Wildlife Technical Articles

Bat Community Structure and Activity in Longleaf and Loblolly Pine Forests of Southwest Georgia

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Abstract: The area of longleaf pine (*Pinus palustris*) forests have declined whereas intensive pine (*Pinus* spp.) silviculture has increased on the southeastern landscape. Because effects of differing pine management scenarios on bat community structure and activity are largely unknown, we used mist nets and acoustic surveys to examine these factors on mature longleaf pine and intensively managed loblolly pine (*P. taeda*) landscapes in southwestern Georgia. We placed mist nets over ponds, small streams, and roadside ditches and placed bat detectors in replicates of four vegetation types (open, closed pine, hardwood, mature pine) on each study site. We captured 649 bats of six species during 83 nights of trapping at both sites. Seminole bats (*Lasiurus seminolus*), red bats (*L. borealis*), and evening bats (*Nycticeius humeralis*) accounted for 95% of captures. For both areas combined, 28% of captures were juveniles and 97% of adult females showed signs of reproduction. Evening bats were more commonly captured on the longleaf site, while red bats were more commonly captured on the intensively-managed site. Bat activity was greater in mature pine than other vegetation types on the longleaf site. Activity was lowest in the hardwood on the managed site, but others did not differ. Timber harvest on the managed site created a diversity and abundance of openings and edges that likely provided foraging habitat for red bats, but probably reduced available roosting habitat for evening bats. This likely increased proportion red bats in the community on the managed site. Management activities that reduce clutter (such as burning or thinning) in hardwood and mature pine may benefit the three common bat species in this study on intensively managed landscapes in the southeast.

Longleaf pine (*Pinus palustris*) forests once covered over 37 million hectares in the southeastern United States, but has been reduced to less than 1.2 million hectares (Landers et al. 1995). Conversely, to meet demands for forest products, intensively-managed pine (*Pinus* spp.) forests are a primary forest type in the Southeast, occurring on 12.9 million ha in 1999 (Wear and Greis 2002), and projected to remain an important component of the southeastern landscape (National Commission on Science for Sustainable Forestry 2005). Over large spatial scales, landscape changes in forest structure associated with the shift from historic longleaf conditions (i.e., large, scattered overstory trees with little to no midstory creating a pine savannah) to intensively-managed landscapes (generally stands with a high density of overstory trees with well-developed midstories) could result in changes in bat communities. This is because most, if not all, of the 18 species of southeastern bats may be directly affected by forest management practices as they rely on forests for their primary roosting and for-

aging sites (Brown 1997, Carter 1998). Management practices that limit available roosting structures may result in changes in species composition or elimination of species with specific roosting requirements (Humphrey 1975). Alterations to foraging habitat may be detrimental or beneficial because selection of foraging habitat is based on morphological and echolocation characteristics of species (Findley 1976, Sherwin et al. 2000, Patriquin and Barclay 2003). However, few studies have attempted to document bat community structure and foraging habitat associations in longleaf or intensively-managed pine landscapes in the Southeast.

Mist net surveys are commonly employed to examine bat community structure throughout North America (Murray et al. 1999, O'Farrell and Gannon 1999). Direct capture of individuals allows positive species identification, reproductive assessment, and estimation of sex and age ratios (Murray et al. 1999, Miller 2003). Previous mist net surveys of pine forests in the Southeast Coastal Plain suggest that the bat communities are dominated by three

common species: red bat (*Lasiurus borealis*), Seminole bat (*L. seminolus*), and evening bat (*Nycticeius humeralis*) (Carter 1998, Miller 2003). Additionally, bat detectors have been used to examine relative activity of bats in relation to different forest management practices (e.g., Furlonger et al. 1987, Grindal and Brigham 1999, Owen 2000, Menzel et al. 2002). These studies have demonstrated importance of old growth or mature forests (Crampton and Barclay 1998, Humes et al. 1999), edge (Menzel et al. 2002), and open (Menzel et al. 2002, Erickson and West 2003) habitats to bats. Habitat associations have been linked to foraging strategies and morphological characteristics of bat species or guilds (Patriquin and Barclay 2003). Acoustic detections of aerial foraging species (e.g., red bats) are greater in open and edge habitats where quick flight can be used to capture prey (Patriquin and Barclay 2003). Vegetation types with clutter are generally avoided by aerial foragers but are regularly used by species which glean insects from vegetation (e.g., northern long-eared bat (*Myotis septentrionalis*); Patriquin and Barclay 2003).

