National Park Service
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Northeast Region
Philadelphia, Pennsylvania

Survey of Bat Communities in the New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River: Species Occurrence, Relative Abundance, Distribution, and Habitat Use

Technical Report NPS/NER/NRTR—2007/101

ON THE COVER
Big brown bat (*Eptesicus fuscus*) captured at New River Gorge National River.
Photograph by: Michael Schirmacher.

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Technical Report NPS/NER/NRTR—2007/101

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December 2007

U.S. Department of the Interior
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Executive Summary

Previous studies of bat communities in the New River Gorge National River and Gauley River National Recreation Area primarily consisted of surveys of abandoned mine portals. In addition, Bluestone National Scenic River had never been inventoried for bats. Although mine surveys are an effective way to detect bat species that use mines as day-roost sites or as hibernacula, these efforts provide less information on 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 (New River Gorge National River [NERI], Gauley River National Recreation Area [GARI], and Bluestone National Scenic River [BLUE]) in south-central West Virginia using a combination of live-capture and acoustic detection techniques. Our objective was to augment previous surveys to provide a more thorough inventory of the bat community and to conduct the first comprehensive inventory of bats at BLUE. Overall, we live-captured 175 bats representing eight species: little brown bat (*Myotis lucifugus*), northern myotis (northern long-eared bat*; M. 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*). We acoustically sampled 680 unique sites across all park units (453 at NERI, 143 at GARI, and 84 at BLUE), detecting the aforementioned eight species as well as the federally endangered Indiana bat (*M. sodalis*). Indiana bat echolocation calls were detected at 60 survey sites across all park units, most of which were in closed-canopy riparian areas, supporting results of previous studies documenting habitat use by the species. Indiana bat maternity colonies have not been documented from the park units, but their presence on the units could reasonably be expected based on the relatively large number of echolocation calls recorded and the discovery of maternity roosts in West Virginia to the southwest and the northeast of the park units. The eastern small footed-myotis, a species considered extremely rare and critically imperiled in the state, was captured at NERI (n=3) and was detected acoustically at 57 sites across all parks. Based on our results, the large areas of relatively contiguous mature forest within these parks provide summer foraging habitat for at least nine bat species, two of which are state and federally listed as vulnerable to extinction, highlighting the potential importance of these park units for bat conservation.

Introduction

In 1991, the National Park Service (NPS) 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 (NPS 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. Beginning in 1992, with additional support by the 1999 Natural Resource Challenge, the NPS implemented a strategy to institutionalize natural resource inventory and monitoring. The effort was undertaken to ensure that the more than 270 park units with significant natural resources possess the information needed for effective, science-based resource management decision-making.

Three park units in south-central West Virginia, New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE), were established in the 1970s and 1980s for their recreational value, scenic beauty, and rare biotic and physical features. The park units collectively represent approximately 35,614 ha (88,003 ac) of primarily mature upland hardwood and riparian forests. While extensive floral and faunal surveys have been conducted on the park units, several aspects of the biotic community are poorly understood and are in need of further study.

Four of the 11 bat species with distributions that include the park units have state and/or federal designation based on their current population status and vulnerability to extinction (WVDNR 2005). Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and the eastern small-footed myotis (*Myotis leibii*) are considered extremely rare and critically imperiled (S1 state ranking) by West Virginia Division of Natural Resources (WVDNR). The Indiana bat (*M. sodalis*) and the Virginia big-eared bat (*C. townsendii virginianus*) are considered rare and critically imperiled (S1 and S3 state rankings, respectively) by WVDNR and are federally listed as endangered. All of these species have been documented using abandoned mine portals in the park units (Johnson et al. 2003, 2005; Gates and Johnson 2006), but little is known about their distribution in other areas of the parks. The mature forests and large riparian zones in the park units likely provide 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 park units also could be potential winter hibernacula and summer roosting habitat for small-footed myotis, Rafinesque's big-eared bats, Virginia big-eared bats, big brown bats, and eastern pipistrelles. Additionally, the large river corridors cutting through the Allegheny Plateau in this region may serve as important spring and fall migration routes for silver-haired bats (*Lasionycteris noctivagans*) (Menzel et al. 2000).

Previous bat research 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 eastern small-footed myotis (Davis 1955) that utilize these habitats at some points during the year if suitable and available. However, they are less effective 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, northern myotis, little brown bats (Barbour and Davis 1969), and Indiana bats (Humphrey et al. 1977) are not commonly associated with mines, caves, or clifflines, but instead form bachelor and maternity colonies in cavities or exfoliating bark of snags and/or live trees. Also, little brown and big brown bats have been documented utilizing man-made structures as day-roosting and maternity colonies (Barbour and Davis 1969; Fenton and Barclay 1980). To fully document bat communities in the park units and the central Appalachians, in general, more complete surveys involving multiple methods are necessary. Our study was undertaken to augment previous work and provide a more comprehensive inventory of bat species at the three park units by surveying a wide range of representative habitats during the breeding and post-breeding seasons.

Study Area

The park units are located in south-central West Virginia (Figure 1) in the Unglaciated Allegheny Plateau, a subsection of the Appalachian Plateau physiographic province. The region 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 122–135 cm (48–53 in). A substantial legacy of anthropogenic impacts exists in the study areas, with railroad grades, logging roads, abandoned buildings, and abandoned mine shafts occurring throughout. For example, NERI and GARI have >120 abandoned deep-mine shafts. Although no mines exist on BLUE, a major oil and gas pipeline transects the park (NPS 2006b).

The park units contain approximately 35,614 ha (88,003 ac) 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*) associated with dry summit forest and/or exposed clifflines (NPS, unpublished data).

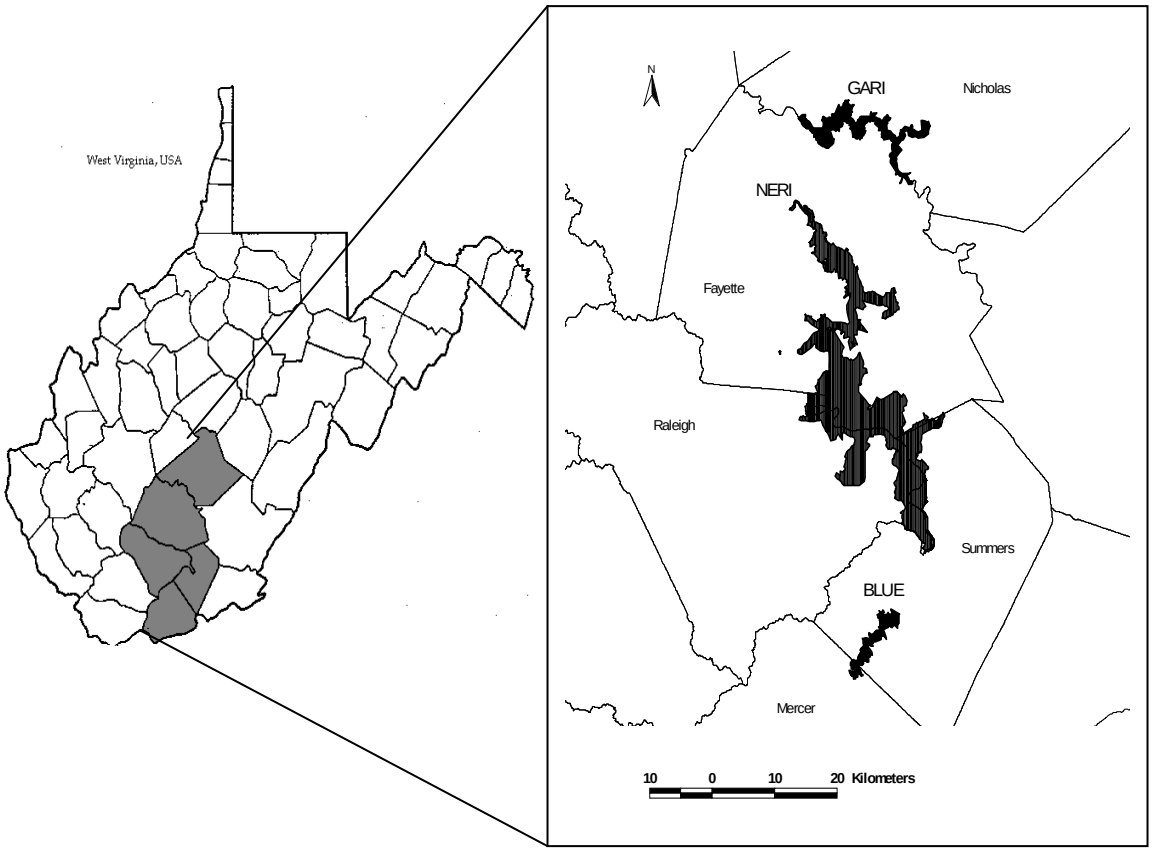

Figure 1. National Park Service units in south-central West Virginia surveyed for bat community composition in 2003 and 2004. The units, from north to south, are Gauley River National Recreation Area (GARI), New River Gorge National River (NERI), and Bluestone National Scenic River (BLUE).

