SURVEY OF BAT COMMUNITIES AT THREE NATIONAL PARK AREAS IN THE CENTRAL APPALACHIANS OF WEST VIRGINIA

by

MICHAEL RICHARD SCHIRMACHER
Under the Direction of Dr. Steven B. Castleberry and Dr. Karl V. Miller

ABSTRACT

During the summers of 2003 and 2004, I used a combination of live-capture and acoustic monitoring techniques to inventory the bat community and to model habitat associations for bat species in the Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, located in the central Appalachians of West Virginia. I live-captured 175 bats representing eight species: little brown bat (*M. lucifugus*), northern myotis (northern long-eared bat; *Myotis septentrionalis*), eastern small-footed myotis (*M. leibii*), silver-haired bat (*Lasionycteris noctivagans*), eastern pipistrelle (*Pipistrellus subflavus*), big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), and hoary bat (*L. cinereus*). Using ultrasonic acoustical detectors (Anabat II), I sampled 680 sites for 20 minutes throughout the three National Park Areas. I detected all species captured, and also recorded the presence of the federally endangered Indiana bat (*Myotis sodalis*) at 18 sites. Using logistic regression, I constructed predictive models of habitat associations based on presence and absence of species using ultrasonic detectors. In addition, I evaluated *a priori* models using Akaike's Information Criteria. My species-specific habitat models demonstrated that habitat use could be predicted for the little brown bat, eastern pipistrelle, big brown bat, and eastern red bat. Landscape level habitat variables such as distance from 1st to 4th

order streams and close proximity to ponds and lakes were important model components for the northern myotis, whereas local habitat structure (open or closed canopy and water at the site) were important habitat factors for predicting the presence of the Indiana bat and the eastern small-footed myotis. In a landscape dominated by closed canopy forest both clutter and open-adapted species used the available habitats as expected. I was probably able to model open-adapted species more effectively because of the limited number of openings which are important foraging areas, and therefore make detecting these species easier in those habitats. Consequently, there was more closed canopy habitat that made modeling the clutter-adapted species more difficult. I detected the northern myotis at twice the number of locations than other clutter-adapted species, thereby suggesting that my inability to model these other clutter-adapted species is linked to these species being less common in the three park units.

INDEX WORDS: Anabat, Akaike's Information Criteria, bats, Bluestone National Scenic River, central Appalachians, Gauley River National Recreation Area, habitat association, habitat use, New River Gorge National River, ultrasonic detectors, West Virginia

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B.S. Biology, Tennessee Technological University, 2002

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial

Fulfillment

of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2006

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December 2006

DEDICATION

This thesis is dedicated to those friends and family that have truly molded me into the person I am today. My family has been my overall inspiration for pursuing this degree. Both my sisters, Michelle Hamilton and Lesa Schirmacher, have influenced me and taught me to work hard but have fun doing it. They have been incredible during my graduate program and I wish to thank them for their moral support during this degree program. Also I would like to dedicate this thesis to my father, Michael Schirmacher, and stepfather, Charles Dickens. They are living through me with the values and lessons they instilled in me growing up. Most of all I would like to dedicate this thesis to my mother, Patricia Dickens. Ever since I was a kid she has always supported my dreams and inspired me to be the best person I can be. Even during tough times, she stood by me and inspired me to not let anything "break my stride".

ACKNOWLEDGEMENTS

Funding was provided under cooperative agreement number 02-CA-11242343-120 between the University of Georgia and United States Department of Agriculture Forest Service. I would like to thank Steven B. Castleberry, W. Mark Ford, and Karl V. Miller for development and securing funding for this project.

I also like to thank Steven B. Castleberry and W. Mark Ford for their valuable guidance, continual patience and support during this project. I would like to thank Cris Hein, Karl V. Miller, and Sara H. Schweitzer for review of previous thesis drafts. I thank Eric Britzke for his guidance and for the use of programs used in my analysis. Thanks to Matt Stover for field assistance and all other volunteers that helped this project run smoothly. I would like to thank the GIS labs of National Park Service and the D. B. Warnell School of forestry and Natural Resources, for help in spatial analysis. I appreciate all of the professors and graduate students for support and an enjoyable graduate experience.

Finally, I would like to thank family and friends for there continued support throughout this project.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Since 1916, the National Park Service (NPS; United States Department of the Interior) has set aside 390 units comprising more than 33 million hectares as public land for recreational benefit or for the appreciation and protection of areas of historical significance, scenic beauty, and natural resources (National Park Service 2005). To identify the significant natural resources for proper conservation and management of biotic communities and physical features, the NPS established the Vail Agenda to promote a comprehensive strategy for protecting these areas (National Park Service 2006a). Accordingly, providing robust natural resource information in a complete and timely manner is the Vail Agenda mandate to the NPS Natural Resource Inventory and Monitoring Program (National Park Service 2006a). The program goal is to acquire the information and expertise needed by park managers so that they can maintain ecosystem integrity and meet regulatory obligations under statutes such as the National Environmental Policy Act and the Endangered Species Act.

The New River Gorge Complex, a candidate for the Vail Agenda, is approximately 35,614 ha of mature hardwood forests and consists of three National Park Units: Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI). These areas are protected for their recreational value, scenic beauty, and rare biotic and physical features. Basic community ecology of flora and fauna has been documented but with the presence of sensitive and endangered bat species, a better understanding of the habitat and their habitat use is needed.

With the scattered presence of endangered or sensitive bat species such as the Indiana bat (*Myotis sodalis*), eastern small-footed bat (*M. leibii*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), and Virginia big-eared bat (*C. townsendii virginianus*) in the central Appalachians, knowledge of their regional and local foraging habitat relationships is needed. This knowledge is important for adequate conservation of these species, as well as the whole bat community, on both public and privately owned land. The three National Park Areas provide an opportunity to examine bat communities and ecological relationships in a central Appalachian landscape that encompasses significant variability in elevation, surface geology, riparian zones, forest types, and legacies of anthropogenic change and impact (e.g. mining, abandoned structures, etc.). Knowledge of these foraging relationships is crucial for land managers attempting to provide suitable habitat for sensitive or endangered bats. Given the need for information regarding bat habitat associations in the region, the objectives of my thesis were to inventory the species of bats in the Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, and to develop predictive species-specific habitat association models. Information gained in this study will be useful in creating management strategies that protect suitable habitat for bats.

This thesis is written in manuscript format. Chapter 1 is an introduction to the study and literature review. Chapter 2 is a species inventory and will be submitted to the National Park Service. Chapter 3 describes bat community structure and activity and will be submitted to the Southeastern Naturalist. Chapter 4 summarizes important findings, management implications and conclusions.

LITERATURE REVIEW

Central Appalachian Landscape

Geology.–The New River Gorge Complex is located within the Unglaciated Allegheny Plateau, a subsection of the Appalachian Plateau physiographic province, which is characterized by having steep slopes, narrow valleys, and plateau-like ridge tops (Fenneman 1938). This portion of the central Appalachians is primarily comprised of sandstones with some limestone, coal and various shales. The lack of karst limestone features limits cave presence. Alternatively, coal mining has occurred historically leaving numerous abandoned deep mines. Deep mines provide habitat similar to caves, creating stable microclimates that animals use to conserve energy, especially in the winter. Similarly, because of the geological composition and steep slopes, two other types of rock openings are found, intergranular openings and fractures (National Park Service 2006b). Intergranular openings are common with coarse-grained sandstone and are formed when rock material is deposited, compacted and cemented (National Park Service 2006b). Stress-relief fractures are caused by uplifting effects (Wyrick and Borchers 1981). The New River Gorge averages about 305 m in depth where exposed sandstone rock faces contain numerous intergranular openings and fractures (Suiter 1995). These types of openings provide unique habitat for some bat species by providing protection and a stable microclimate. These natural features, as well as past anthropogenic impacts, provide habitat for various bat species in the central Appalachians.

Forest Cover.–The central Appalachians are dominated by both mixed-mesophytic and oak (*Quercus* spp.)-hickory (*Carya* spp.) forest types (Braun 1950). The three park units are covered by approximately 35,614 ha of second- or third-growth forests and depending upon aspect, site quality, elevation, and past land-use history, overstories are dominated by chestnut oak (*Q. prinus*), northern red oak (*Q. rubra*), white oak (*Q. alba*), tulip tree (*Liriodendron tulipifera*), red maple (*Acer rubrum*), black oak (*Q. velutina*), sugar maple (*A. saccharum*), and/or yellow buckeye (*Aesculus flava*). Forest understories are dominated by hillside blueberry (*Vaccinium pallidum*), mountain laurel (*Kalmia latifolia*), and wood nettle (*Laportea canadensis*). The larger riparian zones have scattered communities of sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), and ironwood (*Carpinus caroliniana*), whereas eastern hemlock (*Tsuga canadensis*), sweet birch (*Betula lenta*), and rosebay rhododendron (*Rhododrendron maximum*) forest dominated smaller streamside corridors and drains. Other trees found less frequently and in small patches include eastern red cedar (*Juniperus virginiana*) on limestone outcrops and Virginia pine (*Pinus virginiana*), pitch pine (*P. rigida*), and post oak (*Q. stellata*) usually associated with dry summit forest and/or exposed cliff lines (National Park Service, unpublished data).

Land Use.–The thin coal beds of southern West Virginia made this region economically important since the Chesapeake and Ohio Railroad opened the area to mining and timber harvest in the early 1870's (Suiter 1995). From 1900 to 1935, coal mining, timber harvesting, and railroading dominated the economy of this region, but by 1935 the landscape had been dramatically impacted and resources were rapidly deteriorating (Suiter 1995). Coal mining alters both surface water and ground water chemistry of many small watersheds in southern West Virginia (Borchers et al. 1991). The streams in mined areas typically have lower pH and specific conductance, and greater concentrations of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, manganese, and dissolved solids than streams draining unmined areas (National Park Service 2006b). These changes in water chemistry affect bats by decreasing water quality and thereby decreasing the abundance of aquatic invertebrates. Although there are many negative effects of coal mining, other studies have documented bat species taking advantage of these landscape manipulations, especially deep mines for day-roosting and hibernation (Weese 1990, 1991; Johnson et al. 2003, 2005).

The first coal mine in the area currently designated as New River Gorge National River opened in 1891 (Suiter 1995). After resources became depleted many of the settlements built around the earlier extraction period were abandoned. Many years thereafter, three National Park Units were established in the1970's and 1980's, beginning with New River Gorge National River in 1978 and adding the Gauley River National Recreation Area and Bluestone National Scenic Rivers in 1988 (National Park Service 2005). These areas were acquired by the federal government because of their recreational benefit, scenic beauty, historical significance, and natural resources. However, the three National Park Units own only a small portion of the mineral rights, with the Office of Surface Mining responsible for determining if mining can continue or resume in the parks (National Park Service 2006b). The NERI and GARI have >120 abandoned deep-mine shafts. Although no mines exist on BLUE, a major oil and gas pipeline transects the park (National Park Service 2006b). These National Park Units provide an opportunity to examine the recovery of a landscape that has had many anthropogenic impacts.

Central Appalachians Bats

Species Presence.–In the central Appalachians of West Virginia, five of the 13 bat species historically present are listed as sensitive or vulnerable to extinction (West Virginia Division of Natural Resources 2005). These species include the eastern small-footed myotis, gray bat (*M. grisescens*), Rafinesque's big-eared bat, Virginia big-eared bat, and the Indiana bat. There was only a single documentation of two individual gray bats in West Virginia and it was considered accidental (West Virginia Division of Natural Resources 2006). In the central Appalachians, the eastern small-footed myotis and both big-eared bats have been documented using abandoned mine portals as roost sites during the summer and fall (Johnson et al. 2003, 2005). Also, both the eastern small-footed myotis and the Virginia big-eared bat have been documented using standstone rock bluffs as roost sites (McDaniel et al. 1982, Lacki et al. 1994).

In West Virginia, winter populations of Indiana bats have been estimated at approximately 10,000 in approximately 26 caves (Stihler and Wallace 2004). Even with the presence of many hibernacula in West Virginia, within the Allegheny Mountian portion of the central Appalachian temperatures were thought to be too low for Indiana bats to form summer maternity colonies. However, nine maternity colonies were documented in 2003 and 2004 (Beverly and Gumbert 2004). Furthermore, Indiana bats have been documented roosting in dead trees (snags) of many tree species found in the central Appalachians (Humprey et al. 1977, Kurta et al. 1993, Callahan et al. 1997). These tree species include snags of oaks and green ash, as well as live northern red oak and shagbark hickory (*Carya ovata*). With the presence of many hibernacula in close proximity to the three National Park Units and with many tree species used by Indiana bats for maternity colonies, these three parks units have the potential to serve as summer habitat for this endangered species.

In addition to providing potential habitat for several sensitive species, the combination of protected forests and large riverine riparian zones in the region likely provides abundant summer roosting and foraging habitat for more common tree-roosting species such as the little brown bat (*M. lucifugus*) and the northern myotis (*M. septentrionalis*), as well as foliage-roosting eastern red bats (*Lasiurus borealis*) and hoary bats (*L. cinereus*). Clifflines, abandoned deep mines, and abandoned buildings in the parks could be potential winter hibernacula and summer roosting habitat for little brown bats, northern myotis, big brown bats (*Eptesicus fuscus*) and eastern pipistrelles (*Pipistrellus subflavus*). The large river corridors cutting through the Allegheny Plateau in this region may serve as important early-late spring and fall migration routes for silver-haired bats (*Lasionycteris noctivagans*; Menzel et al. 2000). Evening bats (*Nycticeius humeralis*) were historically documented for this region, however, if present, they are considered extremely rare.

Habitat Associations.–In the eastern United States, considerable effort has been expended studying the foraging ecology of bats using radiotelemetry (e.g., Hurst and Lacki 1999, Menzel et al. 2001, Owens et al. 2003, Brack 2006). However, these studies are limited in geographic scope and species coverage because of the cost and difficulty of triangulating highly mobile species, especially in areas with steep terrain. Ultrasonic detectors are relatively cost-effective and highly portable, making them a valuable tool in assessing habitat use in challenging terrain or where large areas need surveyed. Widespread application of ultrasonic detectors has led to an increase in the number studies examining the foraging habitat use of bats over larger scales in a variety of areas, such as the Jura Mountains of Switzerland (Jaberg and Guisan 2001), Britain (Walsh and Harris 1996, Vaugh et al. 1997), northern Ireland (Russ and Montgomery 2002), Canada (Crampton and Barclay 1998, Jung et al. 1999, Hodgberg et al. 2002, Broders et al. 2003), New Hampshire and Maine (Krusic et al. 1996, Zimmerman and Glanz 2000), western United States (Thomas 1988, Erickson and West 2003, Ellison et al. 2005), South Carolina (Menzel et al. 2002; 2005a, b), and the Allegheny Mountains of West Virginia (Owens et al. 2004, Ford et al. 2005). Nonetheless, research using ultrasonic detectors has not reached its fullest potential as most studies have examined general bat activity at a single spatial scale. Erickson and West (2003) suggest that multiple habitat scales might be important for bats because of their high vagility. Studies using ultrasonic detectors to assess species-specific habitat association, at local- and landscape-levels, can be important especially in areas with sensitive and endangered species because their relative low numbers make them difficult to capture using traditional techniques.