To provide information on bat community structure and use of foraging habitat in pine forests of the Southeast, our objectives were to: (1) describe bat community structure, and (2) compare relative activity of foraging bats among vegetation types within intensively-managed loblolly pine (*P. taeda*) and mature longleaf pine landscapes.

Study Area

We conducted our study in the Upper Coastal Plain physiographic region of southwestern Georgia, between 31°50′ and 31°4′ N latitude and 84°40′ and 83°39′ W longitude. This region was characterized by hot, humid summers with average daily temperatures of 27 C (summer) and average annual precipitation was 137 cm/year (http://georgiaweather.net/cgi-bin/AEMN.pl?site=GANE). We selected two sites for study, one that represented the historic longleaf condition and one that represented an intensively-managed pine landscape (Fig. 1). The Joseph W. Jones Ecological Research Center at Ichauway (natural site) in Baker County, Georgia, was a 12,000-ha research site managed with biennial prescribed fire to simulate natural disturbance patterns and promote a landscape similar to the historic longleaf pine ecosystem. Longleaf forests were between 70 to 90 years old, with individual trees >300 years old scattered throughout the site. Southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), and other hardwoods commonly occurred individually within mature pine forests. Snags (especially pine, to a lesser extent hardwoods) were also common. Riparian hardwood forests, mixed pine/hardwood forests, and wildlife openings were scattered throughout the site.
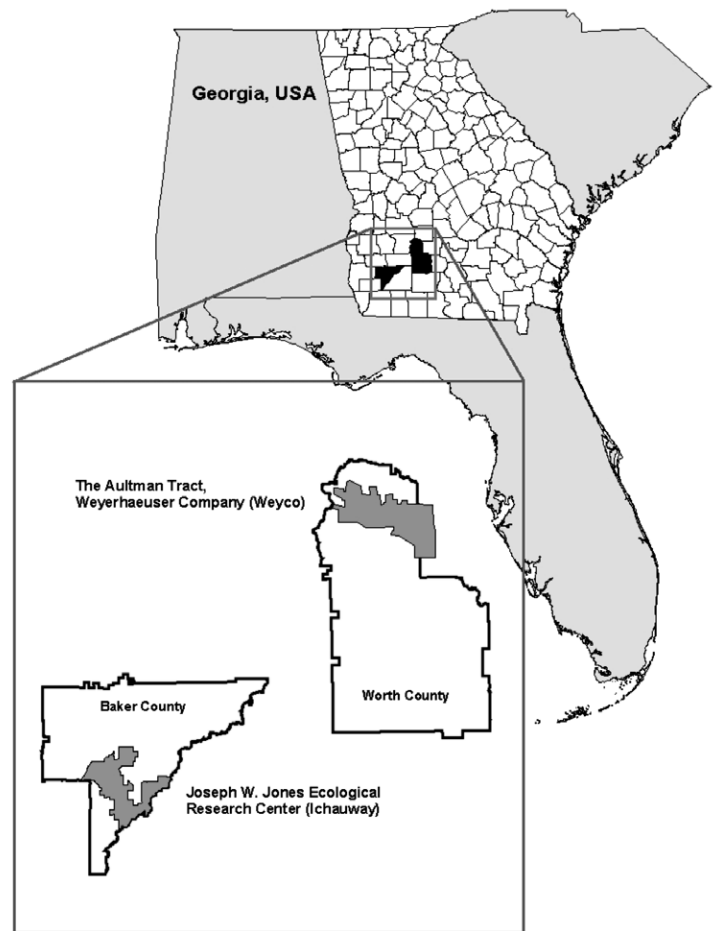

Figure 1. Locations of The Joseph W. Jones Ecological Research Center (natural site) and the Aultman Tract (managed site) study areas in southwestern Georgia used to investigate bat community structure and bat activity from May to September 2002–2003.

