point on the east bank of the BSF. The analysis dataset contained nine samples from this reporting area; five were collected from the main-stem BSF, and four were collected from tributaries. Three samples were appropriate for application of the KIBI and six were suitable for SDI calculation. Three BSF samples were collected at the mouth of Bear Creek, on the three-way border of the Williams Creek, Bear Creek, and Blair Creek reporting areas. Because Bear Creek reporting area does not include any portion of the BSF, we summarized these samples in the upstream Williams Creek area. O'Bara et al. (1982) collected twelve samples within the Williams Creek reporting area, including nine from Williams Creek and its tributaries Puncheoncamp and Grassy Forks, and three from Troublesome Creek. O'Bara et al. (1982) reported that Williams Creek and Puncheoncamp were mildly impacted by mining and road construction, though the impact was less than observed in other east bank tributaries (Figure 32). Grassy Fork and Troublesome Creek did not suffer from negative anthropogenic impacts (O'Bara et al. 1982).

Condition

The condition of the fish assemblage of the Williams Creek reporting area was fair (Table 47). The combined samples in the analysis dataset contained 1,963 individuals of 48 species, with 43 species reported from the BSF and 38 from tributaries (Table 35). Seven species of concern and two non-native species were reported. The sample was composed of 44% intolerant individuals. The mean SDI was 0.60. The mean KIBI score was 52, corresponding to an interpretation of fair. The richest tributary area sampled was Troublesome Creek near its mouth, which had a KIBI score of 0.70 corresponding to an interpretation of good. Other samples in upper Troublesome Creek and in Puncheoncamp Fork had low richness of two to four species and scored poor or fair on the KIBI. The main-stem of Williams Creek was not sampled in recent efforts. Samples from this stream, especially in the lower reaches near the BSF, could change the assessment of this reporting area. We believe this reporting area is particularly difficult to assess because it contains both western and eastern BSF tributaries that have experienced differing levels of protection by the park.

Table 47. The condition of fish assemblages in the 051301040505 (Williams Creek) reporting area was fair. No trend was assigned to fish assemblage condition. The quality of the data was fair.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
051301040505: Fish Assemblages		✓		✓
		2 of 3: Fair		

Trend

We did not assign a trend to the Williams Creek reporting area fish assemblage condition (Table 47). O'Bara et al. (1982) collected 12 samples in Troublesome Creek and Puncheoncamp Fork. When summarized for the reporting area, indices from recent collections in these tributaries were equal to or greater than indices from the historical dataset, for all indices examined (Table 36). However, because many of the historical samples were collected in locations not sampled by recent efforts, interpretation of these comparisons warrants caution. O'Bara et al. (1982) noted that the Williams Creek drainage suffered relatively minor impacts from a single mine and roads, but also noted that the mine was in the process of reclamation, and "should become less of a problem". Individual pair comparisons showed greater recent index values for pairs examined (Table 41). However, some of the indices were calculated from samples with low richness, warranting caution in their interpretation. Given the universally greater values of recent indices relative to historical indices, it could be suggested that the quality of the reporting area is improving. However, we feel that the several caveats mentioned above and the lack of qualitative reports explaining watershed improvement, add uncertainty to the assessment. Furthermore, the situation is complicated because eastern and western tributaries in the reporting area have different histories of anthropogenic disturbance. We believe the condition of fish assemblages in the reporting area is not declining, and that it is probably improving or stable. Nevertheless, uncertainty prevents us applying a trend to this area.

Data Quality

The quality of the data used to assess Williams Creek reporting area fish assemblages was fair (Table 47). The data were collected recently using appropriate methods at a number of locations. However, sampling was not conducted in the main flow of Williams Creek, or in the Williams Creek watershed within the park. Williams Creek is an important tributary of the BSF. Relative to other eastern BSF tributaries, it has a large area of watershed within park boundaries. Therefore, we did not assign a check to the spatial component of the data for this reporting area.

<u>051301040506—Bear Creek</u>

Summary

The Bear Creek reporting area lies in the eastern BSF watershed (Figure 33). It drains an area of 61 km^2 and contains 68 km of streams (Table 31). About 23% of the reporting area lies within park boundaries. The Bear Creek reporting area solely consists of the Bear Creek catchment. The analysis dataset contained a single sample for the area, collected near the mouth of the creek within BISO. This sample was suitable for calculation of SDI and KIBI scores. O'Bara et al.

(1982) collected three samples from Bear Creek, stating that the creek suffered from severe mining-related pollution and was the “most degraded system in the recreational area” (Figure 32). O’Bara et al. (1982) reported that aquatic life in the creek was limited to a few tolerant species. In 2010, a section of Bear Creek inside park boundaries remained listed as 303(d) impaired (Figure 23).

Condition

We did not assign a condition to fish assemblage for the Bear Creek reporting area (Table 48). The single sample for the area contained 234 individuals of 16 species (Table 35). Two species of concern and no non-native species were reported. The sample was composed of 50% intolerant individuals. The SDI value for the sample was 0.70. The KIBI score was 76, corresponding to an interpretation of excellent. Although the recent sample indicates a good quality fish assemblage at the mouth of Bear Creek, a single sample is insufficient to assess quality throughout the reporting area.

Table 48. The fish assemblage in the 051301040506 (Bear Creek) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040506: Fish Assemblages		✓		✓
		2 of 3: Fair		

Trend

No trend was assigned to the Bear Creek reporting area fish assemblage condition (Table 48). O’Bara et al. (1982) sampled three locations in Bear Creek and found 18 creek chubs at a single upstream site and no fish from sampling at the mouth of the creek. Scott (2010) sampled once near the confluence, finding 17 species and reported an assemblage resulting in a KIBI score of excellent (Table 36, Table 41). In 2010, a section of Bear Creek inside park boundaries remained listed as 303(d) impaired (Figure 23). The watershed has received attention and improvement efforts from a cooperative of state and federal agencies (EPA 2011b). Because the system has enjoyed some reclamation, and because the single recent sample shows a diverse fish assemblage in and area previously devoid of fish, it is likely that Bear Creek fish assemblages have improved since the early 1980s. However, because of the general dearth of recent sample data from the watershed, a trend was not assigned.

Data Quality

The quality of the data used to assess Bear Creek reporting area fish assemblages was fair (Table 48). The data were collected recently within park boundaries using appropriate methods. Because only a single location has been sampled recently, we believe there is a need for more data from more upstream portions of the drainage. Therefore, we did not assign a check to the spatial component of the data for this reporting area.

051301040507—Roaring Paunch Creek

Summary

The Roaring Paunch Creek reporting area lies in the eastern BSF watershed (Figure 33). It drains an area of 129 km^2 and contains 171 km of streams (Table 31). Only two percent of the reporting area lies within park boundaries and only about two km of stream are within BISO. The reporting area solely consists of the Roaring Paunch Creek catchment. The analysis dataset contained three samples for the area, collected from lower Roaring Paunch Creek and its tributary Ice Camp Creek. All samples were collected near the park boundary. All samples were appropriate for calculating SDI, and two were suitable for calculating KIBI scores. O'Bara et al. (1982) collected three samples from Roaring Paunch Creek, stating that the creek suffered from severe degradation from mining, construction, and agricultural pollution (Figure 32). In 2010, a segment of the creek outside of park boundaries remained listed as 303(d) impaired (Figure 23).

Condition

The condition of the fish assemblage of the Roaring Paunch Creek reporting area was poor (Table 49). The combined samples in the analysis dataset contained 109 individuals of 11 species (Table 35). One species of concern and one non-native species were reported. The sample was composed of 38% intolerant individuals. The mean SDI was 0.66. The mean KIBI score was 20, corresponding to an interpretation of poor. Roaring Paunch had the lowest overall species richness of any of the 14 fish reporting areas. It also had the lowest number of individuals per sample among the fish reporting areas. Although the amount of sampling has been relatively low in this reporting area, and upstream portions of the watershed have not been well sampled, the evidence suggests that this stream has one of the most degraded fish assemblages among the major BSF tributaries.

Table 49. The condition of fish assemblages in the 051301040507 (Roaring Paunch Creek) reporting area was poor. The trend of fish assemblage condition was improving. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040507: Fish Assemblages	⇧	✓		✓
		2 of 3: Fair		

Trend

The trend of Roaring Paunch reporting area fish assemblage condition was improving (Table 49). In area summary comparisons, richness, KIBI score, and percent intolerant were all higher for recent data relative to historical data (Table 36). The data summarized for these comparisons included three samples for both historical and recent data. Recent samples were collected close to the locations of the historical samples. For these reasons, we believe the comparisons of these data are especially appropriate. In the single pair comparison for the area, metrics from the recent sample were greater than for the historical sample for all metrics examined (Table 41). In 2010, a segment of the creek outside of park boundaries remained listed as 303(d) impaired

(Figure 23). However, a segment of stream upstream of the 2010 impaired section was delisted from 303(d) status between 2006 and 2008 by Tennessee (TDEC 2008).

Data Quality

The quality of the data used to assess Roaring Paunch Creek reporting area fish assemblages was fair (Table 49). The data were collected recently within or near park boundaries using appropriate methods. Because only lower segments of the stream have been sampled recently, we believe there is a need for more data from more upstream portions of the drainage. Therefore, we did not assign a check to the spatial component of the data for this reporting area.

051301040508—Rock Creek

Summary

The Rock Creek reporting area lies in the northwestern BSF watershed (Figure 33). It drains an area of 162 km^2 and contains 214 km of streams (Table 31). The reporting area consists solely of the Rock Creek catchment. Only seven percent of the reporting area lies within park boundaries. A short headwater reach of Rock Creek occurs in the park, as does a short reach at the confluence with the BSF. The analysis dataset contained six samples from this reporting area, collected from the main-stem of Rock Creek. All samples were collected from upper portions of the creek, within or above park boundaries. All six were suitable for SDI calculation, and four were appropriate for KIBI use. O'Bara et al. (1982) collected three samples in Rock Creek, stating that the lower sections of the creek were highly polluted by mining, the upper sections were affected by logging, and that the middle section appeared to be in healthy condition (Figure 32). The Rock Creek watershed has experienced negative impacts from mining and forestry practices (O'Bara et al. 1982; Figure 32), and has been the focus of restoration efforts (Carew 2002). Mining impacts occur primarily in the lower reaches of Rock Creek and in the White Oak tributary, polluting the stream from the confluence of White Oak to the confluence with the BSF, and causing this section to be listed as 303(d) (Figure 23). An upstream section was also listed 303(d) in 2010 as a result of mercury pollution (Figure 23).

Condition

The condition of the fish assemblage of the Rock Creek reporting area was fair (Table 50). The combined samples in the analysis dataset contained 938 individuals of 16 species (Table 35). One species of concern was reported. The sample was composed of 44% intolerant individuals. The mean SDI was 0.47. The mean KIBI score was 58, corresponding to an interpretation of fair. Recent sampling has not been conducted by NPS in lower Rock Creek near the BSF confluence. This is an important data gap, and affects the reliability of the assessment for this reporting area. Further samples are needed in lower Rock Creek. However, 1999 – 2001 samples by non-NPS researchers have contributed to an understanding of fish assemblages there. Carew (2002) reported on fish sampling in lower Rock Creek before and after major mitigation efforts. Of 11 samples, including one control site (above polluted section) and10 affected sites post mitigation, five had poor IBI scores, five had fair scores, and one had a score of good.

Table 50. The condition of fish assemblages in the 051301040508 (Rock Creek) reporting area was fair. The trend of fish assemblage condition was improving. The quality of the data was fair.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
051301040508: Fish Assemblages	⇧	✓		✓
		2 of 3: Fair		

Trend

The trend of the Rock Creek reporting area fish assemblages was improving (Table 50). Lower Rock Creek was historically one of the most degraded western tributaries of the BSF (O'Bara et al. 1982,Carew 2002, EPA 2011a). In area summary comparisons of historical and recent data, KIBI score, and percent intolerant were higher for recent data relative to historical data (Table 36). Species richness and mean SDI were lower for the recent summarized samples. This probably resulted because the O'Bara et al. (1982) historical efforts included sampling in lower Rock Creek, near the BSF confluence, and recent samples were collected only in upper Rock Creek. In the single pair comparison for the area, metrics from the recent sample were greater than for the historical sample for all metrics examined (Table 41). From 1998-2001, extensive reclamation of the area was conducted by a taskforce of state and federal agencies (Carew 2002, EPA 2011a). Monitoring of fish from the watershed before and after mitigation showed generally increasing IBIs and species richness, concurrent with decreasing acidity resulting from limestone dosing (Carew 2002; Figure 34). The mean of each metric across the five locations was greater following mitigation (Figure 34). The improving trend is based upon the observation of improved metrics in recent samples, and upon the reports of monitoring in the creek following restoration efforts.

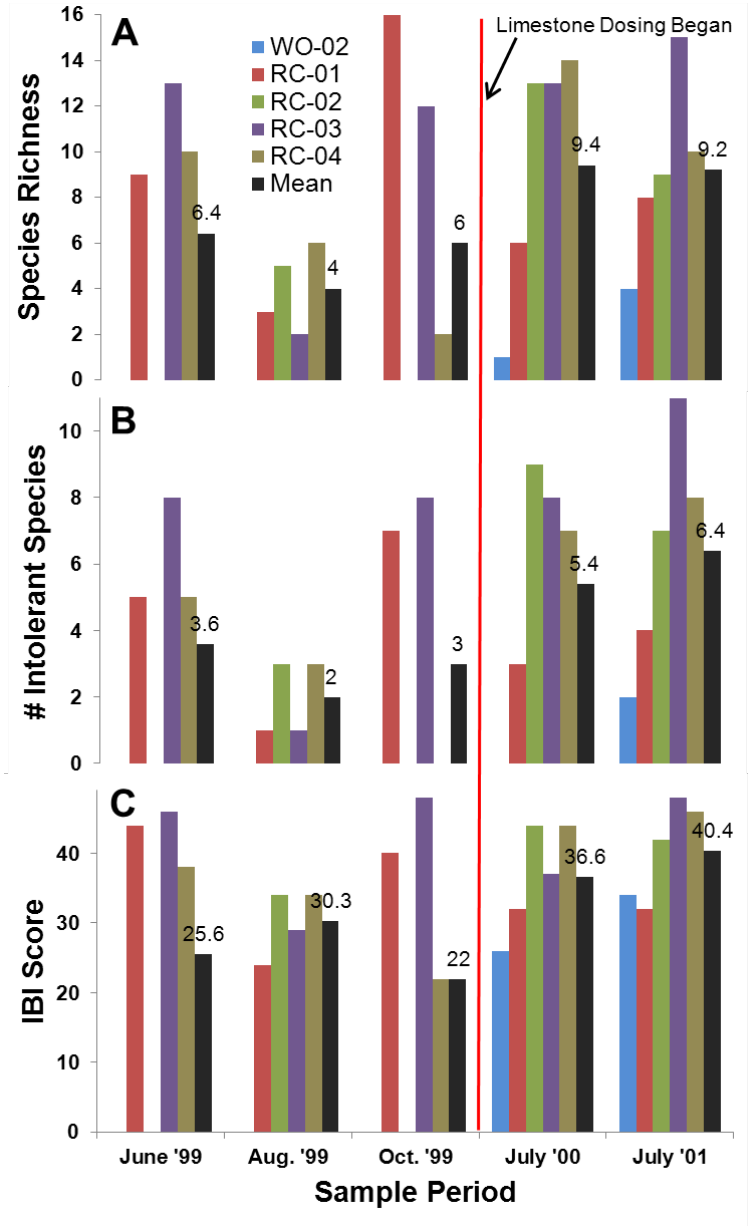

Figure 34. Fish IBI, number of intolerant fish species, and total species richness for five sites in the lower Rock Creek watershed before and after the start of limestone dosing. The black bars and values show the mean for the five sites for each sampling occasion. Data from Carew (2002).

Data Quality

The quality of the data used to assess Rock Creek reporting area fish assemblages was fair (Table 50). The data were collected recently within or near park boundaries using appropriate methods. Because only upper reaches of the stream have been sampled recently, we believe there is a need for more recent data from the lower reaches of the stream. This is especially important because of the history of negative anthropogenic impacts in the lower stream. Therefore, we did not assign a check to the spatial component of the data for this reporting area.

051301040509—Blair Creek

Summary

The Blair Creek reporting area lies in the central BSF watershed (Figure 33). It drains an area of 42 km^2 and contains 58 km of streams (Table 31). It is the smallest fish reporting area used in this report. About 70% of the reporting area lies within park boundaries. The Blair Creek reporting area is bisected by the main-stem of the BSF and includes about 14 km of the river within its boundaries. The Blair Creek reporting area also contains several small tributaries joining the BSF from the east and west. The largest of these is the western tributary Devil's Creek. The analysis dataset contained four samples from this reporting area; two were collected from a single location on the BSF, and two were collected in Devil's Creek. The two samples collected in Devil's Creek were suitable for SDI and KIBI calculation. The BSF samples were collected by boat and by dipnet. No historical samples were collected from the reporting area.

Condition

We did not assign a condition to fish assemblage for the Blair Creek reporting area (Table 51). The combined samples for the area contained 532 individuals of 14 species (Table 35). Six species were reported from Devil's Creek and eight were reported from the BSF. Three species of concern and no non-native species were reported. The sample was composed of 7% intolerant individuals. The mean SDI value for the two Devil's Creek samples was 0.36. The mean KIBI score was 58, corresponding to an interpretation of fair. Because only a single tributary in the reporting area was sampled, and because the BSF samples were collected at a single location, we believed the data were insufficient to determine assemblage quality for the reporting area.

Table 51. The fish assemblage in the 051301040509 (Blair Creek) reporting area was not ranked. No trend was assigned to fish assemblage condition. The quality of the data was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
051301040509: Fish Assemblages		✓		✓
		2 of 3: Fair		

Trend

No trend was assigned to the Blair Creek reporting area fish assemblage condition (Table 51). No historical data were available, so no determination of trend was possible.

Data Quality

The quality of the data used to assess Blair Creek reporting area fish assemblages was fair (Table 51). The data were collected recently within park boundaries using appropriate methods. Only a single location on the BSF was sampled and only Devil's Creek was sampled, of the several tributaries in the reporting area. Therefore, the data did not receive check for spatial quality.

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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). Big South Fork National River and Recreation Area provides breeding, wintering, and migration stopover habitat for a variety of birds. Historically, around 180 species have been reported from the park, though many of those are rare or transient (Stedman and Stedman 2007).

4.8.2 Resource Knowledge

Significant effort has been directed at surveying birds in BISO. Dr. Stephen Stedman inventoried park birds regularly from 1994-2006, using a variety of methods. Data from his body of work are the primary source of current information about park birds. Much of these data are available from Dr. Stedman's website or from his publications. From 1994-2001, Stedman (2011) conducted timed walking transect surveys in the spring and fall counting all birds seen, and also noting species seen outside of the standardized transect sample. These data included four fall samples and five spring samples, each on the same seven transects, and totaling 28-33 hours each season. Starting in 1994, Stedman (2011) conducted yearly driving breeding bird surveys (BBS) in BISO. Birds were sampled in May or June by driving a set route and stopping at regular intervals to conduct five minute, unlimited radius point counts of all birds heard or seen. Each year consisted of 100 total stops. From 1994-1996, stops were divided among three routes and these data were published separately (Stedman 1998). From 1997-2006, the 100 stops were divided among four routes, with one "route" divided into two geographically separated transects, and data were available from Stedman's website (Stedman 2011). From 2000-2002,

Stedman (2011) conducted three wintertime night surveys for Northern Saw-whet Owls (*Aegolius acadicus*), including 50 or 100 stops in each survey.

From 2003-2005, pursuant of the NPS I&M program, Dr. Stedman and his wife conducted a comprehensive bird inventory of BISO using a variety of sample methods (Stedman and Stedman 2007). They used point counts each June, conducting 10-minute, unlimited radius counts at 36 points. Point count data were segmented into 0-3, 3-5, and 5-10 minute time intervals and into <25, 25-50, 50-100, >100 m, and flyover distances. Point count locations were chosen non-randomly to include six plots in each of six habitat types: grassland/shrub, riparian, mesic hardwood, hemlock/white pine, pine-hardwood, and dry hardwood (Stedman and Stedman 2007). Stedman and Stedman (2007) also used timed walking transects on park trails and fields during the first summer and both winters of the inventory period. The winter walking transects were conducted during both winters of the study and were identical to the fall and spring walking transects described above. The summer walking transects were conducted only in 2003, and varied in length and location from the transects described above. The BBS routes described above were completed in each summer studied. Night surveys, using recorded owl calls to illicit responses, were also used. Finally, general, unstructured inventories were conducted during which promising habitats were searched and the presence of species was noted (Stedman and Stedman 2007).

Stedman and Stedman (2007) compiled a list of 173 species that have been reported from BISO during all past known bird work (Appendix E). With results of their own efforts, they included historical reports from a variety of unpublished sources, most significantly from the work of D. and M. Bickford in the late 1970s and early 1980s. Of this complete list, 165 species were listed by NPSpecies as "present in the park" (NPSpecies 2011). The combined work of the Stedman's from 1994-2006 reported 147 species, and their efforts during the I&M inventory (2003-2005) reported 115 species (Appendix E).

An Avian Conservation Implementation Plan (ACIP) has been prepared for BISO, and identifies broad management options and species of concern for the park (Watson 2005). Partners in Flight (PIF), a multi-agency cooperative bird conservation program, assigns a variety of scores expressing the levels of threat faced by individual species throughout their life history (Panjabi et al. 2005). Citing PIF sources, Watson (2005) lists 18 bird species of "highest" or "high" conservation concern for the physiographic region. The two most threatened of these species, Bewick's Wren (*Thryomanes bewickii*) and the Red-cockaded Woodpecker (*Picoides borealis*) are considered extirpated from much of their former range (Jackson 1994, Kennedy and White 1997) and are no longer expected to occur in BISO. A further two species from this list, Bachman's Sparrow (*Peucaea aestivalis*) and Henslow's Sparrow (*Ammodramus henslowii*) have declined throughout much of their range, prefer specialized habitats not common in BISO (Herkert et al. 2002, Dunning 2006), and are therefore highly unlikely to occur in the park. The remaining 14 high priority species have been reported from the park. Watson (2005) also provided lists of relatively high priority species assemblages expected to occur in various habitat types on the Cumberland Plateau.

4.8.3 Data

For all analyses used in this report, we used data collected by Stedman from 1994-2006. These 147 species and the associated data about presence, location, timing, and relative abundance

were termed the "analysis dataset" for use in this report. Different subsets of the data were used for different purposes as identified in the narrative.

4.8.4 Methods

We used basic descriptive metrics and indices to explore BISO bird assemblages. We examined the presence, relative abundance, and stability over time of indicator species and species of management concern. We used descriptive biodiversity metrics including species richness and abundance, and Simpson's Diversity Index to evaluate and compare samples. We also used an index of biotic integrity and a conservation value index which are further described below. We used linear regression to examine trends, as appropriate.

BCI

We used an index of biotic integrity to evaluate BISO bird assemblages. Such indices were originally developed for use with fish data to evaluate the level of anthropogenic disturbance to aquatic habitat (Karr 1981). Similar approaches have been developed using sampled bird assemblages to assess the ecological integrity of terrestrial habitat (Bradford et al. 1998, Canterberry et al. 2000, O'Connell et al. 2000). O'Connell et al. (1998) developed a breeding Bird Community Index (BCI) for the broad region of the eastern U.S. including the Appalachian Mountains and the Mid-Atlantic region. To apply the BCI, bird species are grouped into guilds based upon breeding season life history traits, and the relative proportions of species in each guild are used to create overall scores ranging from 20 (low integrity) to 77 (highest integrity, O'Connell 1998). Table 52 provides the reference range for interpreting BCI scores. The index was developed by analyzing forest bird assemblages and referencing them to independently measured levels of anthropogenic habitat disturbance. Higher scores result when more disturbance-sensitive species and species with forest-specialist life history traits are present in a bird list relative to nest disrupting species, urban-tolerant species, and exotic species (O'Connell 1998).

Table 52. Reference range for interpreting scores from a Bird Condition Index for the Appalachian and Mid-Atlantic Highlands (O'Connell 1998).

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

PIF ranks

We also used a conservation value index to compare selected samples. Such indices are designed to give a greater relative score to samples whose composition is more heavily weighted toward species that face greater threats to persistence (Nuttle et al. 2003). We used a ranking system designed by Nuttle et al. (2003) and based upon regional Partners in Flight scores (Panjabi et al. 2005). Using these scores, Nuttle et al. (2003) developed a method of assigning a single species score ranging from 0-4 with "0" representing exotic species and "4" representing "species of high concern", where high-concern species have populations that "are declining rapidly, have a small range, or high threats". We used these ranks to weight the relative

abundance of species in assemblage samples and summed the weighted values to arrive at composite indices.

Linear Regression

We used linear regression to explore potential trends within the 1997-2006 BBS data. We excluded the 1994-1996 BBS data from regression analyses because they were collected on routes differing from succeeding samples. For count data, the dependent variable was the natural log transformed counts of individuals, and the explanatory variable was time. This design-based approach is a simplified version of a method that was previously commonly used to analyze BBS data, and which has been largely superseded by more sophisticated model-based approaches. (Peterjohn et al. 1995, Link and Sauer 1998). The justifications for newer approaches include the better ability to model observer effects, account for missing data, and combine the results from multiple routes for composite analyses of populations at regional scales (Peterjohn et al. 1995, Link and Sauer 1998, Sauer et al. 2004). Because all counts were conducted by the same observer, the most important aspect of observer bias was eliminated for our analyses. Furthermore, because the first year of data collection was excluded (in the 1994-1996 samples) and because data did not include observations made >20 years after the first year of data collection, we could also ignore the "first year of count" effect and the "observer senescence effect" that have been cited as potential within-observer sources of variance (Link and Sauer 1998). We only analyzed data without "0" counts, thus avoiding issues associated with the addition of a small constant to all counts prior to log transformation (Link and Sauer 1998). Our approach assumed a linear pattern in the log transformed data, and a constant detectability of each species over time. In summary we believe our approach was reasonably robust for our purposes. Many of the reasons justifying more complex analyses did not apply to our specific case. Furthermore, we were analyzing a relatively short time period dataset with limited data and were not claiming wide regional applicability.

4.8.5 Condition and Trend

Summary Description of Bird Assemblages

We used the analysis dataset to provide a summary description of BISO bird assemblages. Assemblages varied by season, with the greatest species richness reported in spring. Of birds in the analysis dataset, 115 had been reported during spring, 93 during summer, 105 in autumn, and 66 in the winter. Thirty seven species were reported in all seasons. The relatively high numbers of species observed during spring and fall result, in part, from the presence of transient migrants during these seasons. We note that detectability is expected to vary among seasons due to variation in bird behavior and habitat condition. We determined the 10 most relatively-abundant species reported from walking transects for each season (Table 53). The level of effort varied considerably among seasons, but other aspects of the sampling were quite standardized. Although S. Stedman had additional observers to assist during some sampling, he was present during all data collection. Spring, fall, and winter surveys were conducted on seven identical transects for each year when they were collected. Summer surveys were conducted over slightly different routes, but had significant overlap with transects used for other seasons.

Table 53**.** The 10 most abundant bird species by season, reported during walking transects in Big South Fork National River and Recreation Area. Relative abundance determined by numbers of individuals detected per hour (#/Hr). Also shown for each season are the total hours sampled, the number of years when samples were conducted, and the months during which samples were collected.

Spring		**Summer**	
Hours Sampled: 155.3		Hours Sampled: 38.1	
Months: Apr/May		Months: May/Jun	
# Years: 5		# Years: 1	
Common Name	**#/Hr**	**Common Name**	**#/Hr**
Red-eyed Vireo	17.8	Red-eyed Vireo	12.6
Black-th. Green Warbler	9.4	Black-th. Green Warbler	7.3
Hooded Warbler	5.0	Hooded Warbler	5.4
Ovenbird	5.0	Ovenbird	3.9
Black-and-Wh. Warbler	3.7	Acadian Flycatcher	3.7
Scarlet Tanager	3.6	Worm-eating Warbler	3.1
Blue-gray Gnatcatcher	2.7	Scarlet Tanager	2.7
Acadian Flycatcher	2.6	Yellow-throated Warbler	2.7
Worm-eating Warbler	2.6	Black-and-Wh. Warbler	2.4
Tufted Titmouse	2.6	Northern Parula	2.3

Fall		**Winter**	
Hours Sampled: 127.9		Hours Sampled: 55.0	
Months: Sep/Oct		Months: Dec-Feb	
# Years: 4		# Years: 2	
Common Name	**#/Hr**	**Common Name**	**#/Hr**
Carolina Chickadee	5.0	Golden-cr. Kinglet*	5.1
Tufted Titmouse	3.1	Carolina Chickadee	3.4
Carolina Wren	2.7	Carolina Wren	2.4
Blue Jay	2.3	Dark-eyed Junco	2.3
Pileated Woodpecker	1.9	Tufted Titmouse	2.2
White-br. Nuthatch	1.6	Pileated Woodpecker	2.1
Hooded Warbler	1.6	Downy Woodpecker	1.4
American Crow	1.2	Winter Wren	1.2
Downy Woodpecker	1.1	White-th. Sparrow	1.1
Wood Thrush	1.0	White-br. Nuthatch	1.1

* The most abundant species during winter was the Common Grackle, not shown, resulting from two sightings of large migrating flocks estimated at 1000+ individuals reported in January, 2004.

Reported assemblages were characterized by a high abundance of forest habitat specialists, relative to early successional species. Watson (2005) provided lists of habitat-associated species with relatively high regional PIF scores. We combined priority "grassland" and "shrub-scrub" birds to create an "early successional" list including 14 species, of which eight were reported in the analysis dataset. We combined the "northern hardwood", "mixed hardwood/pine", and "hemlock/white pine" birds to create a "forest" list including 19 species, of which 18 were reported in the analysis dataset. We used these lists to compare the relative abundance of high priority early successional and forest species in several quantitative samples (Figure 35). Whip-poor-will (*Caprimulgus vociferous*) and Chuck-will's-widow (*Caprimulgus carolinensis*) were excluded from the lists and from the data because they were primarily sampled at night. The

percentage of high priority early successional species was lower in all samples, and particularly low in the walking transect data. This probably occurred because both the BBS (collected along roadsides) and the point count data (including six grassland/shrub plots) contained a greater percentage of early successional habitat than occurs on the forested trials where the walking transects were conducted. These results were expected, given the forested nature of BISO. Stedman and Stedman (2007) stated that the bird diversity of the park was "moderate" resulting from "…its large (mostly forested) area and its somewhat limited area devoted to diverse habitats".

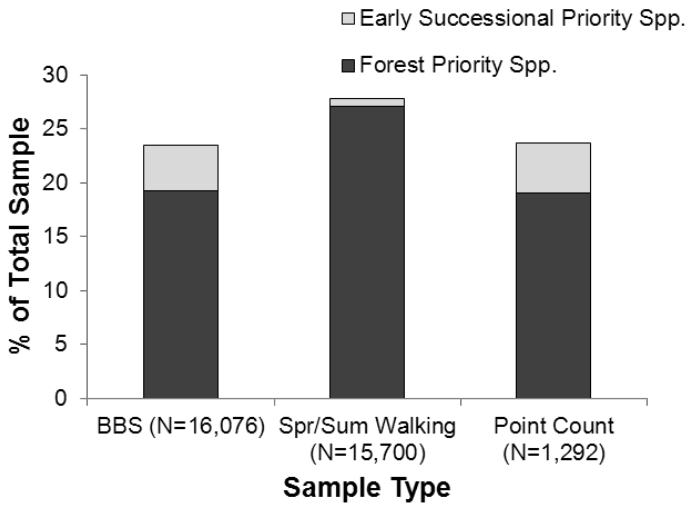

Figure 35. Percentage of priority early successional and forest specialists reported in different types of quantitative bird samples collected in Big South Fork National River and Recreation Area (1994-2006). Samples were combined across years for each type. Winter and fall walking transect data were excluded. N = the number of individuals in the sample.

Observed bird assemblages contained a relatively high abundance of Neotropical migrants. Stedman and Stedman (2007) noted that the "diversity of breeding Neotropical migrants is good to excellent, no doubt as a result of the fairly mature forest covering about 80-90% of the park's area". Of the 147 species in the analysis dataset, 110 (75%) were considered Neotropical migrants by the U.S. Fish and Wildlife Service for legislative purposes (USFWS 2011). Of the 93 species reported during the summer season, 68 (72%) were Neotropical migrants.

The park provided habitat for a number of species of particular conservation concern. Individual states have prepared Comprehensive Wildlife Conservation Strategies (CWCS) identifying species of priority conservation concern. Forty-one of the 147 species in the analysis dataset were included on one or both of Tennessee's or Kentucky's CWCS (TWRA 2005; KDFWR 2010). Eighteen species were listed as threatened, endangered, or of special concern ("deemed in need of management" in Tennessee) by one or both of the states (KDFWR 2009, TNHP 2009; Table 54). Fourteen species were listed by PIF conservation scores as high-priority breeding species for the northern Cumberland Plateau physiographic area (Watson 2005; Table 54). Ten birds received the highest PIF-based conservation rank of "4" (Nuttle et al. 1993), indicating a high level of concern (Table 54). We calculated the percentage of high priority breeding species in three quantitative samples, where high priority species were the "regional high priority" species included in Table 54. From 15-19% of all individuals in these samples were high

priority species. Figure 36 shows the five most relatively abundant conservation priority species in quantitative samples collected during the breeding season.

Table 54. Bird species of conservation concern occurring in BISO, 1994-2006, including state listed species, species identified by total PIF scores as regional high-priority breeders for the physiographic region (Watson 2005), and species receiving a PIF-based conservation rank of 4 (Nuttle et al. 2003). E = endangered; T = threatened; S = special concern (Kentucky); D = deemed in need of management (Tennessee).