Methods

Live Capture

We conducted mist-net surveys during the summers of 2003 and 2004. Timing of mist-net surveys were consistent with the Indiana Bat Recovery Plan (USFWS 1999) which recommends surveying between 15 May and 15 August to optimize the possibility that the female Indiana bats captured during this period are summer residents and likely establishing maternity colonies. Although timing of mist net surveys were consistent with the Indiana Bat Recovery Plan, the netting protocol (i.e., number of consecutive net-nights) outlined by the Recovery Plan was not followed because it conflicted with our objective of surveying a broad geographical area. Mist net locations included areas of concentrated bat activity such as small streams, ephemeral pools, and flight corridors (roads and trails). Likely netting locations were first determined from GIS layers depicting road, trail, stream, and pond locations, and were visited during the day to determine suitability. Other locations were identified while in the field. At each location, we established one or two net "sets," depending on the situation, consisting of 6 or 12 m (19.6 or 39.4 ft) wide × 2.4 m (7.8 ft) high mist nets (38 mm [1.5 in] mesh; Avinet Inc., Dryden, NY). Each set consisting of a single net or a double net (two nets, stacked) as the situation dictated. Starting at sunset, we sampled for approximately five hours, depending on temperature and overall bat activity. 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 (ASM 1998) and were conducted under University of Georgia Institutional Animal Care and Use Committee guidelines (Permit Number A2003-10030-0).

Acoustic Surveys

Acoustic surveys were conducted from May–September 2003 and 2004 using Anabat II detectors (Titley Electronics, Ballina, Australia). In 2003, two hundred seventy points (167 at NERI, 63 at GARI, 40 at BLUE) were acoustically sampled from July–September. Sampling stations were concentrated at the forest edge along hiking trails and roads. The initial station was located at a randomly selected distance along the road/trail and subsequent stations were located by walking for five minutes along the road/trail. Roads and trails were selected to distribute sampling across as much of the geographic area of the park units as possible. At each station, passive sampling was conducted by placing the detector on the ground with the detection cone point directly perpendicular to the ground for 20 minutes. 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. Surveys were conducted during the first 2–3 hours after civil sunset; the time of highest bat activity. Because 2003 sampling concentrated on forest edge habitats, the sampling protocol was modified in 2004 to sample forest interior habitats. From May–August 2004, we sampled 410 points (286 at NERI, 80 at GARI, 44 at BLUE). To determine locations of sampling stations, we first chose a random distance along a road or trail that bisected an area not sampled in 2003. From the point along the road/trail, we followed a random azimuth (constrained to azimuths that were not parallel to the road/trail) for 100 m (328 ft) to the first station. Four subsequent stations were located at 100 m

(328 ft) intervals along the same azimuth, effectively creating a transect of five sampling locations. Passive sampling was conducted as described above for 2003 sampling. As many transects as possible were sampled within the first three hours after sunset each night. In remote areas of the park units (particularly GARI and BLUE), park boundaries and signs marking private in-holdings are not well-marked (or are difficult to see at night), resulting in some of the sampling stations falling outside of the actual park boundaries. Based on the request of the NPS, additional acoustic sampling was conducted at Carnifex Ferry Battlefield State Park and Pipestem State Park because the habitat is similar and contiguous with the park areas. All survey stations were geo-referenced using a Global Positioning System (GPS; Trimble III, Sunnyvale, CA or Garmin GPS V, Olathe, KS). Due to difficulty acquiring satellites with the Trimble unit, some stations were marked with flagging at the time of sampling and were later geo-referenced with the Garmin unit. During both years, we did not sample on nights with strong wind (>10 km/hr [6.2 mi/hr]) or temperatures colder than 10ºC (50ºF).

We identified echolocation call sequences with Analook v 4.9 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 commonly-produced type of echolocation call sequence, have a consistent structure, and possess species-specific characteristics (Simmons et al. 1979; Fenton and Bell 1981; O'Farrell and Gannon 1999). After filtering, we only retained sequences with $\geq$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 (Table 1). The cross-validation process entailed developing the DFA model from two-thirds 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 one-third of the library. Thus, the accuracy rates are unique to our chosen suite of species (Table 1). The gray bat (*Myotis griscesens*) and evening bat (*Nycticeius humeralis*) were not included in the suite of potential species because the few records of the species in the state are extralimital and they were not documented in previous surveys of the park units (Johnson et al. 2003). Although Rafinesque's and Virginia big-eared bats have been documented in the park units (Johnson et al. 2003, 2005), they were excluded because their low-intensity calls cannot be detected with zero-crossing systems (e.g., Anabat). Limiting the cross-validation to only species with a high likelihood of being present ensured the highest accuracy rates possible. The accuracy rates we present are based on single call sequences and, therefore, represent minimum rates. Accuracy rate increases as the number of call sequences identified at a site for a single species increases (Britzke et al. 2002). However, accuracy rate decreases when calls of other species with similar call characteristics are recorded during the same sampling period. Accuracy rates could also potentially change in unknown ways due to changes in echolocation call structure as bats respond to "clutter" (such as the forested understory of this study) in their environment (e.g., Broders et al. 2004). Call libraries for structurally complex environments do not currently exist and it should be noted that the accuracy rates presented below are from "open" or "uncluttered" environments. Therefore, we only considered a species present at a site

Table 1. Accuracy (%) rates of echolocation call identification obtained by cross-validation of a comprehensive call library of bats from the eastern United States using a discriminant-function model developed by Britzke (2003). Columns represent the actual species that emitted the calls, and the rows represent the percentage of calls identified as the corresponding species in each row (model predicted output).

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

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 live-captured eight bat species and detected nine species during acoustic surveys (Table 2), with Indiana bats being detected only acoustically. The only bats known to occur in the park units but not documented using either method were Rafinesque's big-eared bats and Virginia big-eared bats.

Table 2. Comparison of survey techniques (live-capture techniques and acoustic surveys) on eleven 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. An asterisk (*) indicates the capture/detection of the species.

	BLUE		GARI		NERI		Combined	
Common name	Live	Acoustic	Live	Acoustic	Live	Acoustic	Live	Acoustic
little brown bat	*	*	*	*	*	*	*	*
northern myotis		*	*	*	*	*	*	*
Indiana bat		*		*		*		*
eastern small-footed myotis		*		*	*	*	*	*
silver-haired bat		*		*	*	*	*	*
eastern pipistrelle	*	*	*	*	*	*	*	*
big brown bat	*	*	*	*	*	*	*	*
eastern red bat		*	*	*	*	*	*	*
hoary bat		*		*	*	*	*	*

We captured a total of 175 bats during 410 net-hours at 33 sites across all park units (Figures 2, 3, and 4) during the summers of 2003 and 2004. Little brown bats (n=69) and northern myotis (n=50) were the most commonly captured species (Table 3). Eastern small-footed myotis (n=3), silver-haired bat (n=1), eastern pipistrelle (n=17), big brown bat (n=23), and eastern red bat (n=11) were captured infrequently. Only a single capture was recorded for both the silver-haired bat and the hoary bat. Overall captures were comprised of 64 females and 111 males (Table 4). Reproductive females and/or juveniles were documented for seven bat species (all species except Indiana bats and silver-haired bats) during May 15 and August 15, indicating that these species have maternity colonies in the area (Tables 5 and 6). The species with the highest capture rate (number of individuals captured/net hours sampled) across all parks was the little brown bat (0.173 bats/net-hour), while the overall capture rate of all bats across park units was 0.438 bats/net-hour (Table 3).