The Aultman Tract (managed site) in Worth County, Georgia, approximately 70 km to the northeast of Ichauway, was a 14,000-ha area consisting primarily of loblolly pine plantations (approximately 80% of the area) managed by Weyerhaeuser Company for sawtimber on a 30-year rotation. Typical management for pine stands included site preparation and planting, vegetation management, commercial thinning, pruning, and fertilization. This management resulted in even-aged stands of different successional stages distributed in a mosaic throughout the landscape. A dense hardwood midstory of sweetgum, persimmon (*Diospyros virginiana*), and oaks (*Quercus* spp.) often were present in stands between 20 to 30 years old. Interspersed throughout the site were non-plantation stands >50 years old including streamside management zones, mature pine-hardwood and hardwood forests (approximately 20% of the area).

Table 1. Mean overstory basal area (BA; m²/ha) and stem density (trees/ha), with standard error (SE) for vegetation types on a mature, second growth longleaf pine landscape (natural) and on an intensively managed loblolly pine landscape (managed) in southwestern Georgia, 2002–2003.

Study site	Vegetation type (*N*)	Overstory BA		Overstory density		Midstory BA		Midstory density	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Natural	Closed canopy pine (3)	7.9	2.2	425.2	150.8	0.4	0.2	120.7	21.8
Natural	Mature pine (150)	16.8	1.3	201.1	30.9	0.7	0.2	440.8	154.5
Natural	Hardwood (53)	1073.3	1049.9	1264.1	1041.2	1.2	0.4	758.6	265.8
Managed	Closed canopy pine (17)	17.7	3.5	855.5	175.5	2.58	0.49	1361.3	241.2
Managed	Mature pine (42)	14.7	1.2	348.9	27.5	1.09	0.28	735.4	179.5
Managed	Hardwood (41)	72.9	35.0	2061.6	1190.9	5.26	1.72	2869.7	1022.0

Methods

We captured bats from May to early September 2002 and 2003 with 6- to 18-m long by 2.4-m high mist nets set over ponds, small streams, and roadside ditches throughout each study site. Efforts were made to trap bats throughout both study areas and minimize use of the same sites multiple times within short (< 5 days) periods of time. We identified captured bats to species and recorded mass (g), forearm length (mm), gender, age (Anthony 1988), and reproductive condition (Racey 1988). We defined trap-hours as the time mist nets were opened at a capture site. We tested the hypothesis that number of bats captured per trap-hour did not differ between the natural vs. managed sites using a *t*-test with each sample night as the experimental unit. We used Simpson's diversity index (Ludwig and Reynolds 1988; probability that two bats drawn at random will be the same species) to describe bat community structure on each study site. Bat capture and handling was conducted under University of Georgia Institutional Animal Care and Use Committee guidelines (permit number A2002–10108–0).

We used a geographic information system (GIS; ArcInfo, Environmental Systems Research Institute, Redlands, California) to classify each study area into four broad vegetation types (mature pine, closed pine, open, and hardwood) to provide consistency between sites (Table 1). Mature pine included upland stands where pine dominated the canopy on the natural site and thinned pine stands (approximately 13–30 years old) on the managed site. Closed pine stands were approximately 8–13 years old with almost complete canopy closure. Open stands on the natural site included fields and wildlife food plots, but was primarily clearcuts and regeneration stands < 8 years old on the managed site. Hardwood included upland hardwood and mixed pine-hardwood (hardwood dominated) stands, riparian areas, and cypress (*Taxodium distichum*) forested wetlands on each site. Most hardwood areas on the managed site were designated as reserve areas and received limited management.

