Bat Activity in Upland and Riparian Habitats in the Georgia Piedmont

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Abstract: Detailed knowledge of habitat use patterns of forest bats in the southeastern United States is needed to predict how habitat changes from forest management and other land use practices affect bat communities. We used Anabat detectors to survey bat activity on the Oconee National Forest, Georgia, among 3 loblolly pine *(Pinus taeda)* stand ages (clearcut, sapling, and mature) and 3 riparian habitat types (creeks, rivers, and open wetlands). We used echolocation calls to assess differences in relative activity and species richness among stand ages and riparian habitat types. We recorded calls of big brown bats *(Eptesicus fuscus),* eastern red bats *(Lasiurus borealis),* eastern pipistrelles *(Pipistrellus subflavus),* and evening bats *(Nycticeius humeralis).* Regardless of stand age, species richness was greater in riparian areas than upland areas. Activity of eastern red bats and eastern pipistrelles was greater in riparian areas, whereas activity of big brown and evening bats did not differ between upland and riparian areas. In upland stands, species richness and activity were greater in clearcuts than both other stand ages. In riparian areas, species richness did not differ among habitat types. We recorded fewer big brown bat calls than other bat species over wetlands, but found no differences among species in other riparian habitat types. Our results suggest that early successional habitats and large riparian areas are important habitats for bats in the southeastern United States and should be considered in management decisions.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 56:210–218

Understanding habitat use patterns of insectivorous bats on forest lands of the southeastern United States is important because of region-wide changes in forest management activities and management intensity (Menzel et al. 2001*b*). Bat distributions are influenced by proximity to suitable roosting structures and foraging habitat (Furlonger et al. 1987). Forest management practices such as clearcutting (Grindal and Brigham 1998, Krusic et al. 1996) and thinning (Humes et al. 1999) provide suitable foraging habitat for some bat species. Management practices that promote longer rotations, complex canopy structure, and snag formation provide roosting habitat for many southeastern bat species (Menzel et al. 2000*a*).

Riparian areas traditionally have been considered important foraging habitats for bats (Brigham et al. 1992, Rydell et al. 1999, Owen unpub. data), but only recently has this relationship been quantified (Grindal et al. 1999). Few studies have attempted to quantify bat use of riparian areas in the Southeast and no studies have addressed bat activity among different types of riparian habitats. Furthermore, to better predict how changes in upland or riparian communities will affect habitat use patterns of southeastern bat species, comparisons of bat use in upland and riparian areas in the Southeast are needed.

Acoustic techniques facilitate sampling bats that are difficult to sample with nets and traps and yield a more complete inventory of bat species than captures alone (O'Farrell and Gannon 1999). Although limitations of the technique are recognized (Barclay 1999), the calls of North American bats can reliably be identified to species by qualitatively analyzing certain characteristics of calls such as maximum and minimum frequencies and other structural aspects (O'Farrell et al. 1999). Our objective was to use acoustic sampling to survey bat community composition and relative activity in upland and riparian habitats in the Georgia Piedmont. We predicted that bat species richness and activity would be greater over riparian areas and in open forest stands.

We are grateful to E. D. Caldwell for assistance identifying sampling sites and providing spatial data. We thank J. D. Ellis for assistance with data collection and analysis, and W. M. Ford and M. A. Menzel for providing expertise in echolocation call identification. We thank R. L. Hendrick, M. T. Mengak, and R. J. Warren for earlier reviews of the manuscript.

Methods

Our study was conducted on the Oconee National Forest (ONF, 3338N 8317W) which covered 46,684 ha in the Piedmont physiographic region of Georgia. Primary habitat types on the ONF included planted and natural loblolly pine *(Pinus taeda),* mixed pine-hardwood, riparian corridors comprised of various hardwood species, and open wetlands and beaver *(Castor canadensis)* ponds. Our sampling sites were located on the northern-most portion on the ONF.