Research in Ontario, the Pacific Northwest (Jung et al. 1999, Erickson and West 2003), and the Northeast (Krusic et al. 1996) have used ultrasonic detectors to examine stand-level habitat components (density of live and dead trees, stand-class, and forest type) linking high bat activity to potential day-roosts. These studies demonstrated habitat associations with potential roost sites but may miss important habitat features associated with foraging areas. In the Allegheny plateau, Ford et al. (2005) reported local-level factors such as percent canopy cover and width of canopy gaps as important habitat components to bats. Little brown bat, hoary bat, and eastern red bat presence was linked to larger canopy gaps and openings whereas the presence of Indiana bats and northern myotis was related to increased canopy cover. Also in the same region, Owens et al. (2004) documented silver-haired bat and hoary bat using open areas. These studies give insight at the micro-habitat scale by demonstrating habitat use based on morphology of species.

Many studies have examined landscape-level habitat features and their importance to different bat species. Research in Britain (Vaughan et al. 1997, Walsh and Harris 1996), Alberta, Canada (Crampton and Barclay 1998, Hogberg et al. 2002), and South Carolina (Menzel et al. 2002) identified habitat configuration, such as edge, as an important habitat feature for bats. Edge provides habitat with low structural complexity and high insect abundance which is utilized by many bat species. In Switzerland, Jaberg and Guisan (2001) found that elevation and vegetation cover could be used to predict presence of many bat species while anthropogenically modified landscapes (e.g., vineyards) were avoided by many species. In Britain (Vaughan et al. 1997, Walsh and Harris 1996), New Mexico (Ellison et al. 2005), South Carolina (Menzel et al. 2005b), and West Virginia, (Owens et al. 2004, Ford et al. 2005), high levels of bat activity and species richness were found in riparian zones. These studies demonstrate that landscape-level habitat features are utilized by many different bat species in many different geographic regions.

Temporal and climatic factors also are important to bats because of their effect on prey availability and thermoregulation (Graham 1983). Near day-roost areas, Crampton and Barclay (1998) reported higher levels of bat activity the first hour after sunset demonstrating a connection between spatial and temporal factors. Bat activity is positively correlated with higher minimum nightly temperature and these patterns vary within nights, among nights within seasons, and among seasons accordingly (Hayes 1997, Vaughan et al. 1997, Ellison 2005). In Maine, temporal differences in bat activity between summer and fall were related to seasonal fluctuations in water levels (Zimmerman and Glanz 2000). These studies suggest there is variation in habitat use over different temporal scales and temperature ranges.

The New River Gorge and surrounding park units are a template for a central Appalachian landscape that is recovering from past anthropogenic impacts (timber harvest and mining) and provides an opportunity to examine bats response to these changes. This area is logistically difficult to study because of its remoteness, variation in topography, large rivers and mature forest, yet these same features provide habitat for eleven species of bats. Determining bat habitat use in this area will provide park managers with information necessary for them to meet regulatory obligations of the National Environment Policy Act and the Endangered Species Act by protecting and limiting disturbance of endangered species.

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CHAPTER 2

SURVEY OF BAT COMMUNITIES IN THE NEW, GAULEY, AND BLUESTONE RIVER NATIONAL PARK AREAS[1]

[1] Schirmacher, M. R., S. B. Castleberry, W. M. Ford, and K. V. Miller. To be submitted to the National Park Service.

ABSTRACT

Previous studies of bat communities in the New River Gorge National River and Gauley River National Recreation Area primarily involved surveys of abandoned mine portals. Although mine surveys are an effective way to detect bat species that use caves and mines as roost sites, they are ineffective for species that use tree-roosts during all or part of the year. During the summers of 2003 and 2004, we surveyed three National Park Service units (aforementioned two parks and Bluestone National Scenic River) using a combination of live-capture and acoustic monitoring techniques to provide a more thorough inventory of the bat community. We live-captured 175 bats representing eight species: little brown bat (*M. lucifugus*), northern myotis (northern long-eared bat*; Myotis septentrionalis*), eastern small-footed myotis (*M. leibii*), silver-haired bat (*Lasionycteris noctivagans*), eastern pipistrelle (*Pipistrellus subflavus*), big brown bat (*Eptesicus fuscus*), red bat (*Lasiurus borealis*), and hoary bat (*L. cinereus*). The eastern small-footed myotis is considered a federal species of concern and the silver-haired bat had not been previously documented locally. With the Anabat II acoustical detectors, we sampled 680 sites and detected the aforementioned eight species in addition to the endangered Indiana bat (*M. sodalis*). With the exception of the two big-eared bat (*Corynorhinus rafinesquiie* and *C. townsendii*) species, we detected all extant bat species known to occur in the region. In our acoustical surveys, we identified 18 stations that approach 100% predicted probability of Indiana bat presence. Of these 18 sites, most were located in forested riparian zones at a xeric aspect. These sites should be sampled using live-capture techniques to verify presence of the federally endangered Indiana bat and to determine if there is a resident breeding population. If maternity colonies are

confirmed, these sites should be monitored to ensure there is limited disturbance especially during the breeding season.

INTRODUCTION

In 1991, the National Park Service (NPS; United States Department of the Interior) established the Vail Agenda and mandated the NPS Natural Resource Inventory and Monitoring Program to promote a comprehensive strategy for protecting natural resources in National Park Areas (National Park Service 2006a). The program goal was to acquire the information and expertise needed by park managers to maintain ecosystem integrity and meet regulatory obligations under statutes such as the National Environmental Policy Act and the Endangered Species Act.

The New River Gorge Complex, a candidate for the Vail Agenda, is covered by approximately 35,614 ha of mature hardwood forests and consists of three National Park Units: New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and the Bluestone National Scenic River (BLUE). These areas were protected during the 1970's and 1980's for their recreational value, scenic beauty, and rare biotic and physical features. Basic community ecology of flora and fauna has been documented, but with the presence of sensitive and endangered bat species, a better understanding of their occurrence throughout the parks and their habitat use is needed.

Within the Park Complex, four of the 11 bat species present are listed as sensitive or vulnerable to extinction (West Virginia Division of Natural Resources 2005). These species include the eastern small-footed myotis (*Myotis leibii*), Indiana bat (*M. sodalis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), and Virginia big-eared bat (*C.*

townsendii virginianus). All of these species have been documented using abandoned mine portals in the Gauley River National Recreation Area and New River Gorge National River (Johnson et al. 2003, 2005) but little is known about their distribution throughout these areas, as well as in the Bluestone National Scenic River. The combination of mature forests and large riparian zones in the park units likely provides abundant summer roosting and foraging habitat for more common tree-roosting species, such as little brown bats (*M. lucifugus*) and northern myotis (*M. septentrionalis*), as well as foliage-roosting eastern red bats (*Lasiurus borealis*) and hoary bats (*L. cinereus*). Clifflines, abandoned deep mines, and abandoned buildings in the New River Gorge Complex also could be potential winter hibernacula for Indiana bats, little brown bats, and northern myotis as well as both hibernacula and summer roosting habitat for small-footed bats, Rafinesque's big-eared bats, Virginia big-eared bats, big brown bats (*Eptesicus fuscus*), and eastern pipistrelles (*Pipistrellus subflavus*). Additionally, the large river corridors cutting through the Allegheny Plateau in this region may serve as important early-late spring and fall migration routes for silver-haired bats (*Lasionycteris noctivagans*; Menzel et al. 2000).

Previous studies in the park units included surveys of abandoned mine portals (Weese 1990, 1991; Johnson et al. 2003, 2005). Mine surveys are an effective way to detect species such as Virginia big-eared bats (Rippy and Harvey 1965), Rafinesque's big-eared bats, and the eastern small-footed myotis (Davis 1955) that utilize these habitats at some points in the year, if suitable and available. However, they are ineffective for species such as the eastern red bat (Hall and Kelson 1959) and hoary bat (Cowan and Guiguet 1965) that tree-roost throughout the year. Moreover, during the summer months, female northern myotis (Barbour and Davis 1969) and Indiana bats (Humphrey et al. 1977) usually are not associated with mines, caves or clifflines, but instead form maternity colonies in cavities or exfoliating bark of live trees or dead trees (snags). Little brown and big brown bats have been documented utilizing man-made structures (i.e. buildings) as day-roosting and maternity colonies (Barbour and Davis 1969, Fenton and Barclay 1980).

To fully understand bat communities in the park units and the central Appalachians in general, more complete surveys involving multiple methods are necessary. This study was undertaken to augment previous surveys and more fully document bat species at the three park areas. Specifically, the objective was to inventory bats on the New River Gorge National River, Gauley River National Recreation Area, and the Bluestone National Scenic River park areas using mist-net and acoustic surveys.

METHODS

Study Area

The park units are located in the Unglaciated Allegheny Plateau, a subsection of the Appalachian Plateau physiographic province, which is characterized by steep slopes, narrow valleys, and plateau-like ridge tops (Fenneman 1938). The geology of the study areas is characterized primarily by sandstone with some limestone and various shales along with thin beds of coal (Barrett 1995). Annual precipitation ranges from 122 to 135 cm. Temperature averages 11º C during July and the frost-free period ranges from 120 to 150 days (Barrett 1995). A substantial legacy of anthropogenic impacts exists in the study areas, with railroad beds, logging roads, abandoned buildings, and abandoned mine shafts occurring throughout. For example, NERI and GARI have >120 abandoned deep-mine shafts. Although no coal mines exist on BLUE, a major oil and gas pipeline transects the park (National Park Service 2006b).

The three park units are covered by approximately 35,614 ha of second- or third-growth forests dominated by the mixed mesophytic and oak (*Quercus* spp.)-hickory (*Carya* spp.) forest types (Braun 1950). Depending upon aspect, site quality, elevation, and past land-use history, overstories may be dominated by chestnut oak (*Q. prinus*), northern red oak (*Q. rubra*), white oak (*Q. alba*), tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), black oak *(Q. velutina*), sugar maple (*A. saccharum*), and/or yellow buckeye (*Aesculus flava*). Understories are dominated by hillside blueberry (*Vaccinium pallidum*), mountain laurel (*Kalmia latifolia*), and wood nettle (*Laportea canadensis*). The larger riparian zones have scattered communities of sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), and ironwood (*Carpinus caroliniana*) whereas eastern hemlock (*Tsuga canadensis*), sweet birch (*Betula lenta*), and rosebay rhododendron (*Rhododendron maximum*) dominate smaller streamside corridors and drains. Other trees found in lesser amounts and small patches include eastern red cedar (*Juniperus virginiana*) on limestone outcrops and Virginia pine (*P. virginiana*), pitch pine (*P. rigida*), and post oak (*Q. stellata*) usually associated with dry summit forest and/or exposed clifflines (National Park Service, unpublished data).

Live Capture

We conducted mist-net surveys during the summers of 2003 and 2004. When possible, mist-net surveys were consistent with the Indiana Bat Recovery Plan (United States Fish and Wildlife Service 1999), which recommends surveying 15 May – 15 August to determine if there are resident Indiana bats in an area. We captured bats using two net sets of single or double (stacked) six to 12 x 2.4 m mist-nets (Avinet Inc., Dryden, New York) per site. Mist-nets were positioned over areas of concentrated bat activity such as small streams, ephemeral pools, and flight corridors (roads and trails). When possible we sampled mine portals and building to identify possible day roost for species. Starting at sunset, we sampled for approximately five hours depending on temperature and overall bat activity. We calculated net hours (one net hour = one net set per hour sampled) at each site to estimate the effectiveness of our sampling and the abundance of various species. We recorded species, age, sex, forearm length (mm), and weight (g) for each individual. We defined age class as adult or juvenile based on epiphyseal-diaphyseal fusion (Anthony 1988). We took photo vouchers of representatives of each species. Bat capture and handling were consistent with the animal handling guidelines of the American Society of Mammalogists (American Society of Mammalogist 1998) and were conducted under University of Georgia Institutional Animal Care and Use Committee guidelines (permit number A2003-10030-0).

Acoustic Surveys

Starting at sunset, we sampled bats acoustically using Anabat II detectors (Titley Electronics, Ballina, Australia) for 20-min survey periods per station along transects that included approximately five to six stations. Our surveys took place during the first one to two hours after sunset to sample areas during the time of highest bat activity. With an overall goal to sample as much of the three parks as possible, we used hiking trails to effectively reach areas throughout the parks. Therefore in 2003, sampling occurred from July to September and transects were concentrated on hiking trails and roads, and individual survey sites were spaced by five minutes of walking. In 2004, sampling occurred from May to August and we modified our sampling to focus on forest interior habitats. We used hiking trails and roads to gain access to areas of the New River Gorge Park Complex not sampled during 2003. From those features, we sampled the forest interior using block transects consisting of five to six sites with each site located at least 100 m apart. Some sites were located outside of the National Park Units boundary but most of those were located in adjacent state parks, Carnifex Ferry Battlefield State Park and Pipestem State Park, whereas others were located in similar habitats adjacent to National or State Park boundaries. All survey stations were geo-referenced using a Global Positioning System (Trimble III, Sunnyvale, California or Garmin GPS V, Olathe, Kansas). We avoided sampling on nights with strong wind (>10 km/hr) or temperatures colder than 10 C°. We recorded bat echolocation call sequences on compact flash cards within the Zero Crossings Analysis Interface Module (Titley Electronics, Ballina, Australia) and then downloaded to a laptop computer.

