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Sex-specific roost selection by adult red bats in a diverse forested landscape

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Abstract

The eastern red bat (*Lasiurus borealis*) is a common, widespread species that occurs throughout eastern North America; however, information on potential differences in roost selection between sexes is limited. We studied summer diurnal roosting of adult red bats in a diverse forested landscape to: (1) characterize roosts of adult males and females, (2) determine habitat relationships for both sexes, and (3) compare roost selection between the sexes. We radiotracked 21 male and 20 female red bats to 142 roost locations and quantified roost characteristics. Both sexes roosted mostly in overstory hardwoods (82% of male and 81% of female roosts), but males occasionally (8% of roosts) roosted in sapling (<5 cm diameter at breast height; dbh) whereas females did not. Females roosted at greater heights than males but, mean diameter and height of roost trees ≥5 cm dbh did not differ between sexes; roosts trees used by both sexes were greater in diameter and height than random trees. We found no difference between sexes in tree species used for roosting; both sexes preferred to roost in white oaks (*Quercus alba*) and hickories (*Carya* spp.) but avoided Pines (*Pinus* spp.). Sex-specific habitat models created using an information-theoretic approach indicated males were more likely to roosts at sites with more midstory (5–10 cm dbh) and small overstory (10–25 cm dbh) hardwoods, taller hardwoods, shorter pines, and further from the nearest tree than random. Females were more likely to roost at sites with more midstory hardwoods, fewer small overstory pines (10–25 cm dbh), and fewer understory (<5 cm dbh) woody stems than random. Comparisons of mean habitat parameters surrounding roost sites indicated only distance to nearest tree differed ($P < 0.05$) between sexes; females roosted further from the nearest tree than males. Ninety-five percent of male roosts and 92% of female roosts were in stands dominated by mature (≥50 years old) trees, and 45% of male roosts and 40% of female roosts were in stands that had been partially harvested 1–5 years earlier but retained mature overstory hardwoods. Retaining minimum basal areas of 1.1–2.3 m^2/ha of overstory hardwoods and retaining unharvested buffers along stream drains in harvested areas would likely provide adequate roosting habitat for both sexes of red bats in managed landscapes during summer.
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1. Introduction

Forest management alters the structure and function of forests and these alterations can often affect species that rely on forests for the resources needed to sustain viable populations. In forested ecosystems, bats rely on a variety of structural and spatial components such as snags or large overstory trees for roosting and canopy gaps for foraging. In the life history of bats, roosts and food are the two most important resources known to affect bat distribution and abundance (Kunz and Lumsden, 2003). Roosts provide protection from predators, thermoregulatory benefits, and places to raise young and interact socially (Kunz and Lumsden, 2003).

The eastern red bat (*Lasiurus borealis*) is an insectivorous bat that is widely distributed throughout a large portion of North America (Shump and Shump, 1982). It is the most frequently captured forest-dwelling bat in most of Arkansas (Baker and Ward, 1967; Gardner and McDaniel, 1978; Saugey et al., 1989). Because of their abundance and insectivorous diet, red bats likely play important roles in forested ecosystems by consuming forest pests and reducing disease-carrying insects. However, red bat ecology has received little attention until recently.

Bat of the genus *Lasiurus* roost primarily in tree foliage, and during summer, red bats typically roost among deciduous leaves in tree canopies (e.g., Hutchinson and Lacki, 2000; Menzel et al., 1998). Other than females with young, both sexes

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usually roost alone (e.g., Hutchinson and Lacki, 2000). In both urban and forested environments, red bats roost mostly in overstory hardwoods (e.g., *Quercus* spp. and *Carya* spp.; Hutchinson and Lacki, 2000; Menzel et al., 2000; Mager and Nelson, 2001; Limpert et al., 2007).

Recently, studies of red bat roosting have become more plentiful. However, to discern ubiquitous traits of a species from those limited to certain geographic areas, multiple studies from a diversity of ecotypes and geographic locations are required to fully understand the range of habitat tolerances of a species. Furthermore, inferences from studies are usually limited by geographic or ecological conditions of the study area. For example, Hutchinson and Lacki (2000) quantified red bat roosting in an area of hardwood forest that was largely undisturbed by silvicultural activities, Elmore et al. (2004) quantified roosting in an area of industrial timberlands comprised mostly of intensively managed pine (*Pinus* spp.) stands, and Mager and Nelson (2001) quantified red bat roosting in an urban environment. Therefore, to develop effective conservation of bats, multiple studies from a variety of landscapes are essential.

