

FINAL REPORT

To

**Chickamauga and Chattanooga
National Military Park
Box 2128
Fort Oglethorpe, GA 30742**

BATTLEFIELD BAT SURVEY

**NPS Cooperative Agreement #P5040-0200363
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Background and Introduction

Within much of the southeastern United States, the bat fauna represents an important component of regional vertebrate biodiversity. Due to their small size, nocturnal activity patterns and cryptic day-roost habits, most bat species that occur in the Southeast are relatively difficult to research. More recent attempts to examine bat day-roosting in conjunction with forest stand condition and bat foraging to water quality within forested landscapes in the region in general, and regulatory concern over various endangered species and species of special concern such as the Indiana bat (*Myotis sodalis*) have facilitated an upsurge in bat research in the region on both public and private lands (Menzel et al. 2001). In addition to advances in radio-telemetry miniaturization that have enhanced the ability of researchers to conduct day-roost studies, the use of acoustical sampling equipment to compliment bat capture data has become more readily accepted for determining bat community assemblage and species presence or absence across a wide variety of habitats and conditions over an entire landscape (O' Farrell and Gannon 1999, Johnson et al. 2002).

To compliment an ongoing bat natural history and habitat modeling research effort in the Ridge and Valley and Cumberland Plateau physiographic regions in northwest Georgia with emphasis on the endangered gray bat (*Myotis grisescens*), we conducted a preliminary acoustical, mist-netting and harp-trap survey of the Chickamauga and Chattanooga National Military Park. West Chickamauga Creek within the park has been identified as an important foraging and travel corridor for the gray bat locally and at least 3 summer-use, male gray bat bachelor colony caves are known in the region (Menzel et al. 2000b, Johnson et al. 2004). Moreover, the park complex contains several caves and abandoned wells that have some value as winter hibernacula for other bat species (only the gray bat is a year-round cave dwelling obligate in the southeastern United States). Information on the bat assemblage and relative habitat will be critical for future park natural resource management assessments and efforts, particularly with regard to NEPA and ESA. In the larger landscape context, increasing urbanization, sprawl, and habitat fragmentation and conversion in the Atlanta, GA to Chattanooga, TN corridor increased the conservation value of protected semi-natural areas such the park complex. Our overall project objectives were as follows:

- 1) to document bat species assemblage and foraging habitat use in the park complex;
- 2) to quantify potential value of park caves as bat hibernacula;
- 3) to use endangered gray bat presence data for further validation of Johnson's (2002) habitat model;
- 4) and to provide additional presence and absence data on bats in northwest Georgia to facilitate an understanding of factors related to bat species habitat partitioning.

Methods

We surveyed the bat community at the Chickamauga and Chattanooga National Military Park to establish bat species presence and to assess park caves as potential winter

hibernacula using a combination of Anabat II acoustical detectors (Johnson et al 2003), mist-netting and harp trapping (Jones et al. 1996) during the summer (August 22-28) and fall (October 4-8) of 2002 and the spring (March 20-23) of 2003. Our summer work consisted of active Anabat sampling for one 20 minute period at 11 riparian sites, 12 upland forested sites, and 11 upland field sites each in the park complex between sunset and 2400 hr. (Figures 1 and 2). In addition to acoustical sampling, we mist-netted 5 riparian sites (Figures 1 and 2). Mist-netting began at sunset and ended at 2400 hr. Fall 2002 sampling involved harp-trapping 6 and mist-netting 2 cave entrances, respectively, in addition to active Anabat sampling of 3 of those entrances (Figure 1). Spring sampling consisted solely of Anabat surveys of 6 cave entrances. Similar to summer mist-netting, both acoustical work and trapping at cave entrances commenced at sunset and ended at 2400 hr. Bats collected by mist-netting and harp-trapping were sexed, aged and identified to species (Anthony 1988, Menzel et al. 2002b, Racey 1988) and then released. We identified Anabat recordings using a combination of quantitative and qualitative methods with Analook software (Johnson et al. 2003, Owen et al. 2004) within filter parameters similar to those described by Britzke and Murray (2000). We measured 35 habitat and 5 landscape variable at each of the 34 Anabat II survey sites that we believed might be important in explaining presence and absence of bat species (for a complete list and collection methodologies see Johnson 2002). Variable examples included measures of habitat structure and clutter such as immediate forest canopy cover and shrub density, stream order, stream width, water clarity, and surrounding landuse within 1 km radius of sample location. Landuse and landcover metrics were calculated within a GIS (ArcView 3.2; ERSI, Redlands, CA).