We identified echolocation call sequences with Analook v4.9 software (Titley Electronics, Ballina, Australia). All call sequences recorded were processed through customized filters to remove fragmented calls, echoes, extraneous noise, and all other call sequences not consistent with the properties of search-phase echolocation call sequences

(Britzke and Murray 2000). Search-phase calls are useful because they are the most numerous echolocation call sequence, have a consistent structure, and possess species-specific characteristics (Simmons et al. 1979, Fenton and Bell 1981, Betts 1998, O'Farrell et al. 1999). After filtering, we only retained sequences with ≥5 call pulses to increase accuracy of identification. We assigned calls to individual bat species using a discriminate function analysis (DFA) model in conjunction with a comprehensive call library for the eastern United States (Britzke 2003).

We determined accuracy of identification rates for each species by performing cross-validation of the DFA on known calls from the Britzke (2003) call library for the suite of species that have typical distributions that include the park units. The cross-validation process entailed developing the DFA model from 2/3 of the Britzke (2003) call library (randomly drawn) for our chosen suite of species and then validating the model for those species using the remaining 1/3 of the library. The accuracy rates are reported as the percentage of the call sequences correctly identified by the cross-validation of the test sequences by the remaining call library. In addition, we also calculated the percentage of calls misidentified by species (Table 2.1). We used our live-capture surveys as well as past capture records to ensure the model only included species in the region, and therefore giving the highest possible accuracy rate. Although Rafinesque's and Virginia big-eared bats have been documented on the park units (Johnson et al. 2003, 2005), we excluded them from the DFA model because their low intensity calls are difficult to detect with zero-crossing systems (e.g., Anabat). Britzke et al. (2002) stated the difficulty of determining presence when there are multiple species in a community with similar search-phase call structures, but documented that as the number of call sequences identified at a site for a single species increased, so did the accuracy rate of identification, and therefore the probability of presence of that species. As a result, species were only considered present at a site if ≥2 call sequences from that species were recorded during a 20-min sampling period or if it was the only species recorded during that period, in which case a species was considered present based on a single call sequence.

RESULTS

All Parks Combined

During the summers of 2003 and 2004, we captured eight of the 11 species known to occur in or near the park units and detected nine of 11 using acoustic surveys (Table 2.2). Although Indiana bats were detected acoustically, none were live-captured. The only bats known to occur locally but not documented using either method were Rafinesque's big-eared bats and Virginia big-eared bats.

We captured a total of 175 bats during approximately 410 net-hours at 41 sites (Figures 2.2-2.4) during the summers of 2003 and 2004 in the park areas (Table 2.3). Little brown bats (n = 69) and northern myotis (n = 50) were the most commonly captured species. Eastern small-footed myotis (n = 3), silver-haired bat (n = 1), eastern pipistrelle (n = 17), big brown bats (n = 23), eastern red bats (n = 11), and hoary bat (n = 1) were captured infrequently (Table 2.3). Reproductive females and/or juveniles were documented for seven bat species between May 15 and August 15 suggesting that these species have resident maternity colonies (Tables 2.3 and 2.4; United States Fish and Wildlife Service 1999). Of the eight species captured, the only silver-haired bat captured was an adult male, so presence of maternity colonies for this species in this area is unknown. We also calculated the rate of capture by species throughout each park using the number of captures/net hours sampled (Table 2.5). The most frequently captured species across all parks was the little brown bat (0.17/hr), and the mean capture rate for all bats was 0.053/hr (Table 2.5).

During the summers of 2003 and 2004, we acoustically surveyed 680 sites (Figure 2.2-2.4) recording 3,365 call sequences meeting the criteria of quality search-phase calls with $\geq$5 call pulses described above. The nine species detected included all species captured during live-capture efforts, but also included the Indiana bat (Table 2.2). The average accuracy rate (single call sequences) for species identification using the DFA model was 88%, with the lowest accuracy rate of 82.1%, for silver-haired bats, and the highest rate of approximately 100%, for the eastern pipistrelle (Table 2.1). The species detected at the highest percentage of sites, throughout the three parks, was the northern myotis (22.8%; Table 2.6).

Bluestone National Scenic River

We sampled two sites for approximately 20 net-hours using live-capture techniques. We captured six bats comprising three species not previously documented in the BLUE: little brown bat (n = 1), eastern pipistrelle (n = 4), and big brown bat (n = 1; Table 2.3). One pregnant eastern pipistrelle female was documented (Table 2.4). Within the BLUE, the mean capture rate was 0.0375/hr and the highest rate of capture was for the eastern pipistrelle (0.20/hr; Table 2.5).

We acoustically sampled 84 sites and recorded 360 identifiable calls representing 12% of our survey effort. The species that was detected at the highest percentage of sites was the northern myotis (21.4%; Table 2.6). The eight species detected included all three species captured during live-capture efforts, but also included northern myotis, eastern small-footed bat, Indiana bat, silver-haired bat, and eastern red bat. Of the species detected across all park units, the only species not detected in the BLUE was the hoary bat (Table 2.2). None of the eight species have been previous documented for this park.

Gauley River National Recreation Area

We sampled 4 sites for approximately 40 net-hours using live-capture techniques. We captured five individuals of five species, including little brown bat, northern myotis, eastern pipistrelle, big brown bat, and eastern red bat (Table 2.3). Juveniles of two species, big brown bat and eastern red bat, were documented suggesting that these species had maternity colonies in the park or nearby (Table 2.3). Within the GARI, the mean rate of capture was the lowest among the three parks at 0.0156/hr, whereas for all bats there was a capture rate of 0.025/hr (Table 2.5).

We acoustically sampled 143 sites and recorded 495 identifiable call sequences representing 21% of our survey effort. The species that was detected at the highest percentage of sites was the northern myotis (21.7%; Table 2.5). The nine species detected included all five species captured, but also included eastern small-footed myotis, Indiana bat, silver-haired bat and the hoary bat (Table 2.2).

New River Gorge National River

We sampled 35 sites for approximately 350 net-hours using live-capture techniques. We captured 164 bats comprising eight species including little brown bats (n = 67), northern myotis (n = 49), eastern small-footed myotis (n = 3), eastern pipistrelle (n = 12), big brown bats (n = 21), eastern red bats (n = 10), and two species not previously captured at NERI, one silver-haired bat and one hoary bat (Table 2.3). A majority of the little brown bats were captured emerging from maternity roost located in buildings. Two of the three eastern small-footed myotis were captured emerging from day roost in abandoned mine portals. Reproductive females and/or juveniles were documented for seven species of bats (Tables 2.3, 2.4). Within the NERI, the mean rate of capture was the highest among the three parks at 0.059/hr, while the species with the highest capture rate was the little brown bat at 0.191/hr (Table 2.5).

We acoustically sampled 453 sites and recorded 2,510 identifiable call sequences representing 66% of our survey effort. The species detected at the highest percentage of sites was the northern myotis (23.4%; Table 2.6). The nine species detected included all species captured, but also included Indiana bat (Table 2.2).

DISCUSSION

We detected more bat species using acoustic monitoring than using live-capture surveys. These results are consistent with previous studies that compared the two techniques (Murray et al. 1999, O'Farrell and Gannon 1999). Our mean highest capture rate for any one park was 0.059/hr (NERI). Using acoustical surveys we documented presence of bats at 381 sites that is 56% of all the sites surveyed. The steep terrain and large rivers make traditional mist-nets techniques difficult. As a result, acoustic surveys were more effective for adequately surveying bat communities over wider areas. After an area is surveyed acoustically, live-capture techniques can then be employed to verify presence, particularly in the case of sensitive species. The combination of acoustic surveys and live-capture sampling make species inventories for bats more efficient in this region.

Little brown bats and big brown bats have been documented utilizing man-made structures such as buildings (Barbour and Davis 1969, Fenton and Barclay 1980). The park units have many man-made structures that are probably used as summer maternity roost for these species whereas other species such as northern myotis and Indiana bats probably avoid these areas. These developed areas are limited throughout the parks relative to second- and third-generation mixed mesophytic and oak-hickory forest. These closed canopy forests provide abundant roosting and foraging areas particularly for northern myotis, the most captured and ultrasonically detected species in this habitat. This is consistent with Owens et al. (2003) and Ford et al. (2005) in West Virginia, that documented this species using the forest interior. Another type of man-made structure found in the GARI and NERI is abandoned mine portals. In the fall, Johnson et al. (2003, 2005) documented eight species using these structures including the federally endangered Indiana bat and Virginia big-eared bat as well as a federal species of concern, eastern small-footed myotis. Even with our limited surveys of mine portals we captured two of three eastern small-footed myotis upon emergence whereas the third was captured in close proximity to a mine portal.

Reproductive females of two species of foliage roosting bats, hoary bat and eastern red bat, were documented within the park units. Hoary bats have been documented roosting in the foliage of eastern hemlock and other conifer species, whereas in eastern Kentucky, eastern red bats were documented selecting hardwood trees (Hutchinson and Lacki 2000). A majority of our study area is dominated by mixed mesophytic and oak-hickory forest and with the encroachment of the hemlock woolly adelgid (*Adelges tsugae*), this area is probably better suited for red bats than hoary bats. Silver-hair bats are known to occur in high numbers north of the three park units (Kunz 1973) and the single male bat captured in early June was likely a late migrant.

In Iowa, Kunz (1973) reported possible resource partitioning in three bat species, silver-haired bat, eastern red bat, and hoary bat. He documented temporal separation as eastern red bat occurred one to two hours after sunset, silver-haired bat occurred three to four and six to eight hours after sunset whereas hoary bat occurred four to five hours after sunset. He also documented spatial separation in eastern red bats and hoary bats. At our study site we captured 11 red bats, and only one silver-haired bat and one hoary bat. Likewise, acoustically we detected 56 sites with eastern red bats whereas only 12 sites for silver-haired bats and only seven sites with hoary bat presence. The low number of silver-haired bats and hoary bats detected may be associated with their late emergence because our sampling only occurred within the first three to four hours after sunset. Nevertheless, at the Bluestone National Scenic River there were no hoary bats recorded whereas we had the highest percentage of eastern red bat occurrence per site sampled. This may suggest a spatial separation between these two species. Future studies in areas where all three species are extant, should consider a longer sampling period to account for temporal variation.

The interpretation of the acoustic data should be considered when examining management applications. Britzke et al. (2002) cautioned that detection of a species at a site does not necessarily guarantee presence of the species detected. For example, Table 2.1 shows that for a single call sequence the model has an accuracy rate of 86.8% for the Indiana bat with an 8.8% probability of misidentifying the call as a little brown bat and 4.4% probability of misidentifying the call as an eastern small-footed myotis. If a site only has a single call sequence for an Indiana bat there is a 13.2% probability that the call sequence could have been misidentified as a little brown bat or an eastern small-footed myotis. Using a conservative method of determining presence we located 60 sites with a probability >86.8% of an Indiana bat being presence. Of these 60 sites, we identified 18 stations that approach 100% predicted probability of Indiana bat presence based on >4 call sequences identified and low numbers of call sequences of the species most commonly misidentified (little brown bat and eastern small-footed myotis). In northeast Missouri, Britzke et al. (2002) documented the difficulty of capturing Indiana bats, even at a site near a known maternity roost of >100 individuals. In two nights of mist netting, they only captured one individual but recorded approximately 300 call sequences for that species. Undoubtedly Indiana bat are present in the park units, but with our limited capture success and the difficulty of capturing rare species in general, acoustical surveys were a better way of gaining information on habitat use for this species.

Previous studies in West Virginia documented Indiana bats using forested riparian areas (Owens et al. 2004, Ford et al. 2005). A study in eastern Kentucky documented Indiana bats using xeric ridges during the prehibernation swarming period (Kiser and Elliot 1996). When we examined the 18 sites where we documented Indiana bats, we found that these sites had a mean distance of 174 m from a water source and 11 of the 18 were located in closed canopy forest. Also, the mean aspect was south-southeast. Riparian areas have high insect abundance and are important to many species of bats. The xeric aspect has longer exposure to solar radiation, which provides suitable roosting locations and/or foraging areas with high insect abundance. These 18 sites should be surveyed using live-capture techniques to verify Indiana bat presence as well as determine if there are resident breeding populations. Then traditional techniques, such as radiotelemetry, should be used to locate roosts and to gain foraging information on this federally endangered species.

Despite their known occurrence in the park units, we did not capture either Rafinesque's big-eared bat or the Virginia big-eared bat. These species have been documented using mine portals during the summer and fall (Johnson et al. 2003, 2005). In North Carolina, Clark (1991) documented Rafinesque's big-eared bat foraging less than 1 km from their day roost. In Kentucky, Adam et al. (1994) documented the Virginia big-eared bats foraging 0.74 to 1.14 km from their day roost. With these short distances traveled from their roost sites and our live-capture surveys concentrating in areas away from mines, the probability of capturing either species was remote. Acoustically, these species produce low-intensity calls (Griffin et al. 1963) that are difficult to detect using ultrasonic detectors, making this technique inadequate to either confirm or deny presence.

We surveyed stations acoustically for 20-min which over the course of two summers made it possible to survey 680 sites in the three park areas. This methodology allowed us to survey numerous areas in relatively short periods of time. However, because of the presence of many species with similar echolocation call structures (i.e., *Myotis* species), a longer sampling period might be considered for future acoustic monitoring. A longer sampling period will likely increase the accuracy rates for identification of individual species by providing a larger sample size of call sequences per site.

At the three park units, live-capture surveys were difficult because of the large water sources of the Gauley, New, Bluestone Rivers, and Summerville Lake, making it difficult to locate areas of high bat activity along small enough water sources that could effectively be sampled with mist-nets. Acoustical survey efforts were more efficient on subsections of the GARI and NERI because of the legacy of past anthropogenic impacts from timber harvest and mining that left a complex of forest roads and skid trails more easily traversed by foot than less disturbed forest areas on other parts of the study area. Future mist-netting efforts should concentrate on targeted species in areas we acoustically located species to maximize efficiency.

MANAGEMENT IMPLICATIONS

Because four of the bat species that have been documented in the park units are either endangered or species of special concern, these areas are potentially important areas from a bat conservation perspective. The areas surrounding the park units are fragmented and may not provide the necessary habitat for these species. Our study identified areas where two of these species, eastern small-footed myotis and the Indiana bat, occur as well as important habitat components (mine portals and riparian areas). We captured three eastern small-footed myotis, two pregnant females emerging from a mine portal and a non- reproductive female in close proximity to mine portals. This species is considered a federal species of concern (West Virginia Department of Natural Resources 2005) and mines portals where this species was captured should be protected during the maternity season. The Indiana bat has been documented in counties surrounding the park units (Beverly and Gumbert 2004). Protecting riparian zones throughout the three park units will benefit many species including the Indiana bat.

