

INDIANA BAT, *MYOTIS SODALIS*, MATERNITY ROOSTS IN THE SOUTHERN UNITED STATES

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ABSTRACT - We characterized Indiana bat (*Myotis sodalis*) roosting habitat at three maternity colony sites in western North Carolina and eastern Tennessee. Using radio telemetry, we tracked six bats a total of 40 bat days (range 4-9 days/bat). In 1999, we located a primary roost in an eastern hemlock (*Tsuga canadensis*) snag (109 cm DBH) in the Nantahala National Forest, NC. In 2000, we located a primary roost in a pine (*Pinus* sp.) snag (39 cm DBH) in Great Smoky Mountains National Park (GSMNP), TN. Another primary roost was found in a pitch pine snag (*P. rigida*; 55 cm DBH) in GSMNP in 2001. Largest exit counts for the three colonies were 28, 23, and 81 bats. Primary roost sites were exposed to direct sunlight during most of the day. We also located six alternate roost trees: three pine snags, two red oak (*Quercus rubra*) snags, and one live sweet birch (*Betula lenta*). All three primary roosts located in this study were not used during subsequent summers. The eastern hemlock used in 1999 was still standing as of June 2001, while the two primary roosts in GSMNP had fallen within a year of being located. These records represent one of the first descriptions of Indiana bat maternity habitat in the southern United States.

INTRODUCTION

The Indiana bat (*Myotis **sodalis*** Miller and Allen), listed as federally endangered in 1967, continues to experience a rapid population decline (U.S. Fish and Wildlife Service 1999). Indiana bats hibernate in relatively few caves, most in Kentucky, Missouri, and Indiana (US Fish and Wildlife Service 1999). Limited evidence from band recoveries suggests that most females move north from hibernacula to establish maternity colonies of 25-100 individuals (Hall 1962, Kurta 1980, Laval and Laval 1980). Movements of more than 500 km from hibernacula to maternity sites are documented (Kurta and Murray 2002).

Most known maternity sites have been located in forested tracts in agriculturally dominated landscapes (e.g., Missouri, Iowa, Indiana, Illinois) (US Fish and Wildlife Service 1999); however, maternity colonies recently have been reported in heavily forested mountainous areas of western North Carolina and eastern Tennessee (Harvey in press). Colonies generally are found under the loose bark of dead or dying trees, but roosts also have been found in tree cavities (Gardner et

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al. 1991, Kurta et al. 1993a). Indiana bat maternity colonies generally use both primary and alternate roost trees (Callahan et al. 1997, Kurta et al. 1996).

A research priority and management goal for the Indiana bat is to identify and characterize maternity habitat (US Fish and Wildlife Service 1999). Because there was a paucity of information on maternity habitat, especially in the southern United States (US Fish and Wildlife Service 1999), we initiated a study to characterize Indiana bat maternity habitat in that portion of the range. Harvey (in press) briefly described roosts used by three maternity colonies in eastern Tennessee and western North Carolina. Here, we provide a detailed description of the characteristics of roosts used by these colonies as well as a description of the habitat surrounding the roost trees.

METHODS

During the summers of 1999, 2000, and 2001, Indiana bats were captured in mist nets (Avinet, Inc., Dryden, NY) at four sites in the Nantahala National Forest (NNF) in western North Carolina and Great Smoky Mountains National Park (GSMNP) in eastern Tennessee. At each site, 1-4 nets were erected over streams and road corridors. Nets were opened at sunset and monitored at 15-minute intervals for 5 hours past sunset or until activity dropped. Captured bats were identified, sexed, aged, measured (forearm length, mm), and weighed (g). Bats were then banded with either a numbered yellow plastic band (Avinet, Inc., Dryden, NY), or an aluminum lipped band (Lambournes, Ltd., Leominster, England) with "TN Tech U" inscribed on the band. Transmitters (Holohil Systems, Ltd.; Ontario, Canada) weighing 0.5 g were attached to the back of selected bats using surgical glue (Skin-Bond Cement, Smith and Nephew, Inc., Largo, FL). Bats were held for 15 minutes to allow the glue to dry, then released at the point of capture.