We recorded bat activity during 2003 using Anabat II detector systems (Titley Electronics, Ballina, New South Wales, Australia) placed 1.5 m on a tripod angled at 30 degrees (Weller and Zabel 2002). An Anabat II detector system included an Anabat II detector and a CF-Storage ZCAIM (Titley Electronics) placed in a waterproof plastic box. Prior to sampling, we calibrated bat detectors relative to one another using SONIN 60 PRO electronic distance-measuring tool (SONIN, Scarsdale, New York) (Larson and Hayes 2000, Weller and Zabel 2002). On each night sampled, we placed detectors in all four vegetation types on one study area and set them to automatically record simultaneously from dusk till dawn. We moved detectors to a different set of four vegetation types each night. We determined detector locations by selecting a random point generated in the GIS. We placed detectors facing into the forest stand in openings to minimize effect of clutter on the area sampled in different vegetation types (Hayes 2000, Weller and Zabel 2002). Clutter is defined as vegetation structure that interferes with the ability of bats to fly through stands or disrupt echolocation call detection by ultrasonic detectors.

We downloaded files of recorded bat echolocation calls from the CF-Storage ZCAIM to a computer for analysis. We separated files containing bat calls from those containing insect and extraneous noise using a custom filter in Analook software (Version 4.8, Titley Electronics) (Britzke and Murray 2000) and then manually checked files for accuracy. We defined bat activity as number of bat passes per hour, with a "bat pass" defined as a file which contained > 2 clearly defined echolocation pulses. We treated each file that contained a bat pass as one pass, regardless of the number of different bat calls in that file. We tested the hypothesis that bat activity did not differ among vegetation types on each study area using a one-way ANOVA on ranked data (Conover and Iman 1981) and used Tukey's multiple mean comparison for mean separation. All analyses were conducted with SAS (SAS 2001) at an alpha level of 0.05.

Results

We captured 649 bats of six species during 83 nights (239 hours) of trapping at both study sites combined (Table 2). We captured 286 bats of six species in 110 hours on 18 sites in the natural landscape and 363 bats of five species in 129 hours on 31 sites in the managed landscape. Southeastern myotis (*Myotis austroriparius*) were only captured on the natural site (*N* = 6). Seminole bats (47%, *N* = 306), red bats (26%, *N* = 169), and evening bats (22%, *N* = 144) accounted for 95% of all captures. Simpson's diversity index was similar for the natural site (0.64) and the managed site (0.62). We captured more evening bats per net-hour (= 0.8, SE = 0.15) on the natural site than on the managed site (= 0.35; SE = 0.09; *t*-test, t_{80} = 2.63, *P* = 0.01). Red bats (*Lasiurus* spp.) were more commonly captured on the managed site (= 0.96, SE = 1.6 per hour) than the natural site (= 0.28, SE = 0.08 per hour; *t*-test, t_{80} = 3.65, *P* < 0.001). Capture rates of Seminole bats was similar (*t*-test, t_{80} = 0.5, *P* = 0.62) between the natural site (= 1.11; SE = 0.22) and the managed site (= 1.26; SE = 0.19). We captured 134 adult females on the natural site and 189 adult females on the managed site. Of these, 313 (97%) showed evidence of reproduction (pregnant, lactating, or post-lactating). Juvenile bats represented 30% (*N* = 87) of captures on the natural site and 26% (*N* = 95) of captures on the managed site (Table 2).