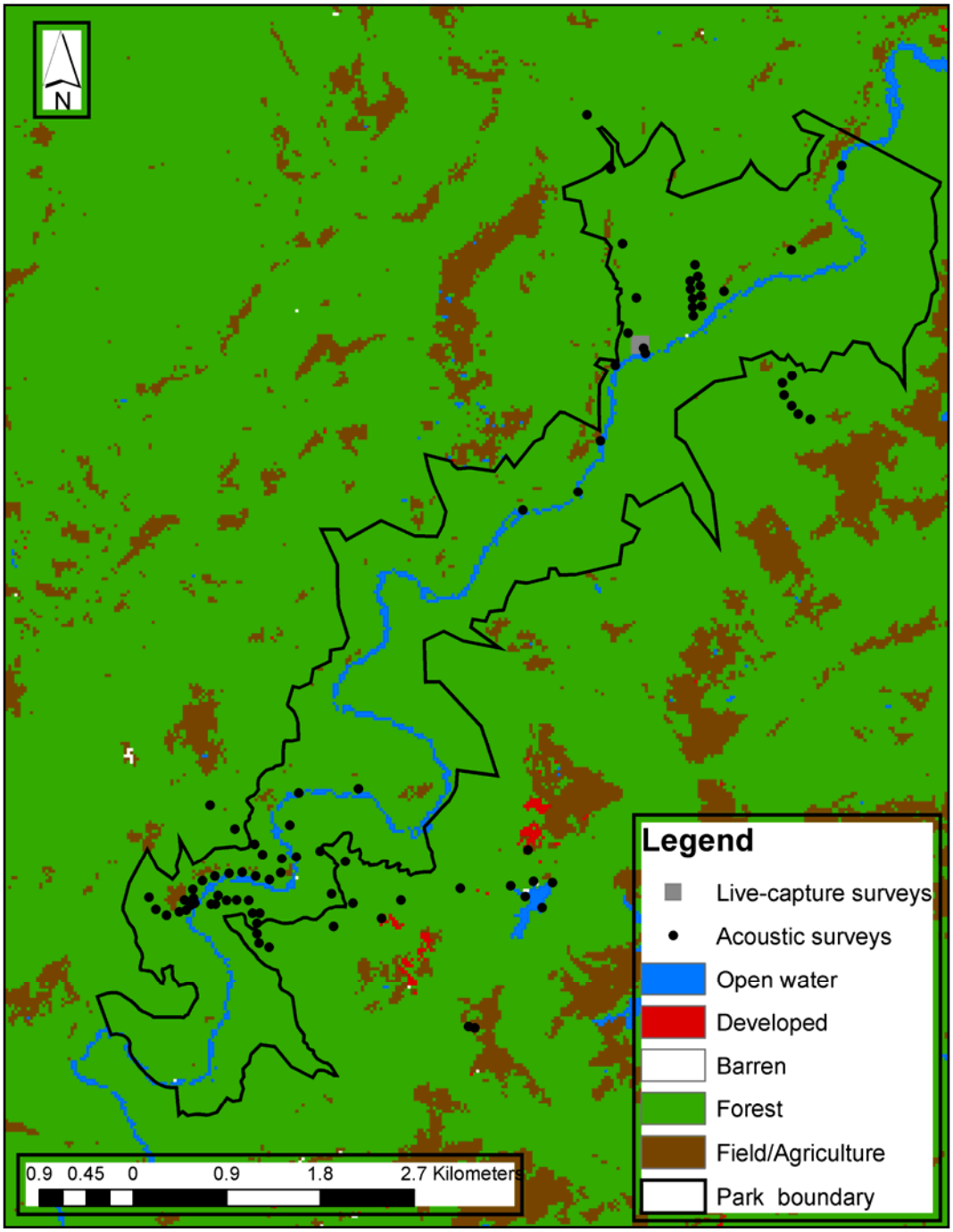

Figure 2. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at Bluestone National Scenic River, West Virginia, May–September 2003–2004.

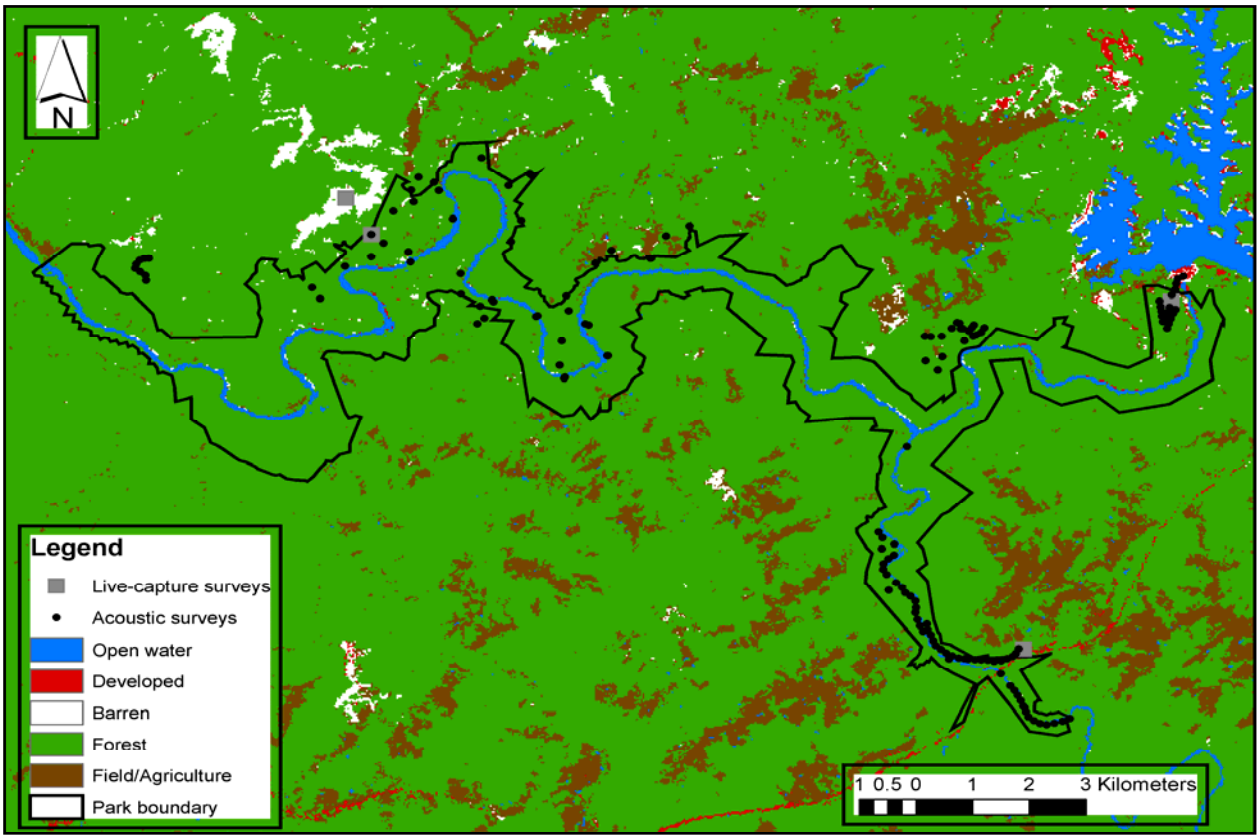

Figure 3. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at Gauley River National Recreation Area, West Virginia, May–September 2003–2004.

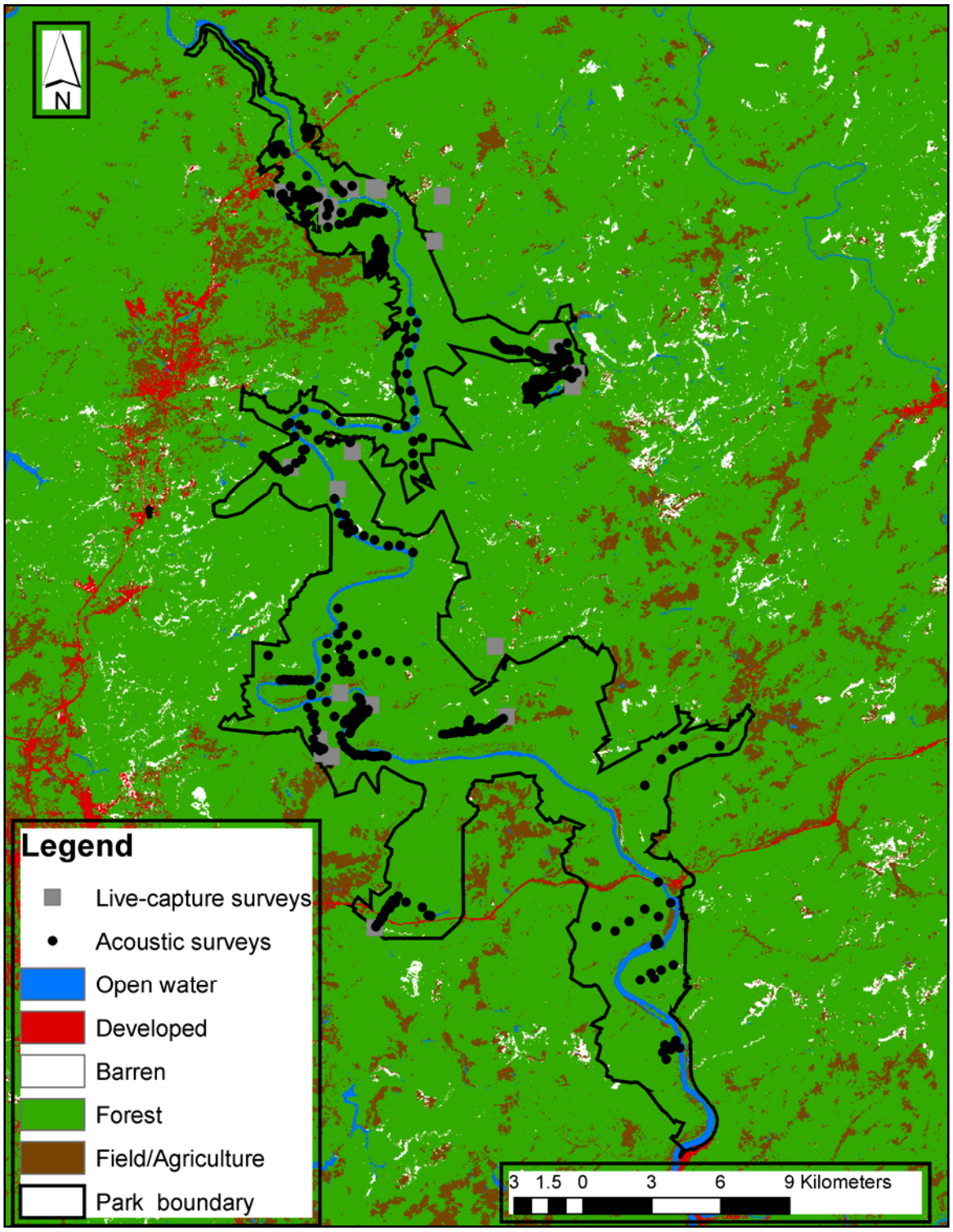

Figure 4. Locations sampled using live-capture techniques and Anabat II detectors (acoustic surveys) at New River Gorge National River, West Virginia, May–September 2003–2004.