To understand the importance of riparian habitats for bats in the area and to assess bat foraging habitat from a physical structure standpoint, we characterized summer Anabat II survey sites as either riparian or upland forest or upland field (Menzel 2003). Accordingly, we analyzed relative numbers of search-phase echolocation calls by species on ranked data using a one-way ANOVA with contrasts, i.e. riparian vs. upland and cluttered, spatially complex vs. uncluttered, open upland habitats (forest vs. field). Because the Chickamauga and Chattanooga National Military Park is within the identified watersheds used by the endangered gray bat in northwest Georgia and southeastern Tennessee (Johnson 2002), we input habitat data into a predictive gray bat macro-habitat model (Johnson et al. 2004) from park complex Anabat II using the following equation:

$$((1/1 + \exp^{(-0.3743 - (0.9156 * \text{STORDER}) - (1.6038 * \text{CLARITY}) - (1.7705 * \text{FIELD}) - (0.2073 * \text{SHRUB}))}) * \text{LANDSCAPE})$$

In this equation, stream order is a discrete value from 1-7, stream clarity is categorical at 1= clear, 2 = semi-turbid, and 3 = turbid, percent pasture is a continuous variable from landuse land classification GIS layers, shrub is a categorical 1-20 measure of vegetative clutter over the riparian area, and landscape is either 0 for absent or 1 for presence based on whole watersheds within northwest Georgia and southeastern Tennessee containing 1 of the 4 known gray bat summer-roost caves (Johnson 2002).

Lastly, we combined Anabat II survey data from the Chickamauga and Chattanooga National Military Park effort with data collected from the previous effort of Johnson (2002) to ascertain what habitat variables were important how the bat community is structured by observed assemblages across a larger ($> 5,000 \text{ km}^2$) area in northwestern Georgia and southeastern Tennessee using multivariate analyses. To determine if the regional bat species assemblage was patterned along known ecological differences among bat species, we analyzed “distance measures” based on number of Anabat II sites where individual species were documented relative to the number of sites containing other species using non-metric multidimensional scaling (SAS/STAT 8e, Statistical Software Analysis, Cary, NC). Secondly, we subjected foraging habitat data collected at Anabat II survey sites across the region to principal component analysis to reduce habitat variables into fewer, orthogonal “factors” to facilitate bat species ordination along axes that could demonstrate habitat gradients (Isebrands and Crows 1975). Categorical habitat variables used included whether the survey site was riparian or upland along with characterizations of stream order, stream flow, riparian forest presence, and surrounding landform class at the site. Continuous and discrete variables measured included elevation, percent of surrounding area in wetlands, forest, fields, and developed land, stream width, stream depth, percent forest canopy cover, surrounding forest height, number of and number of trees with exfoliating bark at the survey site. Mean principal component values for calculated for each bat species and graphed.

Results

Over a 5 net-night effort in August, 2002 at riparian survey sites on the Chickamauga and Chattanooga National Military Park, we netted the following species eastern pipistrelles (*Pipistrellus subflavens*), eastern red bats (*Lasiurus borealis*), an evening bat (*Nyctesicus humeralis*), a gray bat, a hoary bat (*Lasiurus cinereus*), and little brown bats (*Myotis lucifugus*; Table 1). Over an 8 net-night cave harp-trap and mist-netting effort in October 2002, we netted eastern pipistrelles, a northern bat (*Myotis septentrionalis*), and a red bat (Table 1).