We chose upland sampling locations based on stand age and forest type designations. Forest type of all stands was loblolly pine. We chose 3 stands each of mature, sapling, and clearcut. Mature stands were 75–79 years old with basal areas ranging from 15–24 m^2/ha. These stands had open overstory canopies with hardwoods, including sweetgum *(Liquidambar styraciflua),* flowering dogwood *(Cornus florida),* and oaks (*Quercus* spp.), in the midstory. The 3 sapling stands were 8–17 years old with an average basal area approximately 0.5 m^2/ha (only trees $>$12.7 cm dbh were included in calculations) and a closed canopy with virtually no understory. Because of restrictions on clearcutting on the ONF, we chose 3 privately-owned clearcut stands in the vicinity of the other stands. Clearcut stands had been replanted in loblolly pine and ranged from 1–5 years old. Distance among all stands averaged 5.4 km (range 0.08–15.6).

The 9 riparian sampling locations included 3 creeks, 3 wetlands, and 3 sites on the Oconee River. Creek widths ranged from 8.5–13.5 m with relatively full canopy coverage over the creek corridor. We chose 3 locations along the Oconee River, each separated by at least 1 km where the river was 50–70 m across, thus the canopy was open over the river corridor. The overstory surrounding creek and river sites was dominated by river birch *(Betula nigra),* yellow poplar *(Liridodendron tulipifera),* water oak *(Quercus nigra),* American sycamore *(Plantanus occidentalis),* American beech *(Fagus grandifolia),* and sweetgum. Understory was comprised of flowering dogwood, eastern hophornbeam *(Ostrya virginiana),* American hornbeam *(Carpinus caroliniana),* boxelder *(Acer negundo),* Chinese privet *(Ligustrum sinense),* and red mulberry *(Morus rubra).* Mary's grass *(Microstegium vimineum)* and river oats *(Chasmanthium latifolium)* were common on creek and river banks.

Wetland sites contained slow-moving water and had open canopies but were surrounded by forest. Wetland sites ranged from approximately 12–24 ha. Dominant trees bordering wetlands were river birch, American sycamore, American beech, loblolly pine, boxelder, black willow *(Salix nigra),* and hazel alder *(Alnus serrulata).* Vegetation near edges of wetlands was predominantly Johnson grass *(Sorghum halepense),* switchcane *(Arundinaria gigantea),* and ragweed *(Ambrosia artemisiifolia),* with soft rush *(Juncus effusus)* and bulrushes *(Scirpus* spp.) in the wetter areas.

We used Anabat II detectors (Titley Elec., Australia) in conjunction with a zero-crossings analysis interface module (ZCAIM) to actively sample ultrasonic bat calls by following individual bats with the detector as long as possible (Johnson et al. 2002). We sampled each of the 9 sites twice during July and August 2001, alternating between lunar phases to account for lunar phase effects on bat activity. A sampling period was defined as a single 30-minute Anabat recording session in a single replicate of a habitat type (to provide an index of bat activity during a fixed time period). We sampled 2 sites each night with the first sampling period beginning at the detection of the first bat or in cases where there was no audible activity, 30 minutes after sunset. After sampling the first site, we moved to the second site and began the second sampling period upon arrival. Each site was sampled once in the early sampling period and once in the late sampling period. At the upland sites, we entered at least 10 m into the stand and only sampled bats flying within stand boundaries. At the riparian sites, only bats flying over the riparian areas were sampled. We attempted to record each individual bat detected during each 30-minute sampling period.

We saved calls to a laptop computer for later analysis. We used programs Anabat (vers. 4.8i) and Analook (vers. 6.3e) for call analysis. A call was defined as an individual, discrete vocal pulse (O'Farrell et al. 1999). We filtered all calls prior to analysis to remove extraneous noise (Britzke and Murray 2000). We used qualitative call characteristics, primarily minimum frequency, mean frequency, and call shape, to distinguish bat species. We attempted to identify call sequences only if they contained ≥ 3 calls. If the call sequence was indistinguishable to species, it was recorded as unknown.

We compared species richness (mean number of species/sampling period) between upland and riparian sampling locations for pooled data from all riparian habitat types and stand ages using a *t*-test. We compared activity (mean number of calls/sampling period) between upland and riparian sampling locations, among species, and the habitat by species interaction using a 2-way analysis of variance (ANOVA). Within riparian areas and uplands, we compared species richness and activity among riparian habitat types and upland stand ages, among species, and habitat by species interactions using a 2-way ANOVA. In sapling stands, a minimum species richness value of 1 was entered for each sampling period in which bat calls were recorded because all calls ($N = 11$) were indistinguishable to species and classified as unknown. Sites were nested within riparian habitat types and stand ages and used as the error term for testing riparian habitat type and stand age effects. When significant differences were detected, we compared means using Turkey's tests. Activity data were $\log_{10}$ transformed to meet assumptions of normality and homogeneity of variance. Activity comparisons included unknown calls. We conducted statistical analyses with SAS Statistical Software (SAS Inst. 1990). We declared signifigance at $a =$ 0.05.