Table 3. Number and capture rate (captures/net-hour; in parentheses) of bat species documented using live-capture techniques at Bluestone National Scenic River (BLUE; 20 net-hours at 2 sites), Gauley River National Recreation Area (GARI; 30 net-hours at 4 sites), and New River Gorge National River (NERI; 350 net-hours at 35 sites), West Virginia, May–September 2003–2004. Indiana bat was the only species acoustically detected but not captured using live-capture techniques.

Species	BLUE	GARI	NERI	TOTAL
little brown bat	1 (0.050)	1 (0.033)	67 (0.191)	69 (0.173)
northern myotis	-	1 (0.033)	49 (0.140)	50 (0.125)
eastern small-footed myotis	-	-	3 (0.009)	3 (0.008)
silver-haired bat	-	-	1 (0.003)	1 (0.003)
eastern pipistrelle	4 (0.200)	1 (0.033)	12 (0.034)	17 (0.043)
big brown bat	1 (0.050)	1 (0.033)	21 (0.060)	23 (0.058)
eastern red bat	-	1 (0.033)	10 (0.029)	11 (0.028)
hoary bat	-	-	1 (0.003)	1 (0.003)
total	6 (0.300)	5 (0.169)	164 (0.469)	175 (0.438)

Table 4. Bat species, by sex, captured using live-capture techniques during 410 net-hours at 41 sites in Bluestone National Scenic River (BLUE; 20 net-hours), Gauley River National Recreation Area (GARI; 40 net-hours), and New River Gorge National River (NERI; 350 net-hours), West Virginia, May–September 2003–2004. Indiana bat was the only species acoustically detected but not captured using live-capture techniques.

	BLUE		GARI		NERI		TOTAL	
Species	Female	Male	Female	Male	Female	Male	Female	Male
little brown bat	0	1	1	0	49	18	50	19
northern myotis	0	0	0	1	10	39	10	40
eastern small-footed myotis	0	0	0	0	1	2	1	2
silver-haired bat	0	0	0	0	0	1	0	1
eastern pipistrelle	1	3	0	1	0	12	1	16
big brown bat	0	1	0	1	0	21	0	23
eastern red bat	0	0	0	1	1	9	1	10
hoary bat	0	0	0	0	1	0	1	0
total	1	5	1	4	62	102	64	111

Table 5. Bat species, by age class, captured using live-capture techniques during 410 net-hours at 41 sites in Bluestone National Scenic River (BLUE; 20 net-hours), Gauley River National Recreation Area (GARI; 40 net-hours), and New River Gorge National River (NERI; 350 net-hours), West Virginia, May–September 2003–2004. Indiana bat was the only species detected but not captured using live-capture techniques.

Species	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
little brown bat	1	0	1	0	54	12	59	12
northern myotis	0	0	1	0	44	4	42	4
e. small-footed myotis	0	0	0	0	3	0	3	0
silver-haired bat	0	0	0	0	1	0	1	0
eastern pipistrelle	4	0	1	0	7	5	12	5
big brown bat	2	0	0	1	17	4	18	5
eastern red bat	0	0	0	1	7	3	7	4
hoary bat	0	0	0	0	1	0	1	0
total	6	0	3	2	134	28	143	30

Table 6. Reproductive female bats, by species and reproductive condition (lactating or pregnant), captured using live-capture techniques during 400 net-hours at 41 sites at New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE), West Virginia, May–September 2003–2004. Indiana bat was the only species acoustically detected but not captured using live-capture techniques.

	BLUE		GARI		NERI		TOTAL	
Species	Lactating	Pregnant	Lactating	Pregnant	Lactating	Pregnant	Lactating	Pregnant
little brown bat	0	0	0	0	13	1	13	1
northern myotis	0	0	0	0	5	10	5	10
eastern small-footed myotis	0	0	0	0	0	1	0	1
eastern pipistrelle	0	1	0	0	0	0	0	1
eastern red bat	0	0	0	0	0	1	0	1
hoary bat	0	0	0	0	1	0	1	0
total	0	1	0	0	19	13	19	14

During the summers of 2003 and 2004, we acoustically surveyed 680 sites (Figures 2–4) recording 3,365 call sequences meeting the criteria of quality search-phase calls with ≥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). The average accuracy rate (for a single call sequences) using the DFA model was 88.0%, with the lowest accuracy rate of 82.1% (silver-haired bat) and the highest rate of 100% (eastern pipistrelle; Table 1). The northern myotis was the most commonly recorded species, being detected at 22.9% of all sites across the three park units (Table 7).

Bluestone National Scenic River

We sampled one site for approximately 20 net-hours using live-capture techniques at BLUE. We captured six bats representing three species, including the little brown bat, eastern pipistrelle, and big-brown bat (Table 3). One pregnant eastern pipistrelle female was documented (Table 6). The overall capture rate per net hour was 0.30 bats/net-hour while the highest capture rate was for the eastern pipistrelle (0.20 bats/net-hour; Table 3).

We acoustically sampled 84 sites at BLUE, representing 12% of our overall survey effort, and recorded 360 identifiable calls. The species that was detected at the highest percentage of sites was the northern myotis (22.6%; Table 7). The eight species detected included all three species captured during live-capture efforts, but also included northern myotis, eastern small-footed myotis, Indiana bat, silver-haired bat, and eastern red bat. Of the species detected across all park units, the only species not detected in BLUE was the hoary bat (Table 7). None of the eight species had been previously documented for this park.

Gauley River National Recreation Area

We sampled four sites for approximately 40 net-hours using live-capture techniques at GARI. We captured five individuals of five species, including little brown bat, northern myotis, eastern pipistrelle, big brown bat, and eastern red bat (Table 3). Juveniles of two species, big brown bat and eastern red bat, were documented suggesting that these species had maternity colonies in the area (Table 5). Overall capture rate at GARI was the lowest among the three parks at 0.167 bats/net-hour, while capture rate for each of the 5 species was 0.033 (one capture of each species; Table 3).

We acoustically sampled 143 sites at GARI, representing 21% of our overall survey effort, and recorded 495 identifiable call sequences. The nine species detected included all five species captured during live-capture efforts, but also included eastern small-footed myotis, Indiana bat, silver-haired bat, and the hoary bat (Table 7). The species detected at the highest percentage of sites was the northern myotis (21.0%). All nine species documented in the overall project were also documented at GARI with big brown bat, Indiana bat, eastern red bat, silver-haired bat, and hoary bat being documented for the first time in this study. Moreover, small-footed myotis, little brown bat, northern myotis, and eastern pipistrelle were previously only documented at mine portals during the fall swarm (Johnson et al. 2003), in contrast to our breeding-season detections.

Table 7. Number of acoustic survey sites bat species were acoustically detected (call sequences recorded in a 20-min sampling period) out of 680 total sites sampled 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 the total number of points sampled shown in parentheses.

Species	BLUE (n = 84)	GARI (n = 143)	NERI (n = 453)	Total (n = 680)
little brown bat	12 (14.3)	9 (6.3)	40 (8.8)	61 (9.0)
northern myotis	19 (22.6)	30 (21.0)	107 (23.6)	156 (22.9)
Indiana bat	11 (13.1)	14 (9.8)	53 (11.7)	78 (11.5)
eastern small-footed myotis	7 (8.3)	12 (8.4)	45 (9.9)	64 (9.4)
silver-haired bat	1 (1.2)	1 (0.7)	7 (1.5)	9 (1.3)
eastern pipistrelle	9 (10.7)	13 (9.1)	54 (11.9)	76 (11.1)
big brown bat	6 (7.1)	12 (8.4)	52 (11.5)	70 (10.3)
eastern red bat	7 (8.3)	12 (8.4)	18 (4.0)	37 (5.4)
hoary bat	0 (0.0)	1 (0.7)	1 (0.2)	2 (0.3)

New River Gorge National River

We sampled 28 sites for approximately 350 net hours using live-capture techniques. We captured 164 bats of eight species, including little brown bats, northern myotis, eastern small-footed myotis, eastern pipistrelle, big brown bats, eastern red bats, and two species not previously captured at NERI, silver-haired bat and hoary bat (Table 3). Reproductive females and/or juveniles were documented for seven species (Table 5 and 6). The species with the highest capture rate was the little brown bat with 0.191 bats captured/net-hour (Table 3). Capture rate at NERI was the highest among the three parks at 0.469 bats/net-hour.