We recorded 3,420 bat passes on 18 nights in the natural site and 2,367 bat passes on 16 nights in the managed site. We recorded a mean of 6.5 bat passes per hour (SE = 1.1) on the natural site and a mean of 4.3 bat passes per hour (SE = 0.76) on the managed site. On the natural site, mature pine had more passes per hour more than other vegetation types ($F_{3,68}$ = 8.05, *P* < 0.001, Fig. 2). On the managed site, mature pine (= 6.8 passes per hour, SE = 2.2), open (= 4.9, SE = 0.9), and closed canopy pine (= 3.9, SE =1.6) had more passes than hardwood stands (= 1.5; SE = 0.5; $F_{3,60}$ = 5.08, *P* = 0.003, Fig. 2).
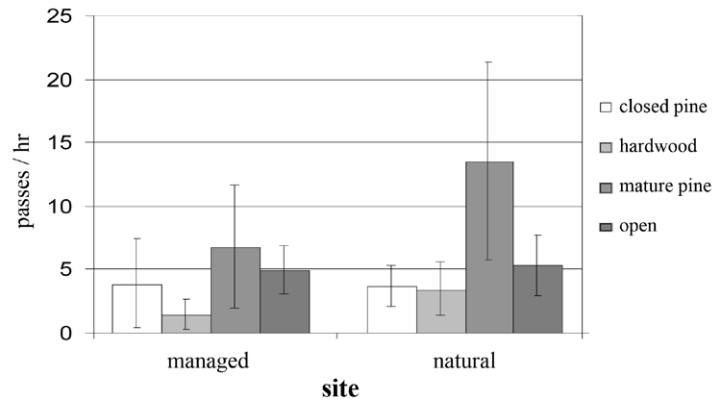

Figure 2. Bat activity (passes/hour) recorded with bat detectors in replicates of four habitat types on natural (n=18) and managed (n=16) sites in southwestern Georgia during summer 2003. Error bars indicate 95% confidence intervals.

Discussion

Similar to past studies in the Southeast Coastal Plain (Lance and Garrett 1997, Menzel et al. 1999, Miller 2003), bat captures on both areas were dominated by three common species (Seminole bat, red bat, and evening bat). However, capture rates of the three common species differed between study sites. We captured more evening bats per hour on the natural site and more red bats per hour on the managed site. We assumed that species capture probabilities were equal between the study sites but could not formally test this assumption. Though there are many potential explanations for the difference in capture rates of common species between the study sites, differences were likely related to roosting preferences and availability of foraging habitat.

Availability of suitable roosting structures may be a limiting factor for species with specific roosting requirements (Humphrey 1975). Evening bats roost under exfoliating bark or in cavities of living or dead trees (Menzel et al. 2000, 2001; Miles et al. 2006). Due to the short rotation of pine stands on the managed site,

Table 2. Sex, age and capture rates (CPUE; total bats/hour) of bats captured during 110 trap-hours on a mature, second growth longleaf pine landscape (natural) and 129 trap-hours on an intensively managed loblolly pine landscape (managed) in southwestern Georgia, 2002–2003.

Species	Natural					Managed				
	Male	Female	Juvenile	Total[a]	CPUE	Male	Female	Juvenile	Total[a]	CPUE
Brazilian free-tailed bat (*Tadarida brasiliensis*)	1	0	2	3	0.03	0	1	1	2	0.02
Evening bat (*Nycticeius humeralis*)	26	56	15	98	0.89	16	21	9	46	0.36
Eastern red bat (*Lasiurus borealis*)	3	19	14	37	0.34	2	74	39	132	1.02
Eastern pipistrelle (*Pipistrellus subflavus*)	1	2	1	4	0.04	1	3	1	5	0.04
Lasiurus spp.[b]	0	0	0	2	0.02	0	0	0	8	0.06
Seminole bat (*Lasiurus seminolus*)	13	56	51	136	1.24	12	90	45	170	1.32
Southeastern myotis (*Myotis austroriparius*)	1	1	4	6	0.05	0	0	0	0	0
Total	45	134	87	286	2.60	31	189	95	363	2.81

a. Includes bats that escaped before sex and age could be determined.
b. Seminole or red bats that escaped before positive identification to species.

availability of suitable roosting structures likely was more limited whereas large trees and snags were common across the landscape on the natural site (Miles et al. 2006). In contrast, both study sites likely provided adequate roosting habitat for red bats roost as they roost in the foliage of hardwood and pine trees (Menzel et al. 1998, Menzel et al. 2000, Elmore et al. 2004). Differences in foraging habitat may be contributing to the difference in red bats captures between the study sites. Red bats typically forage over open and edge habitats (Menzel et al. 2002). The continual harvest and regeneration of intensive forest management creates diverse and abundant open and edge habitats that likely provides foraging habitat for red bats (Elmore et al. 2005). This is not suggestive that foraging habitat is limiting for red bats on the natural site. However, because of limited roosting structure on the managed site for evening bats, red bats are a higher proportion of the overall bat community.