Common Name	Scientific Name	State List	Regional High Priority	PIF4
Acadian Flycatcher	*Empidonax virescens*		X	
Bald Eagle	*Haliaeetus leucocephalus*	T(KY),D(TN)		
Black-throated Blue Warbler	*Dendroica caerulescens*		X	
Blackburnian Warbler	*Dendroica fusca*	T(KY)		
Blue-winged Warbler	*Vermivora pinus*			X
Canada Warbler	*Wilsonia canadensis*	S(KY)		
Cerulean Warbler	*Dendroica cerulea*	D(TN)	X	X
Dark-eyed Junco	*Junco hyemalis*	S(KY)		
Double-crested Cormorant	*Phalacrocorax auritus*	E(KY)		
Eastern Wood-Pewee	*Contopus virens*		X	
Golden-winged Warbler	*Vermivora chrysoptera*	T(KY),D(TN)	X	X
Great Blue Heron	*Ardea herodias*	S(KY)		
Hooded Warbler	*Wilsonia citrina*		X	
Kentucky Warbler	*Oporornis formosus*		X	
Louisiana Waterthrush	*Seiurus motacilla*		X	X
Northern Bobwhite	*Colinus virginianus*			X
N. Rough-winged Swallow	*Stelgidopteryx serripennis*			X
Northern Saw-whet Owl	*Aegolius acadicus*	T(TN)		
Olive-sided Flycatcher	*Contopus cooperi*	D(TN)		X
Osprey	*Pandion haliaetus*	T(KY)		
Pied-billed Grebe	*Podilymbus podiceps*	E(KY)		
Prairie Warbler	*Dendroica discolor*		X	
Red-breasted Nuthatch	*Sitta canadensis*	E(KY)		
Red-headed Woodpecker	*Melanerpes erythrocephalus*			X
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S(KY)		
Ruffed Grouse	*Bonasa umbellus*			X
Sharp-shinned Hawk	*Accipiter striatus*	S(KY),D(TN)		
Spotted Sandpiper	*Actitis macularia*	E(KY)		
Summer Tanager	*Piranga rubra*		X	
Swainson's Warbler	*Limnothlypis swainsonii*	D(TN)	X	X
Wood Thrush	*Hylocichla mustelina*		X	
Worm-eating Warbler	*Helmitheros vermivorus*		X	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	D(TN)		
Yellow-throated Vireo	*Vireo flavifrons*		X	

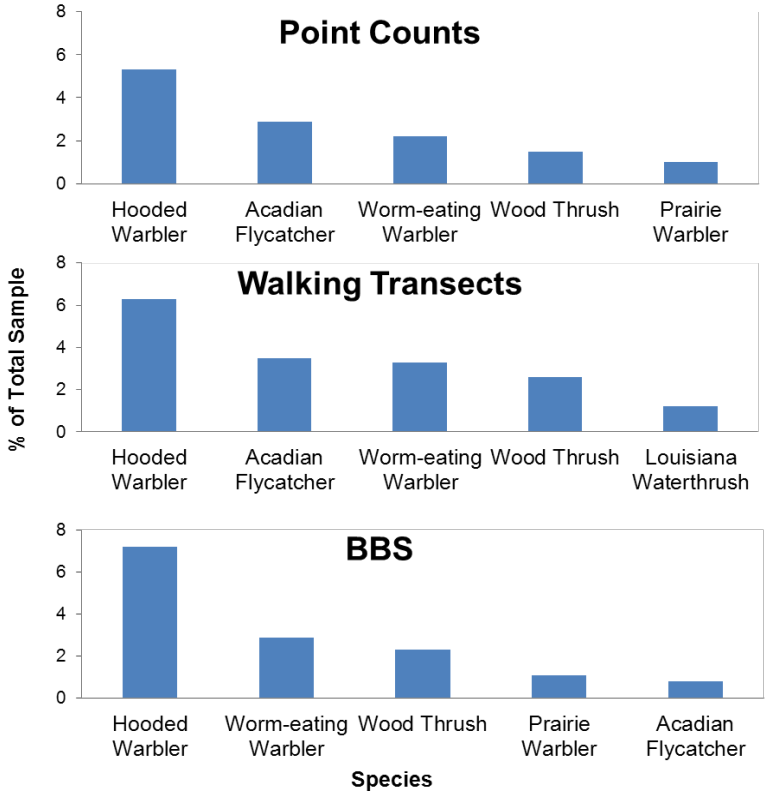

Figure 36. Five most relatively abundant species of high conservation concern in point counts, spring and summer walking transect samples, and breeding bird surveys conducted 1994-2006 in Big South Fork National River and Recreation Area. Total sample sizes for each type are the same as for Figure 35.

We applied the BCI to 2003-2004 point count data from the BISO I&M bird inventory. We calculated scores for each of the 36 individual point counts conducted each year (Figure 37). In 2003, 15 (42%) of the counts scored in the highest integrity category, 16 (44%) scored high, and five (14%) scored in the medium integrity category. The mean score for all 2003 individual scores was 59.1 (SD±6.2) corresponding to an interpretation of high integrity. In 2004, 16 (44%) scored as highest integrity, 11 (31%) scored as high, and nine (25%) scored in the medium integrity category. The mean score for all 2004 individual scores was 58.0 (SD±7.3) corresponding to an interpretation of high integrity. O'Connell et al. (1998) developed the BCI to reflect quality relative to mature, unaltered, forested habitat. This was based upon the assumption that, in the absence of anthropogenic alteration, the majority of randomly encountered locations in the region would consist of such habitat. The point count locations we assessed were chosen non-randomly by habitat type (Stedman and Stedman 2007), and six of 36 points were located in grassland or shrub habitat. In 2003, three of the five medium scores were located in these early successional plots (50% of early successional plots scored as medium integrity). In 2004, six of nine medium scores occurred in early successional plots (100% of early successional plots scored as medium integrity). We point out the high occurrence of lower scores in early successional habitats because, although this result is expected, such habitats may be valued by managers for their role in encouraging high species diversity. Therefore, the mean scores reported here may be viewed as conservative expressions of quality from some management perspectives.

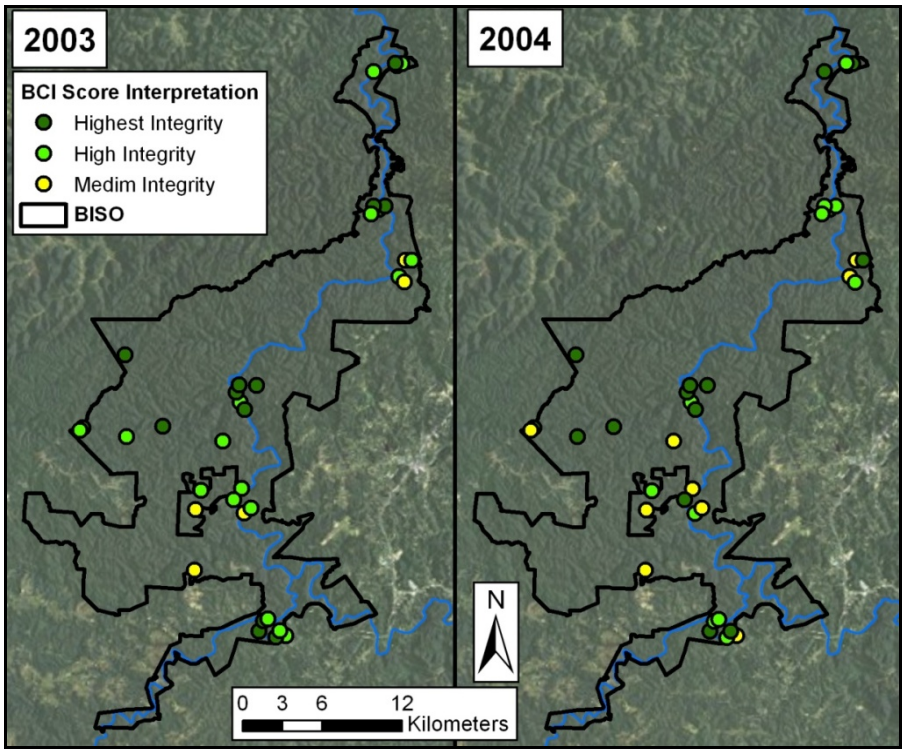

Figure 37. Point count locations and Bird Community Index score interpretations (O'Connell et al. 1998) for individual point counts conducted during 2003 and 2004 at Big South National River and Recreation Area.

The BCI was developed using bird lists compiled from five 10-minute unlimited-radius point counts conducted along a 1 km transect (O'Connell et al. 1998). To better mimic this method, we applied the BCI to bird lists compiled from clusters of 4-6 10-minute unlimited-radius point counts as they occurred on the ground in 2003-2004. Clusters were chosen by placing 1 km buffers around each point, and choosing the clusters where >3 points were included in a discreet polygon when internal boundaries of overlapping buffers were dissolved. Six clusters were chosen by this process (Figure 38). For each year, three clusters scored as high integrity and three scored as highest integrity (Figure 38).

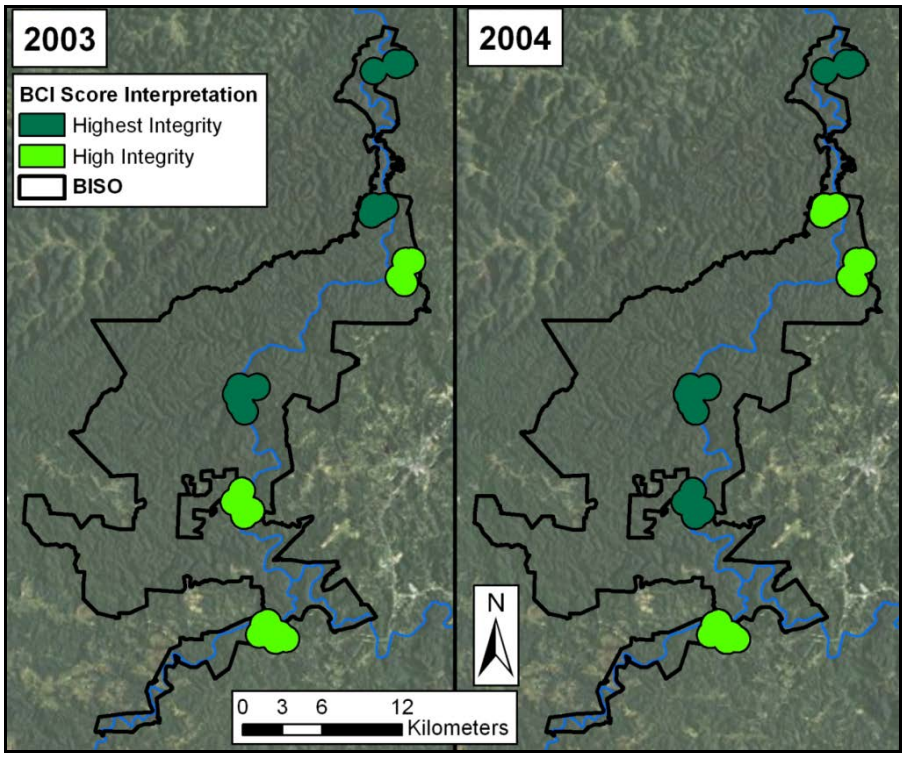

Figure 38. Bird Community Index score interpretations from bird lists compiled from 4-6 point counts occurring in clusters during 2003-2004 in Big South Fork National River and Recreation Area. Scores are represented by colors applied to polygons surrounding each cluster of point counts from which scored lists were sampled.

The BCI used in this assessment was developed from samples collected in Pennsylvania, Maryland, Virginia, and West Virginia (O'Connell et al. 1998). The authors suggested the tool was broadly applicable to the Appalachian region, including the area containing BISO (O'Connell et al. 2003). The BCI analysis list includes 112 species likely to occur during the breeding season in the area of application (O'Connell et al. 1998). Among the BISO samples to which we applied the BCI, all potential BCI species ("songbirds") were actually included on the list, with the exception of Swainson's Warbler (*Limnothlypis swainsonii*). The BCI was designed to assess biotic integrity at a landscape scale, rather than at an individual sample scale. Because of these caveats, interpretation of results of the analyses of BISO birds using this tool warrants some caution. Nevertheless, the index works by assessing occurrence of forest specialist species relative to generalist and urban-adapted species, and we believe it provided useful insight into BISO bird assemblage quality. The results indicated that BISO bird assemblages were characterized by a high occurrence of species requiring natural interior forest habitats.

We ranked the condition bird assemblages at Big South National River and Recreation area as good (Table 55). This ranking resulted, in part, from qualitative findings including the occurrence of a number of species of priority conservation concern, and the predominance of native obligate forest species in the sampled assemblages. It was also the result of the high BCI score results from analysis of breeding season samples. The quality of the data used to make the assessment was fair. Data were collected with appropriate standardized scientific technique and

were suitable for condition assessment. Because data were greater than five years old, they did not receive a temporal checkmark.

Table 55. The condition of bird assemblages in Big South Fork National River and Recreation Area was good. The trend of the condition was stable. The quality of data used to make the assessment was fair.

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

Trend

We plotted several diversity indices and community metrics over time for the combined 1997-2006 BBS data (Figure 39). Of these, only Simpson's Diversity Index had a slope significantly different from "0", and increased over the period when the untransformed values were regressed against time ($P < 0.01$). This may have resulted because of a moderate increase in early successional species in the BBS samples. We plotted the occurrence over time of a suite of eight high priority early successional species and 15 mixed pine/hardwood species (Figure 40). Regression of log transformed counts over time indicated that the slope of the line describing early successional species occurrence was significantly positive ($P < 0.01$). Simpson's Index is heavily influenced by evenness (Huston 1994), so an increase in the relative abundance of rarer species is expected to cause an increase in this value. The modest increase in early successional species was most notable from 2003-2005, a period increase that may have resulted from the initiation of more controlled burns in the unit (NPS 2004), and particularly pre-breeding season burns in 2005 (Stedman and Stedman 2007).

Relatively low values for 2003 were notable for most of the metrics plotted for the combined BBS sample (Figure 39, Figure 40). Date of data collection may have influenced these results. For each year, BBS data were collected on four different days in June, and 2003 date were collected between the 13th and the 24th. June 24th was the latest date of data collection among all BBS sample dates. However, five of the other yearly samples had two or more sample dates from the 13th to the 20th, and the low values of 2003 appear to be the lowest point of a several-year trend, suggesting that the 2003 data accurately depict a summer of unusually low diversity in BISO bird assemblages. One potential influence was a southern pine beetle outbreak, reported by Stedman and Stedman (2007) as occurring during 1999-2002 and having an on the relative abundance of some birds as a result of large-scale pine mortality. This theory is supported by the observed decline of priority mixed forest species in BBS sample data from 2000-2003 (Figure 40).

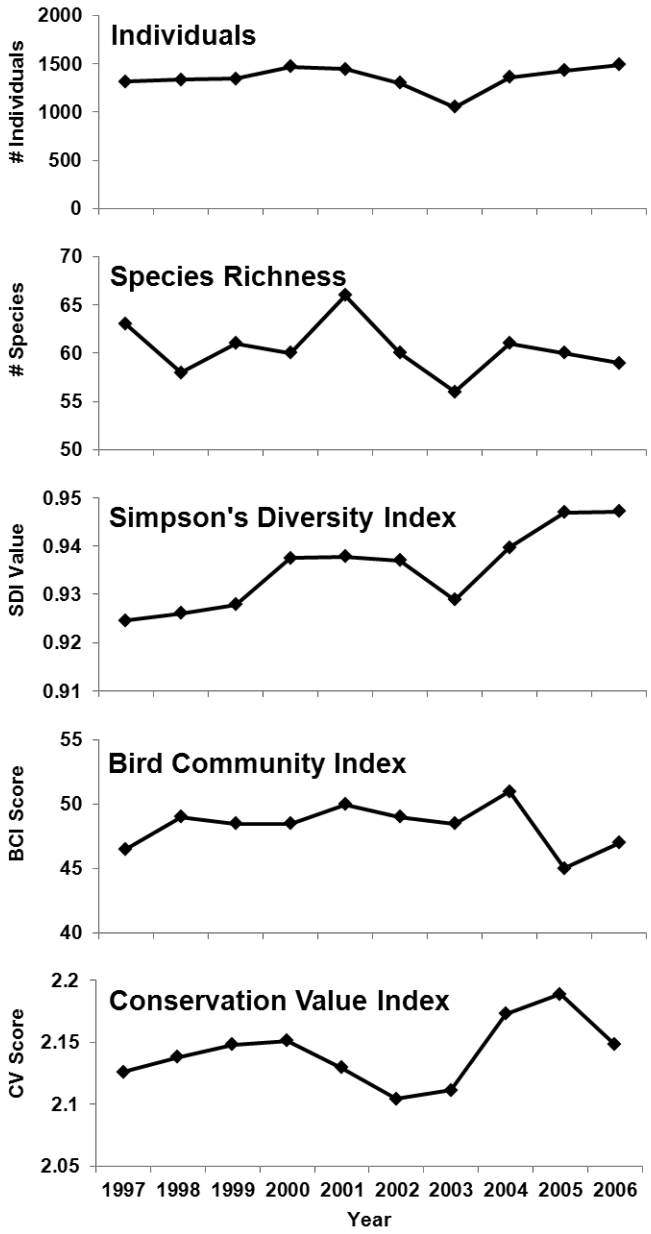

Figure 39. Community metrics and indices over time for breeding bird survey data collected in Big South Fork National River and Recreation Area 1997-2006. All values were calculated on the combined yearly sample.

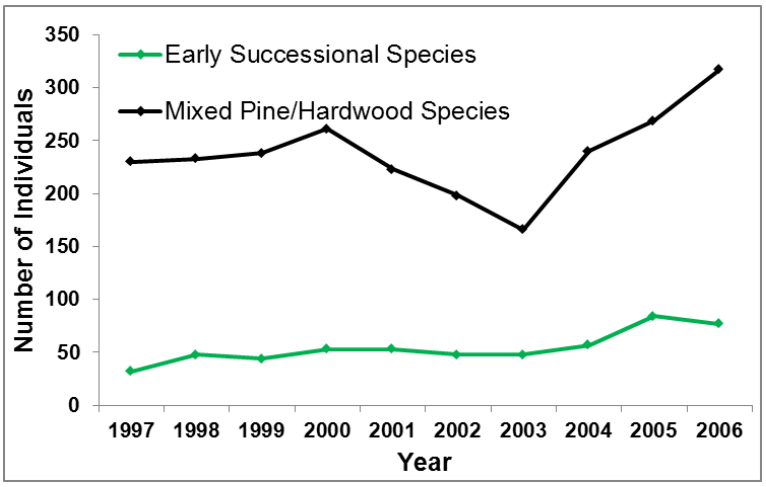

Figure 40. The occurrence of combined totals of high conservation priority early successional birds (eight species), and mixed pine/hardwood birds (15 species) in 1997-2006 BBS samples from Big South Fork National River and Recreation Area.

We used regression to examine species trends at the individual route level in the 1997-2006 BBS sample data. Surveys were conducted on four driving routes within the park (Figure 41). Each route was sampled on a single day, except for the Divide Rd. route in 2002, which was sampled on two different days (Stedman 2011). Two short segments, Station Camp and O & W, were combined into a single route. Though geographically separate, both routes transverse the eastern BSF gorge wall from rim to valley floor. For each combination of year and route, we selected all species reported at least once in each yearly sample, resulting in an analysis set of 94 route-species combinations. We regressed the log transformed count data over time for each species. Twelve species had slopes significantly different from "0" ($P < 0.05$); nine species increased and three decreased over the time period (Table 56; Figure 42).

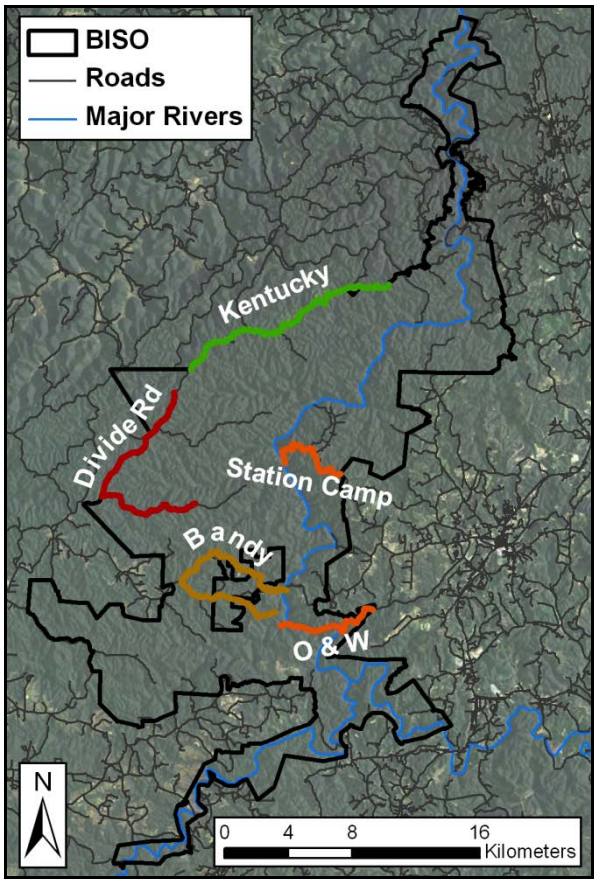

Figure 41. Driving Breeding Bird Survey Routes sampled in Big South Fork National River and Recreation Area, 1997-2006. Station Camp and O & W were combined as a single route and were collected on the same day each year. Each route contained from 24-26 stops.

Table 56. Bird species that had slopes significantly different from "0" in regression of log transformed species counts over time for individual survey routes in Big South Fork National River and Recreation Area, 1997-2006.

Species	Route	Trend	Slope P-value	R-square
American Robin	Bandy	-	<0.01	0.74
Carolina Wren	Bandy	+	0.05	0.41
Yellow-breasted Chat	Bandy	+	<0.01	0.68
Hooded Warbler	Divide Rd.	+	<0.01	0.76
Pine Warbler	Divide Rd.	-	0.01	0.57
Carolina Wren	Kentucky	+	0.01	0.61
Eastern Towhee	Kentucky	+	0.03	0.47
Red-eyed Vireo	Kentucky	-	0.01	0.60
Yellow-breasted Chat	Kentucky	+	<0.01	0.73
Black-throated Green Warbler	St. Camp/O&W	+	0.03	0.45
Carolina Chickadee	St. Camp/O&W	+	0.05	0.41
Yellow-throated Warbler	St. Camp/O&W	+	0.04	0.41

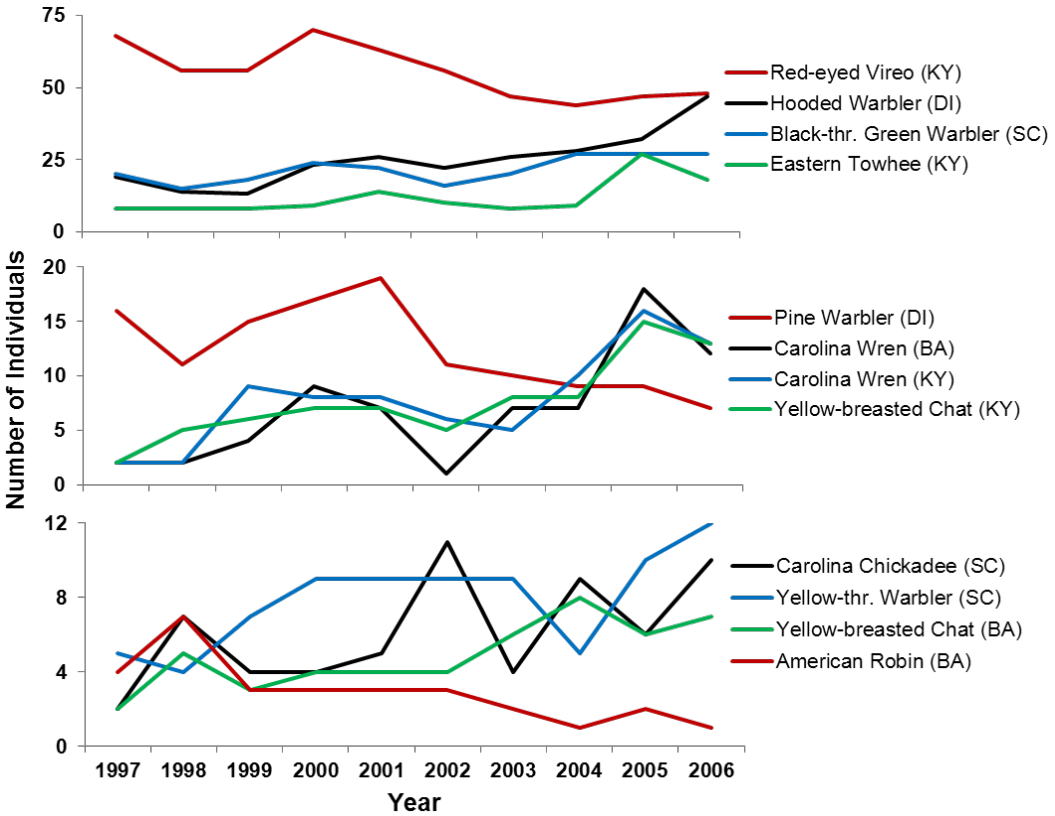

Figure 42. Raw count data from combined yearly BBS counts, 1997-2006, for twelve bird species that had slopes significantly differing from "0" in regressions of log transformed count data over time. Route is indicated in parentheses (KY=Kentucky, DI=Divide, SC=Station Camp, BA=Bandy). Red lines indicate decreasing species and other colors indicate increasing species.

We ranked the trend of BISO bird assemblage condition as stable (Table 55). With the exception of Simpson's Diversity Index, assemblage-wide abundance and diversity indices from standardized samples did not have slopes different from "0" when regressed over a 10-year period (Figure 39). The increase in Simpson's Index may have resulted from a slight increase in the density of early successional species (Figure 40). Of 98 species/route combinations analyzed, nine had significantly positive and three had significantly negative slopes over the 10-year period (Table 56). In summary, while there is limited evidence of slight changes in abundance of or diversity, possibly driven by habitat changes resulting from pest outbreaks or management activities, the overall condition of the greater BISO bird community has remained stable.

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4.9 Mammal Assemblages

4.9.1 Relevance and Context

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

4.9.2 Resource Knowledge

Understanding of current mammal assemblages at BISO is based primarily upon a recent inventory conducted in the park. This inventory was conducted from the autumn of 2003 to the autumn of 2004, and reported 47 species including 42 native and five non-native mammals (Britzke 2007; Table 57). Reported mammals included 15 rodents, 11 bats, 10 carnivores, five insectivores, two cervids, and one species each from the families Dasypodidae, Didelphidae, Leporidae, and Suidae (Britzke 2007). This study sampled non-bat mammals with several types of box-style live traps and lethal snap traps, pitfall buckets, automatic trail cameras, spotlight surveys, and incidental sightings (Britzke 2007). Non-camera trapping efforts included 9,128 trap nights of which 4,557 were Sherman, 4,377 were pitfall, 129 were other live box types, and 65 were snap traps. These trapping efforts resulted in 380 terrestrial mammal captures. The most frequently trapped non-bat mammal was the white-footed mouse (*Peromyscus leucopus*), which accounted for 146 (38%) of all captures. Bats were sampled for 18 nights using mist nets and 25 nights with Anabat II electronic detectors (Britzke 2007). Britzke (2007) sampled mammals at sites chosen to be representative of the available habitat in BISO. Most of these sites occurred in the southern, central portions of the park (Figure 43). One species, the gray bat (*Myotis grisescens*), was federally listed as endangered, and the Allegheny woodrat (*Neotoma magister*), was a candidate species for federal listing (Britzke 2007; Table 57). These and seven other species were state listed as threatened, endangered, or of special concern (Britzke 2007; Table 57). Five non-native mammal species were reported from BISO. These included free-ranging or feral domestic dogs (*Canis familiaris*) and cats (*Felis catus*), feral hogs (*Sus scrofa*), and the range-expanding species nine-banded armadillo (*Dasypus novemcinctus*) and coyote (*Canis latrans*; Table 57).

4.9.3 Threats and Stressors

Threats and stressors to native mammals generally include habitat fragmentation, habitat alteration, consumptive use, disease, and non-native species. Habitat fragmentation can cause loss of species and lowered abundance of some species (Andren 1994). However, because BISO is relatively large, has near-continuous forest cover, and is bordered by national forest along its northern boundaries, fragmentation of habitat is not a prominent threat to mammals in the park, especially when considered in relation to the surrounding landscape. Human development and resource extraction have altered park habitats, although currently many of the deleterious conditions resulting from these activities are recovering and improving. Mining has had important impacts in the park, with lingering effects particularly on aquatic fauna. Surface mining can have profound local effects on small mammal habitat in the region (Larkin et al. 2008), but this level of disturbance does not occur in the park at present. A southern pine beetle infestation altered BISO forests after 1999, causing the deaths of most of the park's yellow pines and some white pines, and possibly affecting mammal habitat (Britzke 2007, Stedman and Stedman 2007).

Table 57**.** Forty-seven species of mammals were reported in BISO from a 2003-2004 survey. The protected listing status of each species is indicated as: S=special concern, deemed in need of management, or candidate for listing; T=threatened; E=endangered. Letters within parentheses indicate listing region: K=Kentucky; T=Tennessee; F=federal.

Scientific Name	Common Name	Listing	Scientific Name	Common Name	Listing
Order Artiodactyla			**Order Insectivora**		
Cervus elaphus	elk		*Blarina brevicauda*	northern short-tailed shrew	
Odocoileus virginianus	white-tailed deer		*Cryptotis parva*	least shrew	
*Sus scrofa****	feral hog		*Scalopus aquaticus*	eastern mole	
Order Carnivora			*Sorex fumeus*	smoky shrew	S(T)
*Canis familiaris****	domestic dog		*Sorex hoyi*	pygmy shrew	
*Canis latrans****	coyote		**Order Lagomorpha**		
*Felis catus****	domestic cat		*Sylvilagus floridanus*	eastern cottontail	
Lontra canadensis	river otter		**Order Rodentia**		
Lynx rufus	bobcat		*Castor canadensis*	beaver	
Mephitis mephitis	striped skunk		*Glaucomys volans*	southern flying squirrel	
Procyon lotor	raccoon		*Marmota monax*	woodchuck	
Urocyon cinereoargenteus	gray fox		*Microtus pinetorum*	woodland vole	
Ursus americanus	black bear	S(K)	*Microtus ochrogastor*	prairie vole	
Vulpes vulpes	red fox		*Napaeozapus insignis*	woodland jumping mouse	S(T)
Order Chiroptera			*Neotoma magister*	Allegheny woodrat	S(F,T)
Corynorhinus rafinesquii	eastern big-eared bat	S(K,T)	*Ochrotomys nuttalli*	golden mouse	
Eptesicus fuscus	big brown bat		*Ondatra zibethicus*	muskrat	
Lasionycteris noctivagans	silver-haired bat		*Peromyscus leucopus*	white-footed mouse	
Lasiurus borealis	red bat		*Reithrodontomys humulis*	eastern harvest mouse	
Lasiurus cinereus	hoary bat		*Sciurus carolinensis*	eastern gray squirrel	
Myotis grisescens	gray bat	T(K), E(F,T)	*Sigmodon hispidus*	hispid cotton rat	
Myotis leibii	eastern small-footed bat	S(T)	*Synaptomys cooperi*	southern bog lemming	S(T)
Myotis lucifugus	little brown bat		*Tamias striatus*	eastern chipmunk	
Myotis septentrionalis	northern long-eared bat		**Order Xenarthra**		
Nycticeius humeralis	evening bat	S(K,T)	*Dasypus novemcinctus****	nine-banded armadillo	
Perimyotis subflavus	tricolored bat				
Order Didelphimorphia					
Didelphis virginiana	Virginia opossum				

* Non-native species

Non-native species may pose threats to BISO mammal communities, although these effects are not well-understood in the park. Feral cats were reported from BISO (Britzke 2007) and are known to prey upon small mammals, although their effect is likely to be localized near forest edges (Baker et al. 2005, Warner 1985). Feral hogs were reported from BISO and can potentially affect mammal communities through habitat alteration, resource competition, or direct predation (Seward et al. 2004), although these impacts have not been quantified in the park. Coyotes occur in the park and may potentially affect mammal communities. Coyotes have expanded into the region 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 such as wolves and cougars have been extirpated (Gompper 2002). Black bears (*Ursus americanus*) share the role of apex predators in BISO, although they are more omnivorous than coyotes. 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 mammals such as the Allegheny woodrat (Gompper 2002). The impact of coyotes on eastern deer populations is not well understood, although researches have suggested that deer herds have shown a decline coincidental with coyote increases in specific areas (Kilgo et al. 2010). Hunter perception that coyotes negatively impact white-tailed deer hunting quality is growing. Deer hunting is permitted in BISO, so the question of whether coyote predation results in additive mortality on deer may be important in the park.

White-nose syndrome (WNS) is a severe and emerging threat to hibernating bats throughout the eastern U.S. (Cyran 2011). This disease, caused solely by infection with the *Geomyces destructans* fungus (Lorch et al. 2011), was discovered in New York in 2006, and has spread rapidly westward including occurrences in Tennessee and Kentucky since 2009 (Cryan 2011). The disease affects hibernating bats and may result in catastrophic declines of >75% in local hibernating populations (Blehert et al. 2009). Of 11 species of bats reported from BISO, eight are hibernating species at risk from WNS and the disease has been found in five of these species (Cryan 2011; Table 58). Because of WNS risk, several species of cave-hibernating bats are being considered for listing under the Federal Endangered Species Act.

Table 58. Eight species of hibernating bats reported from BISO during a 2003-2004 mammal inventory, indicating species for which WNS has been verified and species for which disease has not been verified, but which are believed to be at risk.