Concurrent summer Anabat II surveys at riparian, upland forest and upland field sites produced 711 bat echolocation search-phase calls. Of those calls, 288 were unidentifiable to genus or species, and 49 were identifiable only to *Myotis* spp. We made positive acoustical identifications on the following species: big brown bat (*Eptesicus fuscus*; 32), eastern pipistrelle (231), eastern red bat (21), gray bat (55), hoary bat (1), and little brown bat (5). Total bat and eastern pipistrelle activity was greater along riparian areas than on upland sites, but within upland areas, activity was greater in field habitats than in closed forests (Table 2.). Activity for eastern red bats, gray bats, and *Myotis* spp. was greater at riparian survey sites than upland sites (Table 2).

Anabat II surveys at cave and well entrances to assess hibernacula use by bats on the park complex produced 19 search-phase echolocations in October, 2002 (Table 3) and 128 in March, 2003 (Table 3) of eastern pipistrelles, a single big brown bat, *Myotis* spp. and unidentifiable calls.

All riparian areas with stream order > 1 are considered to have gray bats present at the landscape level as calculated by Johnson (2002). Application of the predictive gray bat macro-habitat model to the 11 riparian Anabat II survey sites correctly predicted species presence at 5 sites where gray bats occurred and correctly predicted species absence at 4 sites where gray bats were not documented. Gray bats were incorrectly predicted to be present at 2 sites where they were not documented. The overall correct classification rate was 82 percent.

Non-metric multidimensional scaling indicated that bat species foraging/activity habitat determined by acoustical sampling throughout the larger northwest Georgia and southeastern Tennessee region does display a structured assembly that segregates along gradients such as clutter and openness or size and type of riparian zone (Figure 3). The first 3 component variables generated by principal component analysis only partially explained variation contained within the selected habitat variable dataset for the region (Eigenvalue = 1.75, percent cumulative variation = 45.6), and were only weakly interpretable (Table 4). Principal component 1 was related to stream size and condition, whereas principal component 2 and 3 were related to forest condition and extent surrounding survey sites. Only mean values for principal components 1 and 2 ordinated by individual bat species produced a meaningful graph (Figure 4).

Discussion and Management Recommendations

Species Occurrence

Anabat II acoustical surveys combined with mist-netting and harp-trapping documented 8 of the 12 species of bats that could possibly occur on the Chickamauga and Chattahoochee National Military Park. Eastern pipistrelle, eastern red bat, endangered gray bat and the big brown bat were the species most commonly encountered in our survey. Though common, the little brown bat and northern bat approach their southernmost distribution in northwest Georgia (Menzel et al. 2000a). The hoary bat is known from records statewide, but the species typically is uncommon throughout the Southeast in the summer (Menzel et al. 2000a, Menzel et al. 2003). Our study provides additional verification that the park's riparian zones, especially along West Chickamauga Creek, are used by gray bats summer-roosting in Frick's Cave in Walker County and Chickamauga Cave in Catoosa County. Gray bats using Lookout Creek possibly are from Sitton's Cave in Dade County or caves in to the north in Tennessee (Menzel et al. 2000b, Johnson 2002). Of the species not encountered in this effort, the endangered Indiana bat was documented in earlier Anabat II survey work in the region (Johnson et al. 2002). Minor winter hibernacula use is known from northwest Georgia, though no summer roost or maternity activity has been documented locally (Menzel et al. 2000a). Summer tree-roosting by Indiana bat maternity colonies has been documented within the Great Smoky Mountains National Park to the northeast within recent years (Britzke et al. 2003). Still, we believe that Indiana bats are not a regular "growing season" component of the bat fauna on the park complex, therefore land management projects that involve clearing or tree removal should not have to address that species. Bat species not observed in this study or that of Johnson et al. (2002) that are known from nearby in northwest Georgia include the

Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), the small-footed bat (*Myotis leibii*) and the silver-haired bat (*Lasionycteris noctivigans*). The silver-haired bat is migratory and is probably only a seasonal transient or limited winter residence, whereas both Rafinesque's big-eared bat and small-footed bat could occur within the park complex, particularly areas on Lookout Mountain where rock outcrop/talus habitats and caves are more numerous. Although both species are not summer cave obligates and have been documented day-roosting under exfoliating bark, tree cavities, and structures such as abandoned cabins and barns, both will continue to use caves, mines, and rock outcrop chimneys and fissures during the summer months (Menzel et al. 2000a). Rafinesque's big-eared bat and the small-footed bat are tracked as species in need of management by the states of Georgia and Tennessee (Laerm et al. 2000). Future bat survey efforts should be tailored to maximize the chances of encountering these species. To document Rafinesque's big-eared bat on the park complex, such efforts would have to include additional mist-netting riparian zones and harp-trapping cave and abandoned well entrances, as well as searching old structures because their low amplitude echolocation makes them a difficult species to survey using acoustical methodologies (Menzel 2003).