Results

We surveyed bat activity during 36 sampling periods, recording 694 bat echolocation sequences during July–August 2001. We identified calls from big brown bats *(Eptesicus fuscus),* eastern red bats *(Lasiurus borealis),* eastern pipstrelles *(Pipistrellus subflavus),* and evening bats *(Nycticeius humeralis)* during the study (Table 1). All 4 species occurred both in upland and riparian areas. Although the only *Lasiurus* species we report is the red bat, red bats and Seminole bats cannot be discriminated based on call characteristics. However, because Seminole bats are rare in the Piedmont of Georgia (Menzel et al. 2000*b*), the number of Seminole bat calls mistakenly reported as red bat calls is probably negligible.

We observed greater species richness ($t = 2.77$, df = 34, $P = 0.009$) in riparian areas ($\bar{x} = 2.33 \pm 0.29$) than upland areas ($\bar{x} = 1.06 \pm 0.36$). For activity, there was an interaction ($F = 6.34$, df = 3,135, $P < 0.001$) between habitat type and species. Activity by eastern red bats ($F = 14.95$, df = 1,34, $P < 0.001$) and eastern pipistrelles (F

Table 1. Mean (±SE) number of calls/sampling period for bat species in 3 replicates of 3 loblolly pine stand ages and 3 riparian habitat types on the Oconee National Forest, Georgia, July–August 2001.

	Riparian			Upland		
	Creek	River	Wetland	Clearcut	Sapling	Mature
Eptesicus fuscus	0.0	0.5±0.3	0.3±0.3B[b]	8.8±3.4	0.0	0.3±0.3
Lasiurus borealis	1.7±0.9	8.0±5.8	7.8±1.9A	2.3±1.1	0.0	0.0
Nycticeius humeralis	0.0	5.8±2.9	7.0±2.9A	5.0±2.0	0.0	0.0
Pipistrellus subflavus	1.7±1.5	13.0±7.5	23.5±10.9A	6.0±4.6	0.0	0.0
Unknown	1.5±0.5	7.5±2.2	5.0±1.2	8.0±2.4	1.8±1.3	0.2±0.2
Overall mean	1.0±0.4	7.0±2.0	8.7±2.6	6.0±1.3A[a]	0.4±0.3B	0.1±0.1B

a. Within a habitat (riparian or upland), means in a row with the same letter are not different at α=0.05.

b. Within a column, means with the same letter are not different at α=0.05.

= 12.37, df = 1,34, $P = 0.001$) was greater in riparian areas, whereas activity by big brown bats ($F = 3.08$, df = 1,34, $P = 0.088$) and evening bats ($F = 2.09$, df = 1,34, $P = 0.157$) did not differ between upland and riparian areas.

Among the 3 upland stand ages, species richness was greater ($F = 34.13$, df = 2,6, $P < 0.001$) in clearcuts ($\bar{x} = 3.00 \pm 0.37$) than in sapling ($\bar{x} = 0.33 \pm 0.21$) or mature ($\bar{x} = 0.17 \pm 0.17$) stands. We detected no differences in the level of activity among bat species in upland habitats. However, the big brown bat was the most common with a mean of 3.06 ± 1.45 calls/sampling period. On average, we recorded 0.78, 1.67, and 2.00 calls/sampling period over all habitat types for eastern red bats, evening bats, and eastern pipistrelles, respectively. For all species combined, activity was greater ($F = 29.89$, df = 2,6, $P < 0.001$) in clearcut stands ($\bar{x} = 6.03 \pm 1.30$) than in sapling or mature stands (Table 1). Few calls were recorded in sapling and mature stands; both averaged fewer than 0.5 bat calls/sampling period.

In riparian areas, species richness did not differ among the 3 habitat types. We observed an interaction ($F = 2.24$, df = 8,69, $P = 0.035$) in activity among species and riparian habitats. We recorded fewer ($F = 9.70$, df = 3,20, $P < 0.001$) big brown bat calls over wetalands than all other bat species (Table 1). There were no differences in number of calls/sampling period among species at creeks ($F = 2.89$, df = 3,20, $P = 0.061$) or rivers ($F = 2.18$, df = 3,20, $P = 0.122$).