Scientific Name	Common Name
WNS Verified	
Eptesicus fuscus	Big brown bat
Myotis leibii	Eastern small-footed bat
Myotis lucifugus	Little brown bat
Myotis septentrionalis	Northern long-eared bat
Perimyotis subflavus	Tricolored bat
WNS Potential	
Corynorhinus rafinesquii	Eastern big-eared bat
Myotis grisescens	Gray bat
Nycticeius humeralis	Evening bat

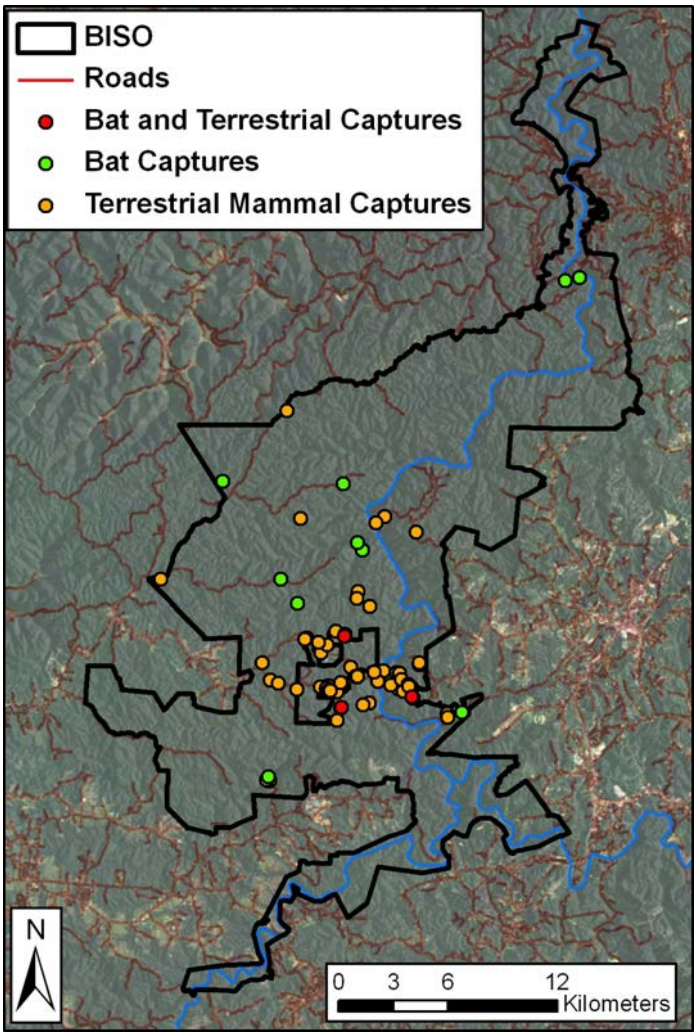

Figure 43. Locations of bat and terrestrial mammals captured in BISO during a 2003-2004 inventory.

4.9.4 Data

For our analyses of BISO mammal condition, we used park data from the most recent I&M survey effort conducted by Britzke (2007). We used data from other parks and other studies in the southeast for comparison purposes.

4.9.5 Reporting Areas

We reported mammal condition at the park level. Although there are distinct habitats within the park, differentiated by landcover and elevation, these areas are mixed homogenously throughout the park, and the recent mammal survey did not sample the entire park area. Therefore, the mammal condition is best applied to the entire combined dataset.

4.9.6 Methods

We compared groups of mammals reported in the analysis dataset to corresponding expected mammal lists and to lists reported from other studies in the southeastern U.S. For the expected mammal list we used the list compiled by Britzke (2007) from literature, through consultation with locally-knowledgeable mammologists, and from personal knowledge and experience. This list was created to include mammal species "known or suspected to be present within the

boundaries of BISO" (Britzke 2007). We compared the entire observed mammal list to the entire expected list, and we compared the lists by categories of mammals. For our comparison of observed BISO mammal richness to the richness observed in comparable studies, we used mammal inventory data from Cumberland Gap National Historical Park (Gumbert et al. 2006), from Mammoth Cave National Park (Thomas in press), and from the George Washington National Forest in northern Virginia (Mitchell et al. 1997). For these analyses we compared shrews and native rats, mice, and voles. We chose these groups because they are the most commonly captured small mammals using trapping techniques common among the compared studies.

4.9.7 Condition and Trend

The recent inventory of BISO mammals reported 42 (79%) of 53 expected native species (Table 59). Some of the mammals missing are considered rare or are difficult to capture. Three expected carnivores were not reported. The mink (*Mustela vison*) and the long-tailed weasel (*Mustela freneta*) are cryptic carnivores that are difficult to document. Britzke (2007) suggested that the spotted skunk (*Spilogale putorius*) was difficult to document because it requires suitable baiting and camera methods that were difficult to apply in the park. The missing insectivores, the hairy-tailed mole (*Parascalops breweri*), the masked shrew (*Sorex cinereus*) and the southeastern shrew (*Sorex longirostris*), are state listed as species of concern, and are rare with discontinuous distributions. Of the missing native mice and rats, Britzke (2007) suggested that the meadow jumping mouse (*Zapus hudsonius*) may have been hibernating in the early spring when much of the suitable habitat for the species was sampled. The comparison of reported mammal lists with expected mammal lists suggests that a high percentage of the expected mammal species are actually present in the park. A caveat for this finding is that compiling an expected list is somewhat subjective. We feel that the expected list created by Britzke (2007) was reasonable for comparison because it listed species that were considered "likely" to occur as opposed to all species that could possibly occur, and did not list historic species that are believed extirpated from the region.

Table 59. Number of native mammal species in different categories expected to occur, and the number and percent of expected species actually reported by Britzke (2007) from Big South Fork National River and Recreation Area.

Native Species Group	Reported	Expected	% Expected Reported
Bats	11	12	92
Native Rats/mice/voles	9	12	75
Non-Rat/mice/vole Rodents	6	7	86
Shrews/moles	5	8	63
Carnivores	7	10	70
Cervids	2	2	100
Lagomorphs	1	1	100
Marsupial	1	1	100
All Native Species	42	53	79

The comparisons of selected BISO trapping results with the results from other studies suggested that the number of shrews and small native rats, mice, and voles found in BISO were generally

similar to the numbers of these species found in other protected forested sites in the southeast (Table 60). These comparisons must be viewed as "general" because of the differences in variety and type of effort used, and the differences in habitat among sites.

Table 60**.** Comparison of the number of shrews and native rats, mice, and voles reported by Britzke (2007) from Big South Fork National River and Recreation Area, and from other mammal surveys in the Cumberland and south-central Appalachian region.

	Britzke 2007	**Gumbert et al. 2006**	**Mitchell et al. 1997**	**Thomas 2011**
Location	Big South Fork National River and Recreation Area, southern eastern Kentucky	Cumberland Gap National Historical Park, southern eastern Kentucky	George Washington National Forest, northern Virginia	Mammoth Cave National Park, western central Kentucky
Habitat	All types including fields, wetlands, forests	All types including fields, wetlands, forests	Gradient from recent clearcut to climax hardwood forest	All types including fields, wetlands, forests
Effort	9,128 trap nights using snap traps, live traps, and unfenced pitfalls	11,348 trap nights using snap traps, live traps and unfenced pitfalls	12,600 trap nights using drift fence pitfall arrays	117,121 trap nights using live traps, pitfalls, and drift fence pitfall arrays
Total Species	13	14	11	12
Shrews	4	5	5	5
Native Rats/mice/voles	9	9	6	7
Unique Species	0	0	2	2

Big South Fork National River and Recreation Area has benefited from a well-conducted mammal survey that has a few limitations worthy of noting. The effort directed toward mammal sampling was moderate, relative to other comprehensive sampling studies. Researchers sampling southeastern mammal assemblages often conducted over 9,000 trap nights and used drift fences with pitfalls as a capture method (Osbourne et al. 2005, Gumbert et al. 2007, Linehan et al. 2008, Thomas 2012). With 9,128 trap nights, the BISO mammal survey effort was within the low range among comparable studies. Although the BISO study used a wide variety of methods, it didn't apply drift fences with pitfalls as a sampling technique. Pitfall traps with drift fence arrays can be particularly effective at sampling insectivores and small rodents (Briese and Smith 1974, Bury and Corn 1987), taxa which include six of the 11 expected mammal species not reported from the park. Much of the trapping effort from the BISO survey was conducted in the southern areas of the park (Figure 43), and much of the roadless area of the park was not sampled. Given the large size of the park, and the present level of sampling effort, we believe it is probable that future efforts will turn up several new species, potentially including species of management concern.

Mammal assemblages are uniquely difficult to sample due to large variations in size, behavior, and habitat preference among species. Obtaining a good working knowledge of assemblage diversity may inherently require more person-hours then would necessarily be expended to gain a similarly complete knowledge of other vertebrate groups. The BISO mammal survey has provided an excellent baseline from which to study mammal diversity in the park.

We ranked the condition of BISO mammal assemblages as good (Table 61). This assessment is based primarily upon the observation that the mammal richness reported at BISO is similar to that seen at other well-protected forest sites within the broad region, and upon the fact that a relatively large percentage of expected mammals have been reported from the park. The presence of a number of species of management concern was also considered an indication of good quality. We ranked the quality of the data used to make this assessment as fair. The spatial data category did not receive a check because much of the sampling coverage occurred in the southern portions of the park and the sampling protocols did not follow a stratified random or systematic design. We note that the methods employed were suitable for the stated mandate of the inventory, which was to document the presence of the greatest possible number of occurring species. The ranking of fair reflects our belief that for a park this large and with this much rugged wilderness area, multiple mammal surveys may be required to understand basic assemblage diversity. We did not assign a trend to mammal assemblage condition. A single baseline survey, conducted over a one-year period, is insufficient to establish changes over time.

Table 61. The condition of mammal assemblages at BISO was good. The quality of the data were fair. No trend was assigned to mammal assemblage condition.

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

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4.10 Herpetofaunal Assemblages

4.10.1 Relevance and Context

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

4.10.2 Resource Knowledge

A baseline inventory of reptiles and amphibians was conducted in BISO from February 2004 to June 2007, and reported 57 species including 17 salamanders, 11 frogs, 16 snakes, six lizards, and seven turtles (Stephens et al. 2008; Table 62). Researchers searched all habitat types using standardized and unstandardized methods including: metal and wood coverboard arrays at 25 locations; road cruising; frog call surveys; constrained areas searches in 30-m radius circles centered in established vegetation sampling plots; unconstrained searches of likely habitats; electroshocking for amphibians in cooperation with ongoing fish surveys; incidental sightings; and spotting scope surveys for aquatic turtles (Stephens et al. 2008). The locations of all observations were recorded (Figure 44). Sampling was conducted throughout the latitudinal and longitudinal range of the park, although many collections were made near roads (Figure 44). No federally threatened or endangered species were reported. Five species were state listed as either threatened or of special concern ("deemed in need of management" in Tennessee) in one or both states (TNHP 2009, KDFWR 2010; Table 62). By federal mandate, states have been required to create Comprehensive Wildlife Conservation Strategies (CWCS) indicating species of priority conservation concern. Fifteen species reported from BISO were included in one or both state's CWCS as species of conservation concern (TWRA 2005, KYCWCS 2010; Table 62).

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 BISO is a large park in a relatively sparsely populated area, consisting largely of forested habitat, habitat fragmentation, habitat degradation, and consumptive use are not expected to pose major threats to herpetofauna in the park. Feral or free-roaming cats can impact native herpetofauna and have been reported from BISO. However, because of the large size and intact habitat of the park, cats are not expected to pose major threats to herpetofauna there (Baker et al. 2005). The long history of mining in the watershed has caused significant impacts on park water quality (see Water Quality section, this report), however impacts on amphibians are not well understood in BISO. The chytrid fungus *Batrachochytrium dendrobatidis* and viruses of the genus *Ranavirus* are known to infect amphibian populations in the southeast with results ranging from sub-clinical infection to local population failure. These diseases have not been tested for in BISO at the time of publishing of this report.

4.10.4 Data

For BISO herpetofaunal data, we used data from the 2004-2007 inventory conducted by Stephens et al. (2008). For comparative purposes, we used species lists compiled from surveys conducted by other researchers in the general region. Comparative studies included Meade (2003), Meade (2005), and Niemellier et al. (2011).

4.10.5 Methods

We compared species lists from the analysis dataset to lists of species expected in the park. For our expected list, we adapted the list compiled by Stephens et al. (2008) which was compiled from literature and published and unpublished data sources, including the researchers' own past efforts in the region. Stephens et al. (2008) created a list of 63 species considered likely to occur in BISO and a list of 12 additional species that were considered possible but not likely. Two of these 12 possible species were reported from the inventory (Stephens et al. 2008). For our comparison list, we used the 63 species considered likely to occur, plus the two possible species actually reported, to create an expected list of 65 species.

We compared species lists from the analysis dataset to other species lists compiled from three efforts in the broad region surrounding BISO. For comparison studies, we used inventories conducted at Cumberland Gap National Historical Park (CUGA; Meade 2003) and at Obed Wild and Scenic River (OBED; Meade 2005). Cumberland Gap is located approximately 85 east of BISO; OBED is located approximately 55 km south of BISO. The area sampled differed considerably among the compared studies and BISO is much larger than either of the comparison sites. Therefore, we plotted the natural log transformed species counts against the area for the three studies. The purpose of doing comparisons of this nature is to provide general context for the BISO results. The comparison sites were chosen because they occurred in the same broad region as BISO and were conducted as total assemblage samples using a variety of methods (Meade 2003, 2005).

Table 62. Reptile and amphibian species reported from Big South Fork National River and Recreation Area during a 2004-2007 inventory, indicating species with official listings at the state level and species included on each state's Comprehensive Wildlife Conservation Strategy (CWCS). Outside parentheses: K=Kentucky; T=Tennessee. Within parentheses: D="deemed in need of management" (Tennessee only); S=species of special concern; T=threatened.

Scientific Name	Common Name	St. List	CWCS	Scientific Name	Common Name	St. List	CWCS
	Lizards				**Anurans**		
Eumeces fasciatus	five-lined skink			*Acris c. blanchardi*	Blanchard's cricket frog		
Eumeces inexpectatus	southeastern five-lined skink	K(S)	K	*Bufo a. americanus*	eastern american toad		
Eumeces laticeps	broadhead skink			*Bufo fowleri*	Fowler's toad		
Ophisaurus a. longicaudus	eastern slender glass lizard	K(T),T(D)	K,T	*Hyla chrysoscelis*	Cope's gray treefrog		
Sceloporus undulatus	eastern fence lizard			*Pseudacris brachyphona*	mountain chorus frog		T
Scincella lateralis	ground skink			*Pseudacris c. crucifer*	northern spring peeper		
	Snakes			*Rana catesbeiana*	bullfrog		
Agkistrodon c. mokasen	northern copperhead			*Rana c. melanota*	green frog		
Carphophis amoenus	eastern worm snake			*Rana palustris*	pickerel frog		K
Coluber constrictor	black racer			*Rana sylvatica*	wood frog		
Crotalus horridus	timber rattlesnake		K,T	*Scaphiopus h. holbrookii*	eastern spadefoot		K
Diadophis p. edwardsii	northern ringneck snake				**Salamanders**		
Elaphe o. obsoleta	black rat snake			*Ambystoma maculatum*	spotted salamander		
Heterodon platirhinos	eastern hognose snake		T	*Ambystoma opacum*	marbled salamander		
Lampropeltis g. nigra	black kingsnake			*Aneides aeneus*	green salamander	T(D)	K,T
Lampropeltis t. triangulum	eastern milk snake			*Desmognathus fuscus*	northern dusky salamander		K
Nerodia s. sipedon	northern water snake			*Desmognathus monticola*	seal salamander		
Opheodrys aestivus	rough green snake			*Desmognathus ochrophaeus*	Allegheny dusky salamander		K
Regina septemvittata	queen snake			*Desmognathus welteri*	black mountain salamander	T(D)	K,T
Storeria d. wrightorum	midland brown snake			*Eurycea cirrigera*	southern two-lined salamander		
Storeria o. occipitomaculata	northern redbelly snake			*Eurycea l. longicauda*	longtail salamander		
Thamnophis sirtalis	common garter snake			*Eurycea lucifuga*	cave salamander		
Virginia v. valeriae	eastern earth snake			*Gyrinophilus p. duryi*	Kentucky spring salamander		
	Turtles		T	*Hemidactylium scutatum*	four-toed salamander	T(D)	K,T
Apalone s. spinifera	eastern spiny softshell			*Necturus maculosus*	common mudpuppy		
Chelydra s. serpentine	common snapping turtle			*Notophthalmus v. viridescens*	red-spotted newt		
Graptemys geographica	common map turtle			*Plethodon glutinosus*	northern slimy salamander		
Graptemys o. ouachitensis	Ouachita map turtle			*Plethodon ventralis*	southern zigzag salamander		K
Pseudemys concinna	river cooter			*Pseudotriton r.ruber*	northern red salamander		
Sternotherus odoratus	common musk turtle						
Terrapene c. carolina	eastern box turtle		T				

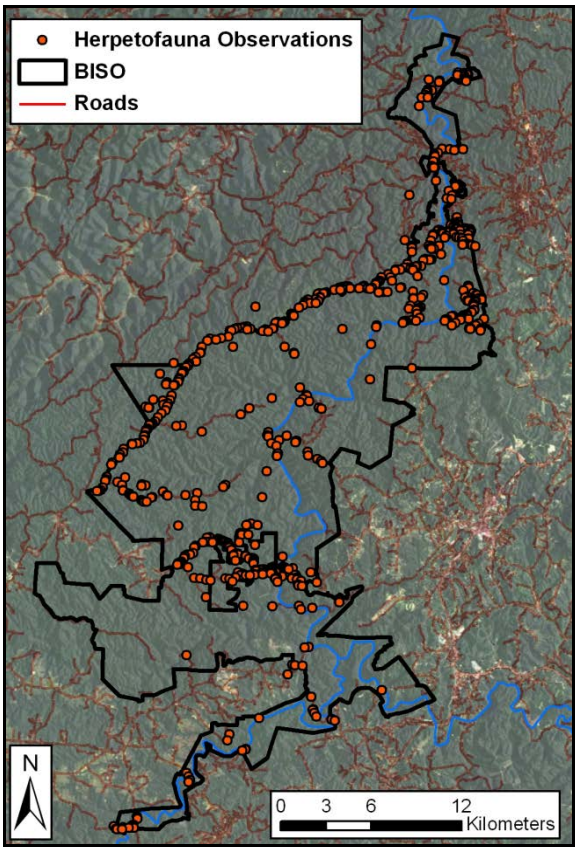

Figure 44. Locations of observed reptiles and amphibians in BISO from a herpetofaunal inventory conducted 2004-2007.

4.10.6 Condition and Trend

About 89% of the expected herpetofaunal species were reported from BISO during the 2004-2007 inventory (Table 63). Greater than 85% of expected species were reported for all categories examined (Table 63). While we acknowledge that the compilation of expected lists is somewhat subjective, the findings from the BISO effort suggest that the park harbors a high percentage of herpetofaunal species expected for the region.

Table 63. Number of reported species of herpetofauna by group, expected number of species, and percent of expected species reported from a herpetofaunal survey of Big South Fork National River and Recreation Area.

Species Group	Reported	Expected	% Expected Reported
All Species	57	64	89
Anurans	11	12	92
Salamanders	17	19	89
Snakes	16	18	89
Lizards	6	7	86
Turtles	7	8	88

Big South Fork National River and Recreation Area had greater species richness than the comparison sites (Table 64). A greater number of species is expected at BISO because it is significantly larger than the comparison sites. When the natural log transformed species counts for BISO and the comparison sites were plotted against area sampled, the relationship was linear (R^2=1.0) (Figure 45). These comparisons suggest that BISO supports a species richness that is highly comparable, for its size, to other well-protected natural sites in the region.

Table 64. Numbers of herpetofaunal species reported at BISO and at three comparison locations within 85 km, including information about location, area, effort, and sampled habitat for each study. Unique species refers to species unique among the three studies.

	Stephens et al. 2008	Meade 2003	Meade 2005
Location	Big South Fork National River and Recreation Area, Northeast TN/Southeast KY	Cumberland Gap National Historical Park, Northeast TN/Southeast KY	Obed Wild and Scenic River, Central Eastern Tennessee
Area (ha)	50,586	9,712	2,064
Effort	Feb. 2004 - June 2007; coverboards, road cruising, call surveys, constrained & unconstrained area searches, spotting scopes	Jan. - Dec. 2003; coverboards, road cruising, constrained and unconstrained area searches, minnow traps, hoop nets	Oct, 2003 - Aug. 2004; coverboards, constrained and unconstrained searches, call surveys, snake trapping
Habitat	Southwestern Appalachians, Cumberland Plateau, all habitats including fields, forests, streams, wetlands	Southwestern Appalachian, Cumberland Plateau, all habitats including fields, forests, streams, caves, wetlands	Southwestern Appalachian, Cumberland Plateau, all habitats including fields, forests, streams, cliffs, boulder-fields, wetlands
All Species	57	36	33
Salamanders	17	14	10
Anurans	11	11*	9
Snakes	16	8	9
Lizards	6	2	3
Turtles	7	1	2
Unique Species	19	4	3

*One species, eastern spadefoot (*Scaphiopus holbrooki*), reported by Petranka 2005.

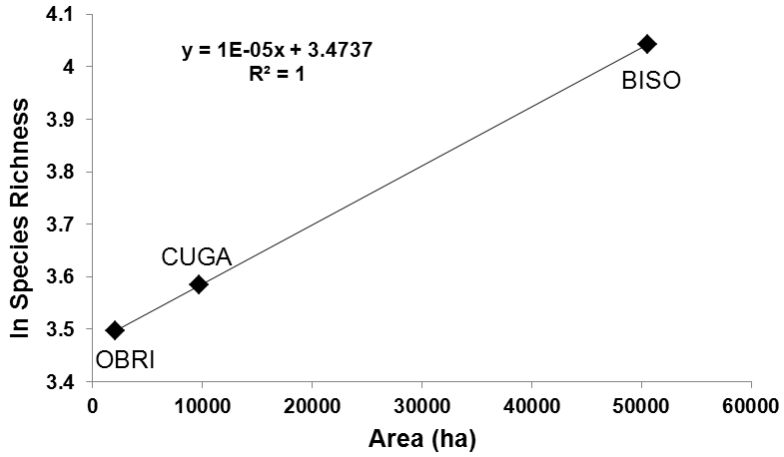

Figure 45. Natural log transformed species richness of herpetofaunal species plotted against area sampled for BISO and two other nearby National Park units in the Cumberland region. OBED=Obed Wild and Scenic River; CUGA=Cumberland Gap National Historical Park.

We ranked the condition of BISO herpetofaunal assemblages as good (Table 65). A high percentage of the expected species were found, and species richness was similar to other well-protected sites on the nearby Cumberland Plateau when area was accounted for. This assessment was based primarily upon species richness. We realize that the density, distribution, and physical condition of animals influence the assessment of condition of herpetofaunal assemblages. However, the efforts to date have been primarily directed at discovering the largest possible number of species and the data preclude more complex analyses. We did not assign a trend to herpetofaunal assemblage condition. A single baseline inventory is insufficient to determine changes in condition over time. The data used to make the assessment was good. Data were collected with significant effort using multiple methods over a multi-year period. Many areas in the park were sampled, although much of the data were collected near roads.

Table 65**.** The condition of BISO reptile and amphibian assemblages was good. The data used to make the assessment was good. No trend was assigned to reptile and amphibian assemblage condition.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Reptile and Amphibian Assemblages		✓	✓	✓
		3 of 3: Good		

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4.11 Freshwater Mussel Assemblages

4.11.1 Relevance and Context

Freshwater mussels are among the most endangered taxonomic groups in North America with over 50% of known species extinct or imperiled (Williams et al. 1993). The southeastern U.S. supports the greatest diversity of freshwater mussel species of any region in the world, and includes around 90% of the species found in North America (Neves et al. 1997). The Cumberland region, containing upper portions of the Tennessee and Cumberland River drainages, has been recognized as a "center of molluscan endemism in North America" (Gordon and Layzer 1989). The true historical mussel richness of the Cumberland River basin is not known, but the river system is known to have historically contained over 90 species, of which at least 11 are presumed extinct, and of which many have been extirpated from significant portions of their original ranges (Gordon and Layzer 1989, Williams et al. 1993, Parmalee and Bogan 1998). The Big South Fork of the Cumberland River, of which the entire free-flowing mainstem exists within BISO, once contained a rich mussel fauna, but was affected by anthropogenic disturbances that reduced species richness. Nonetheless, the river within the park supports "some of the best mussel populations that remain in the Cumberland River system" (Ahlstedt et al. 2003), and recently includes at least 11 species listed as threatened or endangered at the state

or federal level (Table 66). The mussel assemblages of BISO are among the most important natural resources in the park and within the region.

Table 66. Species of freshwater mussels occurring in Big South Fork National River and Recreation Area as evidenced by reports from a recent inventory (I) by Ahlstedt et al. (2003), or release (R) into the river for restoration purposes. References to selected records of historical occurrence in the BSF are provided where: 1=1910-11 (Wilson and Clark 1914), 2=1938-39 (Shoup and Peyton 1940), 3=1947-49 (Neel and Allen 1964), and 4=1985-86 (Bakaletz 1991). The conservation status suggested by Williams et al. (1993) is shown, where: E=endangered, T=threatened, SC=special concern, and CS=considered stable. Also shown are official federal and state listings where: E=endangered, T=threatened, C=candidate, and P=proposed and, in parentheses, F=federal, K=Kentucky, and T=Tennessee.

Scientific Name	Common Name	Occurrence	Historic Records	Cons. Status	Listing
Actinonaias ligamentina	Mucket	R	1,2,3	CS	
Actinonaias pectorosa	Pheasantshell	I	1,3,4	SC	
Alasmidonta atropurpurea	Cumberland elktoe	I	4	E	E(F,K,T)
Alasmidonta marginata	Elktoe	I	1,2	SC	T(K)
Alasmidonta viridis	Slippershell mussel	I	2	T	
Amblema plicata	Threeridge	R		CS	
Cumberlandia monodonta	Spectaclecase	R		T	P(F),E(K)
Cyclonaias tuberculata	Purple wartyback	R	1,3	SC	
Dromus dromus	Dromedary pearlymussel	R	1	E	E(F,K,T)
Ellipsaria lineolata	Butterfly	R	1	SC	
Elliptio crassidens	Elephant ear	I,R	1,3	E	
Elliptio dilatata	Spike	I,R	1,2,3,4	E	
Epioblasma brevidens	Cumberlandian combshell	I,R	1,4	E	E(F,K,T)
Epioblasma capsaeformis	Oyster mussel	R	1,3	E	E(F,K,T)
Epioblasma f. walkeri	Tan riffleshell	I,R	3,4	E	E(F,K,T)
Lampsilis abrupta	Pink mucket	R		E	E(F,K,T)
Lampsilis cardium	Plain pocketbook	I	2,3,4	SC	
Lampsilis fasciola	Wavy-rayed lampmussel	I	1,3,4	CS	
Lasmigona costata	Fluted-shell	I,R	1,2,4	CS	
Leptodea fragilis	Fragile papershell	I,R	1	CS	
Ligumia recta	Black sandshell	I,R	1,2,3,4	SC	
Medionidus conradicus	Cumberland moccasinshell	I	1,4	SC	
Obliquaria reflexa	Threehorn wartyback	R	1	CS	
Pegias fabula	Little-wing pearlymussel	I,R	4	E	E(F,K,T)
Pleurobema clava	Clubshell	I	1	E	E(F,K,T)
Pleurobema cordatum	Ohio pigtoe	R	1	SC	
Pleurobema oviforme	Tennessee clubshell	I	4	SC	E(K)
Pleurobema sintoxia	Round pigtoe	I,R	1,4	CS	
Potamilus alatus	Pink heelsplitter	I,R	1,3,4	CS	
Ptychobranchus fasciolaris	Kidneyshell	I,R	1,3,4	CS	
Ptychobranchus subtentum	Fluted kidneyshell	R	1	SC	C(F),E(K)
Quadrula metanevra	Monkeyface	R		E	
Quadrula p. pustulosa	Pimpleback	I,R	1,2,3,4	CS	
Quadrula quadrula	Mapleleaf	R		CS	
Strophitus undulatus	Squawfoot	I	1,4	CS	
Tritogonia verrucosa	Pistolgrip	I	1,2,4	CS	
Utterbackia imbecillis	Paper pondshell	R		CS	
Villosa iris	Rainbow	I	1,2,4	CS	
Villosa taeniata	Painted creekshell	I	1,2,4	CS	
Villosa trabalis	Cumberland bean	I,R	1,4	E	E(F,K,T)

4.11.2 Threats and Stressors

Freshwater mussels in the park and within the BSF watershed are subject to several current and historical threats and stressors including consumptive use, river impoundment, water quality and substrate degradation, and invasive species. Wilson and Clark (1914) surveyed the Cumberland drainage with the specific goal of inventorying commercially-valuable mussel populations, reporting that the section of the river draining the BSF had commercial harvest for pearls, but not for button manufacture. They reported the two sites sampled in the BSF to be of low commercial value to the button industry, containing among the lowest percentage of commercially-valuable shells among all sites sampled within the drainage (Wilson and Clark 1914). Commercial harvesting for button material had largely ceased by the mid-20th century (Parmalee and Bogan 1998) and consumptive use is not a current threat to BISO mussels. The impoundment of the Cumberland River behind Wolf Creek Dam in the early 1950s had a negative impact on BSF mussel fauna. Dams are among the most important factors causing the loss of native mussel diversity (Williams et al. 1993, Neves et al. 1997). In the lower sections of the BSF, riverine habitat has been altered to a more lentic system, precluding success by many species adapted to free-flowing streams. Furthermore, dams cause changes in the fish assemblages upon which mussels depend and for which they have been specifically adapted (Neves et al. 1997). Lake Cumberland must be considered a permanent stressor on BISO mussel communities. Coal mining has caused extensive mussel habitat degradation in the BSF drainage, including acidification, contamination with metals and chemicals, and sedimentation (Shoup 1940, Shoup and Peyton 1940, Starnes and Starnes 1980, Ahlstedt et al. 2003, Ahlstedt et al. 2008). However, legislation has led to increases in protection of the watershed, and these threats have shown some mitigation in recent years (Ahlstedt et al. 2003, Ahlstedt et al. 2008, elsewhere in this report). The non-native Asian clam (*Corbicula fluminea*) occurs in the BSF drainage, and is widespread and abundant in at least portions of the drainage (ESI 2000, Ahlstedt et al. 2008). Although the mechanisms of competitive interaction between *C. fluminea* and native mussels are poorly understood, evidence suggests that Asian clams have the capacity to negatively impact native fauna (Neves et al. 1998, Yeager et al. 1999).

4.11.3 Resource Knowledge

The historical mussel assemblages of the Big South Fork, prior to anthropogenic disturbance, are imperfectly understood. Estimates of historic species richness are based on museum records and published and unpublished reports. Estimated species lists include species collected within the BSF and species never conclusively reported from the river but which are presumed to have had a high likelihood of being present based on their known occurrence in the drainage nearby. Early records include collections made in 1910-1911 (Wilson and Clark 1914), in 1938-1939 (Shoup and Peyton 1940), and 1947-1949 (Neel and Allen 1964), which combined reported 44 species from the BSF drainage prior to the impoundment of Lake Cumberland. Modern researchers have examined museum records and other literature, and have suggested that from 55-71 species once probably existed in the BSF drainage (Biggins et al. 2001, Ahlstedt et al. 2003).

Several studies have contributed to the understanding of recent mussel assemblages in BISO and in the BSF drainage. During 1985-86 Bakaletz (1991) conducted a comprehensive mussel survey of the BSF within park boundaries, the first study to extensively sample for mussels at multiple locations within the river. Sampling consisted of visual substrate searches at 59 sites within the BSF and tributaries and reported 22 native species, of which three were not reported

in the three studies discussed above (Bakaletz 1991). From 1999-2002, Ahlstedt et al. (2003) conducted comprehensive mussel sampling within BISO with the purpose of documenting the park's mussel fauna for planning and restoration purposes. This effort employed active searching using snorkel and scuba equipment and included moving boulders and digging in the substrate (Ahlstedt et al. 2003). This inventory sampled 39 sites and reported 26 species. From 2006-2008 Ahlstedt et al. (2008) conducted a comprehensive mussel survey of the New River drainage upstream of BISO. Researchers surveyed 78 sites with active searching, including searching with snorkel equipment, overturning boulders, and moving substrate with rakes to search available habitat (Ahlstedt et al. 2008). This effort reported 11 species of native mussel from the New River above BISO boundaries, of which eight were found live, and included an unrecognized species (*Anodontoides denigrada*) which was a new drainage record previously only reported above Cumberland falls (Ahlstedt et al. 2003, Ahlstedt et al. 2008).

Because of the great importance of the BSF and of BISO as a regional mussel resource, restoration and augmentation of native mussels is ongoing in the park. Biggins et al. (2001) identified two primary approaches for mussel releases in the park, including augmentation through the capture, propagation, and release of extant species, and reintroduction, whereby extirpated species would be translocated to the BSF from other suitable locations. From 2002-2004, four federally endangered mussel species were collected from BISO and propagated in facilities at Virginia Tech to create juveniles which were released into suitable habitat within BISO (Mair et al. 2003, NPS unpublished data). Propagation during 2002-2003 was generally successful and resulted in over 50,000 released juveniles (Table 67), and propagation during 2004 was generally unsuccessful and did not result in any releases (NPS unpublished data). In 2008, 300 individuals of four federally endangered or candidate endangered species were translocated into the BSF in BISO (Table 67; NPS unpublished data). These four translocated species had been historically documented (Wilson and Clark 1914, Biggins et al. 2001) from the drainage, but were presumed locally extirpated or extremely limited in abundance in BSF at the time of release (Ahlstedt et al. 2003). In 2010, 20 species were translocated to BISO from the Clinch River in Tennessee (Table 67; NPS unpublished data). Of these species, nine had been reported in BISO by Ahlstedt et al. (2003), and one had been previously released in the park. The 10 remaining species were historically documented species or species that probably occurred in the BSF based on regional records (Biggins et al. 2001).

Table 67. Numbers of mussels released in Big South Fork Nation River and Recreation Area including juveniles propagated from BISO stock and released from 2002-2003, and juveniles and adults translocated into the park from outside locations.

Scientific Name	Common Name	2002-2003 Propagation	2008 Translocation	2010 Translocation
Actinonaias ligamentina	Mucket			6
Amblema plicata	Threeridge			4
Cumberlandia monodonta	Spectaclecase		43	
Cyclonaias tuberculata	Purple wartyback			156
Dromus dromus	Dromedary pearlymussel		19	
Ellipsaria lineolata	Butterfly			50
Elliptio crassidens	Elephant ear			18
Elliptio dilatata	Spike			5
Epioblasma brevidens	Cumberlandian combshell	44,563		
Epioblasma capsaeformis	Oyster mussel		97	508
Epioblasma f. walkeri	Tan riffleshell	8,697		
Lampsilis abrupta	Pink mucket			92
Lasmigona costata	Fluted-shell			2
Leptodea fragilis	Fragile papershell			4
Ligumia recta	Black sandshell			23
Obliquaria reflexa	Threehorn wartyback			2
Pegias fabula	Little-wing pearlymussel	569		
Pleurobema cordatum	Ohio pigtoe			495
Pleurobema sintoxia	Round pigtoe			15
Potamilus alatus	Pink heelsplitter			7
Ptychobranchus fasciolaris	Kidneyshell			34
Ptychobranchus subtentum	Fluted kidneyshell		142	
Quadrula metanevra	Monkeyface			191
Quadrula p. pustulosa	Pimpleback			433
Quadrula quadrula	Mapleleaf			2
Utterbackia imbecillis	Paper pondshell			1
Villosa trabalis	Cumberland bean	1,249		

The current species richness of the BISO mussel assemblage presented in this report includes 40 species (Table 66) that were reported from the most recent comprehensive survey of the park (Ahlstedt et al. 2003), or were introduced into the park for restoration purposes (Table 66, Table 67). Although all translocated species were considered present by definition, some species not known from other recent sources were released in small numbers (i.e. < 10 individuals) (Table 67), and therefore, the existence of viable populations of these species in BISO is questionable. Of the 40 species considered present, 13 (33%) were officially listed as threatened or endangered at the state or federal level (Table 66). Twenty-four (60%) of the 40 species present were considered endangered, threatened or of special concern by Williams et al. (1993). Of the 26 species reported from natural persistence by Ahlstedt et al. (2003), eight (31%) were officially listed as threatened or endangered at the state or federal level (Table 66).