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Table 2.1. Accuracy rates (%) of search-phase call identification obtained by a cross-validation of the discriminant-function analysis model developed for nine extant species in the three National Park Areas in West Virginia, May – September 2003-2004. Numbers in columns represent the percentage of calls identified as the corresponding species in each row.

Species	Little brown bat	Northern myotis	Indiana bat	Small-footed myotis	Silver-haired bat	Eastern pipistrelle	Big brown bat	Eastern red bat	Hoary bat
Little brown bat	94.2		8.8					3.1	
Northern myotis		88.6		11.4					
Indiana bat	5.8	11.4	86.8	4.5					
Small-footed myotis			4.4	84.1					
Silver-haired bat					82.1		15.3		12.5
Eastern pipistrelle						100		12.3	
Big brown bat					14.3		84.7		
Red bat								84.6	
Hoary bat					3.6				87.5

Table 2.2. Comparison of survey techniques (live-capture techniques and acoustic surveys) on nine bat species at Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI), West Virginia, May – September 2003-2004.

	BLUE		GARI		NERI		Combined	
Common name	Live	Acoustic	Live	Acoustic	Live	Acoustic	Live	Acoustic
Little brown bat	*	*	*	*	*	*	*	*
Northern myotis		*	*	*	*	*	*	*
Indiana bat		*		*		*		*
Eastern small-footed bat		*		*	*	*	*	*
Silver-haired bat		*		*	*	*	*	*
Eastern Pipistrelle	*	*	*	*	*	*	*	*
Big brown bat	*	*	*	*	*	*	*	*
Eastern red bat		*	*	*	*	*	*	*
Hoary bat		*		*	*		*	*

Table 2.3. Bat species captured using live-capture techniques during 410 net-hours at 41 sites in Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI), West Virginia, May – September 2003-2004.

	BLUE (20 net hours)				GARI (40 net hours)				NERI (350 net hours)				TOTAL (410 net hours)			
	2003		2004		2003		2004		2003		2004		2003		2004	
Common name	Ad	Juv	Ad	Juv	Ad	Juv	Ad	Juv	Ad	Juv	Ad	Juv	Ad	Juv	Ad	Juv
Little brown bat	1				1				32	8	22	4	34	8	22	4
Northern myotis							1		20		24	4	20		25	4
Indiana bat																
Eastern small-footed bat									1		2		1		2	
Silver-haired bat											1				1	
Eastern pipistrelle			4		1				4	3	3	2	5	3	7	2
Big brown bat			1					1	4		13	4	4		14	5
Eastern red bat								1	4	1	3	2	4	1	3	3
Hoary bat											1				1	
Total	1		5		2		1	2	65	12	69	16	68	12	75	18

* One little brown bat and one northern myotis were not included because age was unknown

Table 2.4. Adult female bats captured using live-capture techniques by species and reproductive condition (lactating or pregnant) during 410 net-hours at 41 sites at Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI), West Virginia, May – September 2003-2004.

	BLUE (20 net hours)		GARI (40 net hours)		NERI (350 net hours)	
Common Name	Lactating	Pregnant	Lactating	Pregnant	Lactating	Pregnant
Little brown bat					13	1
Northern myotis					5	10
Indiana bat						
Eastern small-footed bat						1
Silver-haired bat						
Eastern pipistrelle		1				
Big brown bat						
Eastern red bat						1
Hoary bat					1	
Total bats		1			19	13

Table 2.5. Relative capture rates (captures/net hour) of bat species captured at Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI), West Virginia, May – September 2003-2004.

Common name	BLUE (20 net hours)	GARI (40 net hours)	NERI (350 net hours)	TOTAL (410 net hours)
Little brown bat	0.050	0.025	0.191	0.173
Northern myotis		0.025	0.140	0.112
Eastern small-footed			0.009	0.007
Silver-haired bat			0.003	0.002
Eastern pipistrelle	0.200	0.025	0.034	0.041
Big brown bat	0.050	0.025	0.060	0.056
Eastern red bat		0.025	0.029	0.027
Hoary bat			0.003	0.002
Mean	0.0375	0.0156	0.059	0.053

Table 2.6. Number of acoustical survey stations that bat species were detected out of 680 total sites in the Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River NERI), West Virginia, May – September 2003-2004. Percentage of survey sites with species presence shown in parentheses.

Common Name	BLUE (n = 84)	GARI (n = 143)	NERI (n = 453)	Total (n = 680)
Little brown bat	9 (10.7)	13 (9.1)	30 (6.6)	52 (7.6)
Northern myotis	18 (21.4)	31 (21.7)	106 (23.4)	155 (22.8)
Indiana bat	7 (8.3)	13 (9.1)	40 (8.8)	60 (8.8)
Eastern small-footed bat	8 (9.5)	12 (8.4)	37 (8.2)	57 (8.4)
Silver-haired bat	3 (3.6)	1 (0.7)	8 (1.8)	12 (1.8)
Eastern pipistrelle	12 (14.2)	19 (13.3)	66 (14.7)	97 (14.3)
Big brown bat	10 (11.9)	18 (12.6)	64 (14.1)	92 (13.5)
Eastern red bat	10 (11.9)	16 (11.2)	30 (6.6)	56 (8.2)
Hoary bat	0 (0.0)	2 (1.4)	5 (1.1)	7 (1.0)

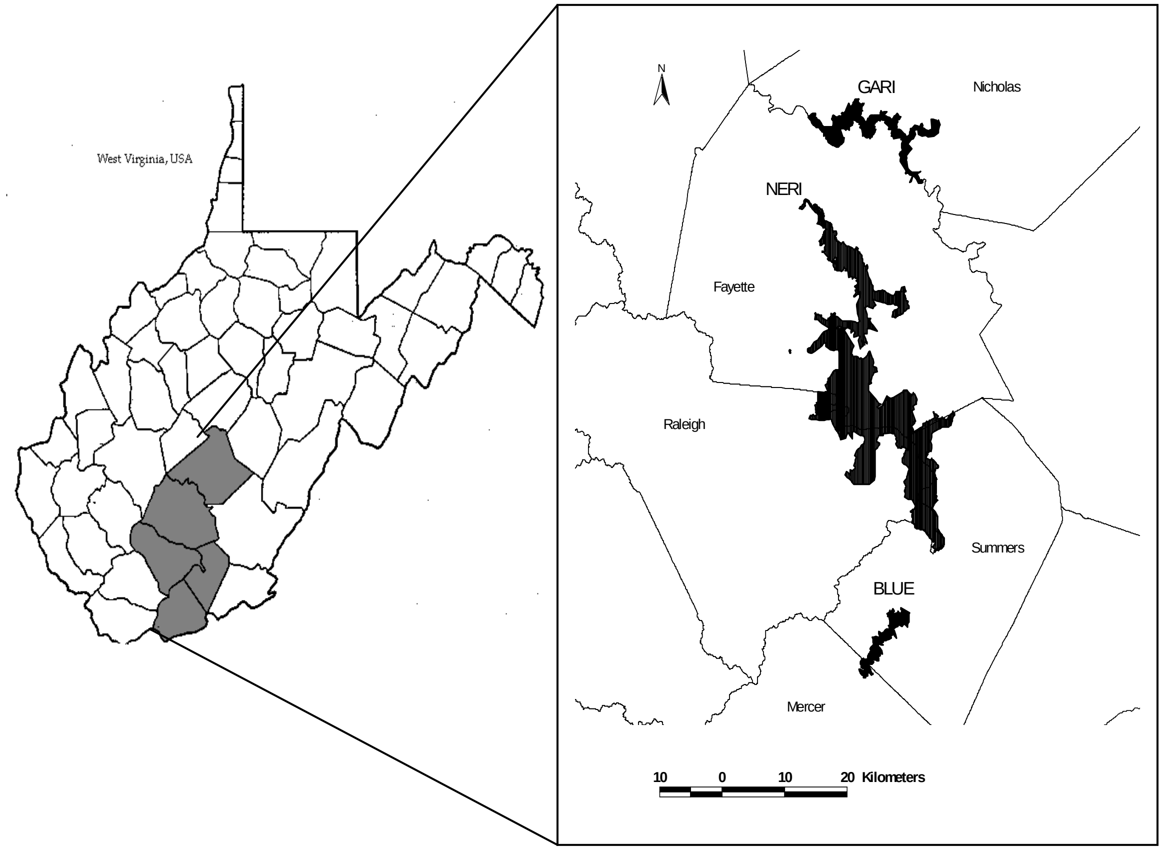

Figure 2.1. National Park Service units in south-central West Virginia surveyed for bat community composition in 2003 and 2004. The units from north to south are Gauley River National Recreation Area (GARI), New River Gorge National River (NERI), and Bluestone National Scenic River (BLUE).

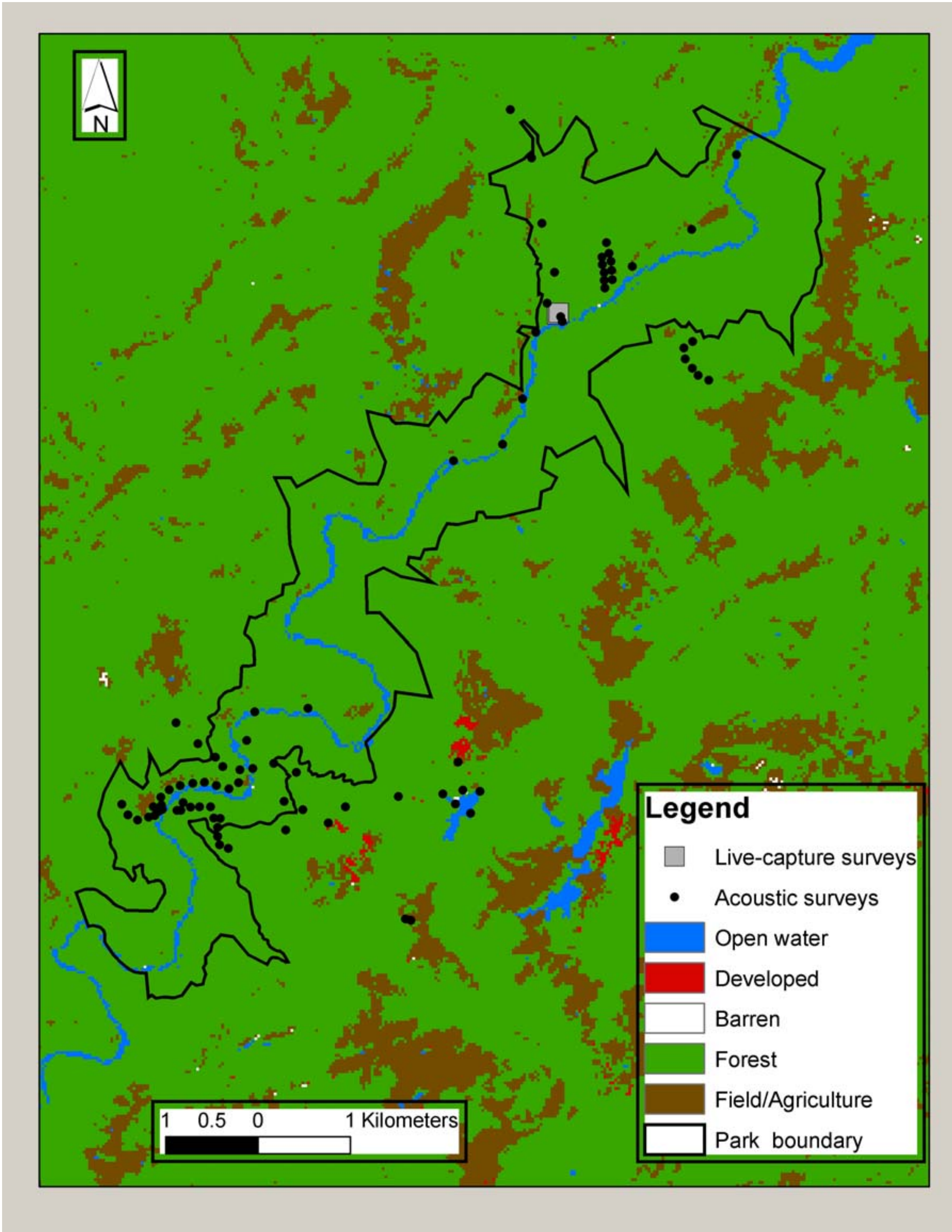

Figure 2.2. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at Bluestone National Scenic River, West Virginia, May – September 2003-2004.