Discussion

Riparian areas are important foraging habitats for bats (Brigham et al. 1992, Grindal et al. 1999, Seidman and Zabel 2001, Owen unpub. data), presumably because of high insect concentrations and little structural clutter, resulting in increased foraging efficiency (Brigham et al. 1997, Rydell et al. 1999). We observed greater bat activity in riparian areas, particularly larger, more open riparian habitats, than upland areas. We observed relatively low use of creeks. Mackey and Barclay (1989) suggested that clutter on the surface and running-water noise of streams produces extraneous background noise that reduces activity by bats that fly near the water surface. However, the creeks in our study were relatively slow-moving with little surface clutter and few riffles. Research in other regions of the United States has found second and third order streams (Owen et al. 2002) and intermittent streams (Seidman and Zabel 2001), comparable in size to our creeks, to be important bat foraging habitats. However, smaller riparian areas are used primarily by *Myotis* species which have relatively low wing loadings, low wing aspect ratios, and higher echolocation call frequencies making them better adapted to foraging in cluttered closed-canopy situations (Norberg 1987). None of the *Myotis* species found in eastern United States are common in the Georgia Piedmont (Menzel et al. 2000*b*), and we recorded none in our study.

Furlonger et al. (1987) found that some bat species were more active along forest edges that often harbor greater densities of insects. Our riparian habitats were all within a primarily forested landscape and were bordered by mature forest. At creek sites, where we recorded the least activity among riparian areas examined, the canopy was almost fully closed with no edge. Conversely, rivers and wetlands had open canopies and were bordered by mature forests. Lack of forest edge, high structural clutter from a closed canopy, and lack of *Myotis* species in the study area likely explains the low activity in creeks we observed.

We observed greater bat species richness and levels of activity in clearcut stands than in other upland stand ages. In the Pacific Northwest, Grindal and Brigham (1998) found that creating relatively small openings in the forest through timber harvesting significantly increased bat activity, even though insect biomass did not differ between harvested and unharvested areas. Echoes reflected from insects are faint and may be masked by extraneous echoes from vegetation (Rydell et al. 1999). Even when insect abundance is similar between forest openings and intact forests, less vegetation interferes with calls in forest openings. Thus, increased activity over clearcut stands may have been related to increased foraging efficiency rather than increased insect abundance.

Sapling stands in our study had dense closed canopies, creating a high level of structural clutter. The low activity we observed in these stands may be related to spatial complexity, as structural clutter can negatively affect foraging activity of some bat species (Brigham et al. 1997). The few calls we recorded while sampling sapling stands appeared to be bats passing over the canopy. Call sequences recorded were short and unlike the search-phase calls we recorded from bats in other habitat types. We suspect these bats were traveling from roosting to foraging sites and the calls we recorded were fragments of transportation calls from bats over the canopy. Because the calls were fragmented, we were unable to distinguish species of any of the calls and were unable to determine species richness. Nonetheless, our results suggest that the area below the canopy of sapling stands received minimal use by bats. Similarly, Humes et al. (1999) found lower bat use of dense unthinned stands in Oregon compared to thinned and oldgrowth stands.

Forest management practices such as clearcutting that reduce or eliminate bat roosting habitat have been criticized. Humes et al. (1999) recognized that forest stands that provide abundant roosts and adequate foraging opportunities are the highest quality habitats for bats. However, they found that thinned stands in Oregon that lacked adequate snags for roosting were used by bats for foraging and commuting areas and thus provide an important habitat component. Krusic et al. (1996) found greater concentrations of foraging activity by little brown bats *(M. lucifugus)* in regenerating (0–9 years) red spruce *(Picea rubens)* /fir *(Abies balsamea)* stands when compared to other stand ages in New Hampshire. Although some management practices may negatively impact bat roosting habitat, if such activities are incorporated with other habitat types adequate foraging and roosting habitat can be provided across the landscape.

Big brown bats are common throughout their range (Menzel et al. 2000*b*) but were the least common species recorded in our study, particularly in riparian areas where we averaged fewer than 0.5 calls/sampling period in all riparian habitats. We recorded no big brown bat calls at creeks or sapling-stage pine stands. Clearcuts were the only habitat type where we recorded substantial numbers of big brown bat calls.