4.11.4 Methods

We made rough comparisons between species richness of current or recent assemblages to estimated richness of historical mussel assemblages. Many changes have occurred in nomenclature and taxonomy of mussels. Within this report, we used the synonymy presented by

Parmalee and Bogan (1998). Because estimates of historical richness are uncertain, we provided these comparisons only as broad qualitative indicators of faunal change.

We used the data presented by Ahlstedt et al. (2003), and Ahlstedt et al. (2008) to determine basic distribution of species richness across sampling locations, and to calculate basic statistics about the occurrence and capture rate of individual species. For these analyses, we excluded reports of relic shells, and included only living individuals or freshly dead shells.

4.11.5 Data

Estimates of historical richness were taken from early primary sources and from recent published reports that summarized early records.

For describing and analyzing the current richness of the park and drainage, we used recent reports by Ahlstedt et al. (2003, 2008) for the BSF and tributaries and for the New River and tributaries. Although we considered mussel releases in BISO when reporting the current number of species possibly present (Table 66), and for qualitative discussions of trend, we did not use these data to determine distribution, richness, or abundance of assemblages and species. The monitoring of augmented and restored populations is in an early ongoing phase and success is not well-known at the time of this report. Therefore for determining current condition, we considered the best available data on extant mussel species that had persisted naturally in the BSF drainage.

4.11.6 Reporting Areas

We reported the condition of BISO mussel assemblages for the entire park. Although mussels and quality mussel habitat are not distributed evenly throughout the park or BSF watershed, knowledge of historical mussel distributions within smaller tributaries is poor. Therefore, we chose to present mussels in a single category, and believe that, within BISO, the main stem of the BSF contains the most important and valuable habitat.

4.11.7 Condition and Trend

Condition

Although the original mussel fauna of the BSF within BISO is not well-understood, a marked decrease in species richness over the course of the 20th century is clearly evident. Even using a conservative estimate—37 species reported from two collection sites in the BSF in 1910-11 compared to 26 species reported from multiple collection sites in 1999-2002—at least 30% of the original species had probably been lost by 2002 (Wilson and Clark 1914, Ahlstedt et al. 2003). In actuality, the BSF drainage is believed to have supported from 55-71 species (Parmalee and Bogan 1998, Biggins et al. 2001, Ahlstedt et al. 2003), suggesting that from 53-63% of species once extant had been extirpated or were extremely rare in the BSF by 2002. At least seven mussel species from the genus *Epioblasma*, which had historically been reported from within or near the BSF, are probably extinct range-wide (Williams et al. 1993). This marked reduction in faunal richness in the BSF is consistent with observations elsewhere within the Cumberland and Tennessee River drainages and within the southeastern U.S. generally (Williams et al. 1993, Neves et al. 1997).

In recent surveys within the BSF drainage, the main stem of the Big South Fork supported the greatest richness of mussel species, with as many as 22 species noted from a single location and eight locations with at least 15 species (Figure 46). The richest locations occurred from approximately 15 km downstream of the confluence of the New and Clear Fork rivers, downstream to around 15 km above the impoundment-influenced segment of the river. Among the locations sampled on main flows of the Clear Fork and New River, the Clear Fork exhibited greater richness, with between four and eight species reported from each of the five sampling locations on the main river (Figure 46). The New River was sampled primarily outside BISO boundaries, and exhibited relatively low richness with from two to five species reported from only four locations on the main river (Figure 46). The tributaries of the main rivers had lower richness, with between one and six species reported from only five of 20 tributaries or tributary basins sampled within the BSF drainage (Figure 47).

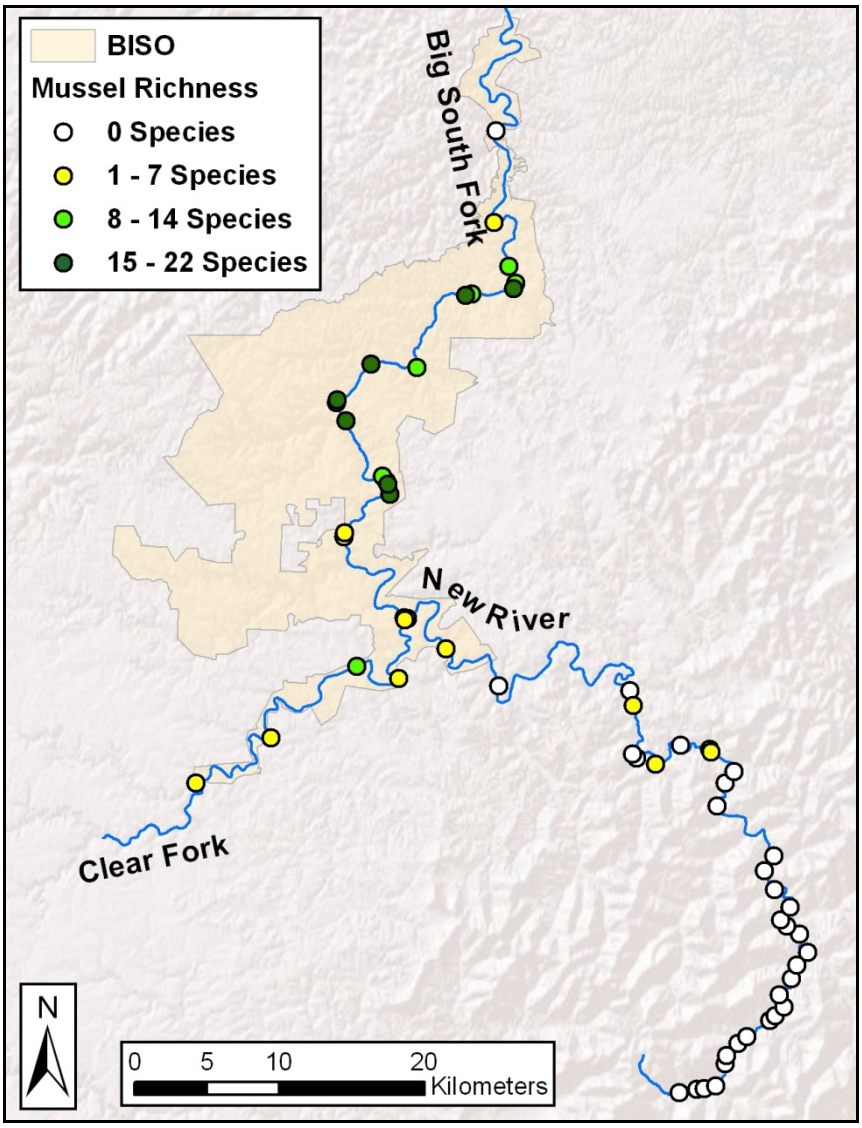

Figure 46. Species richness of freshwater mussels at sampling locations on the main flows of the Big South Fork Cumberland, New, and Clear Fork Rivers, 1999-2008. Where sample location symbols overlap, richer locations are shown uppermost.

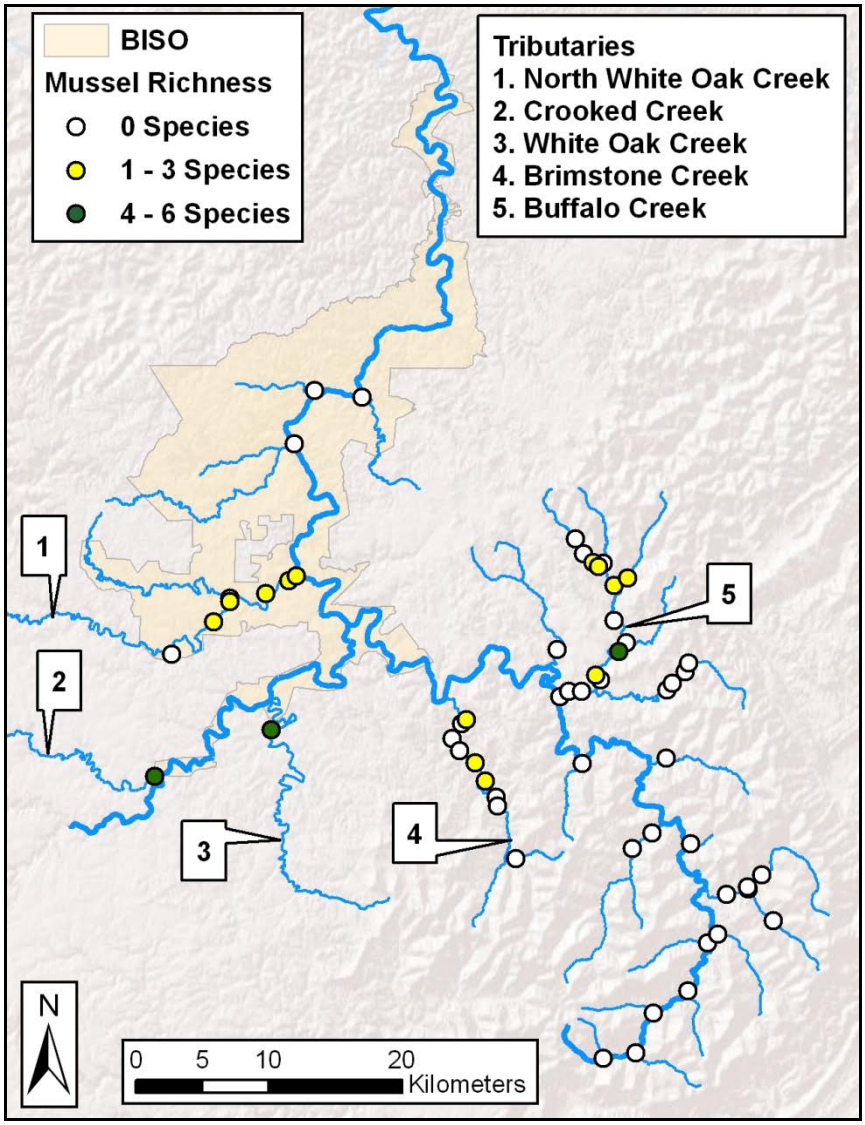

Figure 47. Species richness of freshwater mussel assemblages at sampling locations on tributaries of the Big South Fork Cumberland, New, and Clear Fork Rivers, 1999-2008. Samples that appear to be located on the main-stem rivers were collected in tributaries near the confluence. Names are provided for tributaries where mussels were found. Where sample location symbols overlap, richer locations are shown uppermost.

Twenty-seven species were reported from samples collected at 117 locations within the BSF drainage in recent comprehensive inventories (Table 68). The round pigtoe (*Pleurobema sintoxia*) was the most numerous species among the samples with 1,907 individuals reported from 14 locations (Table 68). The plain pocketbook (*Lampsilis cardium*) was the most widespread among the samples and was reported from 28 locations (Table 68). Eight species were reported from five or fewer locations, and five (*Alasmidonta marginata, Elliptio crassidens, Leptodea fragilis, Pleurobema clava, and P. oviforme*) were reported only as single individuals (Table 68). In general, fewer species were reported from tributaries (including Clear Fork and New River) than were reported from the main BSF, despite the greater number of locations sampled in the tributaries. Only two species (*Alasmidonta atropurpurea*, and

Anodontoides denigrada, an unrecognized species) occurred more commonly in tributary samples than in BSF samples, and only *A. denigrada* was reported solely from tributary samples (Table 68).

Table 68. Species of mussels reported from the Big South Fork drainage during two comprehensive mussel surveys, 1999-2002 and 2006-2008, showing total number of individuals observed, the number of sites where species were observed, and the mean catch per unit effort (CPUE) in number observed per hour among the sites where each species was observed. Occurrence and CPUE data are shown separately for samples taken in the main stem of the BSF and samples collected in tributaries, including the New and Clear Fork rivers. Species in bold were found only within BISO park boundaries.

			Sites Found		Mn. CPUE (obs/hr)	
Scientific Name	**Common Name**	**Total**	**BSF (N=19)**	**Tribs (N=98)**	**BSF**	**Tribs**
Actinonaias pectorosa	**Pheasantshell**	229	14	0	0.97	
Alasmidonta atropurpurea	Cumberland elktoe	365	6	15	0.50	7.73
Alasmidonta marginata	**Elktoe**	1	1	0	0.18	
Alasmidonta viridis	**Slippershell mussel**	4	2	0	0.29	
*Anodontoides denigrada**		20	0	4		3.33
Elliptio crassidens	**Elephant ear**	1	1	0	0.14	
Elliptio dilatata	Spike	1202	16	8	3.45	1.55
Epioblasma brevidens	**Cumberlandian combshell**	261	10	0	0.69	
Epioblasma f. walkeri	**Tan riffleshell**	113	6	0	0.65	
Lampsilis cardium	Plain pocketbook	500	16	12	1.67	0.86
Lampsilis fasciola	Wavy-rayed lampmussel	329	15	12	1.50	1.6
Lasmigona costata	Fluted-shell	563	16	11	1.30	4.15
Leptodea fragilis	**Fragile papershell**	1	1	0	0.14	
Ligumia recta	**Black sandshell**	47	9	0	0.32	
Medionidus conradicus	**Cumberland moccasinshell**	16	5	0	0.49	
Pegias fabula	**Little-wing pearlymussel**	107	7	0	1.19	
Pleurobema clava	**Clubshell**	1	1	0	0.18	
Pleurobema oviforme	**Tennessee clubshell**	1	1	0	0.33	
Pleurobema sintoxia	**Round pigtoe**	1907	14	0	3.69	
Potamilus alatus	**Pink heelsplitter**	772	16	0	3.39	
Ptychobranchus fasciolaris	**Kidneyshell**	131	15	0	0.46	
Quadrula p. pustulosa	**Pimpleback**	879	15	1	3.33	0.20
Strophitus undulatus	**Squawfoot**	131	10	1	0.41	0.40
Tritogonia verrucosa	**Pistolgrip**	162	10	0	1.38	
Villosa iris	Rainbow	102	8	7	0.57	1.20
Villosa taeniata	Painted creekshell	101	12	3	0.46	2.15
Villosa trabalis	**Cumberland bean**	46	7	0	0.36	

*Unrecognized species

We ranked the quality of BISO mussel assemblages as fair (Table 69). The mussel fauna has been significantly reduced from its historical diversity, and this is consistent with the status of mussel assemblages throughout the southeastern U.S. (Williams et al. 1993, Neves et al. 1997). Freshwater mussels are among the most imperiled taxa of aquatic organisms worldwide. In one sense, the status of BISO mussel assemblages, and mussel assemblages generally, might be viewed as poor. However, because BISO is large and enjoys a high level of habitat protection, and because it contains one of the most diverse extant assemblages of endemic Cumberlandian

mussel species, the status of mussels in the park might be viewed as good. The ranking of fair is meant to convey the high value of this resource to the park while highlighting the great need for continued conservation and management. The quality of the data used to make this assessment was good. Although historic data is incomplete for the park and for the region, BISO has benefited from recent comprehensive surveys in the park and in the BSF watershed. These surveys have provided a reasonably detailed modern baseline of mussel distribution and abundance in the park and in the New River watershed.

We ranked the trend of BISO mussel assemblages as improving (Table 69). This trend is based partially upon the existence of an active mussel restoration program in the park. Although the success of restoration activities is not well-known at the time of publishing, the addition of rare, endangered, and previously extirpated species has increased the species richness of BISO mussel assemblages at least temporarily. Furthermore, improvements in water quality and in fish assemblage richness in recent decades should have a positive impact on mussels.

Table 69. The condition of BISO freshwater mussel assemblages was fair. The trend of mussel condition was improving. The data used to make this assessment was good.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Mussel Assemblages	⇧	✓	✓	✓
		3 of 3: Good		

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4.12 Macroinvertebrate Assemblages

4.12.1 Relevance and Context

Freshwater aquatic macroinvertebrates form diverse assemblages and perform a variety of important ecosystem roles (Wallace and Webster 1996). Streams of the southern Appalachians are physically and chemically unique, and possess a rich and highly endemic macroinvertebrate fauna (Morse et al. 1993). The richness, trophic diversity, and environmental sensitivity of macroinvertebrate assemblages, as well as the relative ease with which they can be sampled, make them good indicators of biological integrity (Barbour et al. 1999). Big South Fork National River and Recreation Area contains over 760 km of free flowing streams, ranging from first the seventh order, including the entire free-flowing portion of the Big South Fork of the Cumberland River.

4.12.2 Threats and Stressors

General threats to aquatic macroinvertebrates include contamination of water with nutrients or chemicals, changes in pH, flow, oxygen, or temperature regimes, increased sediment, loss of woody debris, and changes in riparian flora assemblages (Morse et al. 1993). Human activities, most importantly coal mining, have negatively impacted water quality and macroinvertebrate assemblages in the BSF drainage for many years (Shoup 1940, Shoup and Peyton 1940, O'Bara et al. 1982, Parker 2003). Acid mine drainage and sedimentation from mining and forestry practices have been particular problems for BISO watersheds, and tributaries from the eastern side of the BSF have suffered greater levels of perturbation (O'Bara et al. 1982, Parker 2003).

4.12.3 Resource Knowledge

Several studies have sampled macroinvertebrates in the BISO. Shoup and Peyton (1940) collected several types of invertebrates, but only a few were insects. O'Bara et al. (1982) conducted systematic sampling of fishes and macroinvertebrates in park tributaries and reported over 215 taxa. Parker (2003), of the USGS, performed comprehensive macroinvertebrate sampling in BISO and data from this study are the source of the most current description of the assemblage at the time of this report.

Parker (2003) sampled BISO macroinvertebrate assemblages from 1998 – 2001, collecting over 18,000 individuals from 60 samples at 26 sites, and reported at least 414 distinct taxa from his efforts. Of the 414 distinct taxa, 205 were identified to the species level. Two new undescribed

species of Trichoptera were found during the survey. Sample richness ranged from 18 to 80 taxa and total sample size ranged from 54 to 635 individuals. Parker (2003) identified eight annual and 18 rotating sampling sites. During the course of the inventory, each site was sampled from one to four times. Each sample included representatives from each observed taxon collected using kick-nets, D-frame dip nets, fine-mesh samplers, detritus bucket samplers, sand samplers, and visual searches (Parker 2003). The USGS team, assisted by BISO staff, collected all samples. Sampled specimens were identified in the laboratory to lowest possible taxonomic level. The USGS identified 1998 – 2000 samples, and 2001 samples were identified by an independent contractor (Parker 2003).

Parker (2003) calculated a variety of metrics and indices, and conducted analyses of the BISO macroinvertebrate and sample site data. Parker (2003) used existing water quality and landscape data to place an *a priori* subjective quality ranking on each site, independently of macroinvertebrate sampling results. For analysis of the macroinvertebrate sampling data, many of the metrics and indices were based upon bioassessment protocols used by the state of North Carolina. These included categorical ratings based on overall taxa richness and upon Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, and numerical indices calculated using abundance classes and tolerance values for individual taxa. Parker (2003) calculated a numerical Final Biotic Index (BI) combining the results of the EPT categorical ranking and the standard Biotic Index values. These metrics were calculated for the each of the 60 individual samples, and summarized by averaging the values by the 26 sample sites. Samples and sites were also analyzed by cluster analyses of site attributes, sample summary attributes, and sample species composition (Parker 2003).

The interpretation of the results of the categorical rankings, Biotic Index assessments, and community based metrics, differed among methods. Parker (2003) concluded that the EPT richness, the Final BI score, and number of highly intolerant species were the best measures of site disturbance because these metrics were best at recovering the ranks assigned by the *a priori* subjective site assessments. These different measures are not independent (e.g. most highly intolerant species are also EPT species) and are not suitable for combining into a single multi-metric index (Parker 2003). Parker (2003) suggested that these measures could be considered individually or together for monitoring purposes, with declines in all three metrics or declines of pre-determined magnitude of a single metric indicating cause for concern. He further stated that the Final BI, when applied to data collected continuously for at least five to seven years, has proven very sensitive to changes in community structure (Parker 2003).

4.12.4 Data

For this report, we summarized the data presented in the tables, figures, narrative, and appendices of the Parker (2003) report. These data, collectively, were termed the analysis dataset.

4.12.5 Reporting Area

We reported macroinvertebrate assemblage condition by the same reporting area designations used for water quality and fish assemblage conditions (Figure 33). These reporting areas are defined by 10 or 12-digit USGS HUC designations.

4.12.6 Methods

To assess the quality of BISO macroinvertebrate assemblages, we summarized results previously calculated by Parker (2003). Among the faunal inventories used in this report, the Parker (2003) macroinvertebrate inventory was unique because it calculated a variety of metrics and indices designed to assess resource condition. Of the three metrics Parker (2003) considered to be the most useful for monitoring changes and assessing condition, we chose to use the Final BI value and its corresponding bioclassification to apply condition rankings to BISO reporting areas. The index is informed by the number of EPT taxa as well as the abundance and tolerance values of all taxa in the samples. Tolerance values represent a taxon's sensitivity to environmental disturbance. Parker (2003) used tolerance values developed for the North Carolina rapid bioassessment protocols, and also calculated values for some other taxa not included on that list. Parker (2003) provided mean values by site for the 26 sites where samples were collected. We further summarized these mean values by reporting area. We assigned each site to the appropriate reporting area and calculated the mean of Parker's (2003) site means for each reporting area.

We used the summarized data to determined macroinvertebrate assemblage condition and data quality for each reporting area. The mean Final BI was a numerical score from one to five, with narrative classifications of: excellent, good, good/fair, fair, and poor (Table 70). In this report, we interpreted a classification of good/fair as fair. EPT richness values alone also can be used with the same narrative classification scheme (Table 70). We present EPT richness values and classifications for reference, although we did not use them to rank condition. Data quality was assigned to each reporting area based on the number of sites sampled within the area. Good data quality was assigned to areas where two or more sites were sampled, and fair data quality was assigned to areas where only one site was sampled. Reporting areas without sampling effort were not ranked.

Table 70**.** Final BI score range, EPT taxa richness range, and narrative bioclassification used by Parker (2003) in a macroinvertebrate inventory of Big South Fork National River and Recreation Area. Mean Final BI scores were used in this report to assign condition ranks to macroinvertebrate assemblages.

Bioclassification	Final BI Range	EPT Richness Range
Excellent	4.50 - 5.00	> 35
Good	3.50 - 4.49	28 - 35
Fair/Good	2.50 - 3.49	19 - 27
Fair	1.50 - 2.49	11 - 18
Poor	0.00 - 1.49	0 - 10

4.12.7 Condition and Trend

At the individual sample level, Final BI scores resulted in 27 Good ratings, 29 Fair/Good ratings, four Fair ratings, and no Excellent or Poor ratings (Parker 2003). Summarized at the site level, the mean Final BI scores resulted in 12 Good ratings, and 14 Fair/Good ratings (Parker 2003). Table 71 summarizes effort and selected diversity and bioassessment values by reporting area.

Table 71. Number of locations sampled, number of individual samples collected, mean species richness, mean number of individuals (N), mean Shannon's diversity index (H'), mean Final BI score, and mean EPT richness, by reporting area from a macroinvertebrate inventory conducted at BISO 1998 – 2001. Mean values are the means of the site means presented by Parker (2003).

Reporting Area	HUC	Locations	Samples	Sp. Richness	N	H'	Final BI	EPT Richness
White Oak Cr.	512310401	1	3	54	279	3.30	2.90	17
Clear Fork R.	513010402	3	8	58	367	3.46	3.55	25
New R.	513010403	2	6	49	334	3.18	3.02	20
Sinking Cr.	513010407	0	0	N/A	N/A	N/A	N/A	N/A
North White Oak Cr.	513010404	3	5	53	269	3.37	4.02	28
Bandy Cr.	51301040503	2	3	56	463	3.22	3.63	27
Bear Cr.	51301040506	1	3	27	84	2.91	2.70	11
Blair Cr.	51301040509	2	6	41	275	3.05	3.43	20
No Business Cr.	51301040504	2	4	57	340	3.30	3.22	20
Pine Cr.	51301040501	1	4	43	328	3.11	2.73	16
Roaring Paunch Cr.	51301040507	1	4	38	162	3.13	3.40	18
Rock Cr.	51301040508	3	3	36	201	2.82	3.17	16
Station Camp Cr.	51301040502	3	6	42	324	2.88	3.62	21
Williams Cr.	51301040505	2	5	59	383	3.37	3.61	27

Based on the mean of the mean site Final BI scores, five reporting areas were rated as Good and eight were rated as Fair/Good, corresponding to NRCA condition rankings of good and fair, respectively (Table 72). Data quality was good for nine of the reporting areas, and fair for four of the reporting areas (Table 72). The EPT richness metric was more conservative than the Final BI, ranking all sites the same or one rank lower than Final BI rating. No trends were assigned for any of the reporting areas. Many of eastern tributaries of the BSF were ranked as fair, and many of the western tributaries were ranked as good (Figure 48). Many of the reporting areas occurring largely within BISO boundaries were ranked as good (Figure 48), resulting in part because the southern main-stem BSF sample sites tended to be rated as good.

Table 72. The resource condition rank and data quality of macroinvertebrate assemblages, by reporting area, for Big South Fork National River and Recreation Area. Good conditions are indicated by green highlighting, fair conditions are indicated with yellow highlighting, and poor condition are indicated with red highlighting. Data did not receive a temporal quality check because data were over five years old. No trend was assigned to any of the reporting area conditions. Condition rank was based upon Final BI class, though EPT richness classification is also presented for reference.

Name	EPT Richness Rating	Final BI Class	NRCA Rank	NRCA Data Quality	NRCA Trend
White Oak Cr.	Fair	Fair/Good	Fair	Poor	None
Clear Fork R.	Fair/Good	Good	Good	Fair	None
New R.	Fair/Good	Fair/Good	Fair	Fair	None
Sinking Cr.	N/A	N/A	Not Ranked		
North White Oak Cr.	Good	Good	Good	Fair	None
Bandy Cr.	Fair/Good	Good	Good	Fair	None
Bear Cr.	Fair	Fair/Good	Fair	Poor	None
Blair Cr.	Fair/Good	Fair/Good	Fair	Fair	None
No Business Cr.	Fair/Good	Fair/Good	Fair	Fair	None
Pine Cr.	Fair	Fair/Good	Fair	Poor	None
Roaring Paunch Cr.	Fair	Fair/Good	Fair	Poor	None
Rock Cr.	Fair	Fair/Good	Fair	Fair	None
Station Camp Cr.	Fair/Good	Good	Good	Fair	None
Williams Cr.	Fair/Good	Good	Good	Fair	None

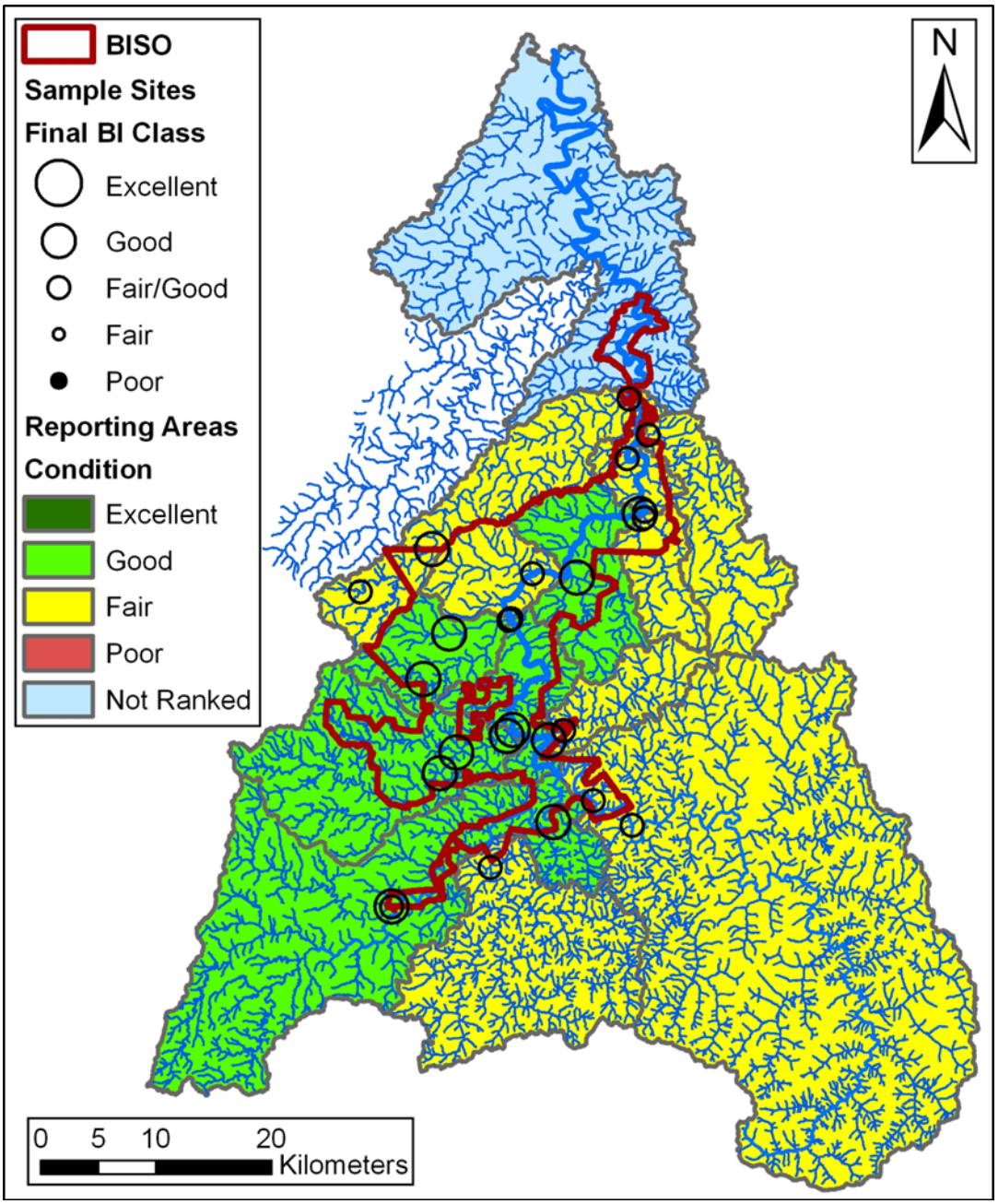

Figure 48. Sample site macroinvertebrate habitat condition rating based from Parker's (2003) mean site Final BI score, and reporting area macroinvertebrate assemblage NRCA condition based on reporting area mean Final BI score.

Evidence suggests that BISO contains a rich macroinvertebrate fauna indicating fair to good habitat throughout the park and larger watershed. An excellent comprehensive macroinvertebrate inventory provides information about these assemblages. The NRCA condition rankings of fair may be conservative because these values were rated as "Good/Fair" on the Final BI bioclassification scale. Data were collected using a variety of methods throughout the park and comprehensively analyzed. Fair and poor data quality rankings occured because sample effort was low for some reporting areas, and because all data were more than

five years old. Therefore these rankings do not reflect the quality of the macroinvertebrate survey work, which was excellent. Reporting areas used for the NRCA were defined after the macroinvertebrate inventory was completed, and the age of the survy obviously has not bearing on the quality of the original work

4.12.8 Literature Cited

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4.13 Landscape Dynamics

Landscape dynamics is a broad category that can potentially utilize a variety of metrics or measures to describe land characteristics and how they change over time. It falls within the category of landscape change—one of the vital signs assigned to the APHN. Multiple processes can affect resources in a park, which in turn may depend on temporal and spatial scale of consideration (Kotliar and Wiens 1990). One of the most relevant considerations associated with landscape dynamics at BISO is habitat loss and fragmentation, which, though independent of each other, often happen in association and can have a tremendous impact on biodiversity and other natural resources (Fahrig 2003, Bender et al. 1998). Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself. The range of a particular species, for example, may be larger than the protected area of a park unit, in which case the periphery area can play a

large role in determining species composition within the park. In addition, changes in the landscape can alter communities over vastly different temporal scales such that effects of a disturbance may not be apparent for many years (Kuussaari et al. 2009). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of the biological habitat in the park (Gross et al. 2009).

It is often difficult to relate large scale landscape monitoring into succinct and specific land management goals at the level of a park unit. Several studies have attempted to do this by identifying land use change thresholds that generally affect certain changes in ecosystems. Stranko et al. (2008), for instance, found that brook trout (*Salvelinus fontinalis*) populations in Maryland generally did not occur in watersheds with greater than 4% impervious surface. In a review of habitat fragmentation and its effects on species populations, Andrén (1994) notes that patch size and isolation become important only when 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).

For the most part, BISO is located in a relatively rural area, though it is alongside several small towns such as Oneida, Jamestown, and Allardt in Tennessee, and Pine Knot, Whitley City, and Stearns in Kentucky. The population of the largest of these towns, Oneida, is <4,000. Gross et al. (2009) point out that even though natural disturbances may alter landscapes in various ways, they are generally temporary and return to habitat area. Conversely, anthropogenic disturbances such as agriculture, forest clearing, and urbanization often result in a permanent loss of habitat. In particular, infringements on the boundary of the park can serve as vectors for invasive species, contribute to increased air and depositional pollution, or facilitate water quality degradation.

4.13.1 NPScape and Landcover Analyses

In order to document land use change and provide landscape-scale information, the NPS created a series of analyses outlines and data products called NPScape. One of the main goals of NPScape is to facilitate natural resource management at a landscape scale for individual park units, and allow users to manipulate the data and products in such a way to meet their own needs (Gross et al. 2009). NPScape data focuses on six main landscape measures: landcover, housing, roads, population, pattern, and conservation status. Landscapes were analyzed at two main scales defined by a 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 1992 and 2001. 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 73. 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 74 depicts landcover proportions for 1992 and 2001 at each buffer width, as well as the change product between those two time periods, adjusted for their different classifications schemes. For the 1992 NLCD classification, the proportion of forested land decreases slightly across scales of analysis from BISO without a buffer (98.7% forested), to the 3 km buffer (96.4%), and finally to the 30 km buffer (89.5%). In turn, relative proportions of pasture/hay and row crop classification increase across scales. In 2001, forested proportions are similarly decreasing across scales, though they are overall lower (Figure 49). The change product shows relatively negligible change within the park unit, while the 3 km buffer shows equivalent conversion of natural areas to both agriculture and urban use. The 30 km buffer class shows a 1.2% conversion from natural areas to agricultural and urban uses, combined, and a moderate gain in natural land use from previously converted areas. Expectedly, as the buffer width increases and BISO comprises a lower proportion of the area, the U-Index increases, representing a more human-influenced landscape. Figure 50 depicts the proportion of natural area within the BISO landscape compared to other NPS units.