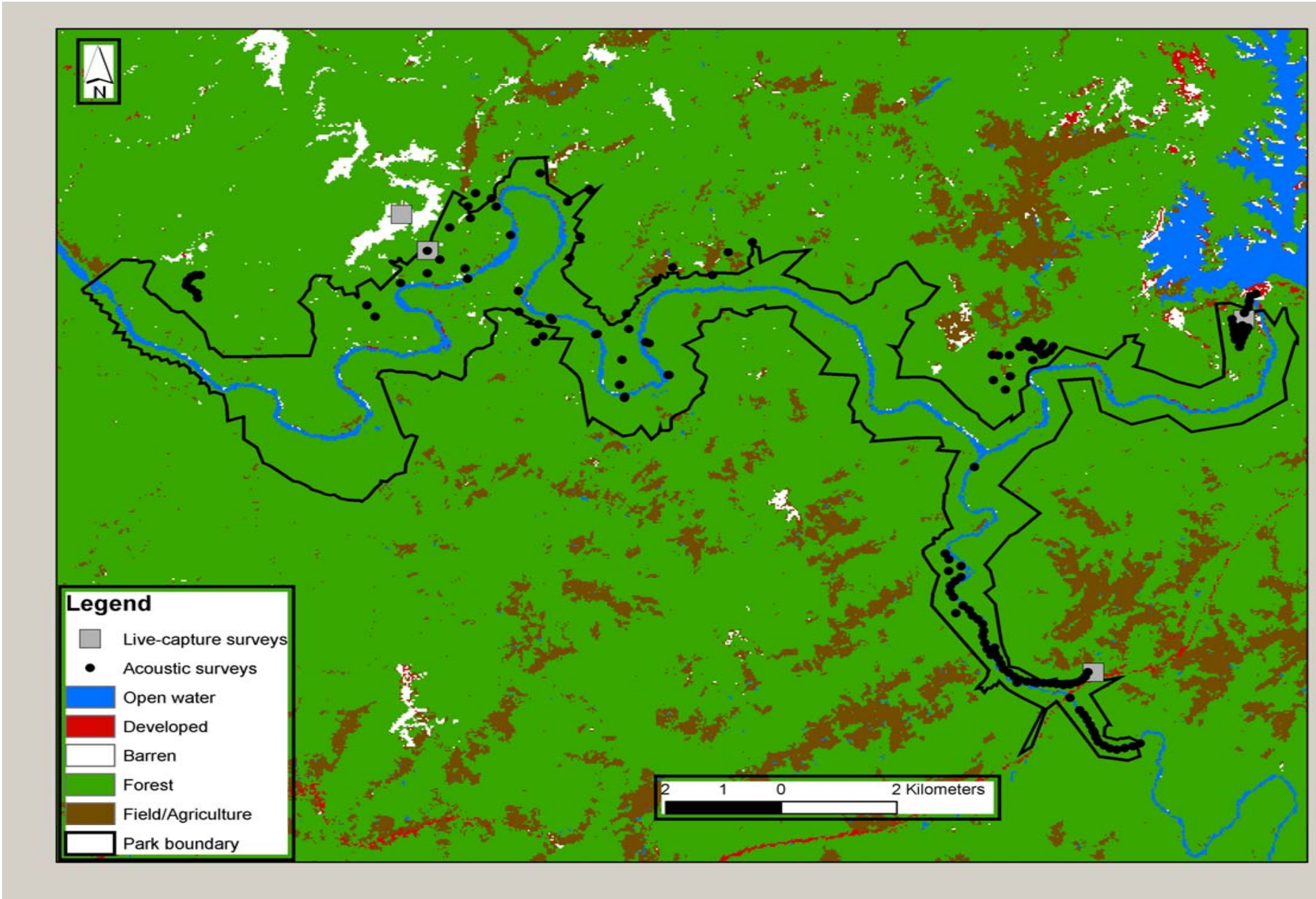

Figure 2.3. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at Gauley River National Recreation Area, West Virginia, May – September 2003-2004

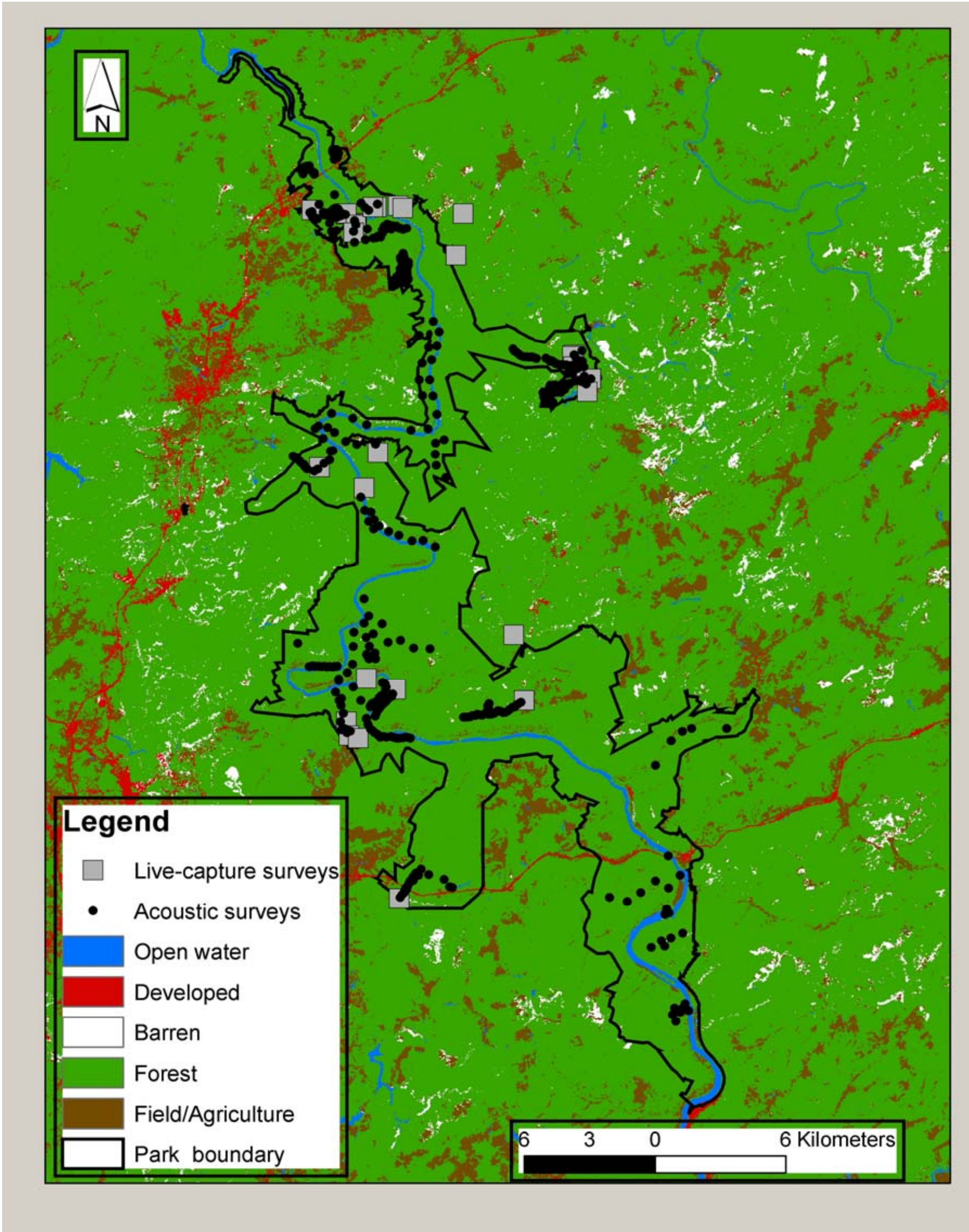

Figure 2.4. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at New River Gorge National River, West Virginia, May – September 2003-2004.

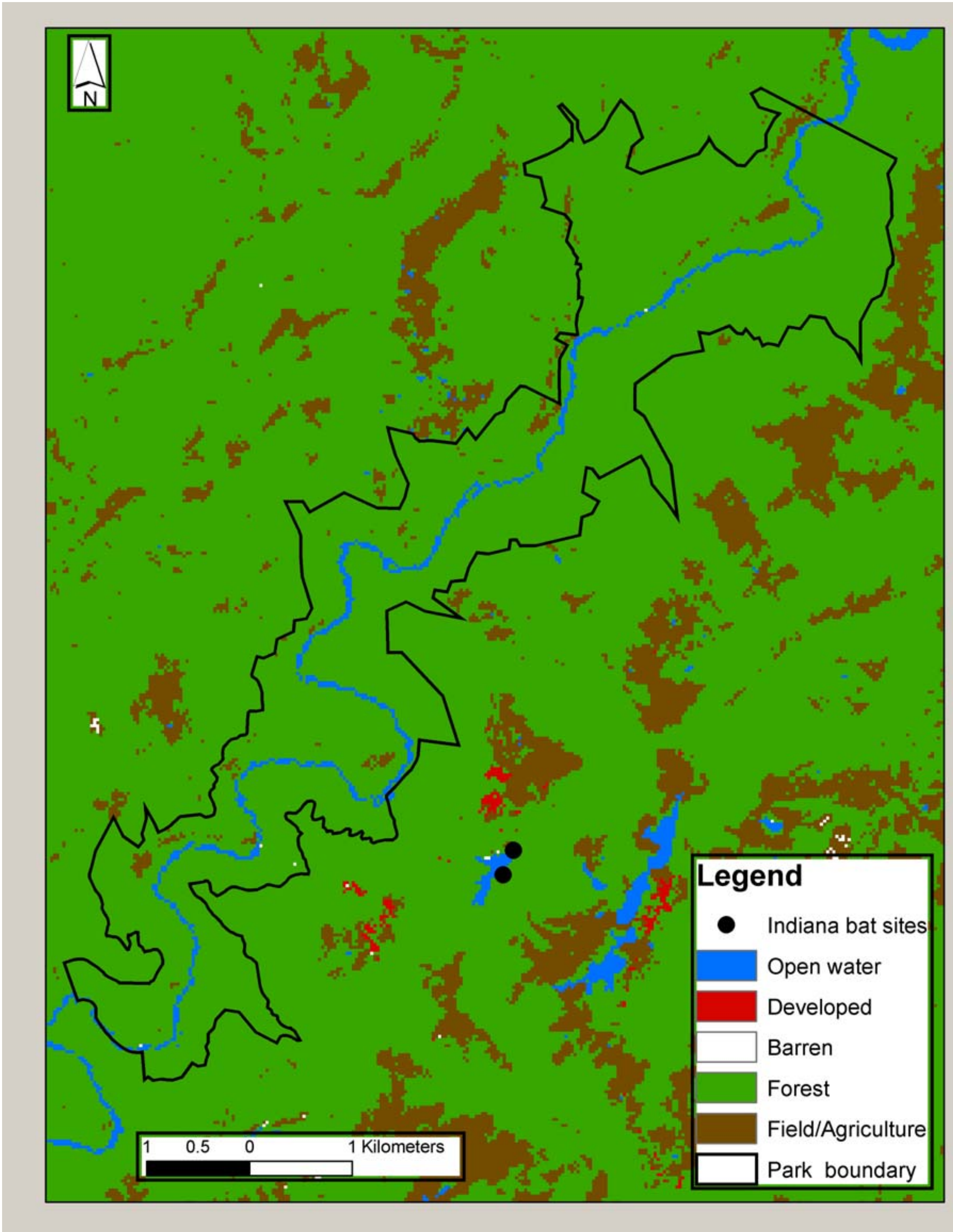

Figure 2.5. Locations sampled using Anabat II detectors with a high probability of Indiana bat (*Myotis sodalis*) presence at Bluestone National Scenic River, West Virginia, May – September 2003-2004.

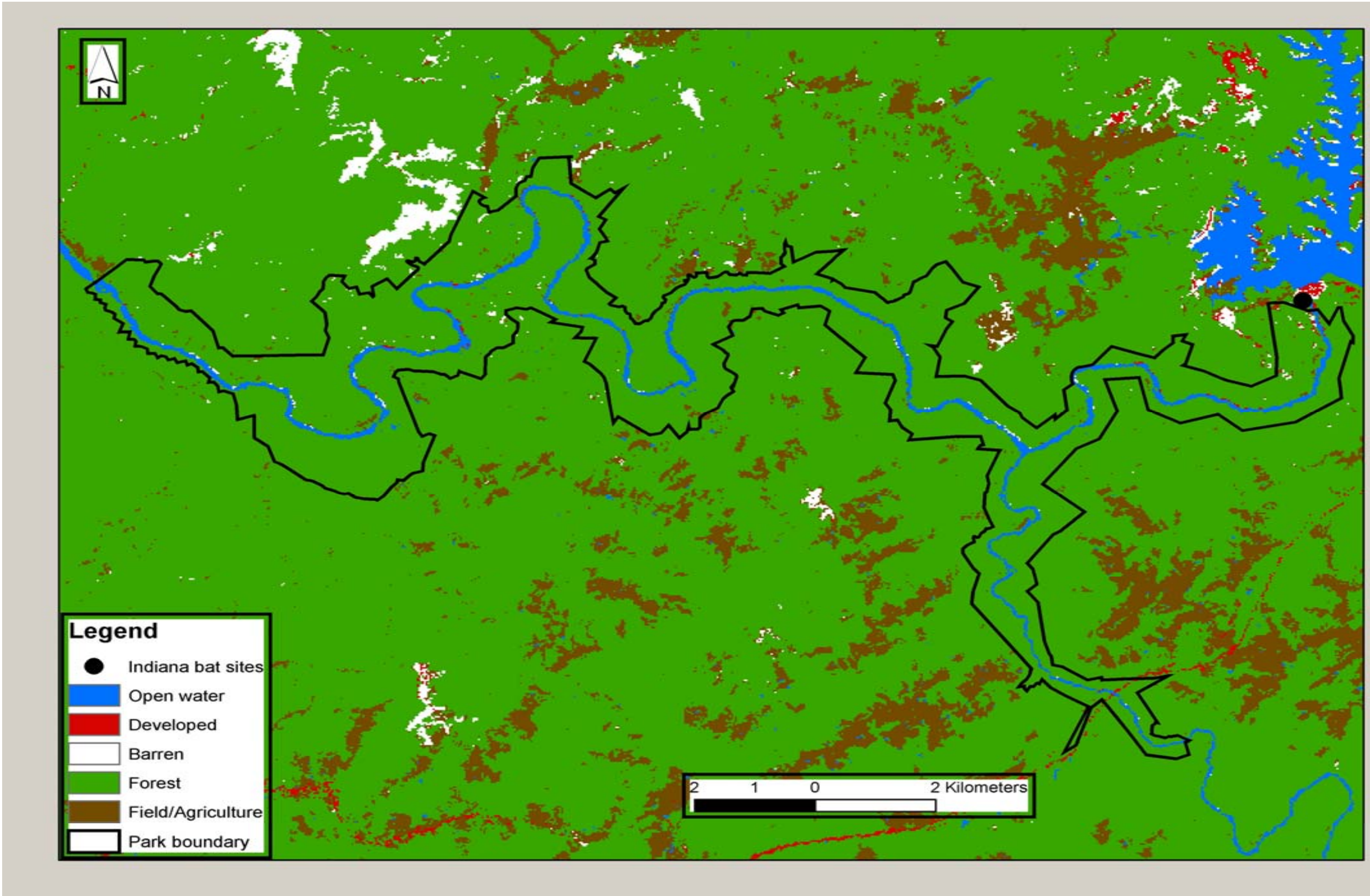

Figure 2.6. Locations sampled using Anabat II detectors with a high probability of Indiana bat (*Myotis sodalis*) presence at Gauley National Recreation Area, West Virginia, May – September 2003-2004.