Because males of many cavity-roosting forest bats typically roost alone whereas females roost in colonies during summer (e.g., Broders and Forbes, 2004; Miles et al., 2006), sex-specific differences in roost selection might be expected for those species. However, potential differences in roost selection between sexes of *Lasiurus* (which typically roost alone) are not obvious. During summer, females may select roosts that differ from males because of added physiological requirements associated with reproduction, lactation, and avoidance of predators when pups are nonvolant, but most previous studies of red bat roosting ecology pooled data across age and sex classes largely because of small sample sizes ($\leq$14 individuals; e.g., Hutchinson and Lacki, 2000; Menzel et al., 2000; Mager and Nelson, 2001). Thus, information on potential differences in roosting ecology between sexes of red bats is needed.

Our objectives were: (1) characterize roost selection by adult male and female red bats in a diversely forested landscape of Arkansas, (2) determine habitat relationships for both males and females, and (3) compare male and female roost selection. We compared roost trees and surrounding sites between sexes and with random trees and sites.

2. Methods

2.1. Study area

We conducted the study in the 6545-ha Upper Lake Winona Basin, situated in northwestern Saline County (34°48′N, 92°58′W) in the Ouachita Mountains of central Arkansas, USA. The Ouachita Mountains are a series of east–west oriented ridges and valleys that extend from central Arkansas into east-central Oklahoma. Elevations in the region range from 152 to 853 m, mean annual precipitation ranges from 112 to 137 cm, and mean annual temperature ranges from 13.9 to 16.1 °C (Skiles, 1981).

No residential areas, houses, or agricultural lands exist in the study portion of the Winona Basin. Most of the basin consists of mixed shortleaf pine (*P. echinata*)—hardwood forests managed by the Forest Service, U.S. Department of Agriculture (Ouachita National Forest). The basin also contains a mix of other forest types, primarily oak (*Quercus* spp.)—hickory forests. Twelve percent (778 ha) of the area is intensively managed industrial timberlands consisting primarily of closed canopy and older thinned loblolly pine (*P. taeda*) plantations. These plantations were generally thinned at about 12–15 years of age and managed on a 30–35-year saw-log rotation.

National forest lands in the basin were divided into six 513–1791-ha management units where different silvicultural treatments were implemented in 2000 (Perry et al., 2007). A 1232-ha pine-grassland restoration unit was initially thinned in 2000; goal of this restoration is to create open woodland conditions maintained by periodic prescribed burning. That area was thinned to 13.8 m^2/ha overstory basal area (BA), of which 1.1 m^2/ha was retained overstory hardwoods (mostly oaks and hickories). An 864-ha single-tree selection unit was also thinned to 13.8 m^2/ha of overstory BA with 2.3 m^2/ha of that being retained hardwoods. Both of the previous 2 treatments underwent partial midstory removal whereby most hardwoods $<$ 15 cm dbh were felled. The study area also contained a 1044-ha group selection unit where openings of 0.40 to 4.05 ha were created in the forest canopy; pines in the forest matrix surrounding those openings were thinned to about 16.0 m^2/ha of overstory BA, but no hardwoods were removed in the matrix. A 1791-ha unit was managed using a mix of treatments and silvicultural systems, including single-tree selection, group selection, and seed-tree cuts in stands of approximately 16 ha. Single-tree selection, group selection, pine woodland restoration areas, and the mixed-management area were all prescribe burned in winter 2000–2001. Harvested stands on Forest Service lands contained unharvested 15–50-m wide buffer strips (greenbelts) around stream drains for water-quality protection. Greenbelts were typically mixed pine-hardwood or hardwood forest containing mature ($\geq$50 years old) trees and no cutting or midstory removal was conducted in greenbelts. The basin also contained an 836-ha, largely untreated area consisting mostly of mature, second-growth pine-hardwood timber. Throughout the basin, unharvested stands were interspersed among these treatment units. Thus, with its silviculture treatment units, untreated areas, and industrial plantations, the Winona Basin contained most of the predominant forest types and forest management practices that existed in the Ouachita Mountains.

2.2. Bat capture and radiotelemetry

We captured red bats between 21:00 and 01:30 h CST using 3–8 mist nets (2.6–12.0 m wide $\times$ 2.6 m tall) at 10 trapping locations distributed throughout the study area. Age (juvenile or adult) was assessed based on degree of ossification of metacarpal–phalanx joints (Racey, 1974) and female reproductive condition was determined by abdominal palpation and by mammae inspection. We followed the guidelines of the