Table 73. Aggregation of NLCD landcover classes into general categories of converted and natural land. [Source: Gross et al. 2009]

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

Table 74. Landcover area and proportions of BISO for each buffer class based on two separate NLCD classifications and change product, as aggregated by Gross et al. (2009).

	-30 km buffer-		-3 km buffer-		-no buffer-	
NLCD 1992	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	67.1	0.9	4.7	0.4	3.5	0.7
Low Intensity Residential	33.9	0.4	2.2	0.2	0.1	0.0
High Intensity Residential	2.1	<0.1	0.0	0.0	0.0	0.0
Commercial/Industrial/Transportation	22.2	0.3	1.4	0.1	0.3	0.1
Quarries/Strip Mines/Gravel Pits	4.0	<0.1	0.1	<0.1	0.0	0.0
Transitional	16.6	0.2	1.0	0.1	0.0	0.0
Deciduous Forest	4420.7	56.9	509.0	45.1	216.2	43.6
Evergreen Forest	920.7	11.9	236.4	20.9	119.6	24.1
Mixed Forest	1603.3	20.7	343.1	30.4	153.9	31.0
Pasture/Hay	513.1	6.6	25.7	2.3	1.2	0.2
Row Crops	123.2	1.6	4.3	0.4	0.3	0.1
Urban/Recreational Grasses	28.0	0.4	1.0	0.1	0.0	0.0
Woody Wetlands	6.9	0.1	0.5	0.0	0.5	0.1
Emergent Herbaceous Wetlands	0.7	<0.1	0.0	0.0	0.0	0.0
NLCD 2001						
Open Water	78.1	1.0	6.2	0.6	4.7	0.9
Developed Open Space	358.7	4.6	4.3	0.4	11.2	2.2
Developed Low Intensity	96.6	1.2	6.4	0.6	0.5	0.1
Developed Medium Intensity	24.8	0.3	1.5	0.1	0.1	0.0
Developed High Intensity	4.2	0.1	0.1	0.0	0	0.0
Barren Land	29.8	0.4	2.7	0.2	1.0	0.2
Deciduous Forest	4734.3	61.0	623.7	57.2	269.9	53.9
Evergreen Forest	133.6	1.7	27.5	2.5	15.2	3.0
Mixed Forest	1031.4	13.3	330.2	30.3	184.5	36.9
Scrub/Shrub	20.3	0.3	2.0	0.2	0.3	0.1
Grassland/Herbaceous	481.0	6.2	50.4	4.6	6.7	1.3
Pasture/Hay	650.3	8.4	34.7	3.2	0.9	0.2
Cultivated Agriculture	112.5	1.4	0.1	0.0	0.1	0.0
Woody Wetlands	6.8	0.1	1.5	0.1	0.6	0.1
Emergent Herbaceous Wetlands	0.1	<0.1	<0.1	<0.1	4.7	0.9
NLCD Change						
--Unchanged--						
Converted	1153.0	14.9	80.1	7.1	12.5	2.5
Natural	6494.9	83.7	1043.8	92.4	482.8	97.4
--Changed--						
Natural to Agriculture	62.7	0.8	2.7	0.2	0.1	<0.1
Natural to Urban	30.5	0.4	2.7	0.2	0.4	0.1
Agriculture to Urban	2.8	0.0	0.0	0.0	0.0	0.0
Converted to Natural	18.8	0.2	0.2	<0.1	0.1	<0.1
U-Index	**--0.16--**		**--0.08--**		**--0.03--**	

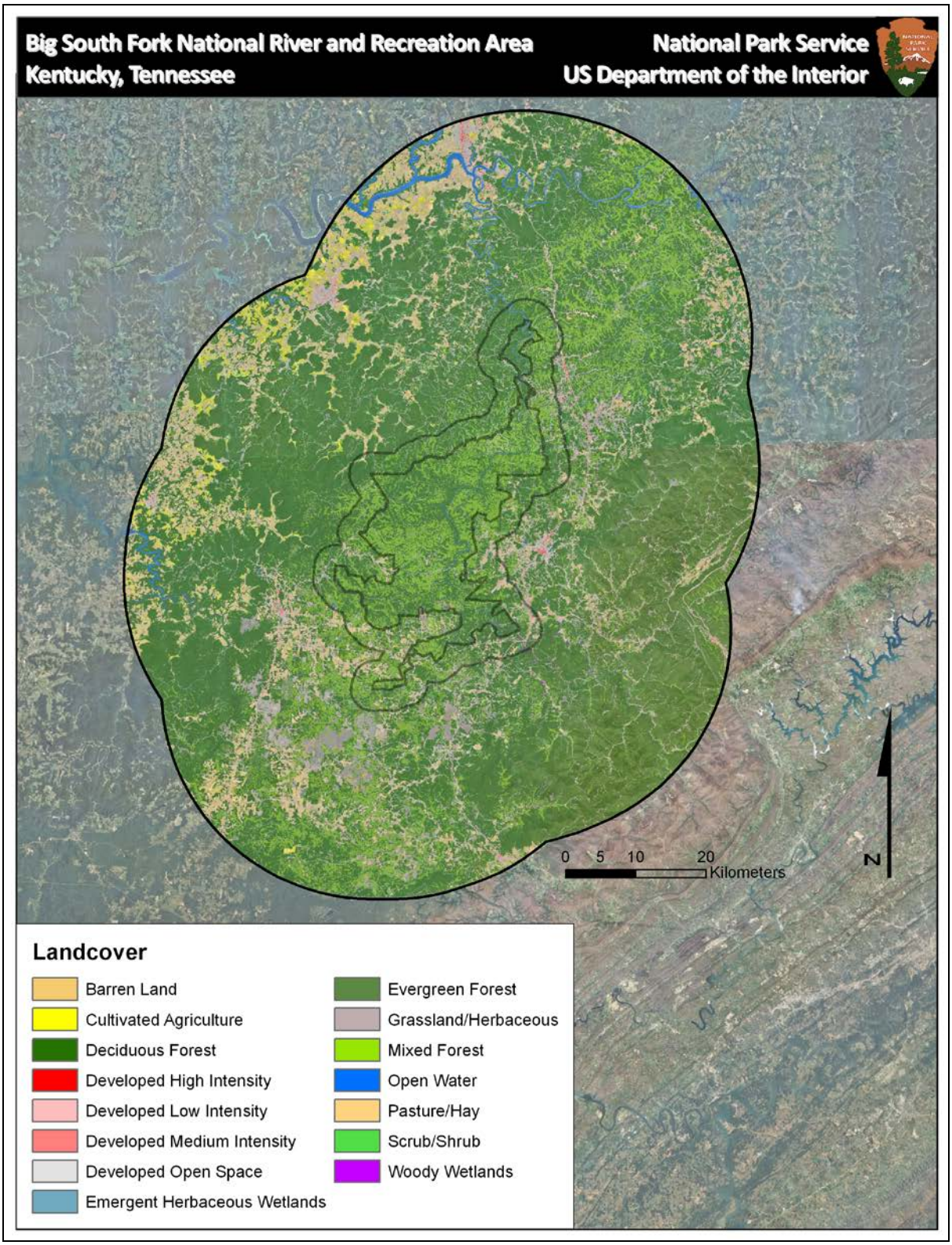

Figure 49. NPScape landcover product showing 2001 NLCD classification for BISO with 30 km buffer.

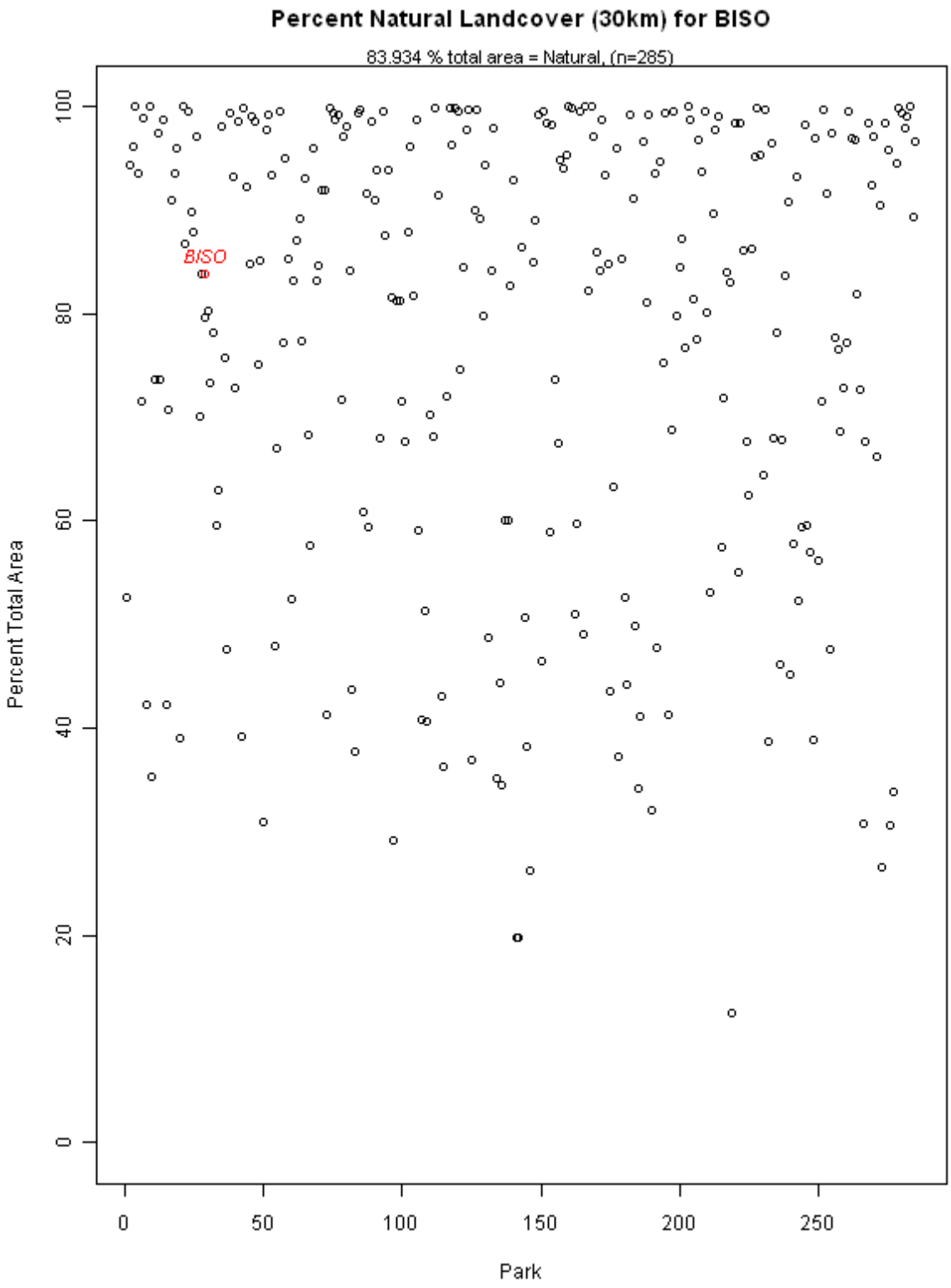

Figure 50. NPScape landcover product showing percent natural landcover of BISO relative to other NPS units. The x-axis is a placeholder index representing other NPS units.

LANDFIRE

Another source of landcover information is the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) Existing Vegetation Type (EVT) dataset, which includes several national data products. The landcover map is based on mid-scale ecological system classifications outlined by Comer et al. (2003). LANDFIRE, despite being classified at a 30m resolution, is mainly intended at a large landscape-scale such as at a state or sub-regional level. Figure 51 depicts the LANDFIRE classification for the 30 km buffer at BISO. Table 75 shows the amount and proportions of 25 landcover classes in BISO with 3km and 30km buffer widths, for which, at each of the buffer widths, the most abundant classes are the Allegheny-Cumberland Dry Oak Forest and Woodland and the South-Central Interior Mesophytic Forest. Within the park boundary alone, these two classes comprise almost 90% of the landcover. Calculation of U-indices at each buffer class show practically identical proportions as those of NLCD data. Story et al. (unpublished) caution, however, that landcover analysis revealed that LANDFIRE data tends to focus on the predominant fuel type in an area, possibly resulting in an overestimation of that type of landcover. This effect is likely minimal, however, because of the consistent U-index with NLCD classification.

Table 75. Landcover area and proportions of BISO based on LANDFIRE classification. Data is presented for two buffer widths and no buffer. '*' depicts 'converted' landcover used to calculate U-index.

	-30 km buffer-		**-3 km buffer-**		**-no buffer-**	
LANDFIRE	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	82.5	1.1	7.5	0.7	5.8	1.2
Developed-Open Space*	357.6	4.6	42.5	3.8	11.2	2.3
Developed-Low Intensity*	95.8	1.2	6.4	0.6	0.5	0.1
Developed-Medium Intensity*	24.5	0.3	1.5	0.1	0.1	<0.1
Developed-High Intensity*	4.2	0.1	0.1	<0.1	-	-
Barren	29.7	0.4	2.7	0.2	1.0	0.2
Agriculture-Pasture and Hay*	693.7	9.0	39.9	3.5	1.2	0.2
Agriculture-Cultivated Crops and Irrigated Agriculture*	111.4	1.4	0.1	<0.1	0.1	<0.1
Southern Interior Low Plateau Dry-Mesic Oak Forest	47.6	0.6	-	-	-	-
Southern Appalachian Northern Hardwood Forest	55.5	0.7	-	-	-	-
Southern Appalachian Oak Forest	413.7	5.3	-	-	-	-
Allegheny-Cumberland Dry Oak Forest and Woodland	2979.4	38.5	739.6	65.5	339.6	68.5
Southern and Central Appalachian Cove Forest	72.3	0.9				
South-Central Interior Mesophytic Forest	2223.3	28.7	202.5	17.9	102.2	20.6
Southern Appalachian Low-Elevation Pine Forest	21.4	0.3	6.4	0.6	3.3	0.7
Southern Ridge and Valley/Cumberland Dry Calcareous Forest	17.5	0.2	3.8	0.3	1.9	0.4
Central Interior Highlands Calcareous Glade and Barrens	4.5	0.1	0.1	<0.1	0.1	<0.1
Bluegrass Savanna and Woodland	0.2	-	-	-	-	-
Central Interior and Appalachian Floodplain Systems	7.7	0.1	1.0	0.1	0.8	0.2
Central Interior and Appalachian Riparian Systems	29.0	0.4	7.4	0.7	4.9	1.0
Central Interior and Appalachian Swamp Systems	1.4	<0.1	0.5	<0.1	0.3	0.1
Ruderal Upland-Old Field	227.4	2.9	22.8	2.0	2.1	0.4
Ruderal Forest-Northern and Central Hardwood and Conifer	247.1	3.2	44.5	3.9	20.6	4.2
Managed Tree Plantation-Northern and Central Hardwood and Conifer Plantation Group*	0.2	<0.1	-	-	-	-
U-Index	**0.17**		**0.08**		**0.03**	

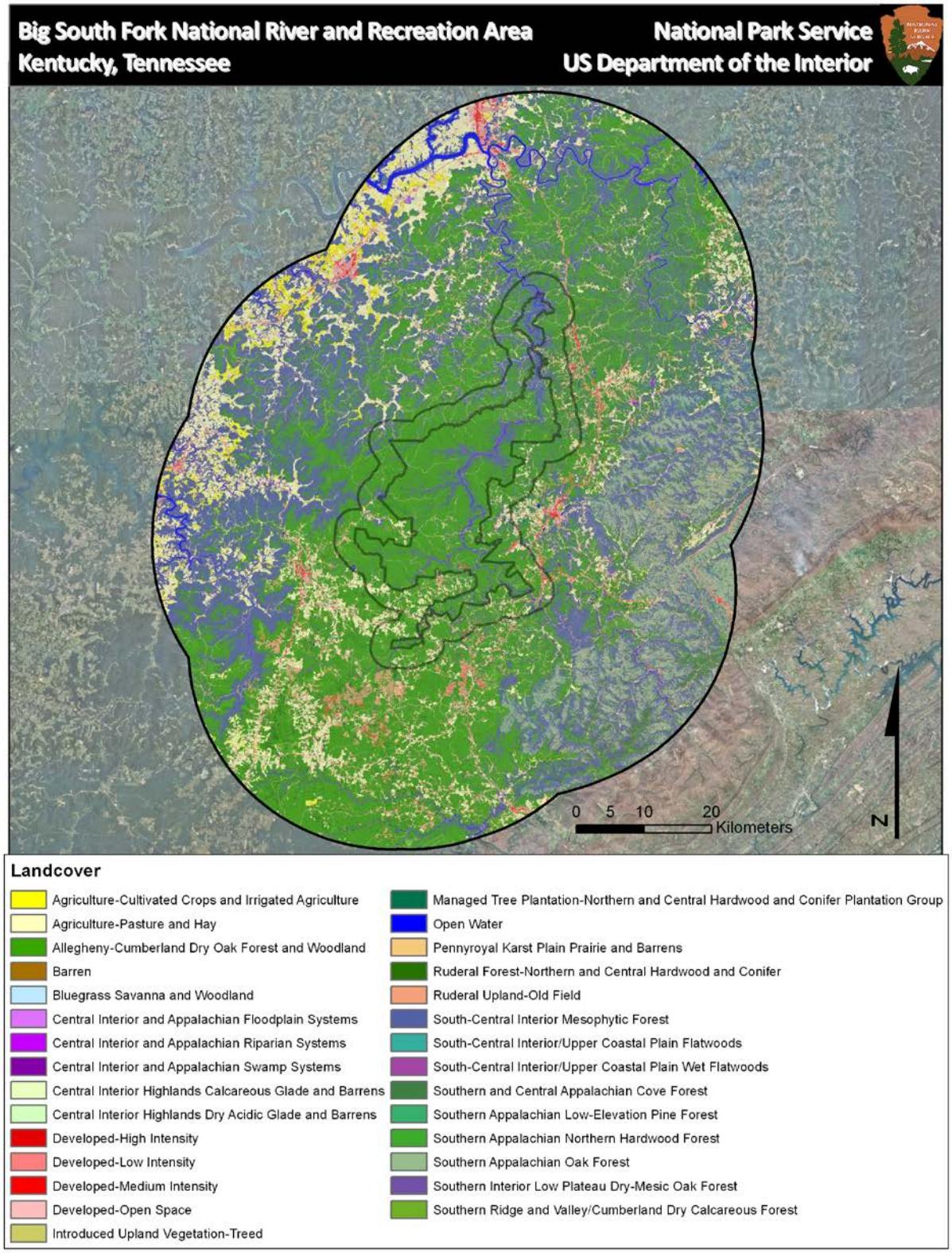

Figure 51. LANDFIRE landcover classification for BISO with 30km buffer.

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 (Figure 52). Like the NLCD program, GAP is part of the MRLC and is intended for use at a relatively large ecoregional scale. The original and main purpose of the GAP project is to monitor the amount of protected area for plant communities and animal habitat in order to "keep common species common" (GAP 2010). A main use of the data products is to compare biodiversity patterns with networks of protected lands in order to identify potential areas for additional conservation efforts (i.e. the "gaps") (Story et al. unpublished). Table 76 shows the comparison of GAP landcover types for BISO by buffer class. Like LANDFIRE, classifications are provided at a mid-scale ecological system level with detailed classes, though the overall classification is slightly more finely classified. For each of the buffer categories, the predominant class is the Allegheny-Cumberland Dry Oak Forest and Woodland, though the remaining forest classes for the GAP landcover are divided among four separate classes. Overall, about 93.1% of BISO is forested land, according to GAP data, and with each subsequent buffer class decreases to 86.5% (3 km) and 75.8% (30 km). In turn, total amount of developed area increases from 2.1% (no buffer) to 4.0% (3 km) and 5.6% (30 km), while pasture/hay areas increase from 0.2%, to 3.0% and 8.1% for the same respective classes. Calculated U-Indices also showed increasing converted landcover proportions comparable to both LANDFIRE and NLCD classes.

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 Urban 2005, Gross et al. 2009). Empirical data supports even lower thresholds (With and Crist 1995; Andrén 1994). The U-Index is one method of assessing the impact of anthropogenic change on an area via converted landcover, as opposed to natural landcover that provide essential habitat (O'Neill et al. 1988). Viewed in this context, the U-Indices representing the ratio of converted to natural habitat for the GAP, LANDFIRE, and NLCD classifications are encouraging. Respectively, the 30 km buffer, 3 km buffer, and no buffer classes average U-Indices plus or minus standard error of 0.163 ± 0.003, 0.077 ± 0.003, and 0.027 ± 0.003. However, the natural landcover category includes multiple vegetation classes, and therefore individual areas of essential habitat likely demonstrate less connectivity than would a U-Index using fewer types of natural landcover. Nevertheless, the indices are encouraging, and are well below even the conservative theoretical threshold for connectivity.

Table 76. Landcover area and proportions of BISO based on GAP classification. Data is shown for two buffer widths and no buffer. '*' depicts 'converted' landcover used to calculate U-index.

Gap Analysis Program (GAP) Landcover	-30 km buffer- Area (km^2)	% Area	-3 km buffer- Area (km^2)	% Area	-no buffer- Area (km^2)	% Area
Open Water (Fresh)	79.1	1.0	6.2	0.5	4.6	0.9
Developed Open Space*	307.6	4.0	36.8	3.3	10.0	2.0
Low Intensity Developed*	97.3	1.3	6.7	0.6	0.6	0.1
Medium Intensity Developed*	23.2	0.3	1.4	0.1	0.1	<0.1
High Intensity Developed*	4.2	0.1	0.2	<0.1	-	-
Bare Soil	0.3	<0.1	-	-	-	-
Quarry/Strip Mine/Gravel Pit*	0.8	<0.1	-	-	-	-
Central Interior Calcareous Cliff and Talus	0.2	<0.1	-	-	-	-
Southern Interior Acid Cliff	4.1	0.1	1.7	0.1	1.3	0.3
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood Modifier	2682.9	34.6	356.1	31.5	144.5	29.2
Southern Interior Low Plateau Dry-Mesic Oak Forest	135.1	1.7	-	-	-	-
South-Central Interior Mesophytic Forest	673.5	8.7	111.4	9.9	44.4	9.0
Southern and Central Appalachian Cove Forest	194.0	2.5	0.1	<0.1	-	-
Southern Ridge and Valley Dry Calcareous Forest - Hardwood Modifier	1162.1	15.0	171.7	15.2	85.0	17.2
Southern Interior Low Plateau Dry-Mesic Oak Forest - Evergreen Modifier	0.1	<0.1	-	-	-	-
Evergreen Plantations*	17.5	0.2	0.1	<0.1	-	-
Southern Appalachian Low Mountain Pine Forest	336.0	4.3	117.4	10.4	71.9	14.5
Southern Appalachian Montane Pine Forest and Woodland	8.2	0.1	-	-	0.1	<0.1
Southern Ridge and Valley Dry Calcareous Forest - Pine Modifier	15.2	0.2	6.0	0.5	4.3	0.9
Appalachian Hemlock-Hardwood Forest	668.9	8.6	214.1	19.0	115.1	23.2
Successional Shrub/Scrub (Utility Swath)*	4.4	0.1	0.6	0.1	0.2	0.1
Successional Shrub/Scrub (Other)	31.7	0.4	2.3	0.2	0.4	0.1
Successional Grassland/Herbaceous	492.2	6.3	54.4	4.8	9.0	1.8
Pasture/Hay*	624.0	8.1	33.6	3.0	1.1	0.2
Row Crop*	113.1	1.5	0.1	<0.1	0.1	<0.1
South-Central Interior Large Floodplain - Forest Modifier	1.2	<0.1	0.2	<0.1	0.2	<0.1
South-Central Interior Small Stream and Riparian	71.9	0.9	8.4	0.7	3.0	0.6
U-Index	**0.16**		**0.07**		**0.02**	

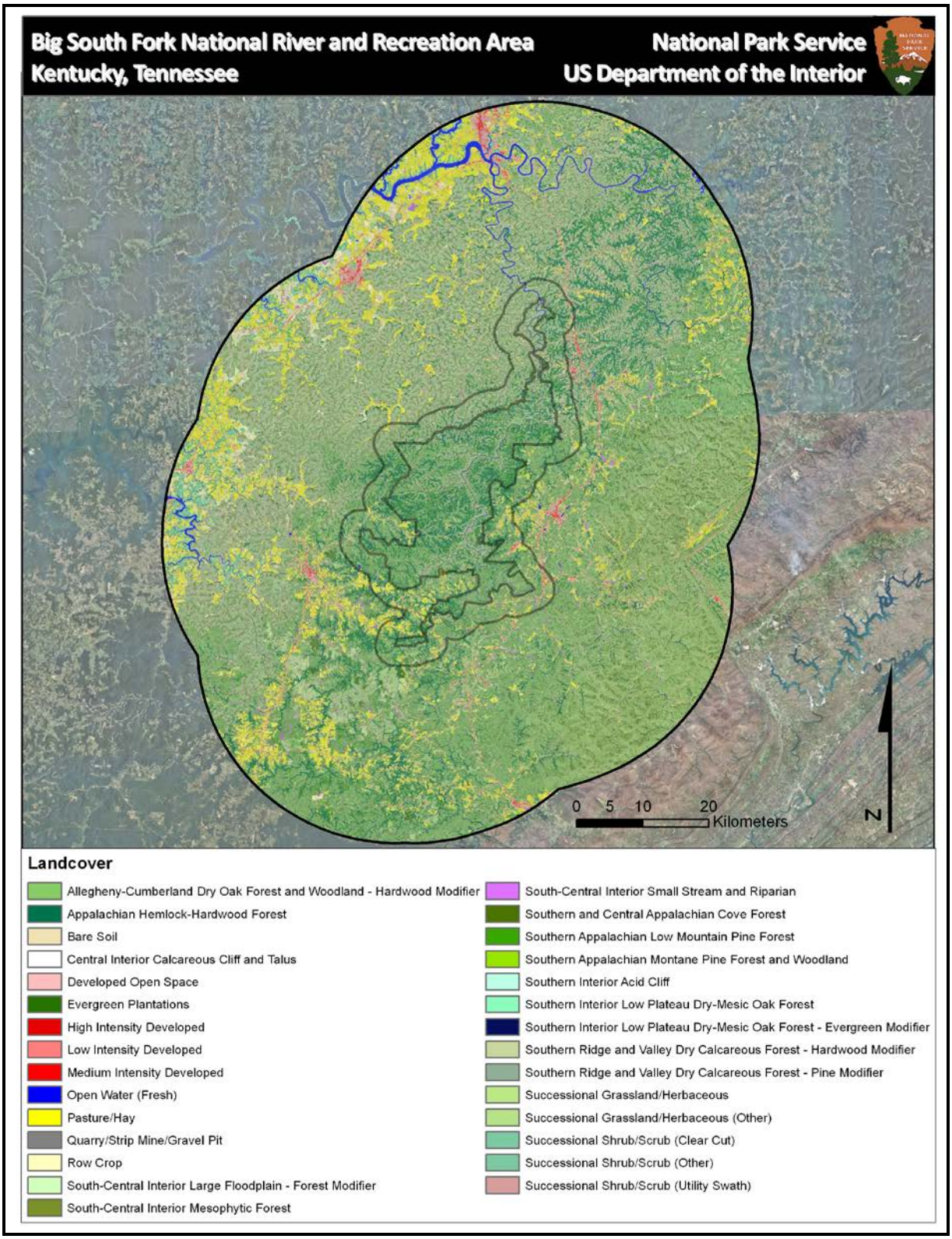

Figure 52. Gap Analysis Program (GAP) landcover with three buffer classes.

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

Many studies have outlined threshold levels of impervious surface at different scales for biotic integrity, and like the thresholds of connectivity for essential habitat, these values vary widely. Stranko et al. (2008), for instance, analyzed several stream catchments in Maryland for the presence of brook trout (*Salvelinus fontinalis*) and found that they were mostly absent from sites with greater than 4% impervious cover. Another 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 South Fork Cumberland watershed, perhaps distinctively, does not contain any major metropolitan area(s), and thus is largely protected from deleterious biotic and geomorphological effects stemming from impervious surface cover. The NPScape version of impervious surface includes landcover classification of bare rock, paved roads, and most developed areas (Gross et al. 2009). Using this classification, there is a slight increase in the proportion of impervious area with each buffer class, from 1.1% within the park boundary, to 1.5% and 1.8% at the 3 km and 30 km buffer widths, respectively. Encouragingly, each of these levels falls below even the conservative estimates for effects from impervious surface.

4.13.2 Roads

Although essential to the access of the park, roads that dissect the landscape can have a tremendous effect on many ecological factors important to the park. 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: (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, or total road length (km) per area (km^2), can directly affect wildlife populations. Steen and Gibbs (2004) reported altered sex ratios and populations of painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) in high road density sites (>1.5 km km^{-2}) in central New York. Gibbs and Shriver (2002) found that areas with >1 km km^{-2} and >100 vehicles $lane^{-1}$ day^{-1} were likely to contribute to the mortality of land turtles, especially in the eastern US where road densities are higher. Analysis of roads in the BISO vicinity reveals that road density within the park boundary is 0.4 km km^{-2}, which increases to 1.0 km km^{-2} at 3 km buffer and 1.3 km km^{-2} at 30 km buffer. Figure 53 shows the NPScape product for weighted road density with the 30 km buffer.

The distance to nearest road can help determine how much they can influence certain ecological factors. Roads, for example, are a main contributor to human-caused vertebrate mortality in addition to altered population densities around zones of road avoidance. Exotic plant species can also be introduced and spread via road corridors up to 1 km from the roadside. Traffic exhaust, another byproduct of road presence, can influence roadside vegetation up to 200 m away (Forman and Alexander 1998). Although the average distance to road is relatively low throughout BISO (Figure 54), roads are much more predominant beginning at the park boundary.

In an attempt to address the influence of roads on landscape fragmentation, the final measurement, effective mesh size, refers to road-created contiguous patches, 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." Figure 55 shows the NPScape version of effective mesh size within the 30 km, from which it is easy to see BISO almost completely contains one of the three largest >100 km^2 landscapes; the other two are southeast of the park unit and comprise in part the Royal Blue and Sundquist Wildlife Management Areas (WMA).

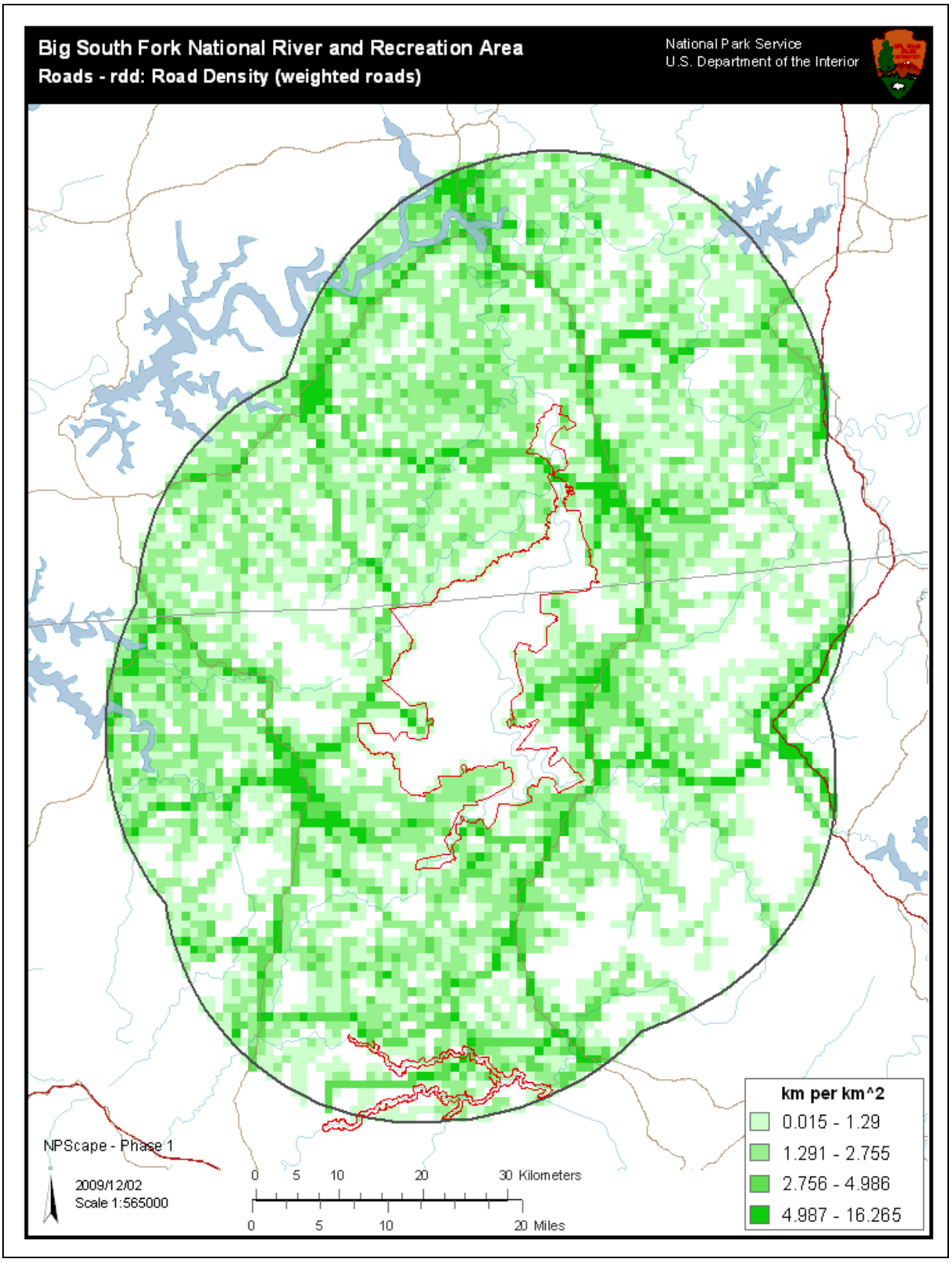

Figure 53. NPScape product (Gross et al. 2009) showing BISO with weighted road density.