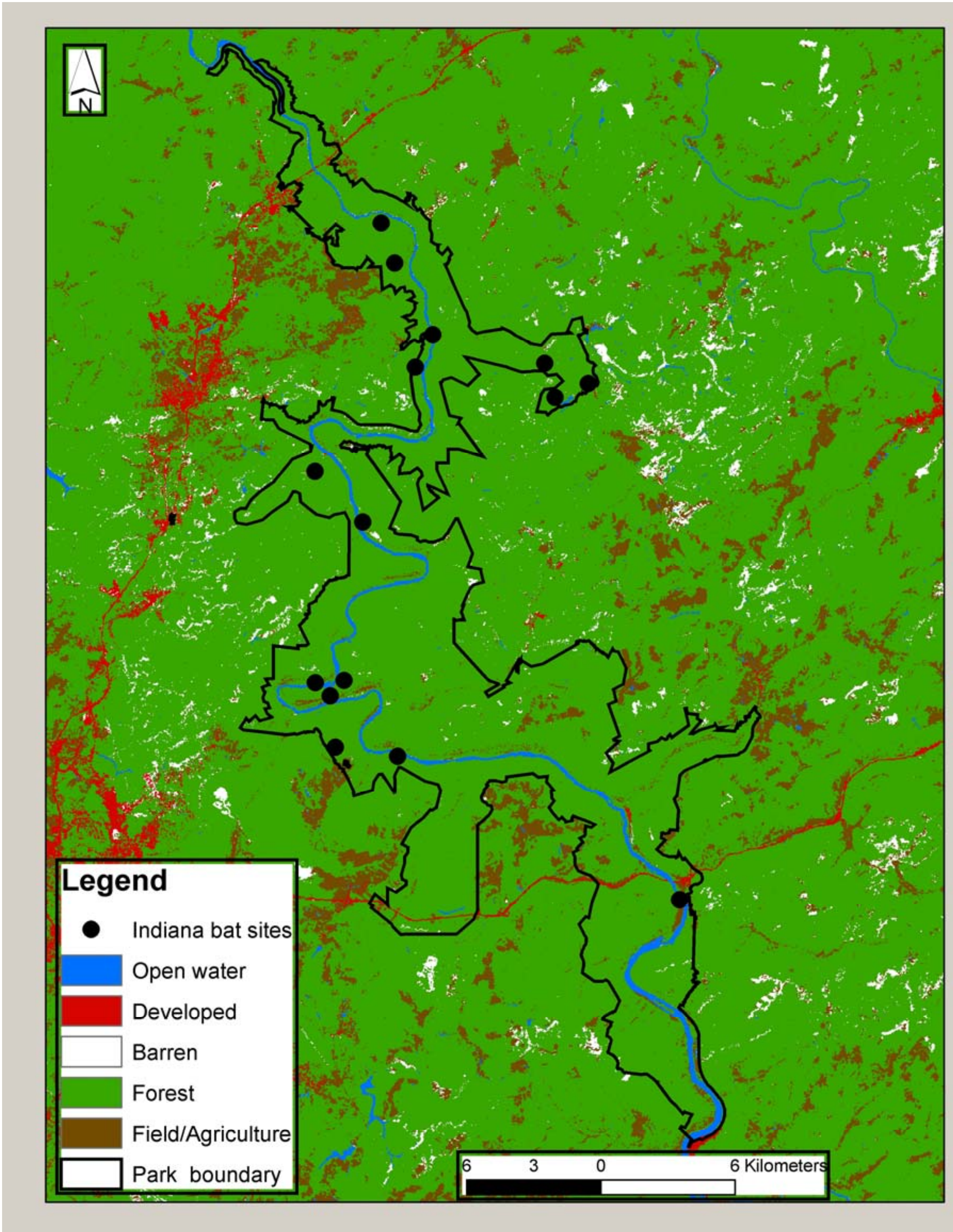

Figure 2.7. Locations sampled using Anabat II detectors with a high probability of Indiana bat (*Myotis sodalis*) presence at New River Gorge National River, West Virginia, May – September 2003-2004.

CHAPTER 3

SPECIES-SPECIFIC HABITAT ASSOCIATION MODELS FOR BATS IN THE CENTRAL APPALACHIANS OF WEST VIRGINIA[1]

[1] Schirmacher, M. R., S. B. Castleberry, W. M. Ford, and K. V. Miller. To be submitted to The Southeastern Naturalist.

ABSTRACT

During the summers of 2003 and 2004, we used ultrasonic detectors to examine species-specific habitat associations for seven species of bats in the central Appalachians of West Virginia. Using logistic regression, we constructed predictive models of habitat association and evaluated our *a priori* models using Akaike's Information Criteria. The best-approximating model for little brown bats (*Myotis lucifugus*), eastern pipistrelle (*Pipistrellus subflavus*), big brown bats (*Eptesicus fuscus*), and eastern red bat (*Lasiurus borealis*) included measures of habitat structure at the survey site, with open canopy habitat as an important model component. Temperature was an important model component for little brown bats, big brown bats, and eastern red bats. Proximity to water was an important predictor for eastern pipistelle and big brown bat presence. The best-approximating model for the northern myotis (*M. septentrionalis*) included landscape-level variables with distance to 1st to 4th order streams as an important contributor to the model. Both Indiana bats (*M. sodalis*) and eastern small-footed myotis (*M. leibii*) had best-approximating models that included local habitat structure, such as closed canopy habitat and water within 40 m of the survey station. In a landscape dominated by closed canopy forest, both clutter and open-adapted species were documented utilizing the available habitats as expected. I was probably able to model open-adapted species more effectively because of the limited number of openings which are important foraging areas, and therefore make detecting these species easier in those habitats. Consequently, there was more available closed canopy habitat that made modeling the clutter-adapted species more difficult. I detected the northern myotis at twice the number of locations than other clutter-adapted species, thereby suggesting that my inability to model these

other clutter-adapted species is linked to these species being less common in the three park units.

INTRODUCTION

Widespread use of ultrasonic detectors has lead to an increase in research examining foraging and habitat use of bats throughout temperate systems, such as the in Jura Mountains of Switzerland (Jaberg and Guisan 2001), Britain (Walsh and Harris 1996, Vaugh et al. 1997), northern Ireland (Russ and Montgomery 2002), Canada (Crampton and Barclay 1998, Jung et al. 1999, Hodgberg et al. 2002, Broders et al. 2003), the western United States (Thomas 1988, Erickson and West 2003, Ellison et al. 2005), northeastern United States (Krusic et al. 1996, Zimmerman and Glanz 2000), southeastern United States (Menzel et al 2002, 2005a, 2005b), and Allegheny Mountains in the eastern United States (Owens et al. 2004, Ford et al. 2005). Moreover, the portability and cost effectiveness of ultrasonic detectors allows researchers to undertake bat habitat studies across larger scales and landscapes than would otherwise be feasible (Ford et al. 2005). Nevertheless, research using ultrasonic detectors has not reached its fullest potential as most studies have examined general bat activity at a single spatial scale. Studies using ultrasonic detectors to assess species-specific habitat association at multiple scales (local- and landscape-levels) can be important by providing land managers valuable information regarding habitats used by different bat species.

Erickson and West (2003) stated that because bats are highly mobile, larger landscape-level features such as habitat configuration, physical structures, land use, and riparian areas probably are important habitat components for bats across most geographic areas. Studies have identified habitat configuration, such as edge, as an important habitat component to bats in Britain (Vaughan et al. 1997, Walsh and Harris 1996), Canada (Crampton and Barclay 1998, Hogberg et al. 2002) and South Carolina, (Menzel et al. 2002). In Switzerland, Jaberg and Guisan (2001) found that elevation and vegetation cover were associated with high activity levels of many bat species, whereas anthropogenically modified landscape structures (e.g., agricultural areas and vineyards) were avoided. Another habitat feature, riparian zones, have been documented as important to many bat species in Britain (Vaughan et al. 1997, Walsh and Harris 1996), New Mexico (Ellison et al. 2005), South Carolina (Menzel et al. 2005b), and West Virginia (Owens et al. 2004, Ford et al. 2005). Riparian zones provide high insect abundance that is utilized by bats. These studies demonstrate that landscape-level features such as habitat configuration, physical structures, land use, and riparian areas are important habitat components for bats across many geographic regions.

Species-specific habitat associations are important because differences in morphology of bats affect habitat use. In the Allegheny Plateau of the central Appalachians, Francl et al. (2004) recorded seven species of bats using high-elevation upland wetlands with the majority of activity attributed to the little brown bat (*Myotis lucifugus*). In the same region, Owens et al. (2004) documented silver-haired bats (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus cinereus*) using open areas. These relatively large bodied species are probably not as maneuverable as other species and must utilize large openings. Ford et al. (2005) observed local-level factors such as percent canopy cover and forest canopy gap width as important habitat components to bats. They documented that little brown bat, eastern red bat (*L. borealis*), big brown bat

(*Eptesicus fuscus*), and hoary bat presence was linked to larger forest canopy gaps and openings, whereas the presence of Indiana bats (*M. sodalis*) and northern myotis (*M. septentrionalis*) was related to increased canopy cover. These studies give insight at the micro-habitat scale by demonstrating habitat use based on differences in morphology. Herein, our objective was to create predictive habitat models at multiple scales (local- and landscape-level) to identify habitat associations for bats in the central Appalachians of West Virginia.

STUDY AREA AND METHODS

Study Areas

Our study was conducted in south-central West Virginia in Fayette, Mercer, Nicholas, Raleigh, and Summers counties on three areas administered by the National Park Service: the New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE; Figure 2.1). Elevation ranged from approximately 275 to 850 m. The park units were located in the Unglaciated Allegheny Plateau, a subsection of the Appalachian Plateau physiographic province which is characterized by steep slopes, narrow valleys, and plateau-like ridge tops (Fenneman 1938). The geology of the study areas is characterized primarily by sandstone with some limestone and various shales along with thin beds of coal (Barrett 1995). Annual precipitation ranges from 122 to 135 cm. Temperature averages 11º C during July and the frost-free period ranges from 120 to 150 days (Barrett 1995). A substantial legacy of anthropogenic impacts exists in the study area, with railroad grades, logging roads, abandoned buildings, and mine shafts occurring throughout. For example, NERI and GARI have >120 abandoned deep-mine shafts. Although no coal mines exist on BLUE, a major oil and gas pipeline transects the park (National Park Service 2006).

The park units are covered by approximately 35,614 ha of second- or third-growth forests dominated by the mixed mesophytic and oak (*Quercus* spp.)-hickory (*Carya* spp.) forest types (Braun 1950). Depending upon aspect, site quality, elevation, and past land-use history, overstories may be dominated by chestnut oak (*Q. prinus*), northern red oak (*Q. rubra*), white oak (*Q. alba*), tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), black oak *(Q. velutina*), sugar maple (*A. saccharum*), and/or yellow buckeye (*Aesculus octandra*). Understories are dominated by hillside blueberry (*Vaccinium pallidum*), mountain laurel (*Kalmia latifolia*), and wood nettle (*Laportea canadensis*). The larger riparian zones have scattered communities of sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), and ironwood (*Carpinus caroliniana*) whereas eastern hemlock (*Tsuga canadensis*), sweet birch (*Betula lenta*), and rosebay rhododendron (*Rhododendron maximum*) dominate smaller streamside corridors and drains. Other trees found in lesser amounts and small patches include eastern red cedar (*Juniperus virginiana*) on limestone outcrops and Virginia pine (*P. virginiana*), pitch pine (*P. rigida*), and post oak (*Q. stellata*) associated with dry summit forest and/or exposed clifflines (National Park Service, unpublished data).

Acoustic Surveys

Starting at sunset, we sampled bats acoustically using Anabat II detectors (Titley Electronics, Ballina, Australia) for 20-min survey periods per station along transects that included approximately five to six stations. Our sampling occurred during the first one to three hours after sunset to sample areas during the time of highest bat activity. With an overall goal to sample as much of the three parks as possible, we used hiking trails to effectively reach areas throughout the parks. Therefore in 2003, our sampling occurred from July to September and transects were concentrated on hiking trails and roads, and individual survey sites were spaced by five minutes of walking. In 2004, sampling occurred from May to August and we modified our sampling to focus on forest interior habitats. We used hiking trails and roads to gain access to areas of the New River Gorge Park Complex not sampled during 2003. From those features, we sampled the forest interior using block transects consisting of five to six sites with each site located at least 100 m apart. Some sites were located outside of the National Park Units boundary but most of those were located in adjacent state parks, Carnifex Ferry Battlefield State Park and Pipestem State Park, whereas others were located in similar habitats adjacent to National or State Park boundaries. All survey stations were geo-referenced using a Global Positioning System (Trimble III, Sunnyvale, California or Garmin GPS V, Olathe, Kansas). We avoided sampling on nights with strong wind (>10 km/hr) or temperatures colder than 10 C°. We recorded bat echolocation call sequences on compact flash cards within the Zero Crossings Analysis Interface Module (Titley Electronics, Ballina, Australia) and then downloaded to a laptop computer.

We identified echolocation call sequences with Analook v4.9 software (Titley Electronics, Ballina, Australia). All call sequences recorded were processed through customized filters to remove fragmented calls, echoes, extraneous noise, and all other call sequences not consistent with the properties of search-phase echolocation call sequences

(Britzke and Murray 2000). Search-phase calls are useful because they are the most numerous echolocation call sequence, have a consistent structure, and possess species-specific characteristics (Simmons et al. 1979, Fenton and Bell 1981, Betts 1998, O'Farrell et al. 1999). After filtering, we only retained sequences with ≥ 5 call pulses to increase accuracy of identification. We assigned calls to individual bat species using a discriminate function analysis (DFA) model in conjunction with a comprehensive call library for the eastern United States (Britzke 2003).

We determined accuracy of identification rates for each species by performing cross-validation of the DFA on known calls from the Britzke (2003) call library for the suite of species that have typical distributions that include the park units. The cross-validation process entailed developing the DFA model from 2/3 of the Britzke (2003) call library (randomly drawn) for our chosen suite of species and then validating the model for those species using the remaining 1/3 of the library. The accuracy rates are reported as the percentage of the call sequences correctly identified by the cross-validation of the test sequences by the remaining call library. In addition, we also calculated the percentage of calls misidentified by species (Table 2.1). We used our live-capture surveys as well as past capture records to ensure the model only included species in the region, giving the highest possible accuracy rate. Although Rafinesque's and Virginia big-eared bats have been documented on the park units (Johnson et al. 2003, 2005), we excluded them from the DFA model because their low intensity calls are difficult to detect with zero-crossing systems (e.g., Anabat). Britzke et al. (2002) stated the difficulty of determining presences when there are multiple species in a community with similar search-phase call structures, but documented that as the number of call sequences identified at a site for a single species increased, so did the accuracy rate of identification, and therefore the probability of presence of that species. As a result, species were only considered present at a site if ≥2 call sequences from that species were recorded during a 20-min sampling period or if it was the only species recorded during that period, in which case a species was considered present based on a single call sequence.