Bat Foraging Habitat

Our survey results are consistent with the findings of other bat researchers. Within forested landscapes, some level of bat activity occurs throughout the landscape, however habitats associated with water typically show the greatest use by bats for foraging (Johnson 2002, Menzel et al. 2002a, Broders et al. 2003, Tibbels and Kurta 2003, Johnson et al. 2004, Owen et al. 2004). This pattern was repeated in this study with the highest overall level of bat activity and the highest level of activity for eastern pipistrelles, eastern red bats, and gray bats occurring along riparian zones in the park complex. Accordingly, riparian area protection and maintaining high water quality standards probably are important considerations for bat conservation at Chickamauga and Chattanooga National Military Park. Furthermore, the macro-habitat model to assess gray bat habitat that was developed by Johnson et al. (2004) could be used to assess riparian areas throughout the park complex to identify zones or areas of high conservation importance.

In general, bat use of riparian areas within forested landscapes is highest because of higher levels of resource (arthropod prey abundance) and lower levels of structural clutter. However, bat species are constrained somewhat to the limitations placed on them by wing morphology, skull/jaw morphology (important factor whether prey is soft-bodied or hard-bodied arthropods) and echolocation call structure (see Menzel [2003] for an outstanding primer on these concepts). Bats with high-wing loadings and low frequency calls tend to forage in open environments such as along larger-order streams and riverine zones or open upland areas whereas bats with lower wing-loadings and higher frequency calls can use cluttered environments such as more closed forests or riparian zones along 1st and 2nd order seeps and streams (Nowak 1994, Owen et al. 2004). For example, on the park the few acoustical observations of the hoary bat and the big brown bat, both large bodied species, occurred in open field habitats. The open battlefields within a largely forested matrix add to the diversity of bat habitat locally. Our multivariate analyses of

Anabat II data from the park complex and the larger northwest Georgia region demonstrate (to some degree) how bat species utilize habitats consistent with their physical adaptations. Although these analyses are preliminary and ongoing, we believe generalized patterns of niche-separation/habitat segregation are evident among bat species in eastern forested landscapes in general and the northwest Georgia study area in particular. Results from this study do show the inadequacies of fully documenting or understanding important micro-habitat conditions for bats, particularly in absence of arthropod abundance and diversity prey data.

Cave Surveys

Results from our cave assessments, both harp-trapping and Anabat II monitoring were disappointing in terms of bat species diversity and numbers. Whether or not these sites are important winter hibernacula in terms of species of high conservation concern such as the Indiana bat or are used by large number of more common bat species such as the little brown bat or northern bat remains unknown. Nonetheless, the number of echolocation calls attributed to *Myotis* spp. in the spring 2003 survey would suggest that Neld's Well and Battlefield Pit #2 are used as bat hibernacula and additional work should be performed to assess their actual status. Accordingly, disturbance during the winter hibernation period should be prohibited and access to these sites should be controlled from early October through late April to ensure full protection for resident bats.

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Table 1. List of mist-net or harp-trap bat captures and at Chickamauga and Chattanooga National Military Park, August 22-28 and October 4-8, 2002.