We acoustically sampled 453 sites at NERI, representing 66% of our overall survey effort, and recorded 2,510 identifiable call sequences. The nine species detected included all species captured during live-capture efforts, but also included Indiana bat (Table 7). The species detected at the highest percentage of sites was the northern myotis (23.6%). Silver-haired bats were previously undocumented at NERI and these are the first breeding-season detections for hoary bats and Indiana bats.

Discussion

We documented nine of the 11 bat species that have primary distributions that include the park units. Based on the combined results of our mist-net and acoustic surveys, the most common bat species found in the units is the northern myotis. The large number of northern myotis detections was not surprising, given the habitat associations of the species. In the central Appalachians, the species is considered a mature forest, interior species (Owen et al. 2003; Ford et al. 2005) indicative of the majority of the land area in the parks. Other common species documented by mist-netting and acoustic surveys, such as the little brown bat, eastern pipistrelle, big brown bat, and the eastern red bat, have ubiquitous distributions and also are commonly reported from the central Appalachians (Carter et al. 2003; Johnson et al. 2003; Ford et al. 2005). Only one hoary bat, a lactating female, was captured during the 410 net-hours of sampling, and the species was recorded at only nine of the 680 acoustic stations. Although Johnson et al. (2003) documented hoary bats from NERI in acoustic surveys, ours represents the first capture from the park units. The capture was significant because we were able to document presence of a lactating female, confirming NERI as a likely maternity area for this less-common species. The silver-haired bat is present in all three parks, but apparently still rare in the area during summer. We captured only a single adult male at NERI and only recorded 12 echolocation calls across all park units, combined.

We captured three eastern small-footed myotis, all in the proximity of abandoned mine portals in NERI. Johnson et al. (2003) documented eastern small-footed myotis in fall surveys of mine portals in NERI and GARI, but captured only one of the 41 bats during summer sampling at NERI. They suggested that the species uses mine portals as hibernacula, but may day-roost in exposed clifflines in summer (McDaniel et al. 1982). Previous survey efforts suggest a paucity of eastern small-footed myotis in the central Appalachians during summer (Edwards et al. 2001; Menzel et al. 2002; Owen et al. 2002; Carter et al. 2003). Although we did not capture the species at sites away from mine portals, our acoustic survey results suggest that the species is relatively abundant in all three of the park units in summer. We attribute this to the extensive cliffline habitats similar to those known to be used by the species as summer roosts (McDaniel et al. 1982). The documented presence of the species and its known association with cliffline habitats could have direct implications on the management of recreational climbing in the areas, especially at NERI. However, further work is needed to determine the impact of climbing on roost site selection by the species.

Although we did not capture Indiana bats during our live-capture surveys, we acoustically detected the species on all three park units and at 9% of the acoustic stations across all park units. Maternity colonies of the Indiana bat have been documented elsewhere in the mountainous portions of West Virginia, including nearby in Boone and Kanawha counties (Brack et al. 2002; Beverly 2004; Beverly and Gumbert 2003, 2004; S. Jones, USFWS, pers. comm.), and individuals of both sexes have been captured at a mine portals on NERI during the fall swarm (Johnson et al. 2003; Gates and Johnson 2006). Maternity activity has not been documented from the parks, but presence of maternity colonies should be considered as moderately to highly likely based on the relatively large number of echolocation calls recorded and the close proximity of the Boone County maternity roosts. Britzke et al. (2002) documented the difficulty of capturing Indiana bats, even at a site near a known maternity roost of >100

individuals in northeast Missouri. In two nights of mist netting they only captured one individual, but recorded approximately 300 call sequences for the species.

With the difficulty of capturing this rare species, we concur with Ford et al. (2005) that acoustical surveys are the most efficient method for obtaining general habitat association data on the Indiana bat. However, being able to correctly identify echolocation calls is critical, especially when dealing with endangered species. Our accuracy rate associated with identifying Indiana bat calls from a single call sequence was 86.8% and we identified 60 locations where at least two echolocation calls were recorded. Even with the probability of misidentifying calls as little brown bats or eastern small-footed myotis 13.2% of the time (Table 1), there were at least 53 sites with a probability of species presence near 1.0. There also were 16 sites with more than four Indiana bat call sequences recorded during a single sampling session.

Taking a conservative approach when making inferences about Indiana bat foraging habitat and using only locations where we recorded more than four call sequences, our results are consistent with previous research in the central Appalachians that have demonstrated a preference for closed canopy riparian areas (Appendix; Butchkoski and Hassinger 2002; Ford et al. 2005). Most Indiana bat calls we recorded were within 200 m (656 ft) of streams within closed-canopy forest. Furthermore, we recorded most calls on south-southeast facing slopes. South-facing aspects have greater exposure to solar radiation, which may provide suitable roosting locations (Ford et al. 2002) and/or foraging areas with higher insect abundance.

Despite their known occurrence in the park units, we did not capture either Rafinesque's or Virginia big-eared bats. These species have been documented using mine portals during the summer and fall, but with most captures occurring during fall (Johnson et al. 2003; Johnson et al. 2005; Gates and Johnson 2006). We failed to capture either species in summer at sites away from portals. In North Carolina, Clark (1990) documented Rafinesque's big-eared bat foraging <1 km (0.62 mi) from their day roost. In Kentucky, Virginia big-eared bats did not forage >1.1 km (0.68 mi) from the day roost (Adam et al. 1994). Given the large geographic area encompassed by the park units, their relatively short foraging distances, and their apparent rarity in the area during summer, 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 zero-crossings (i.e., Anabat) ultrasonic detectors.

We detected more bat species using acoustic monitoring than using live-capture surveys, which is consistent with previous studies comparing the two techniques (Murray et al. 1999; O'Farrell and Gannon 1999). At all three park units, live-capture surveys were difficult because bats concentrate on the associated rivers and riverine habitats, such as back water sloughs, that were difficult to sample with mist nets during this study. Locating areas of high bat activity along small water courses that could be surveyed with mist-nets also proved difficult. Our highest capture rate for any park unit was at NERI with 0.47 captures/hour, or <1 individual for every two net-hours of survey effort. Using acoustic surveys, we located areas of habitat use by bats at 381 sites, or 56% of all the sites surveyed. Acoustical survey efforts were more efficient on sections of GARI and NERI because of the legacy of past anthropogenic impacts from timber harvest and mining that left a complex of forest roads and skidder trails that easily could be used to access remote areas.

Our results demonstrate that the large areas of relatively contiguous mature forest that comprise the park units provide summer foraging habitat for at least nine bat species. From a landscape perspective, the park units comprise large areas of relatively contiguous mature forest within a matrix of forests fragmented by mining, forest management activities, and development. The park units may provide habitat for bat species limited in the surrounding landscape.

Management Implications

Although Indiana bat day-roosting, either bachelor roosts or maternity colonies, has not been documented in the park units, they do occur in surrounding areas (Brack et al. 2002; Beverly 2004; Beverly and Gumbert 2003, 2004). With our verification of this species within the parks during summer, managers should assume that either bachelor roosts or maternity colonies are present, although likely in small numbers. Both roost-types of the Indiana bat typically are located in snags of a variety of tree species (Menzel et al. 2001; Britzke et al. 2003; Beverly and Gumbert 2004) and occasionally in living trees, especially shagbark hickory (*Carya ovata*; Gardner et al. 1991; Callahan et al. 1997; Ford et al. 2002). Retaining snags created through natural processes (e.g., tree senescence, lightning strike, and insect infestation) throughout the parks, when safety concerns allow, should be considered a minimum management practice for providing maternity roost structures. When possible, additional snags should be created by girdling or herbicide injection. Because primary maternity roosts typically are located in areas with high solar exposure and because most Indiana bats we detected were on south-facing slopes (Appendix), we recommend that south-facing slopes be the areas targeted in snag augmentation efforts. Moreover, forest stands on these aspects would respond well structurally and compositionally to a cessation of fire suppression, so prescribed burning activities that open the canopy and create snags could be an effective proactive management tool for enhancing Indiana bat roosting and foraging habitat in the park units. Nonetheless, tracking radiotagged bats is required to positively identify preferred roosting areas to allow for adequate formation of specific management guidelines.

Our acoustic survey protocol consisted of sampling for 20 minutes at each station. Given our goal of surveying bat community composition and relative abundance over a large geographic area, this protocol allowed us to efficiently survey a large number of locations; however, because of the presence of several species with similar echolocation call structures (i.e., *Myotis* spp.), a longer sampling period should be considered in future acoustic surveys for target species (e.g., Indiana bat). Britzke et al. (2002) recognized the difficulty of determining species presence when there are multiple species in a community with similar search-phase call structures. They documented that identification accuracy increases as the number of call sequences identified at a site for a single species increases. Depending on bat activity levels, a longer sampling period may increase accuracy rates of individual species by providing a larger sample size of call sequences. The accuracy rates achieved from our efforts (>84% from a single echolocation call sequence for most species) are acceptable for most surveys; however, when surveying for endangered species it would be prudent to take a conservative approach (as we report here) and use multiple call sequences as the criterion for species presence.