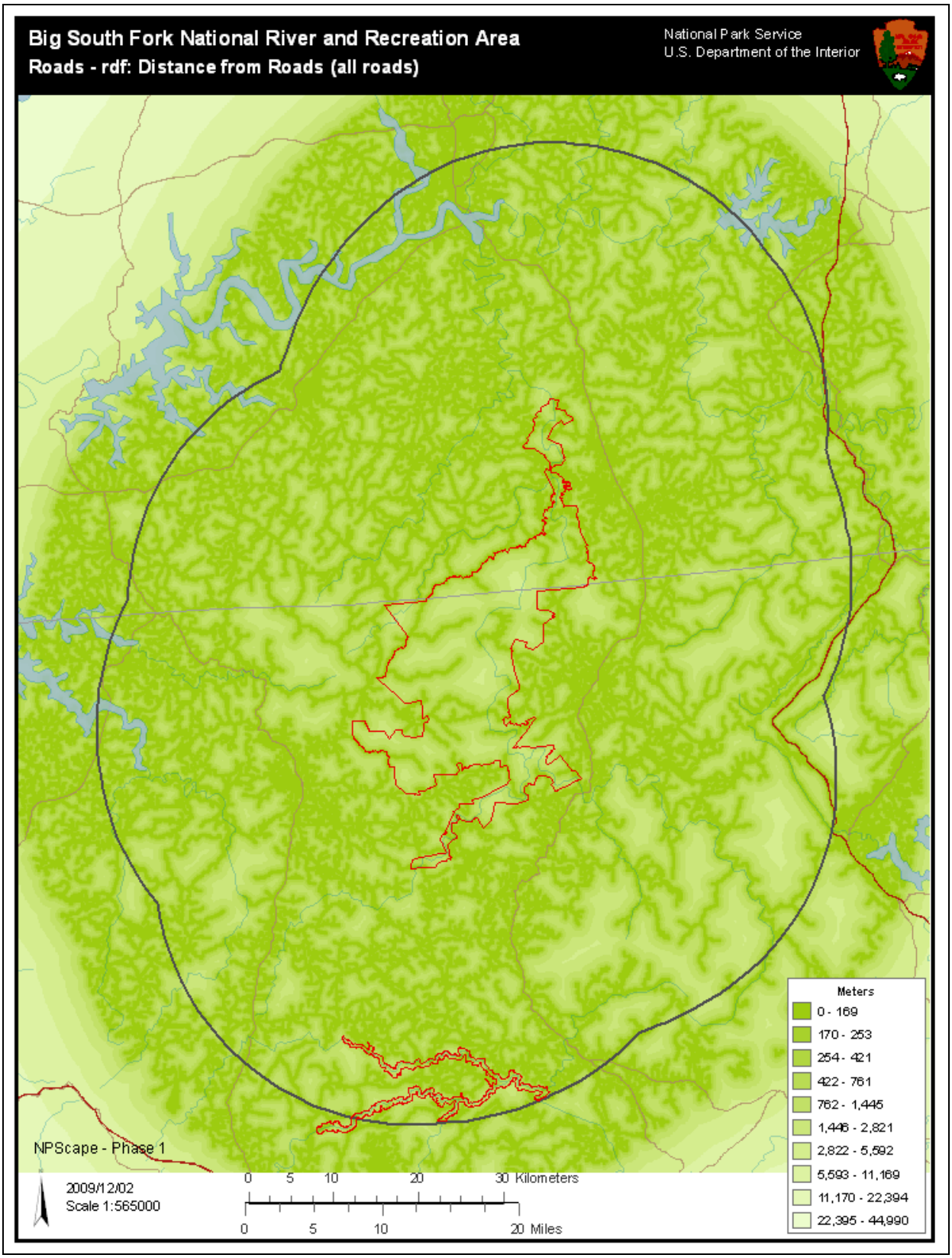

Figure 54. NPScape product (Gross et al. 2009) showing distance to road.

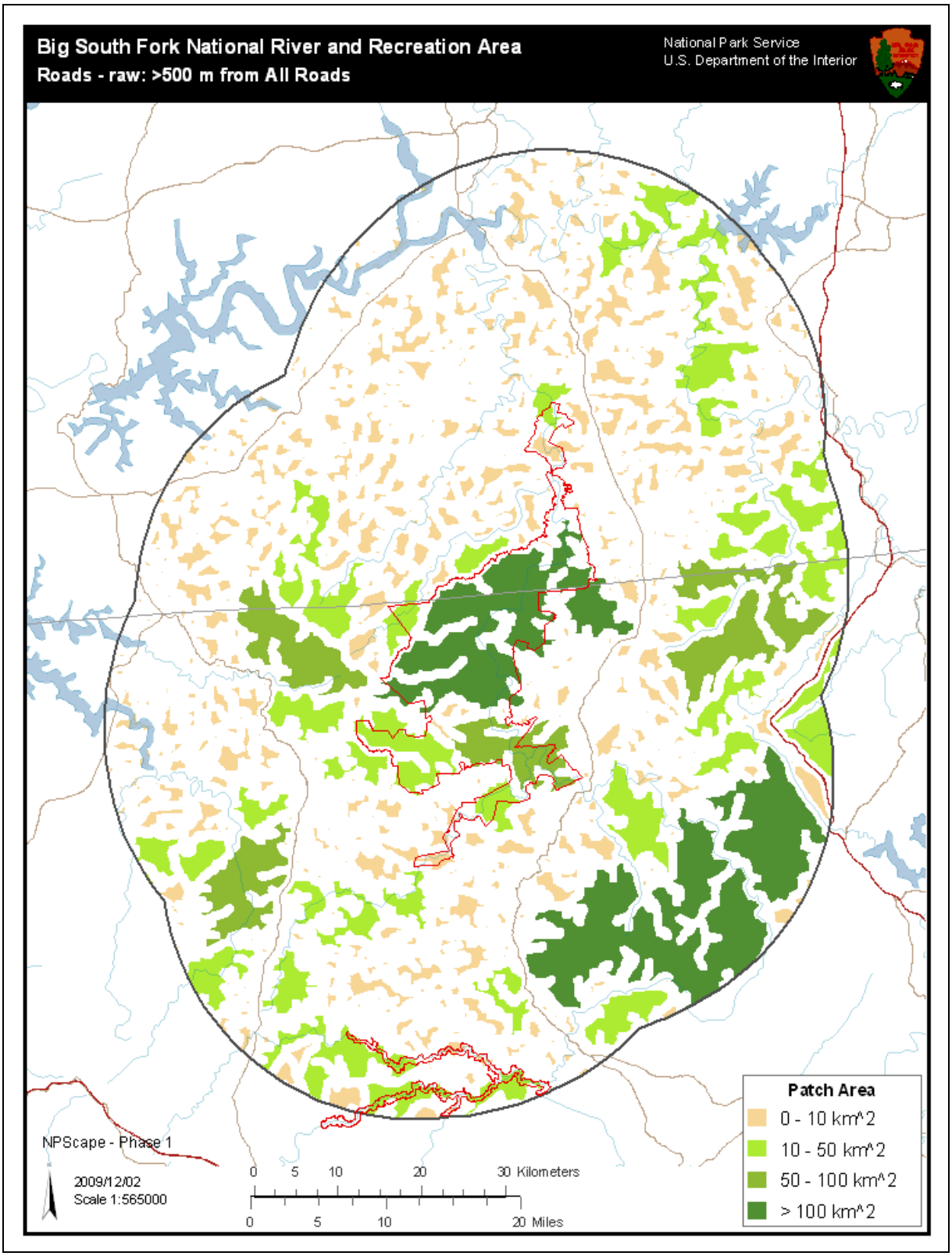

Figure 55. NPScape product (Gross et al. 2009) showing effective mesh size created by roads.

4.13.3 Population and Housing

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

NPScape products developed to analyze trends include population and housing density maps created at the county level from US Census Bureau data. Gross et al. (2009) reports that housing density is closely correlated with population density, but as Liu et al. (2003) point out, housing density also accounts for changing household demographics, such as average household size and per capita consumption. The NPScape product for housing density divides developed areas into 11 classes plotted each decade since 1950. Figure 57 depicts the change of each housing density class within the 30 km buffer. Linear regression reveals that the proportion of private undeveloped land and the lowest housing density class (<1.5 units km^{-2}) decrease at an average rate of 0.30% yr^{-1} ($p = 0.07$) and 0.72% yr^{-1} ($p < 0.01$) while, with some exception, the remaining higher density classes continually increase. 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. Population densities for the five park unit counties (McCreary, Scott, Pickett, Fentress, and Morgan) are similarly increasing from 1790.

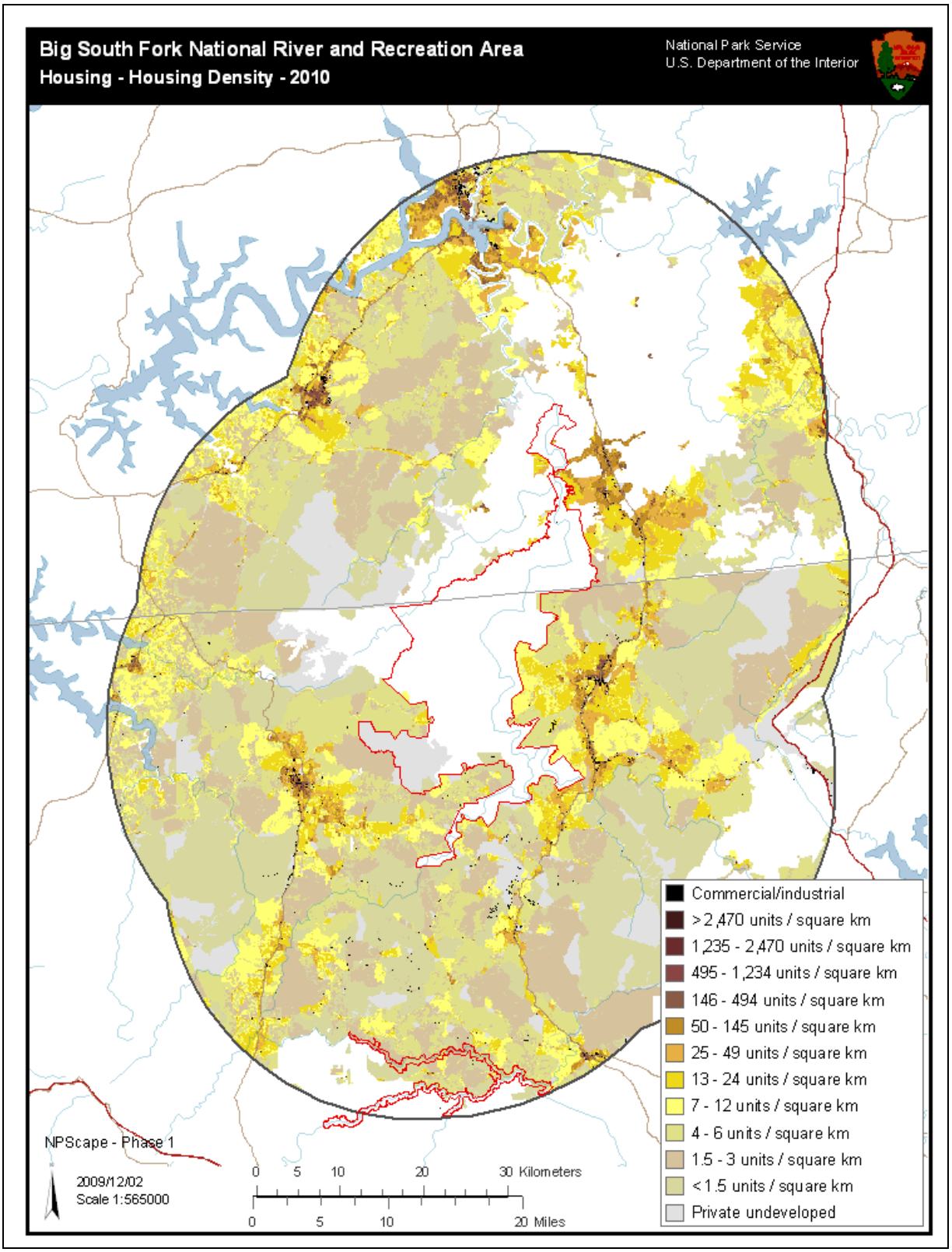

Figure 56. NPScape product predicting housing density in the vicinity of BISO for 2010. [Gross et al. 2010]

Table 77 shows the breakdown of housing density classes in the 2010 prediction for each buffer size. As expected, all housing density classes represent a higher portion of the landscape at the 30 km buffer, though the class representing the largest proportion for the 3 km buffer is of a higher density class than that for the 30 km (Figure 58). This may be due to the influence of the moderately urbanized Oneida/Helenwood area directly east of the park, and the Whitley City/Stearns area to the northeast.

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 59), which shows that BISO falls within an extremely low population density class (16.1 individuals km^{-2}) relative to other NPS units.

Table 77. Proportion of housing density classes for the 2010 NPScape prediction at each buffer size. Classes do not add to 100% because protected areas are not included. Development classes are according to Theobald (2005).

Density Class	**-30 km buffer-**	**-3 km buffer-**	**Development Class**
	-%-		
Private undeveloped	8.7	6.1	Rural
< 1.5 units / square km	24.0	5.9	|
1.5 - 3 units / square km	21.0	8.8	|
4 - 6 units / square km	20.2	11.2	↓
7 - 12 units / square km	12.0	5.5	Exurban
13 - 24 units / square km	7.6	3.7	|
25 - 49 units / square km	3.7	1.9	|
50 - 145 units / square km	1.9	0.7	↓
146 - 494 units / square km	0.6	0.1	Suburban
495 - 1,234 units / square km	0.1	<0.1	Suburban/Urban
1,235 - 2,470 units / square km	<0.1	<0.1	Urban
> 2,470 units / square km	<0.1	<0.1	↓
Commercial/industrial	0.4	0.1	

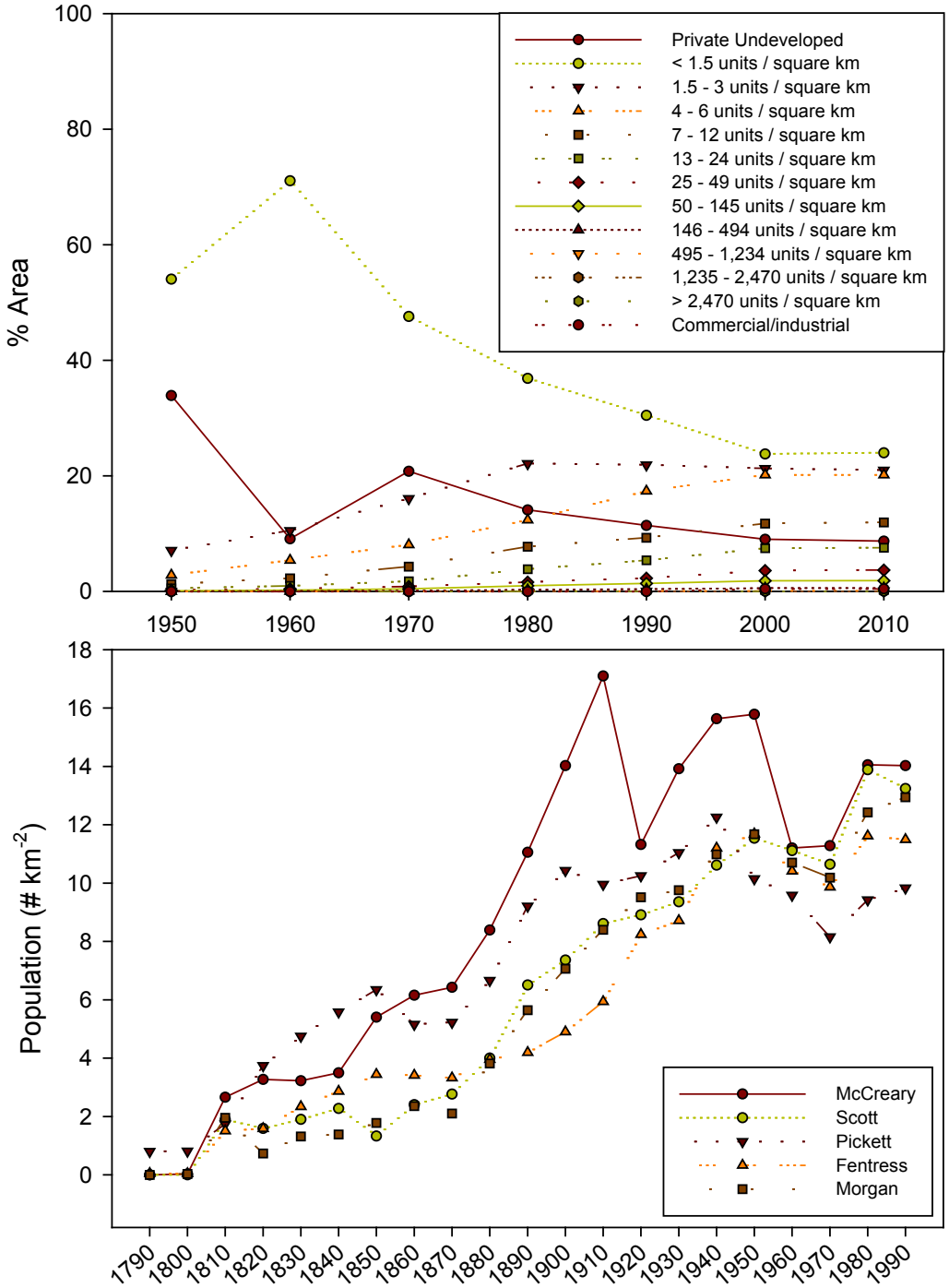

Figure 57. Historical NPScape data for housing density classes within the 30 km buffer (top) and population density by county (bottom).

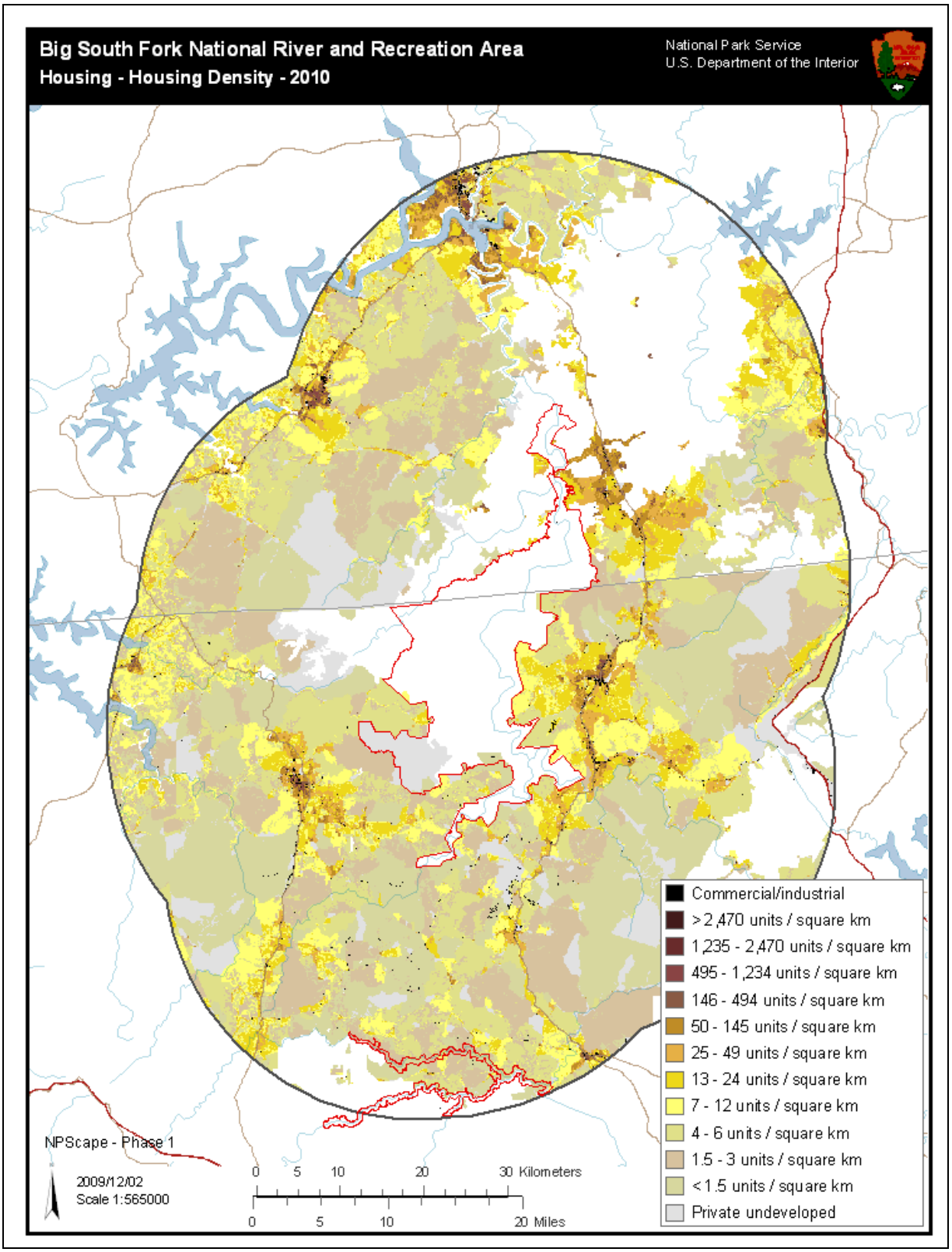

Figure 58. NPScape product predicting housing density in the vicinity of BISO for 2010. [Gross et al. 2010]

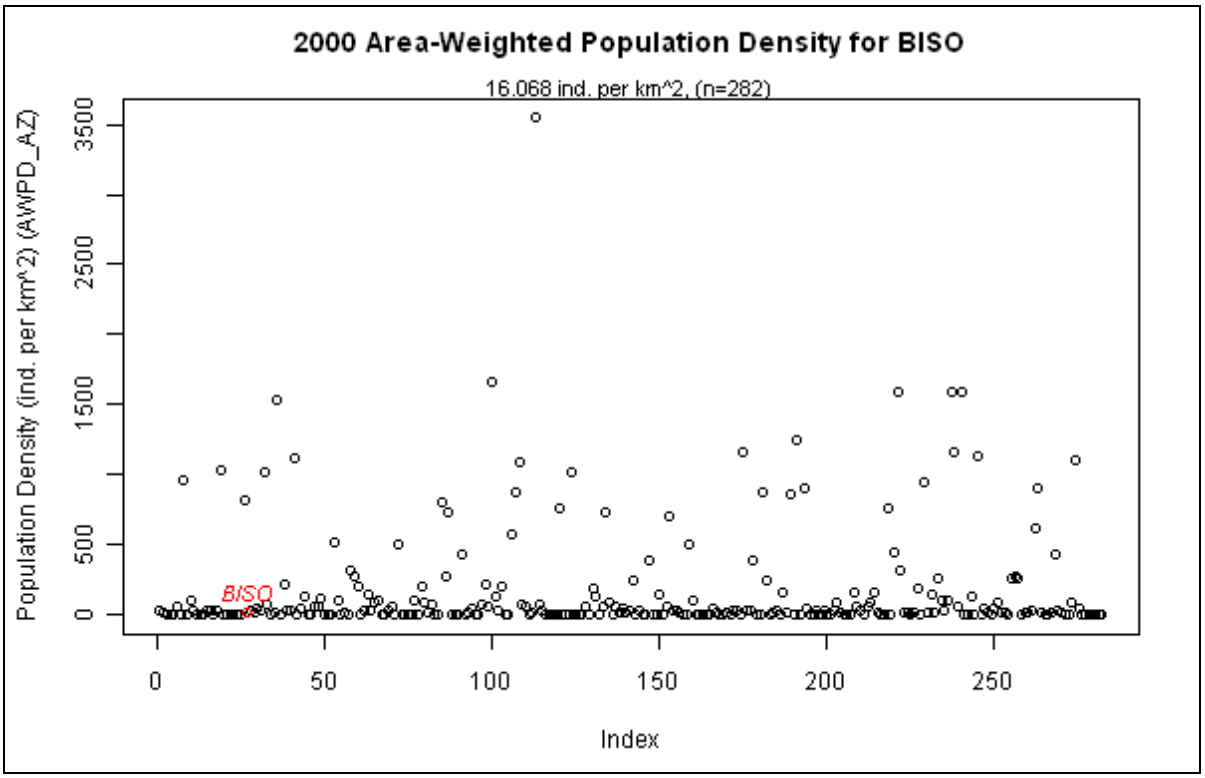

Figure 59. NPScape product showing population density of BISO relative to landscapes of other NPS units. The x-axis is a placeholder index representing other NPS units.

4.13.4 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 on 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 divided and become more patchy, edge density increases, which can affect numerous ecological processes. Conditions at patch edges may be intermediate of those at adjacent patches, such that a forested edge next to an open patch may be hotter, drier, windier, and lighter than interior forest conditions, which may in turn also result in different species composition (Ries et al. 2004). Edges may also alter species composition by facilitating the transport of pollen or other organisms into interior habitat area. Species interactions may also be affected by the presence of edges. Numerous studies report that birds undergo increased rates of parasitism and predation

within edge habitats and demonstrate greater rates of nest success in larger patches (Paton 1994, Donovan et al. 1997, Andrén and Angelstem 1988).

Patch Size

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

The NPScape project constructed maps of core habitat using edge widths of 30 m and 150 m. In an assessment of microclimate variation along forest edges, Matlack (1993) found that edge effects for several factors were detectable at sites of eastern deciduous forest up to 50 m from the edge. Another estimate by Ranney (1977) suggested that edge habitats extend from 5 m up to 20 m and may affect a variety of factors including tree species composition, primary productivity, structure and development, animal activity, and propagule dispersal. Both of these estimates most closely match the 30 m edge width used in the NPScape product describing forest habitat types. 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 78 shows definitions for these features and their respective contribution for each of the classes using a 30 m edge definition. Figure 60 shows the change in core and edge forest type for each buffer class, which respectively increase and decrease as the buffer width decreases. Finally, Figure 61 depicts the proportion of core and edge area within the vicinity of BISO compared to other NPS units.

Table 78. Morphological spatial pattern analysis (MSPA) class types used by NPScape for BISO forest patches at 30 km, 3 km, and no buffer widths.

Pattern type	Definition	-30 km buffer- Area (km^2)	% Area	-3 km buffer- Area (km^2)	% Area	-No buffer- Area (km^2)	% Area
Core	Interior forest area not influenced by edge	4895.8	63.1	855.6	75.8	433.9	87.5
Islet	Patch too small to contain core area	26.8	0.3	1.4	0.1	0.1	<0.1
Perforated	Edge (linear) internal to core forest type (30 km)	88.1	1.1	14.0	1.2	5.4	1.1
Edge	Perimeter (linear) of forest patch (30 km)	709.7	9.1	93.6	8.3	27.4	5.5
Bridge	Non-core (linear) forest connecting disjunct core patches	67.0	0.9	6.2	0.5	1.3	0.3
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	111.1	1.4	10.8	1.0	1.6	0.3
Other	--	1864.1	24.0	147.9	13.1	26.1	5.3

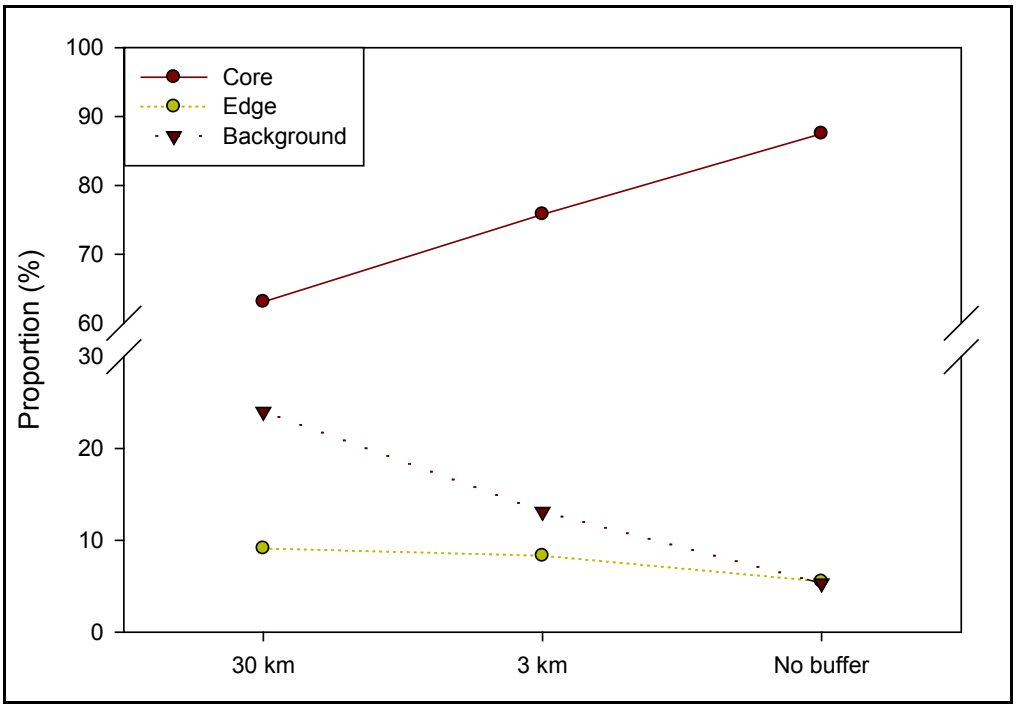

Figure 60. Forest edge and core areas increase and decrease, respectively, as buffer width around BISO increases. Background, representative of non-forested area, also predictably increases with buffer width.

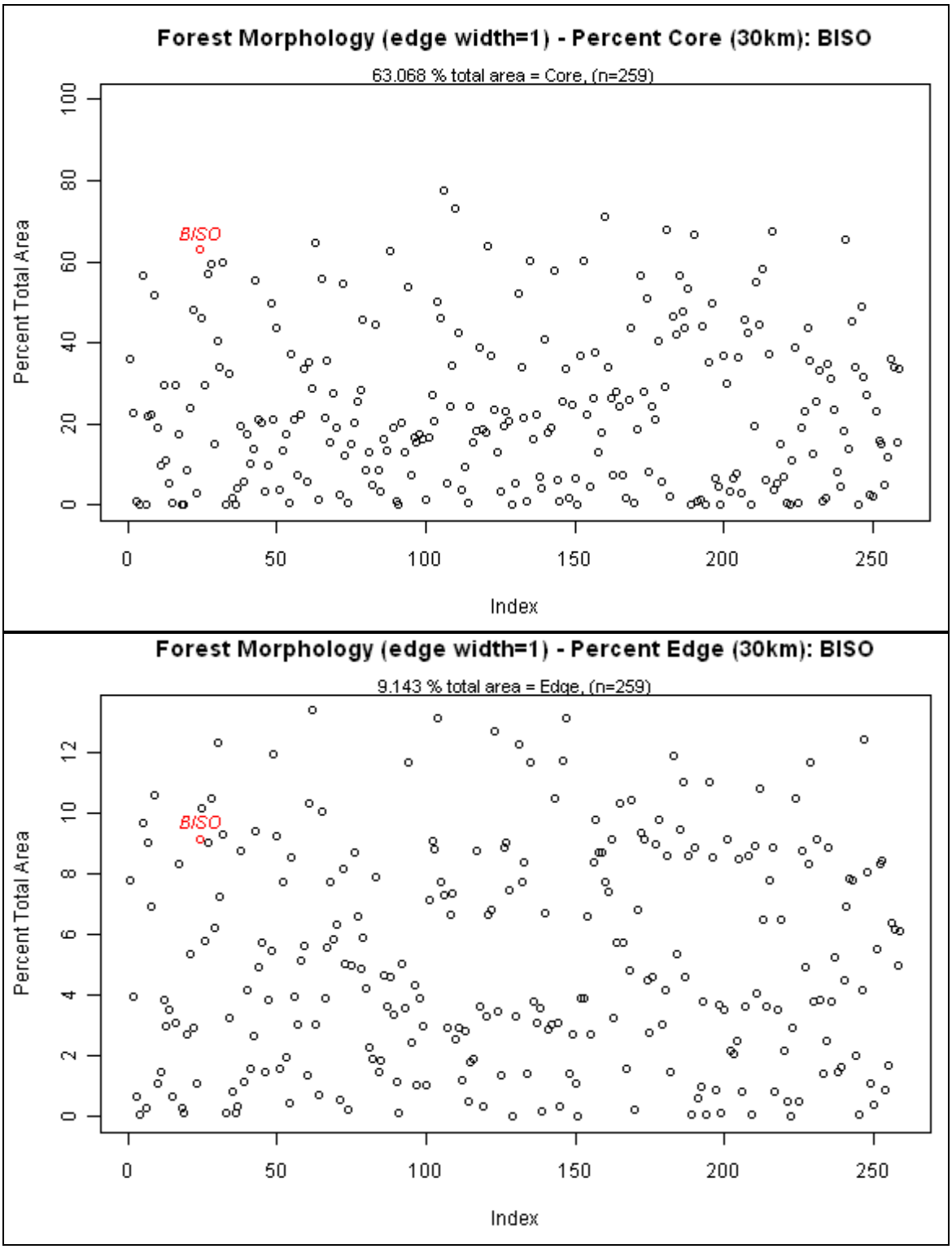

Figure 61. NPScape pattern product showing percent core (top) and percent edge (bottom) for BISO compared to other NPS units. The x-axis is a placeholder index representing other NPS units.

4.13.5 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, GAP has developed the Protected Areas Database (PAD) of the US, based primarily on the prescribed management of individual land units. This database ranks protected areas on a scale of 1 (highest protection) to 4 (lowest protection) depending on the relative degree of biodiversity protection offered by each unit (Gross et al. 2009). This system assigns BISO to a level-3 protection class, noting that while the unit is permanently protected from land use conversion, the important caveat is that the area is subject to extractive uses. In the case of BISO, this rating stems from the extraction of oil and gas resources. Gross et al. (2009) note this classification level is considered typical of "multiple-use" areas, such as those managed by the Bureau of Land Management (BLM) or the USFS. The only other parcel administered by the NPS within the buffer is Obed Wild and Scenic River south of the unit, which receives a level-2 classification.