Location	Date	Captures	Method
<i>Riparian Locations</i>			
Jay's Mill Road	August 22	0	mist-net
Two Bridges	August 25	Eastern pipistrelle (male adult -2) Eastern red bat (male adult - 5) Eastern red bat (female adult - 3) Eastern red bat (sex/age unknown -1) Little brown bat (male adult -1)	mist-net
Brotherton Field	August 25	Eastern pipistrelle (male adult -2) Eastern red bat (male adult -1) Eastern red bat (female adult -5) Evening bat (male adult - 1) Hoary bat (female adult -1) Little brown bat (male adult -2)	mist-net
W. Chickamagua (Dalton's Ford)	August 27	Eastern pipistrelle (male adult -1) Gray bat (female adult -1)	mist-net
Visitor Center Creek	August 28	Eastern red bat (male adult -2) Eastern red bat (female adult -2) Eastern red bat (female juvenile -1)	mist-net
<i>Caves and Wells</i>			
Neld's Well	October 4	Eastern pipistrelle (male adult -1)	harp-trap
Whiteside Well	October 4	Eastern pipistrelle (male adult -1) Eastern pipistrelle (female adult -1)	mist-net
Eatin' Alive Cave	October 5	Eastern red bat (female adult -1)	harp-trap
Haha Cave	October 6	0	harp-trap
Angel Hole Cave	October 6	Eastern pipistrelle (male adult -1)	harp-trap

Eastern pipistrelle (male juvenile –1)

Table 1. cont.

Location	Date	Captures	Method
Battlefield Pit #1	October 7	Northern bat (male adult –1)	harp-trap
Battlefield Pit #2	October 7	Eastern pipistrelle (male adult –1)	harp-trap
Red Barrel Pit	October 8	0	harp-trap

Table 2. Mean search-phase echolocation calls by individual bat species in riparian areas, upland intact forests, and upland fields using Anabat II acoustical sampling at Chickamauga and Chattanooga National Military Park, August 22-28, 2002. Acoustical sampling occurred over 20 minute sessions at each individual site within each habitat type.

	Riparian ($n = 11$)		Forest ($n = 12$)		Field ($n = 11$)	
	0	SE	0	SE	0	SE
Species						
Big brown bat	0.0	0.0	0.0	0.0	2.9	2.9
Eastern pipistrelle ^{1, 2}	18.6	8.8	0.0	0.0	2.4	1.1
Eastern red bat ¹	1.4	1.0	0.0	0.0	0.5	0.4
Gray bat ¹	4.6	2.4	0.3	0.3	0.0	0.0
Hoary bat	0.0	0.0	0.0	0.0	0.1	0.1
Little brown bat	0.4	0.3	0.0	0.0	0.1	0.1
Unknown <i>Myotis</i> ¹	4.1	1.2	0.3	0.3	0.1	0.1
No identification ^{1, 2}	21.0	8.2	1.9	1.7	3.1	1.5
Total ^{1, 2}	52.7	19.6	2.5	2.3	9.2	4.5

¹Riparian greater than upland (forest and field) in contrast on ranked data ($P < 0.05$).

²Field greater than forest in contrast on ranked data ($P < 0.05$).

Table 3. Mean search-phase echolocation calls by individual bat species at cave and well site entrances using Anabat II acoustical sampling at Chickamauga and Chattanooga National Military Park, October 4-5, 2002 and March 20-22, 2003. Acoustical sampling occurred from sunset to 2400 hr.

Location	Date	Species Recorded
Neld's Well	October 4, 2002	No identification – 4 Unknown <i>Myotis</i> –7
	March 21, 2003	0
Whiteside Well	October 4, 2002	Eastern pipistrelle –2 No identification –5 Unknown <i>Myotis</i> –1
	March 21, 2002	Big brown bat –1 No identification –7
Eatin' Alive	October 5, 2002	0
	March 22, 2002	0
Battlefield Pit #1	March 20, 2003	No identification –3
Battlefield Pit #2	March 20, 2003	No identification – 40 Unknown <i>Myotis</i> –76
Red Barrel Pit	March 22, 2003	No identification –1

Table 4. Principal component loadings for 16 habitat variables collected at 361 Anabat II survey sites in northwestern Georgia and southeastern Tennessee, 2000-2002. Variable loadings used in interpretation are in bold text.