The bat species present and the percentage of acoustic survey sites at which species were detected were similar among the park units (Table 7), suggesting that the bat communities are similar among the three units. Because of the similarity of forest habitats, large river corridors, small streamside zones, and geologic features among the three units, our results suggest that, from a bat-community perspective, the park units can be managed as a single unit. The likely exception is that BLUE has minimal cliff habitats and mine portals compared with NERI and GARI and, therefore, species that prefer to roost in cliffs/caves would be reduced. Although active management for the bat community as a whole is not necessary, measures implemented to

benefit target species, such as snag augmentation for Indiana bat maternity roosts, would be equally beneficial at all three park units.

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Appendix. Species-specific habitat association models for bats in the New River, Gauley, and Bluestone River national park units

Summary

Research using ultrasonic detectors to assess species-specific habitat associations at local- and landscape-levels can provide important information to land managers. Recent studies in the Appalachian Mountains have demonstrated that bat habitat relationships determined using acoustic surveys match expectations based on food habits, body-size, wing morphology, and echolocation call characteristics of individual species. In an effort to create predictive bat habitat association models across a large, topographically complex, and relatively intact forested landscape, we conducted acoustic surveys at the New River Gorge National River, Gauley River National Recreation Area, and the Bluestone National Scenic River in southern West Virginia. We *a priori* developed generalized and species-specific groups of multivariate models for seven bat species to predict bat habitat associations. Based on 3,365 search phase calls recorded at 680 sites across the park units, bat association with simple habitat conditions generally conformed to expectations based on previous research in the region. Although variable among species, riparian areas are the most critical component of bat foraging habitat, with open, less structurally cluttered zones most important for little brown bats (*Myotis lucifugus*), eastern pipistrelles (*Pipistrellus subflavus*), and big brown bats (*Eptesicus fuscus*), and, to some extent, eastern red bats (*Lasiurus borealis*). Closed-canopy forested riparian areas in the parks are important for Indiana bats (*M. sodalis*) and eastern small-footed myotis (*M. leibii*). With the results of our study park managers can strengthen management guidelines that maintain and protect riparian health and integrity and concomitantly protect important bat foraging habitat.

Introduction

Widespread use of ultrasonic detectors has lead to an increase in research examining foraging and habitat use of bats throughout temperate systems in Europe (Walsh and Harris 1996; Vaughn et al. 1997; Jaberg and Guisan 2001; Russ and Montgomery 2002), Canada (Crampton and Barclay 1998; Jung et al. 1999; Hogberg et al. 2002; Broders et al. 2003), the western United States (Thomas 1988; Erickson and West 2003; Ellison et al. 2005), New England (Krusic et al. 1996; Zimmerman and Glanz 2000), and the Southeast and mid-Atlantic, including the central Appalachian Mountains (Menzel et al. 2002, 2005a, 2005b; Owen et al. 2004; Ford et al. 2005). Despite the wide disparity of geographic context, many of these studies were highly congruent in terms of microhabitat and landscape-scale linkages to bat presence, i.e. denoting the importance of riparian zones and forest structure heterogeneity as well as overall ecosystem integrity and intactness (Walsh and Harris 1996; Vaughan et al. 1997; Crampton and Barclay 1998; Hogberg et al. 2002; Menzel et al. 2002; Erickson and West 2003; Ellison et al. 2005). The portability and cost-effectiveness of acoustical systems allows researchers to undertake bat habitat studies across larger scales and landscapes that would otherwise be unfeasible (Ford et al. 2005). Research using ultrasonic detectors to assess species-specific habitat association at local- and landscape-levels can be important by providing land managers with valuable information regarding habitat characteristics utilized by different species of bats.

In the Allegheny Mountains and Plateau region of West Virginia, Owen et al. (2004) acoustically examined categorical habitat associations (e.g., replicated silvicultural treatment areas) of bats on

the MeadWestvaco Ecosystem Research Forest; whereas, Ford et al. (2005) acoustically examined bat habitat use on the Fernow Experimental Forest across a full gradient of forest conditions, elevations, and site indices. Both studies documented that specific site-level microhabitat factors such as canopy cover and forest canopy gap metrics, along with proximity to streams, were the variables most important in explaining bat presence of individual species. Little brown bat (*Myotis lucifugus*), eastern red bat (*Lasiurus borealis*), and big brown bat (*Eptesicus fuscus*) presence was linked to larger forest canopy gaps and openings; whereas, presence of Indiana bats (*M. sodalis*) and northern myotis (*M. septentrionalis*) were linked to increased canopy cover. Presence of silver-haired (*Lasionycteris noctivagans*) and hoary (*L. cinereus*) bats was greater in large open areas, such as recent clearcuts. Both studies demonstrated that bat habitat relationships matched expectations based on food habits, body-size, wing morphology, and echolocation call characteristics of individual bat species. Nonetheless, both studies were limited by sample size and the overall lack of inference across a larger central Appalachian landscape. Herein, our objective was to create predictive bat habitat association models derived from acoustic data collected across a large, topographically complex, and relatively intact forested landscape to compliment existing information from the region.

Study Area and Methods

Study Areas

We conducted our study at the Bluestone National Scenic River (BLUE), Gauley River National Recreation Area (GARI), and New River Gorge National River (NERI) in south-central West Virginia. The study areas 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). Elevations in the park units and surrounding landscape range from approximately 250 m (820 ft) to over 1,000 m (3,280 ft). The geology of the area is characterized primarily by sandstone, with some particles of limestone and various shales, along with thin beds of coal. Annual precipitation averages 130 cm (51 in). A substantial legacy of anthropogenic impacts exists in the study area, with railroad grades, logging roads, and abandoned buildings and mineshafts occurring throughout. For example, NERI and GARI have >120 abandoned deep-mine shafts. Although no mines exist on BLUE, major oil and gas pipelines transect the park (NPS 2006).

The park units combined contain 35,614 ha (88,003 ac) 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 are comprised of 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 contain forest communities consisting 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*) forest dominate smaller streamside corridors and drains. Other trees found in small patches include eastern red cedar (*Juniperus virginiana*), usually found 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 (NPS, unpublished data).

Acoustic Surveys

Acoustic surveys were conducted using Anabat II detectors (Titley Electronics, Ballina, Australia) at survey stations located along line transects. At each station, passive sampling was conducted by placing the detector on the ground with the detection cone point directly perpendicular to the ground for 20 minutes (Johnson et al. 2002). Our surveys took place during the first 2–3 hours after sunset to coincide with the time of highest bat activity. With the objective of surveying as much of the park areas as possible, we constrained sampling stations to areas not previously sampled, and no stations were replicated. In 2003, two hundred seventy points were acoustically sampled from July–September. Sampling stations were concentrated at the forest edge along hiking trails and roads. This methodology was used because there are numerous trails and roads present, making it possible to sample large areas of the parks. The initial station was located at a randomly selected distance along the road/trail and subsequent stations were located by walking for five minutes along the road/trail. In 2004, we sampled 410 points from May–August and the sampling protocol was modified to sample forest interior habitats. From randomly chosen points along access roads and trails, we established line-transects of five to six stations that emanated away from the trail or road into the surrounding forest by choosing random azimuths constrained such that the transect was not parallel to the road/trail. Each station was located approximately 100 m (328 ft) apart and stations were sampled sequentially. Some stations (n=66 [approx. 1%]) were located outside of NPS ownership on Carnifex Ferry Battlefield, on Pipestem and Grandview State Parks, or on adjacent private land in similar habitat conditions to that found in the park units. All survey sites were geo-referenced using a Global Positioning System (Trimble III, Sunnyvale, CA or Garmin GPS V, Olathe, KS). We avoided sampling on nights with strong wind (>10 km/hr [6.2 mi/hr]) or temperatures colder than 10ºC (50ºF). We recorded bat echolocation call sequences on compact flash cards within the Zero Crossings Analysis Interface Module (Titley Electronics, Ballina, Australia) and downloaded them 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 commonly produced echolocation call sequences, have a consistent structure, and possess species-specific characteristics (Simmons et al. 1979; Fenton and Bell 1981; Betts 1998; O'Farrell and Gannon 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 two-thirds 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 one-third of the library. Thus, the accuracy rates are unique to our chosen suite of species. The gray bat (*M.*

griscesens) and evening bat (*Nycticeius humeralis*) were not included in the suite of potential species because the few records of the species in the state are extralimital and they were not documented in previous surveys of the park units (Johnson et al. 2003). Although Rafinesque's and Virginia big-eared bats have been documented on the park units (Johnson et al. 2003, 2005), they were excluded because their low-intensity calls cannot be detected with zero-crossing systems (e.g., Anabat). Limiting the cross-validation to only species with a high likelihood of being present ensured the highest accuracy rates possible. The accuracy rates we present are based on single call sequences and, therefore, represent minimum rates; however, accuracy rate increases as the number of call sequences identified at a site for a single species increases, but decreases when calls of other species with similar call characteristics are recorded during the same sampling period (Britzke et al. 2002). Therefore, we only considered a species present at a site if ≥2 call sequences from that species were recorded during a 20-min sampling period, unless it was the only species recorded during that period, in which case a species was considered present based on a single call sequence.

