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# Site occupancy of foraging bats on landscapes of managed pine forest

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ABSTRACT

The ability to fully evaluate potential relationships between forest management and bats is limited without information from relevant spatial scales. Further, knowledge of bat ecology in intensively managed forests is fairly limited even though these forests are a substantial portion of the forested landscape in the southeastern U.S. Therefore, we used occupancy models to examine influence of small-scale vegetation characteristics and large-scale spatial features on foraging patterns of bats within 6 managed-pine (*Pinus* spp.) forest landscapes in the southeastern U.S. Coastal Plain. We conducted repeated acoustic surveys to determine species presence/non-detection and evaluated a priori models relating detection probability and occupancy to site- and landscape-level metrics for 6 species/genera. Detection of big brown (*Eptesicus fuscus*) and eastern red (*Lasiurus borealis*)/Seminole (*L. seminolus*) bats (eastern red and Seminole bats combined) decreased with increasing basal area, and detection of big brown and Brazilian free-tailed bats (*Tadarida brasiliensis*) increased over the summer sampling period. Relationships between occupancy and habitat metrics were species-specific but consistent with previous studies. Occupancy for most bat species was lower at sampling sites with higher vegetation clutter and higher basal area. In contrast to most previous studies, occupancy of all bat species investigated was unrelated to or negatively influenced by distance to water. Although site- and landscape-level features influenced occupancy, our results indicate that site-specific features (vegetation clutter and basal area) influenced most species. Therefore, stand-level management activities that decrease vegetation structure, such as thinning intermediate-aged stands and/or controlling midstory vegetation (e.g., fire or herbicide applications), likely will maintain or increase suitability of managed pine forest stands and landscapes for many bat species in the southeastern Coastal Plain. The forest mosaics that we sampled, consisting primarily of managed pine stands intermingled with non-production habitat types, supported a large proportion of the bat community associated with forests of the Coastal Plain which suggests the compatibility of timber production and bat conservation objectives.



## 1. Introduction

Forests are important to virtually all North American bat species and many use forests exclusively to fulfill life history requirements (Miller et al., 2003). Alteration of forest structure through forest management practices may enhance foraging habitat for some bat species thereby reducing it for others (Aldridge and Rautenbach, 1987; Patriquin and Barclay, 2003), making management decisions that benefit entire bat communities challenging. Differences in morphology and echolocation call structure among bats suggest that species are adapted to small-scale (within stand), structural habitat features (Aldridge and Rautenbach, 1987; Brigham et al., 1997). However, bats are capable of commuting among habitat patches across the landscape (Bernard and Fenton, 2003) and likely perceive habitat conditions at large spatial scales (Zimmerman and Glanz, 2000). Because effects of forest management on bat foraging ecology are scale-dependent (Grindal and Brigham, 1999), simultaneous consideration of small- and large-scale habitat features is necessary when evaluating potential management effects (Erickson and West, 2003; Zimmerman and Glanz, 2000).

Small-scale habitat use by foraging bats is often attributed to amount of structural complexity (i.e., clutter; Brigham et al., 1997; Ford et al., 2005; Loeb and O'Keefe, 2006; Sleep and Brigham, 2003). The degree to which bats use cluttered habitat types is related to bat morphology, including body mass, wing

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loading, wing aspect ratio, and echolocation call characteristics (Aldridge and Rautenbach, 1987). In general, smaller species are better adapted to foraging in cluttered forest conditions (Sleep and Brigham, 2003) whereas larger bats often forage over the forest canopy (Menzel et al., 2005) or in forest openings (Ford et al., 2006; Menzel et al., 2005). Increased bat activity in areas of reduced vegetation structure has been documented in a variety of forested landscapes (Erickson and West, 2003; Ford et al., 2006; Humes et al., 1999; Loeb and O'Keefe, 2006; Loeb and Waldrop, 2008; Yates and Muzika, 2006). In intensively managed forests, vegetation structure is determined by a variety of factors including stand age, tree spacing, and midstory management (Guldin et al., 2007) which are influenced by stand-level silvicultural treatments (Wigley et al., 2007). Thus, with proper planning and consideration, forest management practices can improve conditions for foraging bats within landowner's management and economic constraints (Wigley et al., 2007).

Results of previous studies have generally concluded that landscape characteristics, such as amount of forest cover, proximity to water, and edge, influence bat occupancy or foraging activity (Duff and Morrell, 2007; Ford et al., 2006; Grindal and Brigham, 1999; Walsh and Harris, 1996; Yates and Muzika, 2006). However, extent of influence and relevant landscape features are species-specific. Foraging and commuting activities of some species may be related to specific features (e.g., open water), whereas others conduct activities over a range of stand conditions (Brigham, 1991; Elmore et al., 2004; Yates and Muzika, 2006). Some studies have suggested that landscape characteristics and habitat mosaics have a greater influence on bat habitat use in intensively-managed landscapes because of potential for reduced small-scale heterogeneity due to even-aged management of forest stands (Erickson and West, 2003; Ford et al., 2006; Miles et al., 2006). Under homogenous forest conditions, foraging bats may have to travel farther from roost sites to find suitable foraging conditions. Additionally, managed forests may have lower roost availability for some species (Miles et al., 2006) which can influence foraging habitat selection (Crampton and Barclay, 1998).