Conversely, Brigham (1991) documented big brown bats in Ontario foraging over riparian areas along with a variety of other habitat types, demonstrating flexible habitat preference. Furlonger et al. (1987) reported that presence of big brown bats was not correlated with degree of urbanization, presence of open water, habitat type, or presence or absence of woody vegetation. In the Georgia Piedmont, Menzel et al. (2001*c*) found that radio tracked female big brown bats from a maternity colony avoided open areas during all stages of reproduction except late lactation when open areas were neither selected nor avoided. Contrary to these previous findings that suggest generalized, opportunistic foraging habits and avoidance of open areas, big brown bats in our study were recorded more frequently in open upland habitats than other habitats sampled. Based on the relatively large body size and low mean call frequency, we would predict big brown bats to forage more in open habitats (Owen unpub. data) such as clearcuts, than sapling and mature stands. However, these predictions based on body morphology and call characteristics do not explain the limited use of large riparian areas. Also, we were unable to consider sex or reproductive condition which can influence habitat use of big brown bats (Menzel et al. 2001*c*).

Based on body size, eastern pipistrelles should be more prevalent in cluttered habitats such as creeks, where their small body size would allow them to forage more efficiently than larger bats. However, maneuverability is more closely related to wing aspect ratio, wing loading, and call structure. The wing morphology and call structure of eastern pipistrelles make them better adapted to foraging in open areas than cluttered areas. As predicted by these characteristics, we found eastern pipistrelles more commonly over rivers and open wetlands than creeks or cluttered forest stands. Other studies have documented eastern pipistrelles commonly foraging over large streams and farm ponds (Davis and Mumford 1962). Similarly, eastern red bats and evening bats were recorded more often in rivers and wetlands than other riparian or upland habitats, although eastern red bats were the only species other than eastern pipistrelles recorded over creeks. Despite the differences in size, eastern red bats and eastern pipistrelles are common foraging associates (Davis and Mumford 1962) because of similar wing morphology and echolocation call characteristics.

Detectability differences among habitat types could have affected our findings. Humes et al. (1999) speculated that using acoustic detection as an index of bat activity may be sensitive to differences in detectability among stand types depending upon the amount of structural clutter. Our creek sites and sapling and mature stands had levels of canopy cover which could have reduced detection range. Furthermore, it is unlikely that we fully inventoried bats over the canopy of these stands. Accordingly, we limited our inferences to bat activity beneath the canopy. Limited research in the Southeast suggests that activity occurs above the forest canopy and that bat species assemblages above the canopy may differ from assemblages below the canopy (Menzel et al. 2001*a*). Additional research is underway to further assess bat foraging over the canopy of forest stands in the Southeast (M.A. Menzel, pers. commun.).

Management Implications

Our results emphasize the importance of riparian areas as bat habitat in the Georgia Piedmont. Common bat species in this area infrequently used small creek corridors. We recorded only 2 of 4 species over creeks, and the amount of activity was minimal compared to larger riparian areas. Additionally, presence of forest edge around wetlands and along river corridors may positively influence bat use. We recommend that management strategies for bats consider retention or creation of open wetlands and maintenance of forested river corridors.

Humes et al. (1999) concluded that structural changes caused by forest management might benefit bats in the short term by creating habitat structure in young stands that bats can use more efficiently. Thinning of sapling-stage stands with dense, closed canopies may increase bat foraging efficiency, making them more suitable as foraging areas. However, the value of thinned or unthinned sapling-stage pine plantations as roosting habitat is unclear. Although clearcutting apparently creates suitable foraging habitat for some bat species, overutilization of this harvesting method would not allow for the maintenance of sufficient roosting habitat across an intensively-managed forest landscape. Mature forests appear to be an important landscape component for bat roosting in the Southeast (Menzel et al. 1998, Hutchinson and Lacki 2000, Menzel et al. 2001*b*), but may not provide adequate foraging habitat (Krusic et al. 1996). Thus, from a bat conservation perspective, retention of habitat diversity should be incorporated into land management plans. A balance of forest types should be the objective and should include forest openings, intact tracts of mature forest, and the use of management tools such as thinning and streamside management zone retention to provide foraging and roosting habitat for bats.

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