The NPScape product for protected areas calculates the amount of land within a 30 km buffer classified as either 1 or 2, but not 3 or 4. Ironically, this excludes BISO itself from the proportion of protected land within its buffer (Figure 62). Using this method, there are 662 km^2 of protected area within the buffer, or approximately 8.5% of the land area, not including water. Only 6 km^2, or 1% of the protected area, is listed as level-1 protection, which includes the 88-ha Rock Creek Research Natural Area (RNA) and the Cumberland Falls State Park Nature Reserve. Figure 63 plots the amount of protected area around BISO with that of other NPS units, wherein BISO appears to fall within an average to slightly above average range.

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

Besides thresholds of protection, Gross et al. (2009) outline out a metric described by Hoekstra et al. (2005) 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 area converted to the area protected. Hoekstra et al. (2005) outlines thresholds for the index based on the IUCN Red List species, such that areas where habitat conversion is > 20% and CRI > 2 is classified as vulnerable; those with conversion > 40% and CRI > 10 as endangered; and those with conversion > 50% and CRI > 25 as critically endangered. When applied to BISO using GAP

level-1 and -2 protected areas (i.e. excluding BISO) and NLCD 2001 converted area over the 30 km buffer, the CRI yields a value of 1.88, while 16.1% of the area is classified as converted landcover according to 2001 NLCD. If level-3 GAP status land was included as well, BISO and portions of the Daniel Boone NF would reduce the CRI even more.

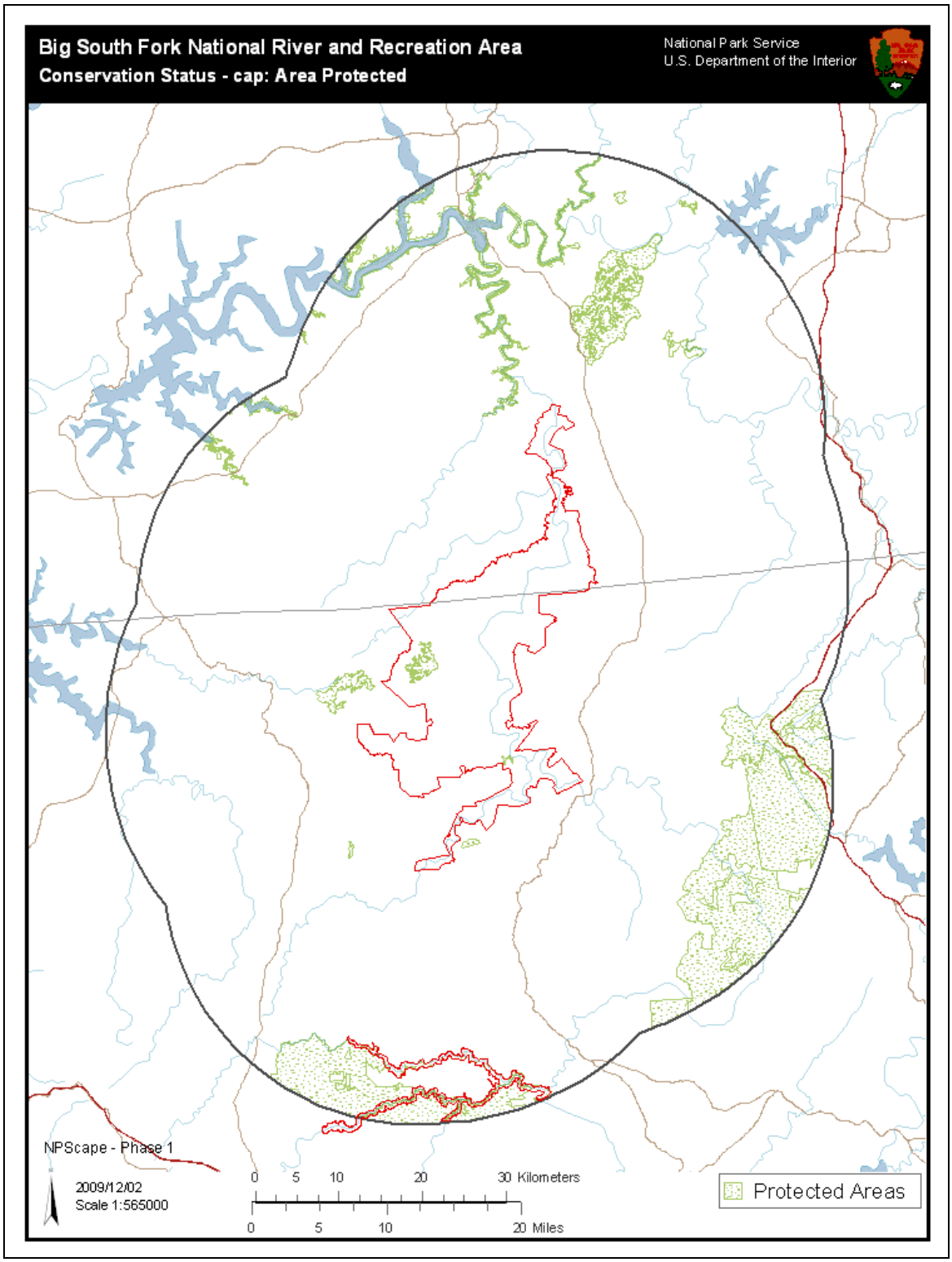

Figure 62. NPScape product depicting protected areas, as defined by the Gap Analysis Program (GAP), within a 30 km buffer of BISO (Gross et al. 2009). GAP-defined protected areas only include class 1 and 2 land units, and thus the classification of BISO as class 3 (i.e. multi-use) excludes it from the list of protected areas.

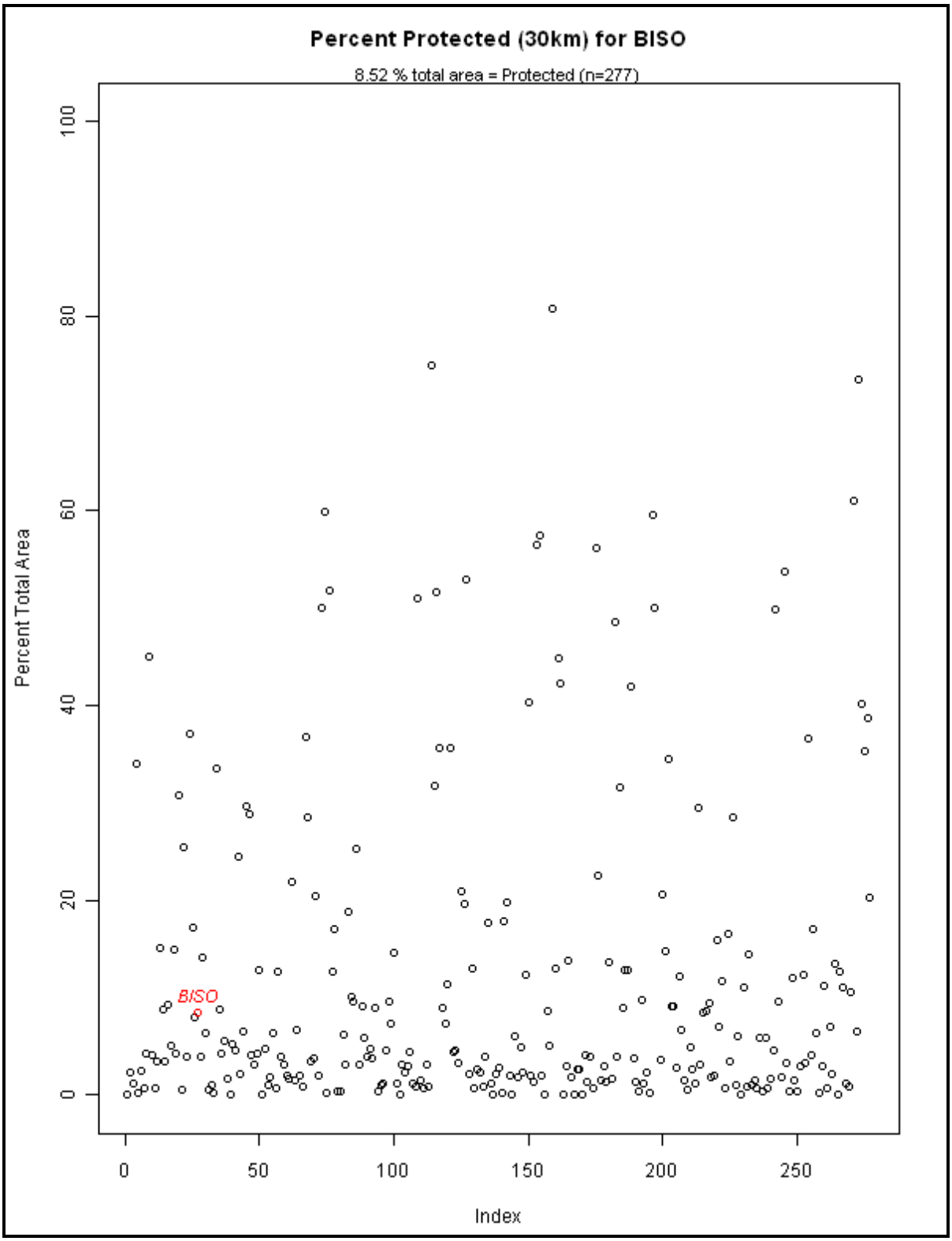

Figure 63. NPScape conservation status product showing percent protected area of BISO within the 30 km buffer relative to landscapes of other NPS units.

4.13.6 Landscape Synthesis and Considerations

The NPScape effort that directs much of the landscape dynamics section was designed to outline specific measureable features that would reflect resource condition within individual park units. Because most of the park units lie within larger ecosystems and exchange 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 BISO for each section.

Landcover

Analyses of landcover was based mainly on data from the National Landcover Dataset (NLCD), which includes 1992 and 2001 classifications, in addition to a change product between the two periods designed to reconcile different classification schemes and devise an NPScape product outlining natural and converted areas. The other two classifications included Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) existing vegetation type (EVT) and Gap Analysis Program (GAP). 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 79)

Table 79. U-indices for three landcover sources at each buffer width.

	-U-Index-		
-Data Source-	**-30 km-**	**-3 km-**	**-No buffer-**
NLCD	0.16	0.08	0.03
LANDFIRE	0.17	0.08	0.03
GAP	0.16	0.07	0.02
Average	**0.17**	**0.08**	**0.03**

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. Although no specific thresholds were offered, O'Neill et al. (1988) calculated the index for 94 landscapes in the eastern US, for which the average value was 3.22 ± 0.71 SE.

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 that tries to relate specific thresholds to changes in water and habitat quality. Some of the lowest thresholds, identified by Paul and Meyer (2001), indicate potential for changes in geomorphological characteristics—mainly stream channel enlargement and destabilization—at levels of 2% to 6% imperviousness. Several studies also focus on how impervious surface affects stream habitat quality. Klein (1979) defined a limit of 10% imperviousness for areas with trout populations, while Stranko et al. (2008) found a much lower threshold of 4% imperviousness for brook trout populations in Maryland stream catchments. Klein (1979) suggests that larger thresholds such as 12% - 15% imperviousness are where stream water quality begins to degrade.

- Average values for the BISO landscape predictably increase with area, but are overall quite low and represent a small proportion of converted area.

- At BISO, imperviousness proportions at each successive buffer width range from 1.1%, 1.5%, to 1.8%. All of these estimates fall auspiciously below the thresholds outlined above.

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, 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 began to be affected, while effect on the landscape reached a saturation level at 1.6 km km^{-2}.

- At BISO, road density—the only measure expressible by a single summary metric for each buffer size—predictably increases from 0.4 km km^{-2} with no buffer, 1.0 km km^{-2} at 3 km, and 1.3 km km^{-2} at 30 km. Lin (2006) offers that the average road density throughout the US is 0.67 km km^{-2}. The park itself appears to be lower than the example thresholds offered above that indicate an effect on wildlife, though the road density is greatly elevated even at the smallest buffer.

- For the distance to road measure, there is no single metric to describe each buffer class, though figure 25 clearly indicates that more isolated areas are present within the central portion of the park.

- Similar to the distance to road metric, there is no single metric to summarize each buffer class, though most of the roadless area in BISO comprises a single, > 100 km^2 patch. Immediately adjacent to the park unit, only Pickett State Forest to the west creates a large (> 50 km^2) contiguous roadless patch.

- Each of these three measures shows a relatively roadless, intact area within the park unit, though this contrasts strongly with the area outside the park unit. Even within the 3 km buffer width, the area becomes much more dissected by road, creating numerous non-contiguous areas.

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) points out several studies that make general observations regarding the influences of human settlements on plants and vertebrates. In a study involving exurban areas in Colorado, Maestas et al. (2002), for example, found (1) increased

richness and cover of non-native plant species, (2) increased densities of human-commensal bird species such as blue jays (*Cyanocitta cristata*) and black-billed magpies (*Pica hudsonia*), and (3) high densities of domestic dogs and cats. In a study in California, Merenlender et al. (2009) found lower proportions of temperate migrant bird species in exurban and suburban areas, and in dense housing areas found higher relative abundances of urban adapter species like American crow (*Corvus brachyrhynchos*) and turkey vulture (*Cathartes aura*).

- Relative to other NPS units, BISO falls within one of the lowest population density classes for its surrounding vicinity. Within the 30 km^2 buffer, the average population density is 16.1 individuals per km^2.

- Although most developed area in the park vicinity falls within the rural class, the most predominant density class is higher for the 3 km buffer than it is for the 30 km buffer. This may be due to the effect of cities immediately adjacent to the park unit.

- Since 1950, undeveloped land and very low density housing (<1.5 units km^{-2}) shows a decreasing trend.

Pattern.

The NPScape product used the GUIDOS package to derive a set of eight metric classes for the landcover around BISO. 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.

- Each of the landscape metrics calculated by the GUIDOS package for NPScape change predictably with each buffer width. Core forested area proportion decreases with increasing buffer width, while the respective proportions of islet, edge, bridge, and branch are consistently increasing, reflective of a more fragmented forested landscape outside the park unit.

- Proportion of background pattern, representative of non-forested area, also increases with buffer width, which is consistent with the decrease in forested land outlined in the landcover analysis section.

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 BISO. Protected areas are assigned a rating of 1 to 4 corresponding to a descending scale of the amount of biodiversity protection offered by each land unit. As a guideline, 10% to 12% protected area is often posed as a minimum objective (Rodrigues and Gaston 2001), though a review of

evidence-based studies by Svancara et al. (2005) yielded a considerably higher minimum threshold of 41.6% ± 7.7 %.

An additional guidelines for amount of protected area outlined by Gross et al. (2009) is the Conservation Risk Index (CRI). The index is the ratio of converted area to protected area. Hoekstra et al. (2005) describes thresholds based on the amount of habitat conversion and the CRI.

- Notably, the PAD assigns a rating of 3 to units that protect against natural landcover alteration but allow resource extraction. The protected areas product created by NPScape only includes land units classified as either level-1 or level-2 protection, and thus they surprisingly do not include BISO (or Daniel Boone NF) in the protected areas in the landscape.

- The ratio of converted area to protected area within the vicinity of BISO is 1.88. Combined with the 16.1% classification of converted area taken from the 2001 NLCD, this yields a conservation risk rating below the criteria for a vulnerable classification (Hoekstra et al. 2005).

4.13.7 Landscape Conclusions

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

1) Overall low landcover U-indices for three buffer classes.
2) Small proportion of land converted (1.2%) from natural landcover within the entire BISO vicinity (30 km) according to the NLCD change product.
3) Low rates of imperviousness at all three buffer classes, below even the most conservative literature thresholds.
4) Relatively undeveloped surrounding area, given the predominance of rural development classes for all 3 buffer classes.
5) Low CRI for the entire (30 km) BISO vicinity, despite the conservative estimate for protected area that excludes level-3 PAD units.

Other aspects of the analysis are less encouraging, especially when viewed across each buffer class:

1) U-Indices, despite being low, double with each successive buffer class.
2) Proportion of converted land more than doubles with each successive buffer class.
3) Road densities, especially at the larger buffer classes, are higher than many of the literature thresholds offered for terrestrial turtles and large mammals. Although road density in the park unit is low and roadless patches are large, these attributes reverse immediately adjacent to the park boundary, resulting in a patchier landscape.
4) Landcover and pattern analysis show a decrease in proportion of forest cover and core area, and an increase in edge proportion, across buffer classes.

The combination of these phenomena suggests that the amount of suitable habitat decreases in the landscape around BISO. At the 30 km buffer width, core forest habitat reaches a low of 63.1%, which is only slightly above the theoretical 60% percolation threshold (Gardner and Urban 2005). Of note though, is that other evidence-based studies have suggested much lower thresholds, on the order of 30% (Andrén 1994, With and Crist 1995). Because conversion and development can remove disproportionately larger amounts of core habitat than it can natural, unconverted land, the current status of core forest area within the BISO landscape may be particularly vulnerable to falling below this threshold. In addition, because the NLCD landcover layer used to derive this estimate is from 2001, the current core forest proportion may be currently below this theoretical threshold. Overall, the surrounding landscape of BISO also has one of the highest proportions of core forested area when compared to landscapes surrounding other NPS units (n = 259) (Figure 33).

The complexity of the landscape change vital sign makes it difficult to summarize into a single condition status ranking. By summarizing each of the NPScape aspects into key points as above, it becomes easier to pick out the most significant landscape qualities. By using this approach, landscape change is assigned an overall ranking of good (Table 80). Many of the metrics used in the analysis reflect low overall anthropogenic influence in the landscape of BISO. When these same metrics are compared across buffer classes, however, the degradation of landscape quality radially from the park unit is concerning, and suggests that development in the vicinity of BISO does and will continue to have an effect on the park unit. For that reason, landscape change at BISO is assigned a decreasing trend.

Table 80. Landscape change condition status for BISO was assigned a condition of good with a degrading trend. Data quality for this attribute was good.

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

4.13.8 Literature Cited

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Chapter 5 Conclusions

5.1 Summary

Based on a review of available ecological information at BISO, we addressed the current condition of 14 natural resource attributes in the park. Three attributes—water quality, fish assemblages, and aquatic macroinvertebrate assemblages—were divided into smaller spatial scales for assessment and reporting. These attributes were assessed for reporting areas defined by USGS HUC 10 and HUC 12 watershed and sub-watershed designations. To include these attributes in the park-wide summary, we used the proportion of each condition rank within the attribute. Overall, natural resource attribute conditions in BISO were ranked 48% good, 39% fair, and 3% poor. The remaining 10% were not ranked.

Summarized into broad Level-1 categories (Table 2) the condition rankings were:

Air and Climate (five attributes)—20% Good, 60% Fair, 20% Not ranked
Water (one attribute)—14% Good, 50% Fair, 36% Poor
Biological Integrity (seven attributes)—65% Good, 28% Fair, 1% Poor, and 6% Not ranked
Landscapes (one attribute)—100% Good

We assigned trends to natural resource attribute conditions where appropriate. Because long-term data were relatively uncommon, trends were not assessed for many attributes. Attributes assessed for multiple reporting areas were summarized as described above. Overall, natural resource condition trends in BISO were 24% improving, 17.3% stable, and 14.3% declining. The remaining 44.4% were not assigned a trend.

Summarized into broad Level-1 categories (Table 2) the condition trend assignments were:

Air and Climate (five attributes)—40% Improving, 20% Stable, 20% Declining, 20% Not ranked
Water (one attribute)—14% Improving, 36% Stable, 50% Not ranked
Biological Integrity (seven attributes)—17.3% Improving, 15.3% Stable, and 67.3% Not ranked
Landscapes (one attribute)—100% Declining

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. Attributes assessed for multiple reporting areas were summarized as described above. Data quality was assessed for all instances where data existed. Therefore, with one exception, all individual condition assessments were assigned a data quality ranking, regardless of whether the attribute was assigned a condition rank. One reporting area, among those assessed for macroinvertebrate assemblages, was not assigned a data quality rank because no data existed for the area. Overall, natural resource attribute data quality, for existing data, was ranked 59.7% good, 30.6% fair, 9.2% poor, and 0.5% unranked.

Summarized into broad Level-1 categories (Table 2) the data quality rankings were:

Air and Climate (five attributes)—40% Good, 40% Fair, 20% Poor
Water (one attribute)—100% Good
Biological Integrity (seven attributes)—62% Good, 33% Fair, 4% Poor, and 1% Unranked
Landscapes (one attribute)—100% Good

5.2 Assessments by Attribute

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

5.2.1 Ozone

Data for ozone concentration came from two monitoring stations: one in nearby Somerset, KY (2000-2003) and one from a Portable Ozone Monitoring Station at BISO (2003 – 2005 ozone season). Interpolations from the NPS Air Resources Division were also available for three separate five-year periods. Concentrations collected at Somerset, KY were much higher than subsequent observations in the park, which likely had to do with their proximity to pollution sources. Using the standard ozone metric for EPA NAAQS, which is averaged over a three year period, neither station exhibited levels that exceeded NAAQS. The five-year NPS ARD interpolations did exceed these standards for periods representing 1995 to 2003, though they are likely the least reliable data source. Based on the POMS, which is the most reliable data source, ozone concentrations appear well below EPA NAAQS, and therefore a good condition is assigned.

<u>Data quality</u>
Ozone data quality received a good ranking. Although on-the-ground monitoring was available within the park from the POMS, this was only briefly. Continued monitoring in the park would be ideal to ensure that ozone concentrations are not elevated, though based on what data is available, this does not appear to be a danger.

5.2.2 Foliar injury

Risk of ozone damage to vegetation is closely tied to ozone concentrations, though it is also affected by exposure duration, species sensitivity, and soil moisture conditions. The severity of the three foliar injury metrics interpreted from national interpolation maps was inconsistent at BISO, though they overall averaged a moderate risk. Two of the metrics displayed an increasing trend. As a result, foliar injury received a condition status of fair with a degrading trend. Available data for soil moisture showed moisture levels did not appear to exacerbate foliar injury.

<u>Data quality</u>
Foliar injury metrics are useful for assessing risk to vegetation, though at BISO they were only available in 1995 through 1999 as interpolations. On-the-ground foliar injury surveys would be the most efficient way of determining ozone damage at the park. It would also be useful to calculate foliar injury metrics based on data collected from the POMS during 2003 – 2005.

Because data for this attribute was only available from predictions and during the period 1995 to 1999, data quality was poor, lacking spatial and temporal checks.

5.2.3 Atmospheric Deposition

Monitoring for wet, dry, total, and mercury deposition was available from several sites ranging from 60 to 140 km away from BISO. Data from regional stations in TN show relatively low rates of total annual deposition for both N and S as compared to the overall eastern US. NPS ARD estimates, like those for ozone concentrations, were much higher for wet deposition rates than those observed near the park, placing it in the range for significant concern of ecosystem harm. As a result, a fair condition rating was assigned. Many of the periods of observation showed clear reductions as well, resulting in an improving trend.

Data Quality

Sufficient data was available for the region around BISO for various types of atmospheric deposition, including mercury. Data was also complete and fairly recent. However, because of the distance of some of the measuring locations from BISO, the spatial data quality ranking did not receive a check.

5.2.4 Visibility and Particulate Matter

Monitoring for particulate matter was available only at GRSM and MACA, each of which is about 140 km from BISO. Monitoring from 1988 and 1991 through 2004 at each site showed no NAAQS violations for the two particle size classes PM_{10} and $PM_{2.5}$. Visibility was ranked based on NPS ARD interpolations, which calculated a value over the limit of concern for visibility conditions. Based on the pair of these considerations, this attribute was assigned a condition of fair. Because particulate matter data showed significant decreasing trends at both sites for both size classes, an improving trend was assigned.

Data Quality

Once again, measurements for particulate matter are taken at locations quite far from BISO, such that values may not be reflective of actual conditions in the park. Visibility conditions, though derived specifically for BISO, are estimates and are not the result of measurements at BISO. As a result, this attribute does not receive a check for spatial data quality.

5.2.5 Weather and Climate

Data from weather stations around BISO show long-term trends in temperature and precipitation. A single Remote Automated Weather Station (RAWS) has collected data within the park since 2000, while three additional stations from the Cooperative Observer Program (COOP) have collected data since as early as 1928. Based on monitoring for precipitation, none of the stations showed trends over the course of the data period. Frequency of daily maximum precipitation observations increased at the Stearns and Oneida stations, indicating a possible increase in the frequency of intense storm events over the period of record. For temperature and growing degree days (GDD), a derivation of temperature, stations showed some significant increasing and decreasing trends, though most metrics displayed no trend. Wind data was also available from the RAWS from 2000 to 2010, during which the direction of wind origin was predominantly from the SW.

Data Quality
The combination of data collected inside BISO from the RAWS and data from the COOP stations will continue to elucidate any short or long-term trends in weather and climate. The data quality for this attribute is ranked as good.

5.2.6 Water Quality

Due to a history of impacts from coal mining and other types of resource extraction, as well as the particular vulnerability of species within the Big South Fork and its associated systems, water quality within the park unit is an especially important issue. Research in the 1980s did much to elucidate the impacts of resource extraction in watersheds affecting the park. Since that time, extraction has decreased throughout the cataloging unit, though residual effects from coal mining in particular still impact many areas of the park negatively.

Presently, areas in the park with the most impacted water quality include the Pine Creek, Bear Creek, Roaring Paunch Creek, and Rock Creek subwatersheds, all of which are currently and historically 303(d) listed impaired waters and received a poor condition rating. Pine Creek has been impacted by sedimentation and bacterial contamination from the town of Oneida, TN, in addition to oil and coal extraction. Bear Creek was one of the most heavily impacted areas from mining, showing high levels of heavy metals and sulfates, the most notable of which was aluminum, which has an especially debilitating impact on aquatic life. Current 303(d) listings reflect continued impact of acid mine drainage. This stream may be one of the most polluted sources entering Big South Fork inside the park unit—sampling at the park boundary or confluence is important to reveal if water quality is improving. Roaring Paunch is in many ways similar to Bear Creek because of the clear impact of heavy mining activity in the past, though recent delisting of portions provide hope that water quality is improving. This stream would also greatly benefit from sampling at the park boundary or confluence with Big South Fork. Rock Creek may be the most storied of these subwatersheds, with a history of timber extraction in the headwaters and heavy mining on its lower portion below its confluence with White Oak Creek, which was also heavily mined. In between these areas, Rock Creek is listed as a state exceptional water. Extensive reclamation efforts along the downstream portion have attempted to reduce acidic loading to Big South Fork. Sampling near the park boundary is essential to determine their efficacy.

Other subwatersheds within the park unit—Blair Creek, Bandy Creek, and Williams Creek—are all bisected by Big South Fork and were ranked as fair condition status, mainly because of the influence of these highly impacted drainages originating outside the park. The New River watershed, also ranked as fair condition, had perhaps the highest density of mines in the cataloging unit, and was historically impacted. However, later data showed less metal contaminants and the overall watershed appears to be improving. The White Oak Creek watershed south of the park was ranked fair due to past influence from oil and gas activity, as well as bacterial contamination likely resulting from Sunbright, TN. The North White Oak Creek watershed also received a fair condition ranking, due to bacterial contamination resulting from agricultural runoff, as well as oil and gas impacts on Mill Creek, a tributary. However, no recent data was available for this watershed. The Clear Fork watershed also showed a history of mining impacts, though sampling was very sparse. Minimal modern data showed a continued impact, albeit small.

The remaining watersheds—Little South Fork and Lake Cumberland—as well as subwatersheds Station Camp and No Business Creek were ranked as good, displaying little or no evidence of adverse impacts.

Data Quality

Besides acid mine drainage, the biggest water quality issue evident from available sampling was an overall lack of data. Previous assessments were helpful in determining how water quality had changed over time. More often than not, it appeared that water quality issues were improving throughout surrounding watersheds. However, continued sampling, especially on heavily impacted streams as they enter the park boundary, is essential to document continued impacts on water quality, or hopefully, eventual recovery. Based on criteria, the data quality for this attribute is good.

5.2.7 Vegetation

Previous efforts have classified vegetation types throughout the park, which include five rare communities that harbor a large proportion of plant diversity in the park. These notably include the Cumberland Rockhouse and Riverside Scour Prairie communities, the latter of which has been more extensively studied in the park and is also now the subject of a targeted monitoring program. Numerous state and globally rare plants are found in this community type, including the Federally Threatened Cumberland rosemary and Virginia spirea. Presently, the greatest threat to these rare communities appears to be competition from exotic plant species.

Data Quality

Recent assessments have provided a good foundation from which to pinpoint rare communities and protect them from threats such as exotics. Rare communities such as the Cumberland Rockhouse type may benefit from targeted monitoring similarly to the river scour prairies. Presently, data quality is good for this assessment.

5.2.8 Fish Assemblages

Fish are an important aquatic resource in BISO. Around 80 species have been reported recently, and around 90 species have been reported by combined sources from the last century. Around 18 species not known to occur within or near park boundaries are present in the Little South Fork or the broader region. These species could occur in BISO or could immigrate into the park. *Cyprinidae* was the most numerically common and widespread family of fishes reported from BISO. Family *Percidae* was also abundant and found in many park samples. A number of species of conservation concern were reported from the park. These included the endangered tuxedo darter and the threatened blackside dace. Four additional species were listed as threatened or endangered at the state level. Five non-native species were reported from the recent inventory, though none were common.

Mining and other land use practices in the BSF drainage have greatly impacted the quality of fish habitat in the park. The worst negative impacts occur outside and hydrologically above park boundaries. Eastern BSF tributaries are worse, in general, than western tributaries. Fish data indicate that fish habitat is improving from historic lows in some streams.

We assessed the condition of fish assemblages in 14 reporting areas. We found that three (21%) were in good condition, five (36%) were fair, and one (7%) was poor. The remaining five

reporting areas were not ranked. No Business Creek, Station Camp Creek, and North White Oak Creek watersheds, western BSF tributaries, were ranked as good and are largely protected by park boundaries. Roaring Paunch Creek, an eastern tributary with a history of degradation, was ranked as poor, but occurs primarily outside park boundaries. The five reporting areas not ranked primarily lacked sufficient data to support a ranking.

Data Quality

Considered as a whole, the body of data available for BISO fishes was good. Data used were primarily from a recent inventory. These data were collected recently using appropriate methods in or near park boundaries. A detailed narrative report and raw electronic data were available, and data were fully spatially explicit. Data quality was ranked as fair for some reporting areas because of limited sampling in the area. It should be noted that the inventory collecting the data was not designed to sample separate reporting areas within the park. These reporting areas were used in this report to facilitate data summary and target management considerations. It should also be noted that the reporting areas varied significantly in the percent of area actually occurring in BISO. Of the 14 reporting areas where fish were assessed, five (36%) were ranked with good data quality and nine (64%) were ranked as fair.

5.2.9 Bird Assemblages

BISO supports a moderately rich bird assemblage dominated by interior forest habitat specialists. The park has benefited from standardized bird sampling efforts conducted from 1994 – 2006. These efforts reported 147 species, including nine species threatened or endangered at the state level. The observed species list was composed of 75% neotropical migrant species. Non-native species were reported from BISO but were uncommon. Native early successional habitat species were uncommon relative to forest species. Using an index of biotic integrity and several diversity indices, we assessed the bird assemblage condition as good. Using linear regression of BBS data, we assigned a trend of stable to the bird assemblage condition. Several assemblage-level indicators we analyzed over the 10-year time period showed a low point around 2003, probably coincident with a significant pine die-off resulting from a pine beetle infestation. These values increased in subsequent years and the overall trend for most indicators was stable. A group of early successional species showed a moderate but statistically-significant increase over the 10-year period, possibly in response to controlled burning near areas where data were collected.

Data Quality

The quality of bird data for BISO was fair. The recent comprehensive bird inventory with narrative report was accompanied by a multi-year dataset of standardized bird sampling results. This standardized sample data allowed an examination of trend that was uniquely robust among the vertebrate and invertebrate assemblage analyses we performed for this report. The data ranking of fair resulted because the data were more than five years old.

5.2.10 Mammal Assemblages

BISO contains a relatively rich mammal assemblage containing at least 47 species. One federally endangered bat, and several species of state concern were reported from the park. At least five non-native species occur, but were not noted as common in the recent mammal inventory report. The park supports black bears and elk, species requiring relatively large tracts of natural habitat. The mammal list for BISO was similar to lists compiled from efforts

conducted in other protected forest habitats in the broad area, and 79% of expected native species were actually reported from the park. We ranked the mammal assemblage condition as good. No trend was assigned to mammal assemblage condition.

Data Quality

The quality of BISO mammal data was fair. We acknowledge that mammal sampling is uniquely challenging because of the great variety in size and life history of mammals. The single mammal inventory in the park was well conducted and employed a variety of appropriate scientific techniques. Reliably documenting the diversity of mammals may require multiple efforts. The ranking of fair was given primarily because much of the sampling effort was concentrated in the southern areas of the park.

5.2.11 Herpetofauna Assemblages

A single inventory of BISO reptiles and amphibians was conducted from 2004 – 2007 and reported 57 species. Five species were listed as threatened or species of concern at the state level. The species richness of BISO was greater than for other smaller NPS units in the general area and was similar as a ratio of park area to number of species. The observed list of herpetofauna included 89% of the species on the expected list. We ranked the condition of herpetofauna assemblages as good. We did not assign a trend to herpetofauna assemblage condition.

Data Quality

The quality of the herpetofauna data was good. Knowledge of herpetofaunal assemblages in BISO comes primarily from a single baseline inventory that was well-conducted with multiple appropriate methods and had relatively good spatial coverage of the park.

5.2.12 Freshwater Mussel Assemblages

Freshwater mussels are among BISO's most significant resources. Two recent multi-year studies have inventoried the mussels of the park and of the New River drainage. As with mussel assemblages throughout the southeast, BSF mussel diversity was greatly reduced during the 20th century. Historical richness is poorly understood, but evidence suggests that anthropogenic activity reduced the BSF mussel richness by 30 - 60%. At least 26 species naturally persisted in the park in 2002, including six federally listed species. Because BISO is recognized as a major stronghold of native mussel diversity in the region, a number of species have been re-introduced into park habitat for conservation reasons. When these species are counted as present, BISO may contain 39 mussel species including 13 species listed as threatened or endangered at the state or federal level. A single species reported from the New River drainage has not been reported in BISO. Mussel diversity is concentrated in the main-stem BSF through the central portion of the park. Mussel richness was lower in the Clear Fork and New Rivers than it was in the BSF, and New River sites had fewer species than Clear Fork sites did.