For each sample site, 17 habitat parameters were recorded in the field or subsequently derived using GIS (ArcGIS and ArcView 3.2, ERSI Inc., Redlands, California; Table 3.1). Topographic variables including slope, aspect, and elevation, were determined from ArcGIS using a 30-m digital elevation model (DEM). We modified Beers et al. (1966) approach to transforming aspect into a gradient of zero to two with two representing 270 or the xeric aspect. Flat aspect received a value of one. We placed slope into three categories: (1) gentle slope (0-15º), (2) moderate slope (15-25º), and (3) steep slope (>26º). We calculated four landscape measurements for distance to water sources. Proximity to water was calculated using 1-m orthophotos (West Virginia GIS Technical Center 2003) and we digitized water sources other than streams (ponds and lakes) and then we measured the straight-line distance from each station to the nearest water source. We calculated distance to stream using a digitized stream layer (30-m resolution) and measuring straight-line distance from each station to the nearest stream (1st through 4th order). Distance to a major stream (> 4th order) was calculated using ArcView 3.2 and we measured straight-line distance from each station to the nearest large river channel (Bluestone, Gauley, Little Bluestone, Meadow, and New Rivers). We calculated distance to nearest water by measuring the straight-line distance from our station to the nearest water source regardless of size or type. We calculated distances to mines by measuring the distance from each site to the nearest mine portal. We identified clifflines by an abrupt change in slope and calculated distance from each site to the nearest cliffline. We measured the cumulative linear measurement (m) of roads within a 150-m buffer around each survey station. Also within a 150-m buffer, we estimated the percent of forest using a land use and land cover layer for West Virginia.

At each station, we recorded forest cover as either open canopy or closed canopy. We measured width of forest canopy gaps (m) including width of corridors such as roads, trails, abandoned railroad grades, or watercourse channels. In the field, we visually estimated stand-class and mid-story density at each station and placed them into a set of categories (Table 3.1). We measured temperature at each survey station at the end of our 20 minute acoustical sampling period using a digital thermometer (Acurite, Jamestown, New York). We noted if water was within the detection range of our ultrasonic detector, approximately 40 meters from the site.

Model Development and Analysis

We evaluated seven *a priori* multivariate models for seven bat species to assess species-specific habitat associations (Table 3.2). Our first model, MACRO TO LANDSCAPE was constructed from variables representing landscape-level variables. The FOREST STRUCTURE model was constructed of variables that represented measurements of forest structure collected at each survey station. Our SIMPLE STRUCTURE model was constructed of only two variables: water at the station and either open or closed canopy. Two models included the SIMPLE STRUCTURE plus either physical variables, slope, aspect, elevation (SIMPLE STRUCTURE+ PHYSICAL), or temperature (SIMPLE STRUCTURE + TEMP). We also constructed a model using a combination of all variables (GLOBAL). Lastly, we constructed a unique model for each species (COMBO) that was comprised of variables identified as biologically significant to individual bat species (McDainels et al. 1982, Kiser and Elliot 1996, Johnson et al. 2003, Francl et al. 2004, Owens et al. 2003, 2004; Ford et al. 2005; Table 3.3). For the little brown bat, our COMBO model variables included distance to streams, large canopy openings, and elevation (Owens et al. 2004, Ford et al. 2005). Our COMBO model for the northern myotis was constructed of variables representing forest structure because this species has been documented as a forest interior specialist (Owens et al. 2003, 2004; Ford et al. 2005). Our COMBO model for the Indiana bat included variables that represented this species' preference for riparian zones and the use of xeric ridges (Kiser and Elliot 1996, Ford et al. 2005). Our COMBO model was constructed of variables representing roosting structures, such as mines and clifflines, and distance to a water source (McDainels et al. 1982). Our COMBO model for the eastern pipistrelle (*Pipistrellus subflavus*) represented this species' preference of water sources as foraging areas and areas with larger trees (Francl et al. 2004). Our COMBO model for the big brown bat included variables representing this species use of open areas in close proximity to water at low elevations (Francl et al. 2004, Ford et al. 2005). Our COMBO model for the eastern red bat was constructed of variables representing this species preference of open areas with a water source (Francl et al. 2004, Owens et al. 2004, Ford et al. 2005).

We pooled acoustic data across years and park units to provide an overall assessment of which habitat parameters were most important to each species. We used Spearman rank correlation to prevent us from including highly correlated variables (r

>0.7) in the same model. Models were analyzed using logistic regression and second order Akaike's Information Criterium (AICc) was used to identify the most parsimonious model and predict variable importance (Burnham and Anderson 2002). Models with the lowest AICc and all models ≤4 Δ_i (Δ_i = AICc – min AIC_c) were considered the best-approximating models. We also calculated the Akaike weight (w_i) for each model, representing the probability of that model being the best-approximating model in the set of candidate models (Burnham and Anderson 2002). Additionally, for the model with the lowest AICc for each bat species, we calculated Hosmer and Lemeshow's Goodness-of-Fit and Nagelkerke's rescaled r^2 (SAS Institute 1995) to assess the relative fit and strength of the models. To compute a percent correct classification for correctly assigned presence and absence at a cutoff value of 0.50, we performed a jackknife validation procedure (SAS Institute 1995). We used parameter estimates to identify variables important to species presence.

RESULTS

Acoustic Surveys

In 2003 and 2004, we recorded 3,365 search-phase echolocation passes that met our quality criteria across 680 acoustical survey sites. We detected nine bat species across all three parks. The species detected (with the number of sites at which the species was detected in parentheses) included little brown bats (n = 52), northern myotis (n = 155), Indiana bat (n = 60), eastern small-footed myotis (n = 57), silver-haired bats (n = 12), eastern pipistrelles (n = 97), big brown bats (n = 92), eastern red bats (n = 56), and hoary bats (n = 7). The accuracy of identification for each species detected ranged from

82.1 to 100% with an average of 88% for a single call sequence for all species (Table 2.1). We excluded 140 survey stations from the analysis because of unacceptably low (< 84%) species identification accuracy rates or because of incomplete habitat parameters.

Species-specific Habitat Association Models

We were able to create predictive logistic regression models for seven bat species including little brown bats, northern myotis, Indiana bats, eastern small-footed myotis, eastern pipistrelle, big brown bats, and eastern red bats. We excluded the silver-haired bat and hoary bat from modeling because of small sample sizes.

Our SIMPLE STRUCTURE model was the best-approximating model for Indiana bats, eastern small-footed myotis, and eastern pipistrelle (Table 3.4). For the Indiana bat, SIMPLE STRUCTURE + TEMP, FOREST STRUCTURE, and SIMPLE STRUCTURE + PHYSICAL models also received support (Table 3.4). For both the eastern small-footed myotis and the eastern pipistrelle, SIMPLE STRUCTURE + TEMP and SIMPLE STRUCTURE + PHYSICAL models also received support (Table 3.4). Open habitat and presence of water at the site were important model components for the eastern pipistrelle (Table 3.5). No single variable in the best-approximating model was identified as an important model component for the Indiana bat or the eastern small-footed myotis (Table 3.5).

Our SIMPLE STRUCTURE + TEMP model was the best-approximating model for little brown bats and eastern red bats (Table 3.4). For little brown bats, SIMPLE STRUTURE + PHYSICAL, GLOBAL, and SIMPLE STRUCTURE models also received support, whereas for eastern red bats SIMPLE STRUCTURE model also received support (Table 3.4). Open canopy habitat was an important model component for the little brown bat and eastern red bat (Table 3.5). In addition, warmer temperatures were important predictors for presence of these two species.

The most parsimonious model for northern myotis was MACRO to LANDSCAPE (Table 3.4). Distance to 1st to 4th order streams was identified as an important predictor of northern myotis presence (Table 3.5). For big brown bats, the best-approximating model was our GLOBAL model (Table 3.4). Open canopy habitat, low mid-story density and proximity to water were important predictors of big brown bat presence (Table 3.5). In addition, warmer temperatures were important predictors of this species presence.

DISCUSSION

In West Virginia, Ford et al. (2005) documented presence of little brown bats, big brown bats, and eastern red bats in areas with large forest canopy gaps. They suggested that in areas where landscapes are comprised primarily of closed canopy forest, open-adapted species may have to utilize the relatively limited open areas at a greater level, and thereby making them easier to detect. In our study areas, open canopy habitats are likewise limited, making these areas important foraging habitats for open-adapted species. Alternatively, areas surrounding the parks are mostly developed/agricultural areas which may not provide the insect abundance that undeveloped open areas provide. In Britain, Walsh and Harris (1996) documented low levels of bat activity at water sources in close proximity to agricultural areas and speculated that chemical runoff affected insect abundance.

Three of the extant myotis species to the Park Complex, eastern small-footed myotis, northern myotis, and Indiana bat, are small bodied and have low wing aspect ratios making them more maneuverable in cluttered environment. In the Allegheny plateau, Owens et al. (2003) and Ford et al. (2005) documented northern myotis as a forest interior species. Similarly, Indiana bats have been documented foraging in cluttered environments such as riparian zones (Owens et al. 2004, Ford et al. 2005). Little is known about eastern small-footed myotis foraging habits, but its wing morphology is similar to other clutter-adapted species. In West Virginia, northern myotis have been reported using intact forest and vernal pools (Owens et al. 2003, Ford et al. 2005). In Massachusetts, this species also was observed foraging above small streams (Brooks and Ford 2005). Likewise, we documented presence of northern myotis at small streams. Both the Indiana bat and eastern small-footed myotis had local habitat features, such as closed or open canopy habitat and water at the site, as their best-approximating model suggesting that closed canopy forest is the most important attribute for these species in the three park units. We detected the northern myotis at twice the locations than other clutter-adapted species, and thereby suggesting that our inability to model these other clutter-adapted species is linked to these species being less common in the three park units.

We sampled random areas throughout the three National Park Areas, rather than sampling specific habitats (i.e. riparian zones, upland) similar to Owens et al. (2004), which used a stratified approach to forest harvest units and undisturbed forest stand-class conditions. With our approach, our models identified local habitat features (open or closed canopy habitat and water at the site) as important predictors for presence of six bat species. Another approach could have been to sample these habitats previously documented as important such as trails and vernal pools for northern myotis (Owens et al. 2003) and riparian areas of low streams order riparian zones for Indiana bats (Owens et al. 2004, Ford et al. 2005). Using this approach, our models may have identified other variables important to these species (i.e., low mid-story density). For example, when we examined the data for closed canopy habitats with and without Indiana bat presence, we found that at those stations where the Indiana bat was present, the sample site had a higher percent forest, a higher density of trails within a 150-m buffer, were at lower elevations, had a lower mid-story density, and were further from large river corridors, although they were also further from smaller streams. These observations are similar to the finding by Ford et al. (2005) and Menzel et al. (2005c) who documented greater Indiana bat activity at lower elevations, lower mid-story density, in closed canopy forest, and along trails. In 2003, our sampling occurred on trails and roads throughout the three parks, whereas in 2004 we attempted to sample the forest interior. The difference in sampling from year to year along with the low number of sites with species presence may account for the difficulty of modeling the Indiana bat. Alternatively, when we only examined the closed canopy habitat for Indiana bats we observed trends similar to other studies in our region. This suggests that when modeling rare species in a large area, that sampling should target preferred habitat based on previous studies (i.e. riparian zones for Indiana bats). This may help to increase the number of sites with species presence, and therefore make modeling this species more effective.

The COMBO model was not the best-approximating model for any of the seven bat species. When examining the COMBO model, four species used the habitats predicted by other studies in this region, although they were not the variables we selected. Little brown bats and eastern red bats preferred open areas and were more active when temperatures were higher. Eastern pipistrelle preferred opens areas and sites with water. The big brown bat preferred open areas with low mid-story density and were in close proximity to water. All of these habitat associations have been documented for this region (Francl et al. 2004, Owens et al. 2004, Ford et al. 2005). The difficulty of selecting the correct combination of variables for these generalist species made our COMBO models seemingly unimportant. The lack of the COMBO model as the best-approximating model suggests that when attempting to model species habitat use, using categories of variables rather than individual variables may improve the predictability of presence for these species. For example, for open-adapted species, one could use only low mid-story density as a model component. Alternatively, combining variables that demonstrate low structural complexity, such as open canopy habitats and water sources which may also have low mid-story density, would better explain habitat use for open-adapted species.

Although the strengths of our models were low, most models fit relatively well. The low Nagelkerke's rescaled r^2 for the logistic regressions are probably due to bats occurring in such a range of conditions that most variables poorly discriminated presence versus absence. Also, we sampled for 20 minutes without replication. This was effective for surveying a large area but made it difficult to quantify high probability of species presence over a large enough subset of survey stations for effective model input. Also, our sampling regime may not have captured temporal variation among bat species present. Kunz (1973) documented temporal separation, with eastern red bat occurring one to two hours after sunset, silver-haired bat occurring three to four and six to eight hours after sunset whereas hoary bat occurred four to five hours after sunset. Future studies using ultrasonic detectors to develop species-specific habitat models in areas with similar landscape and similar species may require a longer sampling period or a larger sample size. This may provide more sites with species presence and may control for temporal separation demonstrated in some species.

MANAGEMENT IMPLICATIONS

Four of the 11 bat species documented in the park units are listed as either federally endangered or species of special concern, making this area important for protecting these species. Most of the areas surrounding the three park units are fragmented and developed and may not provide the necessary habitats for some bat species. Likewise, the proposed housing developments surrounding the National Park Areas may affect roosting and foraging habitat for clutter-adapted species. We documented little brown bats, eastern pipstrelle, big brown bats, and eastern red bats using open canopy habitats. The three parks are dominated by closed canopy forest and with the surrounding areas fragmented and developed, these relatively limited undeveloped open canopy habitats maybe important foraging habitat for these species.

Our study identified closed canopy forest and water at the site as important habitat components for Indiana bats. Protecting forested riparian zones is important for Indiana bats, as well as other species such as the northern myotis. Furthermore, with an increase of maternity colonies documented for Indiana bats in this region and with the park units located between many known hibernacula, these three park units might be more important habitat for resident Indiana bats than previously believed. Live-capture techniques should be used to verifying presence of the Indiana bat and determining if there is a resident breeding population. If verified, maternity colonies should be located to limit disturbance during the maternity season.

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Table 3.1. Descriptions of variables collected at acoustic survey sites or derived from ArcGIS or ArcView 3.2. Combinations of variables were used to develop a priori habitat association models for seven bat species detected in the three National Park Areas during May – September 2003-2004.