Habitat Parameters

For each acoustically sampled site, 17 habitat parameters were recorded in the field or subsequently derived using a GIS (ArcGIS and ArcView 3.2, ERSI Inc., Redlands, CA; Table A1). Topographic variables, including slope, aspect, and elevation, were determined from a 30-m digital elevation model (DEM) in ArcGIS. We transformed aspect into a linearized gradient of 0–2 with 2 representing the most xeric aspect and 0 representing the mesic aspect (Ford et al. 2002a). Flat aspect received a value of 1. We placed slope into three categories: (1) gentle (0–15º), (2) moderate (15–25º), and (3) steep (>26º). We calculated distance to nearest stream (1st through 4th order) using a digitized stream layer (30-m resolution) by measuring straight-line distance from each station. Straight-line distance to the nearest large river (Bluestone, Gauley, Little Bluestone, Meadow, or New) was calculated using a digitized GIS layer (30-m resolution). Proximity to water source other than streams (i.e., ponds and lakes) was determined by digitizing water sources from digital orthophoto-quads (WVDEP; http://gis.wvdep.org/data/doqq.php) and measuring the straight-line distance from each survey station. The distance of the survey station to the nearest water source, regardless of type, was measured using the appropriate GIS layer described for the various water sources. We calculated distances to mines by measuring the distance from each survey point to the nearest mine portal in ArcView using our point location layers and mine location layers obtained from NPS. We identified clifflines by an abrupt change in slope and calculated distance from each survey point to the nearest cliffline. We measured the cumulative linear measurement (m) of roads within a 150-m (492-ft) buffer around each survey station. The buffer size was an arbitrary number that was used to gain information at a larger spatial scale. Also within our 150-m (492-ft) buffer, we estimated the percentage of forest using the Land Use and Land Cover (LULC) layer for West Virginia based on 1992 Landsat TM imagery with 30-m resolution (USGS Earth Observation Systems Data Center, Denver, CO; http://edc.usgs.gov/geodata; http://store.usgs.gov/). In the field, we visually estimated stand-class and mid-story density at each station and placed them into one of four categories. We categorized habitat type at each station as either an open (0–50%) or closed (51–100%) canopy. We estimated width of corridor (road, trail, abandoned railroad grade, or watercourse channel) or forest canopy gap (m) at each station. We measured temperature at each survey station at the end of our 20-minute sampling period using a digital thermometer (Acurite Inc., Jamestown,

Table A1. Variables collected at acoustic survey sites or derived from a GIS and used to develop a priori habitat association models for seven bat species detected in Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, 2003–04.

Variable	Description
Slope (S)	Slope measured from 30-m DEM; categorized as gentle (0–15º), moderate (16–25º), or steep (>26º).
Aspect (A)	Transformed aspect value from mesic to xeric (0–2) measured from 30-m DEM
Elevation (E)	Elevation (m) measured from 30-m DEM
Distance to stream (DS)	Distance to nearest stream (1st–4th order; m)
Distance to major stream (DMS)	Distance to the nearest major river (m): Bluestone, Gauley, Little Bluestone, Meadow, or New rivers
Proximity to water (PW)	Distance to water sources other than 1st–4th order stream or major stream (m)
Distance to nearest water (DW)	Distance to the nearest water source (m)
Distance to mine (DM)	Distance to nearest mine (m)
Distance to cliff line (DC)	Distance from site to nearest cliff line (m); cliff lines were identified as an abrupt change in slope
Linear measurement of road (LR)	Cumulative length of roads (m) within 150 m buffer encircling survey site
Percent forest (PF)	Percent forest from Land Use and Land Cover within 150 m buffer encircling survey site
Stand Class (SC)	Stand class category: 1) regeneration (0–5 cm dbh), 2) seedling-sapling (5–23 cm dbh), 3) small sawtimber (23 –46 cm dbh), 4) large sawtimber (>46 cm dbh)
Mid-story (MS)	A visual estimate of mid-story woody percent coverage categories: 0–25%, 25–50%, 50–75%, 75–100%
Habitat Type (H)	Habitat type at each site categorized as open canopy (0–50%) or closed (51–100%) canopy
Width of Corridor (WC)	Corridor width or forest canopy gap diameter (m) at each site
Temperature (T)	Temperature (Cº) at end of 20-min. sampling period
Water at the site (WS)	Presence or absence of water within 40 m of site

NY). We also noted presence or absence of water within the detection range (40 m [131 ft]) of our ultrasonic detectors.

Model Development

Based on findings of previous acoustic bat surveys from the Allegheny Mountain and Plateau region (Owen et al. 2004; Francl et al. 2004; Ford et al. 2005) as well as recent data from other acoustical and radio-telemetric research in the eastern United States (Kiser and Elliot 1996; Menzel et al. 2002, 2005a, b, c; Johnson et al. 2003, 2005; Owen et al. 2003), we developed six generalized and one species-specific group of *a priori* multivariate models for each of seven bat species to create predictive species-specific habitat associations (Table A2.). The MACRO TO LANDSCAPE model was constructed from variables representing landscape-level variables. The FOREST STRUCTURE model was constructed of variables that represented measurements or condition of forest structure collected at each survey station. The SIMPLE STRUCTURE model was comprised of variables representing simple habitat examinations at each station, i.e.,

Table A2. Variable composition of *a priori* habitat association models for seven bat species detected in Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, 2003–04.

Model	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

presence of water and open or closed forest canopy. Two variations on the SIMPLE STRUCTURE model models included the SIMPLE STRUCTURE plus either physical variables, slope, aspect, elevation (SIMPLE STRUCTURE+ PHYSICAL), or temperature (SIMPLE STRUCTURE + TEMP). The GLOBAL model contained all variables we collected for each acoustical monitoring site. Lastly, we constructed species-specific combination models (COMBO; Table A3.) for each species appropriate for each species' wing morphology, echolocation call characteristics, food habitats, and roosting structure preference as well as foraging habitat preferences for the Allegheny Mountains and Plateau as noted by Owen et al. (2004) and Ford et al. (2005).

Table A3. Variable composition of species-specific (COMBO) *a priori* habitat association models for seven bat species detected in Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, 2003–04.

Species	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

Model Evaluation

We pooled acoustic data across years and park units to provide an overall assessment of which habitat parameters were most important to each species across the landscape. We used Spearman rank correlation to test for variable autocorrelation within models and chose the most biological meaningful variable when ≥2 variables were highly ($r_s > 0.7$) correlated. We analyzed models using multiple logistic regression and used second order Akaike's Information Criterion (AICc) 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 top and best approximating models, respectively. We also calculated the Akaike weight (w_i) for each model which represented the probability of that model being the top model in the set of candidate models (Burnham and Anderson 2002). Additionally, for the best approximating model 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 model fit and strength. Using a probability cutoff value of 0.50, we used a jackknife procedure to compute model correct classification rates (SAS Institute 1995). We defined parameters important to species presence as those with confidence intervals that did not include zero.

Results

Acoustic Surveys

In 2003 and 2004 combined, we recorded 3,365 search-phase echolocation passes that met our quality criteria over 680 acoustical survey sites. For modeling purposes, our final analysis included 540 sites. The remaining 140 survey sites were excluded either because species identification accuracy rates were unacceptably low (< 84%) or incomplete habitat parameters existed. We detected a total of nine bat species across the park units and surrounding areas. Species detected (with number of survey sites each species was detected are in parentheses) included little brown bats (n=52), northern myotis (n=155), Indiana bat (n=60), eastern small-footed myotis (*M. leibii*; n=57), silver-haired bats (n=12), eastern pipistrelles (*Pipistrellus subflavus*; 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 82.1–100%, with an average of 88% for a single call sequence for all species combined.

Habitat Association Models

We were able to create predictive logistic regression models for seven species, including little brown bat, northern myotis, Indiana bat, eastern small-footed myotis, eastern pipistrelle, big brown bat, and eastern red bat. Small sample sizes precluded our ability to model silver-haired bat and hoary bat habitat associations. The SIMPLE STRUCTURE was the top approximating model for Indiana bats, eastern small-footed myotis, and eastern pipistrelle (Table A4). For the Indiana bat, SIMPLE STRUCTURE + TEMP, FOREST STRUCTURE, and SIMPLE STRUCTURE + PHYSICAL models also received support. For both the eastern small-footed myotis and the eastern pipistrelle, SIMPLE STRUCTURE + TEMP and SIMPLE STRUCTURE + PHYSICAL models also received support. Open habitat and presence of water were important model components for predicting the presence of the eastern pipistrelle (Table A5). No

Table A4. The best-approximating logistic regression models (within 4 AICc) for seven species of bats. Models were used to predict the probability of occurrence in the New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River, 2003–04.