Mature pine had greatest bat activity on the natural site. The mature longleaf pine stands were burned on a two-year fire rotation, resulting in open, park-like stands with little midstory. Importance of non-cluttered vegetation types to many bat species, especially aerial hawkers, has been noted by other researchers (e.g., Brigham and Fenton 1986, Grindal and Brigham 1999, Kalcounis et al. 1999). Mature pine stands on the managed site often had a dense hardwood midstory, which may have decreased bat activity in these stands (relative to other vegetation types) because of increased clutter (Table 1). Hardwood stands had the least activity on the managed site. Again, a great degree of clutter associated with this vegetation type likely reduced its value as foraging habitat. However, two of the common species (red bat and evening bat) frequently roost in hardwood stands (Menzel et al. 2000, Elmore et al. 2004, Miles et al. 2006). Thus, these areas may be important roosting areas for bats despite the limited foraging activity observed in them.

Bat activity measured with bat detectors is highly variable both spatially and temporally (Hayes 1997, Sherwin et al. 2000, Weller and Zabel 2002). We controlled for spatial and temporal variability by simultaneously sampling vegetation types of interest within a study area and sampling multiple replicates of each vegetation type throughout the summer. We did not simultaneously sample the two study sites. Therefore we did not make direct comparisons of habitat-associated bat activity between the study sites. We assumed equal detection probabilities between vegetation types during each sampling period (Sherwin et al. 2000) although we had no formal method of testing this assumption. Britzke (2003) noted that detection probabilities between open and cluttered vegetation types were not equal, and Weller and Zabel (2002) noted

large variations in activity at a single location within a forest depending on orientation of bat detectors. We attempted to reduce potential bias by orienting all detectors toward openings within each vegetation type. On the managed site, one of the more cluttered forest stands (closed canopy) had similar activity to less-cluttered vegetation types, indicating that if the assumption of equal detection probability between vegetation types was violated, the effect may not have been strong enough to affect results.

We did not attempt to identify bat passes to species because we were unable to create a large enough library of reference calls specific to the vegetation types in our study area. In a comparison of mist net and bat detector species assemblages, Murray et al. (1999) found that more species were detected acoustically than with mist nets. Therefore it is possible that species that were rarely or not captured in mist nets may have been detected in the study sites acoustically but were not identified. Owen (2000), however, found that the most common species captured in mist nets were also the most commonly detected species in his study areas. Given the simple bat community present on the study area, we assume that the majority of calls recorded were from the three most common species (Seminole bat, red bat, and evening bat).

Management Implications

The natural and managed study sites had similar bat communities and provided habitat of sufficient quality to allow reproduction. We suggest that differences in capture rates of common species are related to habitat conditions of the sites. Because we only conducted the study on two study sites, our inferential space is limited to the landscapes in which we conducted the study. The results of this study, therefore, should be used in conjunction with previous and future research in the region to create management recommendations. Management activities that reduce clutter (such as burning or thinning) may benefit common bat species by increasing available foraging habitat. This is based on results of our study and previous research (Brigham and Fenton 1986, Grindal and Brigham 1999, Kalcounis et al. 1999).

Because we did not identify bat passes to species, it was not possible to assess presence of bats of conservation concern. Future research should strive to use a combination of mist net and acoustic surveys to more completely document bat communities in different forest landscapes, including presence of species of conservation concern. Because most forest managers are not going to manage for individual bat species except for known presence of legally protected species, additional research is also needed to examine possible relationships between landscape characteristics and bat communities so that informed decisions can be made regarding

effects of forest management options at the landscape scale on bat communities.

Acknowledgments

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