We ranked the condition of BISO mussel assemblages as fair. This assessment was based largely upon qualitative factors. From one viewpoint, park mussel richness is significantly reduced from historical levels and could be considered poor for this reason. From another viewpoint, because freshwater mussel assemblages are highly imperiled globally, and in the Cumberland River drainage specifically, BISO contains one of the most complete endemic mussel faunas in the region. Therefore, mussel assemblages might be considered good in the

park. We assigned an improving trend to mussel assemblage condition. As with the condition ranking, this was based upon qualitative factors. At the time of publishing, there were insufficient long-term monitoring data to formally analyze for trend. The improving value reflects the fact that substantial efforts are ongoing to restore and conserve BISO mussel fauna.

Data Quality

The quality of mussel data was good. Two comprehensive inventories have been conducted using appropriate techniques. Unpublished data on mussel releases were available.

5.2.13 Macroinvertebrate Assemblages

BISO has a relatively rich assemblage of insect macroinvertebrates. Macroinvertebrates are an important indicator of aquatic ecosystem health. A recent comprehensive inventory of park macroinvertebrates reported at least 414 distinct taxa, of which 205 were identified to species level. Two undescribed species were found in the park. The recent macroinvertebrate inventory report included a number of analyses and presented multiple diversity and quality indices. We based our assessment solely upon the results of these analyses. We reported BISO macroinvertebrate condition in 13 reporting areas based upon USGS HUC 10 and HUC 12 watershed designations. Reporting areas were the same as those used for water quality and fish assemblages, one reporting area (Sinking Creek) was not reported on because no data existed for the area. Of the 13 reporting areas, five were ranked as good and eight were ranked as fair. These ranking were based upon summaries of the Final BI score presented in the macroinvertebrate inventory. We did not assign a trend to any of the macroinvertebrate condition rankings.

Data Quality

Overall the quality of macroinvertebrate data for BISO was fair. This ranking reflects the age of the data and the low amount of data collected in some reporting areas. Because reporting areas were defined for the NRCA, these factors do not reflect upon the quality of the macroinvertebrate survey, which was very good. The inventory was based upon comprehensive samples collected with a variety of methods. A long-term monitoring protocol was created for the park, based upon successful monitoring protocols employed in other National Parks. The inventory included a number of analyses and discussion assessing the quality and diversity of the resource. We reported condition in 13 separate reporting areas. When considered by reporting area, the data quality of four reporting areas was poor. The remaining nine had fair data quality.

5.2.14 Landscape Dynamics

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

- Landcover analysis shows a relatively undeveloped landscape surrounding BISO, with very low U-indices and proportion imperviousness.
- Road density is predictably low inside the park, though it predictably increases at the periphery. Patchless areas show large amounts of intact space inside the park.

- Overall population density in the BISO landscape is one of the lowest of all NPS units, though the area is becoming more populated. Development in the immediate vicinity of the park is slightly higher than the overall landscape, reflecting the influence of the cities of Oneida, TN and Stearns, KY.
- Pattern analysis reveals increasing fragmentation outside the park unit and decreasing background pattern, reflective of non-forested area.
- The protected areas database ranks BISO as a level-3 protected area, which excludes it from consideration as a conservation area when calculating the Conservation Risk Index for the landscape. Considering this conservative assessment of conservation risk, the BISO landscape still falls below even a minimal threat rating.

Because of these encouraging points, condition status for landscape dynamics receives a ranking of good. Due to the continuing development of the area surrounding the park and the dramatic drop in habitat area, the condition is additionally assigned a degrading trend.

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. Currently, the second phase of this project is underway for BISO, which will update data sources. For now, it meets the data criteria, resulting in a quality ranking of good.

Appendix A. List of Initial Scoping Meeting Attendees

Big South Fork National River and Recreation Area:

Tom Blount, Chief Resource Manager
Ron Cornelius, GIS Specialist
Steve Bakaletz, Wildlife Biologist

Appalachian/Highlands Inventory and Monitoring Network:

Robert Emmott, Coordinator
Patrick Flaherty, Data Manager

University of Georgia:

Nate Nibbelink, Principal Investigator
Gary Sundin, Research Professional
Luke Worsham, Research Professional

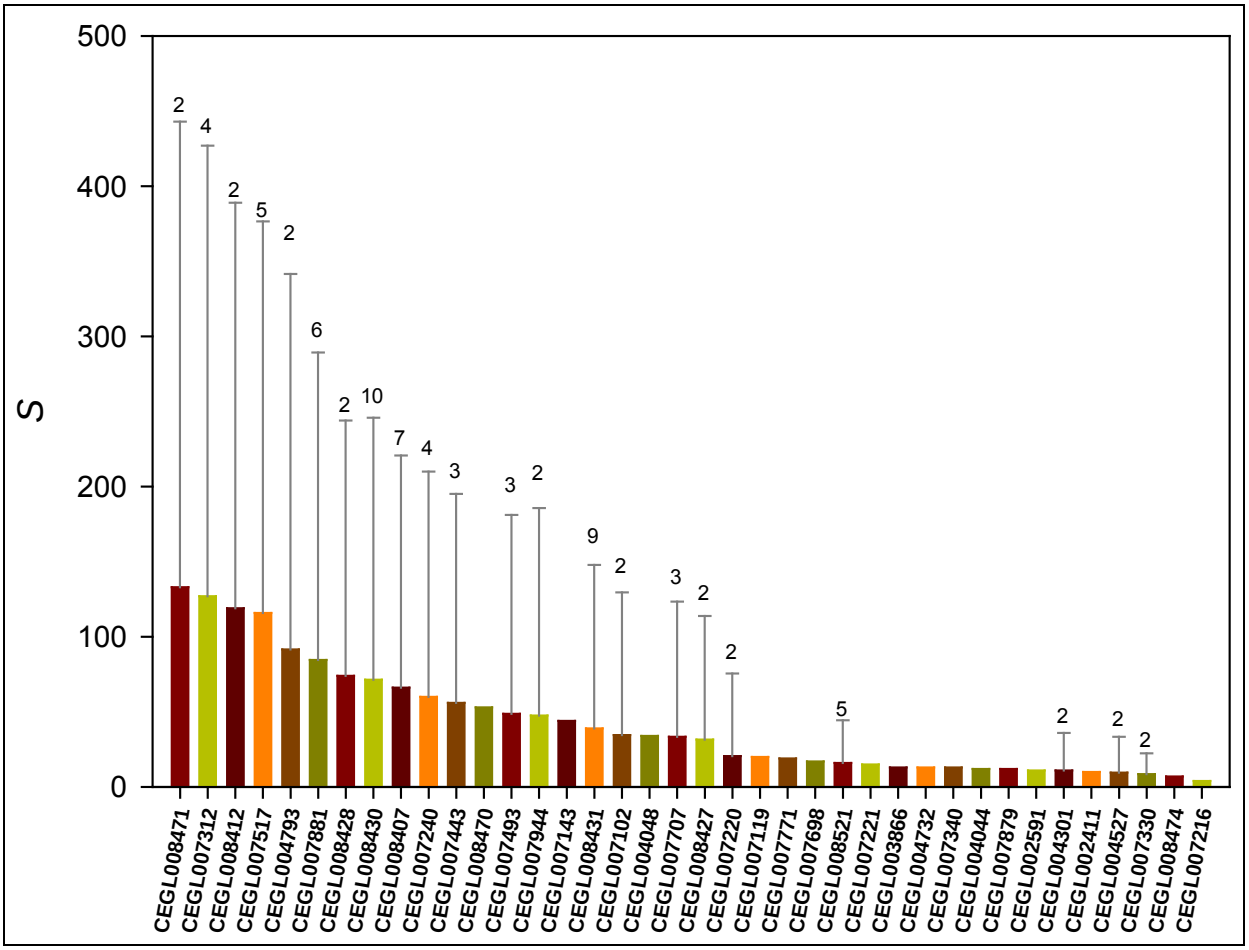
Southeast Regional Office:

Dale McPherson, Regional NRCA Program Coordinator

Appendix B. Major soil complexes at BISO. Information adapted from soil descriptions by Natural Resources Conservation Service (NRCS 2010).

Major Soil Complexes	Area* (ha)	Description	Associated Vegetation
Lily	22446 (45%)	Mostly on upland ridges/hillsides on variable; formed in residuum from acid sandstone; well-drained	Often used for agriculture; forested areas are generally mixed hardwood, pine with understory present
Gilpin	18376 (37%)	Primarily on convex dissected uplands on variable slopes; deep, well-drained; formed in residuum of interbedded shale, siltstone, or sandstone	Often used for agriculture; wooded areas typically consist of hardwoods, generally oak (*Quercus* spp.)
Rock Outcrop	3020 (6%)	These areas are generally on steep slopes and have no developed soil layers	--
Shelocta	2508 (5%)	Soils formed in mixed colluviums from shale, siltstone, or sandstone and generally found on mountain slopes, foot slopes, or benches	Approximately ¼ cleared for agriculture; forested areas are oak-pine mixed hardwoods with some higher elevation species like hemlock (*Tsuga*) and cucumbertree (*Magnolia acuminate*)
Lonewood	949 (2%)	Soils generally on shallow slopes in the Cumberland Mountains area, containing a silty mantle with underlying weathered shale and sandstone residuum; well-drained and mostly on smooth plateau or ridge top areas	About half of the extent is cleared for pasture and hay; forested areas mainly consist of oak-hickory with a few pines
Pope	919 (2%)	Soils are relatively undeveloped, formed on floodplain areas in alluvium weathered from sandstone, silt, and shale; generally well-drained and occurs on flat areas with areas that flood occasionally	Extensively cultivated for a variety of crops including corn, grains, and tobacco; forested areas consist generally of mixed deciduous hardwoods
Water	646 (1%)	--	--
Wernock	322 (1%)	Formed from residuum from acid siltstones, shales, and sandstone on mostly shallow slopes on narrow upland ridgetops	Often used for agriculture (corn, grains, hay, tobacco); forested areas are generally deciduous hardwood with developed understory
Atkins	309 (1%)	Primarily on level floodplains, formed by acidic upland alluvium formed in shale or sandstone; poorly drained with relatively high water table and occasional flooding	Used for pasture; forested areas consist of water-tolerant mixed hardwoods, in addition to aquatic grasses and sedges
Itmann	21 (<1%)	Soils associated with deep mined coal areas (i.e. mine spoils), mainly composed of regolith and acidic carbolith with smaller amounts of siltstone, sandstone, and shale; slopes vary widely from mild to very steep: 0 – 80%	Soils are generally barren, though may support sparse grasses, annuals, or pioneer hardwoods. Sites are commonly reclaimed with planted grasses and legumes.
Skidmore	4 (<1%)	Formed on narrow and flat floodplain areas in gravelly, cobbly, or channery alluvium; subject to occasional flooding; well- to excessively-drained	Mostly converted to agriculture for corn, tobacco, or pasture; forested areas area generally deciduous oak-hickory
Total	**49521**	--	--

Appendix C. Mean species richness for NatureServe plot vegetation associations.



Appendix D. Fishes reported from the Big South Fork watershed upstream of the northernmost BISO boundary in selected studies and NPS unpublished sources 1870-2010.

Scientific Name	Common Name	NPSpecies Dbase	APHN Dbase	Scott 2010	Evans 1998	O'Bara et al. 1982	Brazinski 1979	Comiskey & Etnier 1972	Shoup & Peyton 1940	Kirsch 1893	Cope 1870
Acipenser fulvescens	lake sturgeon	X									
Ambloplites rupestris	rock bass	X	X	X	X	X	X	X	X	X	
Ameiurus natalis	yellow bullhead	X	X	X	X		X	X			
Aplodinotus grunniens	freshwater drum	X	X	X		X					
Campostoma anomalum	central stoneroller	X	X	X	X	X	X	X	X	X	
Campostoma oligolepis	largescale stoneroller	X	X	X							
Carpiodes cyprinus	quillback						X				
Catostomus commersoni	white sucker	X	X	X	X	X	X	X	X		
Clinostomus funduloides	rosyside dace							X	X		
Cyprinella galactura	whitetail shiner	X	X	X	X	X	X	X	X	X	
Cyprinella spiloptera	spotfin shiner	X	X	X		X		X	X	X	
*Cyprinus carpio**	common carp	X	X	X	X		X				
Dorosoma cepedianum	gizzard shad	X	X	X							
Erimystax dissimilis	streamline chub	X	X	X							
Esox masquinongy	muskellunge	X	X	X							
Etheostoma baileyi	emerald darter	X	X	X	X		X	X			
Etheostoma blennioides	greenside darter	X	X	X	X	X	X	X	X	X	X
Etheostoma caeruleum	rainbow darter	X	X	X	X	X	X	X	X	X	X
Etheostoma camurum	bluebreast darter	X	X	X	X	X	X	X		X	
Etheostoma cinereum	ashy darter	X	X	X	X	X		X		X	
Etheostoma kennicotti	stripetail darter							X	X		
Etheostoma nigrum	Johnny darter	X	X	X					X		
Etheostoma obeyense	barcheek darter	X	X	X		X		X		X	
Etheostoma lemniscatum	tuxedo darter	X	X	X				X			
Etheostoma sagitta	arrow darter	X	X	X		X		X			
Etheostoma sanguifluum	bloodfin darter		X	X	X	X	X	X		X	X

Appendix D (continued)

Scientific Name	Common Name	NPSpecies Dbase	APHN Dbase	Scott 2010	Evans 1998	O'Bara et al. 1982	Brazinski 1979	Comiskey & Etnier 1972	Shoup & Peyton 1940	Kirsch 1893	Cope 1870
Etheostoma stigmaeum	longhunt darter	X	X	X		X		X		X	
Etheostoma tippecanoe	Tippecanoe darter	X	X	X				X			
Etheostoma zonale	banded darter	X	X	X				X	X		
Fundulus catenatus	northern studfish	X	X	X							
Hybopsis amblops	bigeye chub	X	X	X		X				X	
Hybopsis amnis†	pallid shiner										
Hypentelium nigricans	northern hog sucker	X	X	X	X	X	X	X	X	X	
Ichthyomyzon bdellium	Ohio lamprey	X	X	X							
Ichthyomyzon greeleyi	mt. brook lamprey	X	X	X		X					
Ictalurus punctatus	channel catfish	X	X	X	X	X	X	X			
Ictiobus bubalus	smallmouth buffalo	X	X	X							
Labidesthes sicculus	brook silverside	X	X	X				X			
Lepisosteus osseus	longnose gar	X	X	X							
*Lepomis auritus**	redbreast sunfish	X	X	X	X						
Lepomis cyanellus	green sunfish	X	X	X	X						
Lepomis gulosus	warmouth		X	X	X	X					
Lepomis macrochirus	bluegill	X	X	X	X	X	X	X	X		
Lepomis megalotis	longear sunfish	X	X	X	X	X	X	X	X	X	
Lepomis microlophus	redear sunfish	X	X	X	X						
Luxilus chrysocephalus	striped shiner	X	X	X	X	X	X	X	X		
Lythrurus fasciolaris	scarlet shiner	X	X	X	X	X	X	X	X	X	
Micropterus dolomieu	smallmouth bass	X	X	X	X	X	X	X	X	X	
Micropterus punctulatus	spotted bass	X	X	X	X	X	X	X			
Micropterus salmoides	largemouth bass	X	X	X	X	X	X			X	
Morone chrysops	white bass	X		X				X			
*Morone saxatilis**	striped bass	X	X	X							
Moxostoma anisurum	silver redhorse	X	X	X							
Moxostoma breviceps	smallmouth redhorse	X	X	X	X			X			

Appendix D (continued)

Scientific Name	Common Name	NPSpecies Dbase	APHN Dbase	Scott 2010	Evans 1998	O'Bara et al. 1982	Brazinski 1979	Comiskey & Etnier 1972	Shoup & Peyton 1940	Kirsch 1893	Cope 1870
Moxostoma carinatum	river redhorse	X	X	X	X						
Moxostoma duquesnei	black redhorse	X	X	X	X	X	X	X	X	X	
Moxostoma erythrurum	golden redhorse	X	X	X	X		X	X	X		
Nocomis effusus	redtail chub		X								
Nocomis micropogon	river chub	X	X	X	X	X		X	X	X	
Notemigonus crysoleucas	golden shiner		X				X				
Notropis ariommus	popeye shiner	X	X	X					X	X	
Notropis atherinoides	emerald shiner	X	X	X				X		X	
Notropis leuciodus	Tennessee shiner	X		X				X	X		
Notropis micropteryx	highland shiner	X	X	X	X	X	X	X	X		
Notropis photogenis	silver shiner	X	X	X							
Notropis sp.	sawfin shiner		X	X		X		X	X		
Notropis stramineus	sand shiner	X	X	X	X	X	X	X	X		
Notropis telescopus	telescope shiner	X	X	X	X	X		X	X	X	
Notropis volucellus	mimic shiner	X	X	X	X	X	X	X	X		
Noturus exilis	slender madtom				X						
Noturus flavus	stonecat	X	X	X		X		X			
*Oncorhynchus mykiss**	rainbow trout	X	X	X		X			X		
Percina caprodes	logperch	X	X	X	X	X	X	X	X	X	X
Percina copelandi	channel darter	X	X	X				X			
Percina maculata	blackside darter	X	X	X	X	X	X	X	X	X	
Percina sciera	dusky darter	X	X	X				X			
Percina squamata	olive darter	X	X	X		X		X			
Phoxinus cumberlandensis	blackside dace	X	X	X							
Phoxinus erythrogaster	southern redbelly dace	X	X	X		X		X			
Pimephales notatus	bluntnose minnow		X	X				X	X		
Pimephales promelas	fathead minnow	X	X	X							
Pimephales vigilax	bullhead minnow	X		X							
Pylodictis olivaris	flathead catfish	X	X	X	X	X		X			

Appendix D (continued)

Scientific Name	Common Name	NPSpecies Dbase	APHN Dbase	Scott 2010	Evans 1998	O'Bara et al. 1982	Brazinski 1979	Comiskey & Etnier 1972	Shoup & Peyton 1940	Kirsch 1893	Cope 1870
Rhinichthys atratulus	western blacknose dace	X	X	X	X	X	X	X	X		
*Salmo trutta**	brown trout					X		X			
Salvelinus fontinalis	brook trout								X		
Sander canadensis	sauger	X	X	X							
Sander vitreus	walleye	X	X	X	X	X		X			
Semotilus atromaculatus	creek chub	X	X	X	X	X	X	X	X		
	TOTALS	**76**	**78**	**79**	**41**	**44**	**31**	**54**	**34**	**24**	**4**

***** Non-native

† *H. amnis* reported second-hand by Scott (2010) and attributed to sampling conducted by KDFWR in 2005.

Appendix E. Bird species, compiled by Stedman and Stedman (2007), reported from Big South National River and Recreation Area from all sources. Includes indication of whether species were listed as "present" in NPSpecies, reported by Stedman at any point during research in the park, reported by Stedman and Stedman during the I&M inventory period, the season(s) of reported occurrence (1994-2006), whether the species is included as a priority concern species an either state's Comprehensive Wildlife Conservation Strategy (CWCS), or listed by either state as endangered (E), threatened (T), special concern (S), or deemed in need of management (D).

					Seasonal Occurrence					
Common Name	**Scientific Name**	**NPSpecies**	**Stedman 1994-2006**	**I&M 2003-2005**	**Spr**	**Sum**	**Aut**	**Win**	**CWCS**	**State List**
Cooper's Hawk	*Accipiter cooperi*	x	x	x		x	x			
Sharp-shinned Hawk	*Accipiter striatus*	x	x		x	x	x		KY,TN	S(KY),D(TN)
Spotted Sandpiper	*Actitis macularia*	x	x		x					E(KY)
Northern Saw-whet Owl	*Aegolius acadicus*	x	x	x				x	TN	T(TN)
Red-winged Blackbird	*Agelaius phoeniceus*	x	x	x	x	x	x	x		
Wood Duck	*Aix sponsa*	x	x	x	x	x	x	x		
Green-winged Teal	*Anas crecca*	x								
Blue-winged Teal	*Anas discors*	x								T(KY)
Mallard	*Anas platyrhynchos*	x	x	x				x		
American Black Duck	*Anas rubripes*	x	x	x				x	KY	
American Pipit	*Anthus rubescens*	x								
Ruby-thr. Hummingbird	*Archilochus colubris*	x	x	x	x	x	x			
Great Blue Heron	*Ardea herodias*	x	x	x	x	x	x			S(KY)
Short-eared Owl	*Asio flammeus*								KY,TN	E(KY)
Ring-necked Duck	*Aythya collaris*	x								
Tufted Titmouse	*Baeolophus bicolor*	x	x	x	x	x	x	x		
Cedar Waxwing	*Bombycilla cedrorum*	x	x	x	x	x	x	x		
Ruffed Grouse	*Bonasa umbellus*	x	x	x	x	x	x	x		
Canada Goose	*Branta canadensis*	x	x	x				x		
Great Horned Owl	*Bubo virginianus*	x	x	x				x		
Red-tailed Hawk	*Buteo jamaicensis*	x	x	x	x	x	x	x		
Red-shouldered Hawk	*Buteo lineatus*	x	x	x	x	x	x	x		
Broad-winged Hawk	*Buteo platypterus*	x	x	x	x	x	x			
Green Heron	*Butorides virescens*	x	x	x	x	x				
Chuck-will's-widow	*Caprimulgus carolinensis*	x	x	x		x			TN	
Whip-poor-will	*Caprimulgus vociferus*	x	x	x	x	x			TN	
Northern Cardinal	*Cardinalis cardinalis*	x	x	x	x	x	x	x		
Pine Siskin	Carduelis pinus	x	x	x	x		x			

Appendix E (continued)

Common Name	Scientific Name	NPSpecies	Stedman 1994-2006	I&M 2003-2005	Seasonal Occurrence Spr	Sum	Aut	Win	CWCS	State List
American Goldfinch	*Carduelis tristis*	x	x	x	x	x	x	x		
House Finch	*Carpodacus mexicanus*	x	x	x	x	x	x	x		
Purple Finch	*Carpodacus purpureus*	x	x	x	x			x		
Turkey Vulture	*Cathartes aura*	x	x	x	x	x	x	x		
Veery	*Catharus fuscescens*	x	x		x		x			
Hermit Thrush	*Catharus guttatus*	x	x	x			x	x		
Gray-cheeked Thrush	*Catharus minimus*	x	x				x			
Swainson's Thrush	*Catharus ustulatus*	x	x	x	x	x	x			
Brown Creeper	*Certhia americana*	x	x	x			x	x	KY,TN	
Belted Kingfisher	*Ceryle alcyon*	x	x	x	x	x	x	x		
Chimney Swift	*Chaetura pelagica*	x	x	x	x	x	x			
Killdeer	*Charadrius vociferus*	x	x	x		x	x	x		
Common Nighthawk	*Chordeiles minor*	x								
Northern Harrier	*Circus cyanea*	x							KY,TN	T(KY),D(TN)
Marsh Wren	*Cistothorus palustris*	x								
Yellow-billed Cuckoo	*Coccyzus americanus*	x	x	x	x	x	x		TN	
Black-billed Cuckoo	*Coccyzus erythropthalmus*	x	x		x					
Northern Flicker	*Colaptes auratus*	x	x	x	x	x	x	x		
Northern Bobwhite	*Colinus virginianus*	x	x		x				KY	
Rock Pigeon	*Columba livia*	x	x	x		x		x		
Olive-sided Flycatcher	*Contopus cooperi*	x	x		x				TN	D(TN)
Eastern Wood-Pewee	*Contopus virens*	x	x	x	x	x	x			
Evening Grosbeak	*Coocothrautes vespertinus*	x							TN	
Black Vulture	*Coragyps atratus*	x	x	x	x	x	x	x		
American Crow	*Corvus brachyrhynchos*	x	x	x	x	x	x	x		
Blue Jay	*Cyanocitta cristata*	x	x	x	x	x	x	x		
Black-thr. Blue Warbler	*Dendroica caerulescens*	x	x				x		TN	
Bay-breasted Warbler	*Dendroica castanea*	x	x		x		x			
Cerulean Warbler	*Dendroica cerulea*	x	x	x	x	x			KY,TN	D(TN)

Appendix E (continued)

Common Name	Scientific Name	NPSpecies	Stedman 1994-2006	I&M 2003-2005	Seasonal Occurrence Spr	Sum	Aut	Win	CWCS	State List
Yellow-rumped warbler	*Dendroica coronata*	x	x	x	x		x	x		
Prairie Warbler	*Dendroica discolor*	x	x	x	x	x			KY,TN	
Yellow-throated Warbler	*Dendroica dominica*	x	x	x	x	x	x		TN	
Blackburnian Warbler	*Dendroica fusca*	x	x		x		x		KY	T(KY)
Magnolia Warbler	*Dendroica magnolia*	x	x				x			
Palm Warbler	*Dendroica palmarum*	x	x		x		x			
Chestnut-sided Warbler	*Dendroica pensylvanica*	x	x	x	x	x	x			
Yellow Warbler	*Dendroica petechia*	x	x		x					
Pine Warbler	*Dendroica pinus*	x	x	x	x	x	x	x		
Blackpoll Warbler	*Dendroica striata*	x	x		x	x				
Cape May Warbler	*Dendroica tigrina*	x	x		x					
Black-thr. Green Warbler	*Dendroica virens*	x	x	x	x	x	x		TN	
Bobolink	*Dolichonyx oryzivorus*								KY	S(KY)
Pileated Woodpecker	*Dryocopus pileatus*	x	x	x	x	x	x	x		
Gray Catbird	*Dumetella carolinensis*	x	x	x	x	x	x			
Least Flycatcher	*Empidonax minimus*								KY,TN	E(KY)
Acadian Flycatcher	*Empidonax virescens*	x	x	x	x	x	x		TN	
Merlin	*Falco columbarius*	x								
Peregrine Falcon	*Falco peregrinus*								KY,TN	E(KY,TN)
American Kestrel	*Falco sparverius*	x	x				x			
American Coot	*Fulica americana*	x								E(KY)
Wilson's Snipe	*Gallinago delicata*	x	x				x		KY	
Common Loon	*Gavia immer*	x								
Common Yellowthroat	*Geothlypis trichas*	x	x	x	x	x	x			
Sandhill Crane	*Grus canadensis*	x	x	x				x		
Bald Eagle	*Haliaeetus leucocephalus*	x	x	x				x	KY,TN	T(KY),D(TN)
Worm-eating Warbler	*Helmitheros vermivorus*	x	x	x	x	x	x		KY,TN	
Barn Swallow	*Hirundo rustica*	x	x	x	x	x				
Wood Thrush	*Hylocichla mustelina*	x	x	x	x	x	x		KY,TN	
Yellow-breasted Chat	*Icteria virens*	x	x	x	x	x				
Baltimore Oriole	*Icterus galbula*	x	x		x					
Orchard Oriole	*Icterus spurius*	x	x		x	x			TN	

Appendix E (continued)

Common Name	Scientific Name	NPSpecies	Stedman 1994-2006	I&M 2003-2005	Seasonal Occurrence Spr	Sum	Aut	Win	CWCS	State List
Dark-eyed Junco	*Junco hyemalis*	x	x	x	x		x	x		S(KY)
Loggerhead Shrike	*Lanius ludovicianus*								KY,TN	D(TN)
Swainson's Warbler	*Limnothlypis swainsonii*	x	x	x	x	x			KY,TN	D(TN)
Hooded Merganser	*Lophodytes cucullatus*	x							KY	T(KY)
Red Crossbill	*Loxia curvirostra*									
Red-bellied Woodpecker	*Melanerpes carolinus*	x	x	x	x	x	x	x		
Red-headed Woodpecker	*Melanerpes erythrocephalus*	x	x	x			x		KY,TN	
Surf Scoter	*Melanitta perspicillata*	x	x		x					
Wild Turkey	*Meleagris gallopavo*	x	x	x	x	x	x	x		
Swamp Sparrow	*Melospiza georgiana*	x	x	x	x		x	x		
Lincoln's Sparrow	*Melospiza lincolnii*	x								
Song Sparrow	*Melospiza melodia*	x	x	x	x	x	x	x		
Northern Mockingbird	*Mimus polyglottus*	x	x	x						
Black-and-White Warbler	*Mniotilta varia*	x	x	x	x	x	x			
Brown-headed Cowbird	*Molothrus ater*	x	x	x	x	x		x		
Great Crested Flycatcher	*Myiarchus crinitus*	x	x	x	x	x				
Kentucky Warbler	*Oporornis formosus*	x	x	x	x	x			KY,TN	
Mourning Warbler	*Oporornis philadelphia*	x	x	x		x				
Eastern Screech-Owl	*Otus asio*	x	x	x		x	x	x		
Osprey	*Pandion haliaetus*	x	x		x		x		KY	T(KY)
Northern Parula	*Parula americana*	x	x	x	x	x	x		TN	
House Sparrow	*Passer domesticus*	x	x	x	x	x	x	x		
Savannah Sparrow	*Passerculus sandwichensis*	x							KY,TN	S(KY)
Fox Sparrow	*Passerella iliaca*	x	x	x			x	x		
Blue Grosbeak	*Passerina caerulea*	x	x	x		x				
Indigo Bunting	*Passerina cyanea*	x	x	x	x	x	x			
Double-crested Cormorant	*Phalacrocorax auritus*	x	x	x		x				E(KY)
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	x	x		x		x		KY	S(KY)

Appendix E (continued)

Common Name	Scientific Name	NPSpecies	Stedman 1994-2006	I&M 2003-2005	Seasonal Occurrence Spr	Sum	Aut	Win	CWCS	State List
Red-cockaded Woodpecker	*Picoides borealis*								KY	E(F, KY)
Downy Woodpecker	*Picoides pubescens*	x	x	x	x	x	x	x		
Hairy Woodpecker	*Picoides villosus*	x	x	x	x	x	x	x		
Eastern Towhee	*Pipilo erythrophthalmus*	x	x	x	x	x	x	x		
Scarlet Tanager	*Piranga olivacea*	x	x	x	x	x	x			
Summer Tanager	*Piranga rubra*	x	x	x	x	x	x			
Pied-billed Grebe	*Podilymbus podiceps*	x	x				x		KY	E(KY)
Carolina Chickadee	*Poecile carolinensis*	x	x	x	x	x	x	x		
Blue-gray Gnatcatcher	*Polioptila caerulea*	x	x	x	x	x	x			
Vesper Sparrow	*Pooecetes gramineus*	x							KY,TN	E(KY),D(TN)
Purple Martin	*Progne subis*	x	x	x	x	x				
Prothonotary Warbler	*Protonotaria citrea*	x	x	x	x			x	KY,TN	
Common Grackle	*Quiscalus quiscula*	x	x	x	x	x		x		
Ruby-crowned Kinglet	*Regulus calendula*	x	x	x	x		x	x		
Golden-crowned Kinglet	*Regulus satrapa*	x	x	x	x		x	x	TN	
Eastern Phoebe	*Sayornis phoebe*	x	x	x	x	x	x	x		
American Woodcock	*Scolopax minor*	x	x	x	x	x		x	KY,TN	
Ovenbird	*Seiurus aurocapillus*	x	x	x	x	x	x			
Louisiana Waterthrush	*Seiurus motacilla*	x	x	x	x	x			KY,TN	
Northern Waterthrush	*Seiurus noveboracensis*	x	x				x			
American Redstart	*Setophaga ruticilla*	x	x	x	x	x	x			
Eastern Bluebird	*Sialia sialis*	x	x	x	x	x	x	x		
Red-breasted Nuthatch	*Sitta canadensis*	x	x	x	x	x	x	x	KY,TN	E(KY)
White-breasted Nuthatch	*Sitta carolinensis*	x	x	x	x	x	x	x		
Yellow-bellied Sapsucker	*Sphyrapicus varius*	x	x	x			x	x	TN	D(TN)
American Tree Sparrow	*Spizella arborea*	x								
Chipping Sparrow	*Spizella passerina*	x	x	x	x	x	x			
Field Sparrow	*Spizella pusilla*	x	x	x	x	x	x	x		
N. Rough-winged Swallow	*Stelgidopteryx serripennis*	x	x	x	x	x				
Barred Owl	*Strix varia*	x	x	x	x	x	x	x		
Eastern Meadowlark	*Sturnella magna*	x	x	x	x	x		x		

Appendix E (continued)

Common Name	Scientific Name	NPSpecies	Stedman 1994-2006	I&M 2003-2005	Seasonal Occurrence Spr	Sum	Aut	Win	CWCS	State List
European Starling	*Sturnus vulgaris*	x	x	x	x	x	x	x		
Tree Swallow	*Tachycineta bicolor*	x								
Carolina Wren	*Thryothorus ludovicianus*	x	x	x	x	x	x	x		
Brown Thrasher	*Toxostoma rufum*	x	x	x	x	x	x	x		
Greater Yellowlegs	*Tringa melanoleuca*	x								
Solitary Sandpiper	*Tringa solitaria*								KY	
House Wren	*Troglodytes aedon*	x	x	x	x		x	x		
Winter Wren	*Troglodytes troglodytes*	x	x	x			x	x	TN	
American Robin	*Turdus migratorius*	x	x	x	x	x	x	x		
Eastern Kingbird	*Tyrannus tyrannus*	x	x	x	x	x				
Orange-crowned Warbler	*Vermivora celata*	x	x				x			
Golden-winged Warbler	*Vermivora chrysoptera*	x	x		x		x		KY,TN	T(KY),D(TN)
Tennessee Warbler	*Vermivora peregrina*	x	x		x		x			
Blue-winged Warbler	*Vermivora pinus*	x	x		x		x		KY,TN	
Nashville Warbler	*Vermivora ruficapilla*	x	x		x		x			
Yellow-throated Vireo	*Vireo flavifrons*	x	x	x	x	x	x		TN	
White-eyed Vireo	*Vireo griseus*	x	x	x	x	x	x		TN	
Red-eyed Vireo	*Vireo olivaceous*	x	x	x	x	x	x	x		
Philadelphia Vireo	*Vireo philadelphicus*	x	x				x			
Blue-headed Vireo	*Vireo solitarius*	x	x	x	x	x	x			
Canada Warbler	*Wilsonia canadensis*	x	x		x		x		KY	S(KY)
Hooded Warbler	*Wilsonia citrina*	x	x	x	x	x	x		TN	
Mourning Dove	*Zenaida macroura*	x	x	x	x	x	x	x		
White-throated Sparrow	*Zonotrichia albicollis*	x	x	x	x		x	x		
White-crowned Sparrow	*Zonotrichia leucophrys*	x	x				x			
	Total	**165**	**147**	**115**	**115**	**94**	**15**	**66**		

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National Park Service
U.S. Department of the Interior

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

www.nature.nps.gov