Model	K[a]	AICc	Δi [b]	Wi [c]
little brown bat				
SIMPLE STRUCTURE + TEMP	4	244.26	0.00	0.55
SIMPLE STRUCTURE + PHYSICAL	6	246.17	1.91	0.21
GLOBAL	18	247.04	2.78	0.14
SIMPLE STRUCTURE	3	247.46	3.20	0.11
northern myotis				
MACRO TO LANDSCAPE	8	572.52	0.00	0.88
Indiana bat				
SIMPLE STRUCTURE	3	326.77	0.00	0.51
SIMPLE STRUCTURE + TEMP	4	328.57	1.80	0.21
FOREST STRUCTURE	5	328.68	1.92	0.19
SIMPLE STRUCTURE + PHYSICAL	6	330.55	3.79	0.08
eastern small-footed myotis				
SIMPLE STRUCTURE	3	299.38	0.00	0.48
SIMPLE STRUCTURE + TEMP	4	300.48	1.10	0.28
SIMPLE STRUCTURE + PHYSICAL	6	300.89	1.51	0.22
eastern pipistrelle				
SIMPLE STRUCTURE	3	399.35	0.00	0.51
SIMPLE STRUCTURE + TEMP	4	399.71	0.36	0.42
SIMPLE STRUCTURE + PHYSICAL	6	403.23	3.88	0.07
big brown bat				
GLOBAL	18	402.69	0.00	0.98
eastern red bat				
SIMPLE STRUCTURE + TEMP	4	254.85	0.00	0.75
SIMPLE STRUCTURE	3	257.23	2.39	0.23

[a]Number of parameters in the model.
[b]Distance of the model from the best model (Δi = AICc–min AICc).
[c]The estimated probability of being the best model (Akaike weight).

Table A5. Parameter estimates from the top-approximating logistic regression models (lowest AICc) explaining presences of seven bat species at acoustical survey sites in the Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, 2003–04.

Parameter	Estimate	SE	*P*> Wald²	Odds ratio	95% CL
little brown bat (SIMPLE STRUCTURE + TEMP)					
Intercept	-7.4654	2.5592	0.0035	-	-
H	-1.8179	0.4094	<.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	<.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%					
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%					
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%					
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

Table A5. Parameter estimates from the top-approximating logistic regression models (lowest AICc) explaining presences of seven bat species at acoustical survey sites in the Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River, 2003-04 (continued).

Parameter	Estimate	SE	*P*> Wald²	Odds ratio	95% CL
big brown bat (GLOBAL) (continued)					
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%					

individual variables in the top approximating models were identified as influential model components for the Indiana bat or the eastern small-footed myotis.

SIMPLE STRUCTURE + TEMP was the top approximating model for little brown bats and eastern red bats (Table A4). For the little brown bat, SIMPLE STRUTURE + PHYSICAL, GLOBAL, and SIMPLE STRUCTURE models also received support; whereas, for the eastern red bat, only the SIMPLE STRUCTURE model also received support. Open canopy habitat and warm temperatures were important model components predicting the presence of the little brown bat and eastern red bat (Table A5).

For northern myotis, MACRO to LANDSCAPE was the top approximating model (Table A4) with distance to smaller order streams identified as the most important model component (Table A5). The GLOBAL model was the top approximating model for the big brown bat (Table A4). Important model components for the big brown bat were open canopy habitat, low mid-story density, warm temperatures, and proximity to water (Table A5).

Discussion

The results of our modeling generally were consistent with our expectations based on previous research in the Allegheny Mountains and Plateau (Owen et al. 2004; Francl et al. 2004; Ford et al. 2005), albeit with some exceptions. Although model fit and classification rates for the top-approximating models were good, overall model weight of evidence was low, reducing the ability to draw strong inferences across the park unit landscape beyond broad generalities. Although we integrated existing information of bat habitat associations in the region when developing *a priori* models, given the general lack of knowledge regarding bat habitat associations, our choice of habitat parameters may not have been optimal for elucidating fine-scale bat habitat relationships across a large, complex landscape. Recent modeling efforts in the

Coastal Plain of South Carolina (Menzel et al. 2005b; Ford et al. 2006a) highlight the fact that incorporation of expert opinion in choosing habitat parameters can still result in an inaccurate picture of bat foraging habitat use over large scales.

Nonetheless, bat response to simple habitat conditions for the most part conformed to expectations. Model results indicate that simple habitat assessments, i.e. open or closed forest canopy and proximity to water provided the most meaningful and resolute description of bat habitat associations in the park units. As has been documented in the region and elsewhere (Owen et al. 2004; Francl et al. 2004; Ford et al. 2005; Menzel et al. 2005a, b, c; Carter 2006), the largest proportion of bat activity in total and by individual species occurred along riparian/aquatic habitats. Some spatial measure of water proximity was included in every best- and top-approximating model for each bat species in this study. Assuming presence of water, little brown bats and eastern pipistrelles were more likely to be present where forest habitats were open, i.e., large forest canopy gaps or open corridors; whereas, eastern small-footed myotis and Indiana bat presence was associated with closed forest conditions. Although our best-approximating models used simple, binary variables of water presence or absence and habitat open or closed, within central Appalachian landscapes most open, uncluttered habitats in proximity to water likely represent larger-order streams and rivers; whereas, forested sites near water are indicative of closed, 1st–4th order forest riparian zones. Ford et al. (2005) demonstrated this same pattern of differential habitat use of little brown bats and eastern pipistrelles versus Indiana bats on the Fernow Experimental Forest in northeastern West Virginia. For big brown bats, support for the GLOBAL model as the best-approximating model suggests that none of the models we developed included the appropriate combination of variables to predict presence of the species. However, congruent with Ford et al. (2005) and Ford et al. (2006a), the meaningful variables indicated big brown bat association with open habitats or forested habitats with a more sparse midstory structure and always in association with water or riparian habitats.

Two species, the eastern red bat and northern myotis, conformed to our initial expectations less than expected. As would be predicted based on its medium body size, mid-range echolocation characteristics, and food habits, eastern red bats display wide habitat use associations, and are able to successfully forage in both open, uncluttered environments as well as closed forest settings (Carter et al. 2004; Menzel et al. 2005b; Ford et al. 2006a) and in both upland (Ford et al. 2005) and riparian (Owen et al. 2004; Menzel et al. 2005b) conditions. Accordingly, the generalist nature of this species can make habitat association determination difficult. Our work herein showed that eastern red bat presence in the park complex mirrored that of little brown bats and eastern pipistrelles. Previous studies have shown eastern red bats and eastern pipistrelles to be common foraging associates (Davis and Mumford 1962; Ellis et al. 2002). Owen et al. (2003) indicated that the northern myotis is an interior-forest obligate that selects within-stand micro-habitat components and is less linked to riparian zones relative to other bat species in the Appalachian region. However, our top-approximating model included landscape-level variables in addition to forest stand-level variables. Paradoxically, there was a weak relationship with percent forest cover and a significant positive relationship to measures of water proximity, although weight of evidence of the top-approximating model was low. The reason for this disparity is unknown, but may be due to the differences between the relatively intact forested landscape in our study and the highly fragmented study area of Owen et al. (2003) that consisted largely of an industrial forest setting.

Higher evening temperatures were associated with presence of little brown bats, eastern red bats, and big brown bats. Although, Kiser and Elliot (1996) observed Indiana bats shifting foraging habitat use from cooler, mesic forest sites to warmer, more xeric sites in the fall pre-hibernation swarm in Kentucky, we did not see any evidence of similar habitat use variation during summer by eastern red bats, little brown bats, or big brown bats. Thus, during summer within the park units bat activity increases with temperature, resulting in a higher probability of acoustically recording a species at a site given that the habitat components/structure are appropriate for the species.

Management Implications

Our findings add to the level of knowledge about bats in the Bluestone National Scenic River, Gauley River National Recreation Area, New River Gorge National River, and surrounding areas. Although bat foraging activity occurs over much of the park landscape, riparian areas are the most critical component of bat foraging habitat. Open, less structurally cluttered zones, such as the large riparian areas, are most important for little brown bats, eastern pipistrelles, and big brown bats, and, to a lesser extent, eastern red bats. Closed-canopy forested riparian areas are important for Indiana bats in the parks. While our model results are congruent with other studies in finding closed-canopy forested riparian areas as important foraging habitat for Indiana bats, further research using radiotelemetry will be needed to identify important roosting areas in the park units for this endangered species.

Using our results, park managers can strengthen management guidelines that maintain and protect riparian health and integrity, concomitantly protecting important bat foraging habitat. Moreover, these data, combined with recent growing season/swarm day-roost findings (tree, cave, and cliffline) in the park units and elsewhere in the central Appalachians (Ford et al. 2002b; Menzel et al. 2002; Johnson 2003, 2005; Beverly and Gumbert 2004; Ford et al. 2006b), efforts to link bat habitat management to other land management activities within the park units should be feasible. For example, Beverly and Gumbert (2004) and Keyser and Ford (2006) documented Indiana bat maternity and bachelor roosts in snags and residual live trees with exfoliating bark (primarily sugar maple and shagbark hickory [*C. ovata*]) in heavily thinned and spring-burned forest stands in the Allegheny Mountains near known hibernacula and 1st–4th order forested riparian zones. Accordingly, community restoration activities designed to restore or perpetuate oak-hickory dominated stands or the creation of historically present oak savannahs through prescribed burning should be prioritized to occur in close proximity to riparian zones where Indiana bats were observed acoustically in this study.

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