Conducting foraging studies on bats is difficult because of their small size, vagility, and nocturnal nature (Duff and Morrell, 2007). Because radiotelemetry is expensive and logistically challenging, most studies examining habitat use by foraging bats rely on acoustic methods (Morris et al., 2011b). Morris et al. (2011b) cautioned against using acoustic methods to infer habitat selection at larger spatial scales because bat echolocation calls are more likely to be recorded (i.e., detected) in habitat types where bats echolocate more (e.g., those used for foraging) than in those where they echolocate less (e.g., those used for roosting). The resulting false absences (species is present but not detected; MacKenzie, 2005) may influence results and inferences unless accounted for in analyses (Gu and Swihart, 2004). Because bats are imperfectly detected and detection may be influenced by habitat characteristics, occupancy modeling has recently been applied to acoustic surveys for bats (Amelon, 2007; Gorreson et al., 2008; Hein et al., 2009; Weller and Baldwin, 2012; Yates and Muzika, 2006). Occupancy modeling allows simultaneous investigation of factors influencing occupancy and detection probabilities, improving the ability to make inferences about species use of landscape features (MacKenzie et al., 2002; MacKenzie, 2005).

Intensively managed pine (*Pinus* spp.) forests covers >12 million ha in the southeastern U.S. (Smith et al., 2009). Owners of managed forest lands are increasingly committed to conserving biodiversity as evidenced by voluntary enrollment in sustainable forestry certification programs which include biodiversity principles (Wigley et al., 2007). However, limited data on selection of foraging habitat in managed forest landscapes hinders our ability to evaluate management decisions that may influence bats. Therefore, we used occupancy modeling to examine influence of site- and landscape-level characteristics on foraging bats in managed pine landscapes of the southeastern U.S. Coastal Plain. Elucidating factors influencing foraging habitat selection will complement existing limited data on foraging and roosting habitat selection in managed pine landscapes, allowing for more informed management decisions to maximize benefit to bat communities.

## 2. Methods

### 2.1. Study sites

We conducted our study on 6 intensively-managed forest landscapes in corporate ownership/management across five states (Butler Co., Alabama (Site AL); Ashley Co., Arkansas (Site AR); Decatur Co., Georgia (reference site in detection models); Brunswick (Site NC-1) and Beaufort/Martin Cos. (Site NC-2), North Carolina; Charleston and Dorchester Cos., South Carolina (Site SC) in the Coastal Plain of the southeastern U.S. The southeastern Coastal Plain is generally characterized by flat topography and sandy soils. Soils of the region are highly variable in the amount of organic matter and permeability (Hubbard et al., 2004) resulting in a diverse regional vegetation community. However, forests dominate the regional land cover and agriculture is the primary land use on non-forest lands within this physiographic region (Hubbard et al., 2004; Wear and Greis, 2002).

Our study landscapes consisted primarily of planted loblolly pine (*Pinus taeda*) forests interspersed with streamside management zones and other inclusions dominated by mature (>40 yrs old) hardwoods or mixed pine-hardwoods. Although specific management at study sites varied by individual landowner, typical management of planted pine forests included clear-cutting at 20–35 yrs, mechanical and/or chemical site preparation, and planting 1–2-yr-old nursery stock in raised beds at 182–283 trees/ha. Competing vegetation was temporarily suppressed through herbicide application (banded or broadcast spraying) the first growing season after stand establishment and potentially later during early- and mid-rotation, and most stands were commercially thinned at least once. All landowners were participating in a forest certification program (Guynn et al., 2004).

### 2.2. Acoustic detection and call classification

We conducted acoustic surveys at our study landscapes from May–August, 2007–2008. Bats were surveyed at 22–36 sample points on each landscape (mean = 26.3) once during the 2-yr study (3 sites/year) over an approximately 1-month period. Sample points were distributed across the landscape in a grid arrangement with 900 m between points. We selected a 900 m spacing to encompass a core area that constitutes much of an individual's foraging movements (Everson, 2005; Menzel et al., 2001a; Morris et al., 2011a; O'Donnell, 2001). Core foraging areas generally constitute a small percentage of an individual's home range (Morris et al., 2011a; O'Donnell, 2001; Zeale et al., 2012) and recent evidence suggests that home and core ranges are smaller in actively managed plantation forests than in landscapes where stands have not been harvested recently (Borkin and Parsons, 2014). Although spacing was consistent, grids were necessarily irregularly shaped because of the irregular shape of study sites. The order of sampling at each study site was based on proximity of sampling points, accessibility, and other logistical considerations to allow sampling multiple points each night. We generally conducted acoustic sampling for 2 consecutive nights to minimize temporal variability, but sampled additional nights opportunistically to improve occupancy and detection estimates.