Habitat Variable	Principal Component		
	1	2	3
Elevation	-0.2487	0.0922	0.1719
Percent wetland	0.1556	-0.0079	0.1562
Percent forested	-0.1956	0.4336	0.3894
Percent field	0.1084	-0.3625	-0.5043
Percent developed	0.0129	-0.2488	0.1010
Stream depth	0.4060	-0.1045	0.2888
Stream width	0.1643	-0.1544	0.4041
Canopy cover	-0.1229	0.3734	-0.4194
Forest height	0.3078	0.3706	-0.0948
Snag abundance	-0.0217	0.1458	0.1668
Exfoliating bark	-0.0149	0.1910	-0.1008
Riparian classification	0.4197	0.0184	-0.1432
Stream order	0.4184	0.1000	-0.1219
Stream flow	0.3893	0.0648	-0.0888
Surrounding landform	-0.0431	0.1723	0.0596
Riparian forest presence	0.2376	0.4430	-0.1163
Cumulative variation	0.2219	0.3465	0.4559
Eigenvalue	3.3909	2.1533	1.7506

Figure 3. Non-metric multidimensional scaling of individual bat species distance measures using presence and absence assembly data from northwest Georgia and southeast Tennessee, 2000-2002. Based on known natural history characteristics, dimension 1 is an indirect ordination of bat species from closed forest canopy to open habitat conditions (right to left) whereas dimension 2 probably shows an ordination along a measure of riparian condition (bottom to top) from standing water/wetland to stream/riverine to upland, non-aquatic.

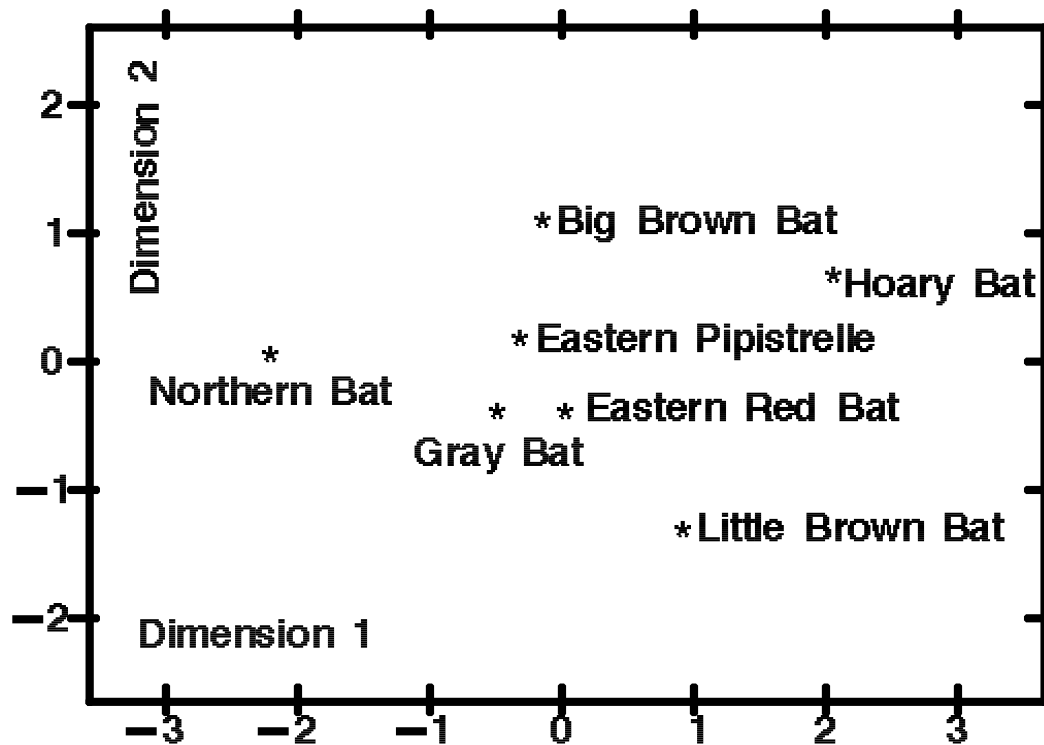


Figure 4. Mean principal component habitat scores by individual bat species in northwest Georgia and southeast Tennessee, 2000-2002. Note the strong separation of hoary bat from other species based on its affinity for open, structurally uncluttered habitats and the likewise affinity for gray bats in habitats classified as riverine riparian.