Variable	Description
Slope (S)	Slope measured from DEM at 30m resolution. Categorized as gentle (1 = 0-15º), Moderate (2 = 16-25º), or Steep (3 = >26º).
Aspect (A)	Aspect measured from DEM at 30m resolution. Cosine transformed around an azimuth of 270 into a value of 0-2 (Beers et al. 1966). Flat aspect received a value of one.
Elevation (E)	Elevation measured from DEM at 30m resolution.
Distance to mine (DM)	Measurement from site to nearest mine (m).
Distance to stream (DS)	Measurement from site to nearest stream (1^{st}-4^{th} order) (m) at 30m resolution.
Distance to cliff line (DC)	Measurement from site to nearest cliff lines (m).
Linear measurement of road (LR)	Cumulative length of roads measured within a 150 m buffer around each site (m).
Percent Forest (PF)	Percentage of forested areas within a 150 m buffer around each site, estimated using a land use and land cover layer.
Proximity to water (PW)	The closest distance to a water source (other than streams) identified through aerial photographs from each site (m).

Table 3.1. Continued

Variable	Description
Width of Corridor (WC)	Width of a corridor or forest canopy gap (m) at each site.
Stand Class (SC)	Four stand class categories (1) early regeneration (0-5.1 cm dbh) (2) seedling-sapling (5.1-22.9 cm dbh) (3) small sawtimber (22.9-45.7 cm dbh) (4) large sawtimber (>45.7 cm dbh).
Mid-story Percentage (MS)	An estimate of four mid-story density categories (1) 0-25% (2) 25-50% (3) 50-75% (4) 75-100%.
Habitat Type (H)	Forest cover at each site as either open canopy (0) or closed canopy (1).
Temperature (T)	Temperature (F°) measured during sampling.
Water at the site (WS)	Absence (0) or presence (1) of water within 40 m of a site.
Distance to nearest water (DW)	Distance from the site to the nearest water source.
Distance to major stream (DMS)	Distance to the nearest major river (m): Bluestone, Gauley, Little Bluestone, Meadow, or New Rivers.

Table 3.2. Variables included in each of the six species-specific habitat association models developed for seven species of bats in three National Park Areas during May – September 2003-2004.

Model name	Variables
MACRO TO LANDSCAPE	DM, DC, DS, DMS, PW, LR, PF
FOREST STRUCTURE	SC, MS, DW, WC
SIMPLE STRUCTURE	H, WS
SIMPLE STRUCTURE+PHYSICAL	H, WS, S, A, E
SIMPLE STRUCTURE+TEMP	H, WS, T
GLOBAL	DM, DC, DS, DMS, PW, LR, PF, SC, MS, DW, WC, H, WS, S, A, E, T

Abbreviations for variables are listed in Table 3.1.

Table 3.3. Combination model (COMBO) developed for seven species of bats detected in three National Park Areas during May – September 2003-2004. These were constructed of biologically significant variables identified in previous studies for these species in this region.

Species	COMBO model variables
Little brown bat	DS, DMS, WC, E
Northern myotis	SC, MS
Indiana bat	SC, MS, DS, PW, A
Eastern small-footed myotis	DM, DC DW
Eastern pipistrelle	DS, DMS, SC
Big brown bat	E, WC, DW
Eastern red bat	WC, DW

Abbreviations for variables are listed in Table 3.1.

Table 3.4. The best-approximating logistic regression models (within 4 AICc) for seven species of bats (n = 554). Models used to predict the probability of occurrence in the New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River, West Virginia, May – September 2003-2004.

Model	K[a]	AICc	Δi[b]	Wi[c]
Little brown bat				
SIMPLE STRUCTURE + TEMP	4	244.2588	0.00	0.5448
SIMPLE STRUCTURE + PHYSICAL	6	246.1706	1.91	0.2094
GLOBAL	18	247.0379	2.78	0.1357
SIMPLE STRUCTURE	3	247.4578	3.20	0.1100
Northern myotis				
MACRO TO LANDSCAPE	8	572.5172	0.00	0.8805
Indiana bat				
SIMPLE STRUCTURE	3	326.7618	0.00	0.5062
SIMPLE STRUCTURE + TEMP	4	328.5618	1.80	0.2058
FOREST STRUCTURE	5	328.6784	1.92	0.1941
SIMPLE STRUCTURE + PHYSICAL	6	330.5486	3.79	0.0762
Eastern small-footed myotis				
SIMPLE STRUCTURE	3	299.3768	0.00	0.4777
SIMPLE STRUCTURE + TEMP	4	300.4758	1.10	0.2758
SIMPLE STRUCTURE + PHYSICAL	6	300.8896	1.51	0.2242
Eastern pipistrelle				
SIMPLE STRUCTURE	3	399.3468	0.00	0.5055
SIMPLE STRUCTURE + TEMP	4	399.7088	0.36	0.4218
SIMPLE STRUCTURE + PHYSICAL	6	403.2306	3.88	0.0725
Big brown bat				
GLOBAL	18	402.6869	0.00	0.9821
Eastern red bat				
SIMPLE STRUCTURE + TEMP	4	254.8418	0.00	0.7502
SIMPLE STRUCTURE	3	257.2268	2.39	0.2276

[a] Number of parameters in the model.
[b] Distance of the model from the best model ($\Delta_i = AIC_c - \min AIC_c$).
[c] The estimated probability of being the best model (Akaike weight).
Abbreviations for variables are listed in Table 3.1.

Table 3.5. The best-approximating logistic regression models (lowest AICc) explaining presences of seven bat species at 680 acoustical survey sites in the Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, West Virginia, May – September 2003-2004.

Parameter	Estimate	SE	P> X^2 Wald	Odds ratio	95% CL
Little brown bat (SIMPLE STRUCTURE + TEMP)					
Intercept	-7.4654	2.5592	0.0035	-	-
H	-1.8179	0.4094	<0.0001	0.162	0.073-0.362
WS	0.2913	0.3785	0.4415	1.338	0.637-2.810
T	0.0848	0.0381	0.0261	1.088	1.010-1.173
Rescaled r^2 = 0.1534, Goodness –of-fit P= 0.1030, Correct classification 93%					
Northern myotis (MACRO TO LANDSCAPE)					
Intercept	-0.9043	0.777	0.2445	-	-
DM	-4.57E-06	0.000011	0.6714	1.000	1.000-1.000
DC	-0.00023	0.0004	0.5661	1.000	0.999-1.001
DS	0.000711	0.00024	0.003	1.001	1.000-1.001
DMS	0.000015	0.000068	0.8276	1.000	1.000-1.000
PW	0.000377	0.000216	0.0818	1.000	1.000-1.001
LR	-0.00026	0.00065	0.688	1.000	0.998-1.001
PF	-0.0109	0.00716	0.1273	0.989	0.975-1.003
Rescaled r^2 = 0.0510, Goodness –of-fit P= 0.8235, Correct classification 78%					
Indiana bat (SIMPLE STRUCTURE)					
Intercept	-2.6673	0.3197	<0.0001	-	-
H	0.2637	0.3417	0.4403	1.302	0.666-2.543
WS	0.6451	0.3516	0.0666	1.906	0.957-3.797
Rescaled r^2 = 0.0133, Goodness –of-fit P 0.0442, Correct classification 91%					
Eastern small-footed myotis (SIMPLE STRUCTURE)					
Intercept	1	-2.5887	0.3071	-	-
H	1	-0.3858	0.335	0.680	0.353-1.311
WS	1.00E+00	1.3155	0.3361	3.726	1.928-7.202
Rescaled r^2 = 0.0873, Goodness –of-fit P= 0.1239, Correct classification 92%					

Abbreviations for variables are listed in Table 3.1.

Table 3.5. Continued.

Parameter	Estimate	SE	P> X^2 Wald	Odds ratio	95% CL
Eastern pipistrelle (SIMPLE STRUCTURE)					
Intercept	-1.3072	0.2114	<0.0001	-	-
H	-1.3863	0.2761	<0.0001	0.250	0.146-0.429
WS	0.7456	0.2795	0.0076	2.108	1.219-3.645
Rescaled r^2 0.1453, Goodness –of-fit P= 0.6527, Correct classification 86%					
Big brown bat (GLOBAL)					
Intercept	-9.2448	2.6282	0.0004	-	-
H	-0.7581	0.333	0.0228	0.469	0.244-0.900
WS	0.4855	0.405	0.2306	1.625	0.735-3.594
T	0.0884	0.0324	0.0064	1.092	1.025-1.164
DM	-0.00001	0.000017	0.4174	1.000	1.000-1.000
DMS	-0.00011	0.000144	0.4544	1.000	1.000-1.000
DC	0.00062	0.000513	0.2268	1.001	1.000-1.002
DS	0.000977	0.000379	0.01	1.001	1.000-1.002
PW	0.000994	0.000313	0.0015	1.001	1.000-1.002
LR	-0.00013	0.000873	0.8794	1.000	0.998-1.002
PF	-0.00026	0.00908	0.9775	1.000	0.982-1.018
SC	-0.00247	0.2310	0.9915	0.998	0.634-1.569
MS	-0.401	0.16890	0.0176	0.670	0.481-0.932
DW	-0.00172	0.000858	0.0449	0.998	0.997-1.000
WC	-0.00529	0.00742	0.4762	0.995	0.980-1.009
S	-0.1238	0.168	0.4611	0.884	0.636-1.228
A	0.2045	0.2071	0.3234	1.227	0.818-1.841
E	0.00283	0.00202	0.1603	1.003	0.999-1.007
Rescaled r^2 = 0.1996, Goodness –of-fit P= 0.4337, Correct classification 86%					
Eastern red bat (SIMPLE STRUCTURE + TEMP)					
Intercept	-6.9886	2.4803	0.0048	-	-
H	-1.5229	0.3858	<0.0001	0.218	0.102-0.465
WS	0.4417	0.371	0.2338	1.555	0.752-3.218
T	0.0759	0.037	0.0400	1.079	1.003-1.160
Rescaled r^2 = 0.1275 , Goodness –of-fit P= 0.8449, Correct classification 93%					

Abbreviations for variables are listed in Table 3.1.

CHAPTER 4

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

With the presence of sensitive species, such as Indiana bat (*Myotis sodalis*), eastern small-footed bat (*M. leibii*), Rafinesques big-eared bat (*Corynorhinus rafinesquii*) and Virginia big-eared bat (*C. townsendii virginianus*) in the central Appalachians, a greater knowledge of regional and local foraging habitat relationships is needed for adequate conservation of these and other species. Given the need for information on bat habitat associations in the region, the objectives of my thesis were to inventory the species of bats in the New River Gorge National River, Gauley National Recreation Area, and Bluestone National Scenic River and to create species-specific habitat association models for those species in this region. Information gained in this study will be useful in creating management strategies that provide suitable habitat for forest bats of this region.

I used a combination of mist-nets and ultrasonic detectors to inventory and model habitat use for individual bat species. Using the protocol of 20 minute surveys, I sampled approximately 700 sites during the summers of 2003 and 2004. The rugged terrain and large "unnettable" water make using traditional techniques, such as mist-netting, logistically difficult. Ultrasonic detectors are portable and cost efficient making them a better tool for surveying large areas in these conditions. I recommend continuing ultrasonic surveys to identify locations of targeted species before mist-netting is preformed to maximize efficiency. Also, my sampling method of surveying sites for a 20-minute period without replication was effective in surveying a large area in a short period of time, but made it difficult to quantify high probability of species presence over a large enough subset of survey stations for effective model input. Also, Kunz (1973) documented temporal separation, where eastern red bat occurred one to two hours after sunset, silver-haired bat occurred three to four and six to eight hours after sunset whereas hoary bat occurred four to five hours after sunset. Future studies using ultrasonic detectors to develop species-specific habitat models in areas with similar landscape and similar species, should consider a longer sampling period. This may provide more sites with species presence and control for temporal separation demonstrated by some species.

The eastern small-footed myotis has been documented using abandoned mine portals (Johnson et al. 2003). I captured three individuals, one pregnant female and one male emerging from mine portals and one pregnant female in close proximity to mine portals. Although my models for eastern small-footed myotis did not identify distance to mine portals as important, my results did demonstrate the difficulty of modeling clutter-adapted species in a landscape dominated by closed canopy forest. Mine portals throughout the parks areas should be surveyed to document presence of eastern small-footed myotis especially during the maternity season.

My habitat association models predicted the use of open canopy habitats for little brown bats (*M. lucifugus*), eastern pipstrelle (*Pipistrellus subflavus*), big brown bats (*Eptesicus fuscus*), and eastern red bats (*Lasiurus borealis*). The park units are dominated by closed canopy forest and with the surrounding areas fragmented and developed, these open canopy habitats maybe important foraging areas for these species. My ability to effectively model these open-adapted species in open areas with reduced clutter demonstrates their high level of occurrence and hence the importance of these areas. Maintaining these open areas with prescribed fire may help by minimizing regeneration of forest and may provide foraging habitat for these open-adapted species. 1^{st} to 4^{th} order streams were an important model component to northern myotis. Forested riparian zones are important features for many bat species including the endangered Indiana bat. Protecting forested riparian areas is an important component of bat conservation.

My models identified local habitat structure, such as closed canopy, as important to Indiana bats. When I examined the trends at stations with closed canopy habitats with and without Indiana bat presence, these stations with the Indiana bat present tended to have a higher percentage of forest, lower elevation, lower mid-story density and a higher density of trails within a 150 m buffer than did stations without Indiana bats. Forested riparian zones and roads located around the 18 stations identified as approaching 100% predicted probability of Indiana bat presence, should be sampled using live-capture methods to verify species presence and determine if there is a resident breeding population. Also Indiana bats have strong site fidelity to summer roosts and foraging habitat and females may return to the same roost year after year (Humphrey et al. 1977, Gardner et al. 1991a,b; Callahan et al. 1997). Once presence has been confirmed these areas should be monitored to ensure limited disturbance, especially during the maternity season.

The mature mixed-mesophytic forest, sandstone cliffs, large rivers, abandoned mine portals are common features throughout the Park units, but are a unique combination in this region. My results, in combination with past surveys (Johnson et al. 2003, 2005) have identified that these unique features provide habitat for eleven species of bats. Although, previous studies examined presence at abandoned mine portals

(Weese 1990, 1991; Johnson et al. 2003, 2005), my study demonstrated other features important to bats. The contiguous mixed-mesophytic forest provides foraging and roosting habitat for forest interior specialist such as the northern myotis and Indiana bat. The open areas and large water sources provide forging habitat for little brown bats, eastern pipistrelles, big brown bats, and eastern red bats. The availability of these habitat features throughout the New River Gorge National River, Gauley River National Recreation Area, and the Bluestone National Scenic River provide habitat for common and rare bat species alike.

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