Bats were tracked daily using a 3-element Yagi antennae and TRX-10000 receivers (Wildlife Materials, Inc., Carbondale, IL) until a transmitter ceased functioning, the bat shed the transmitter, or the bat had moved out of the area. For each roost tree, we recorded species, status (alive or dead), % bark remaining, diameter at breast height (DBH) (cm), and height (m). We also recorded species, DBH, relative height (above or below the roost site), and status of all trees within an 8-m radius circular plot (0.02 ha). We initially measured canopy cover using a spherical densiometer; however, we felt that these measurements did not accurately reflect cover at the roost site. Instead we classified each tree surrounding the roost tree as being above or below the roost site. Due to small samples sizes, the differences in roost

characteristics between primary and alternate roost trees were not statistically compared.

We determined the location of each roost tree with a GPS unit (Trimble Pathfinder Pro XR, Sunnyvale, CA) and entered these data into ArcView 3.2 (ESRI, Inc., Redlands, CA). Tree locations were overlaid on the GIS habitat association maps obtained from GSMNP and the NNF to determine habitat type of each stand containing the roost trees. We also determined dominant tree species (based on basal area) in each stand from the 0.02 ha plot surrounding the roost tree and another randomly located 0.02 ha plot within the stand. Exit counts were conducted at roost trees as time allowed. Counts lasted until 10 minutes after the last bat exited or it was too dark to see emerging bats.

Because two of three colonies were relatively small, we modified the definition of primary and alternate roosts described by Callahan et al. (1997). Our primary roosts were trees that were used for more than two bat days (one radio-tagged bat located for one day equals one bat day) by each colony, while alternate roosts were used for shorter periods of time. Indiana bats have been shown to exhibit strong philopatry to the summer maternity areas (Callahan et al. 1997, Gardner et al. 1991, Humphrey et al., 1977, Kurta and Murray 2002). We therefore assumed that roost trees found in the same area during 2000 and 2001 represented roost sites of the same maternity colony. This allowed us to designate the roosts as primary and alternate for this colony based on the criteria above.

RESULTS

Sixteen *sodalis* (eleven adult females, three juveniles, and two adult males) were captured during the three summers. Radio transmitters were attached to six **bats** (five adult females and one juvenile male) that were tracked for a total of 40 bat days (4-9 days / bat). We located roosts under exfoliating bark of eight roost trees associated with three maternity colonies (Table 1). The NNF colony was located in 1999, and a colony in GSMNP (1) was found in 2000. Three alternate roosts were located for GSMNP 2 during 2000, while the primary roost tree was found in 2002. All primary roosts were located in conifer snags, while all alternate roost trees except one were in pine (*Pinus*) or red oak (*Quercus rubra*) snags (Table 1).

Tracking revealed a large number proportion of the bat days for each colony were spent in the primary tree (Table 1). Overall roost switching was low with an average of a roost switch every 5.7 days. This number would likely be much higher except for one individual from the GSMNP 2 colony that switched roosts two times in four days. Exit counts

conducted after young became volant revealed largest colony sizes for each colony ranging from 23 (GSMNP 1) to 81 (GSMNP 2; Table 1).

Primary roost trees were larger in diameter and taller than the alternate roost trees utilized by the same colony (Table 1). Density of trees was higher around primary roosts, and primary roosts were generally taller than surrounding trees while alternate roost trees were generally shorter than surrounding trees (Table 2). Both primary and alternate roost trees were larger in diameter than surrounding trees (Table 2).

Most of the roosts were mid- to upper slope although the NNF trees and alternate roost for GSMNP 1 were along streams. The NNF primary and alternate trees were in a stand that was classified as hemlock-

Table 1. Characteristics of Indiana bat maternity roosts in the Nantahala National Forest (NNF) and Great Smoky Mountains National Park (GSMNP). A single bat with a radio transmitter spending a single day in a roost was considered 1 bat day. Trees were designated as primary (P) or alternate (A) roosts. Percentage bark indicates the amount of all bark remaining on the tree. Colony size is the range in number of bats observed during exit counts. Number in parenthesis indicates number of counts made.

Site	Species	Alive or snag	Roost type	# Bat days	DBH (cm)	Height (m)	% Bark	Exit counts
NNF	<i>Tsuga canadensis</i>	Snag	P	4	109	28	75	25-28 (3)
	<i>Betula lenta</i>	Alive	A	2	49	17	90	---
GSMNP 1	<i>Pinus</i> sp.	Snag	P	20	39	19	5	10-23 (4)
	<i>Quercus rubra</i>	Snag	A	1	26	9.5	90	4 (1)
GSMNP 2	<i>P. rigida</i>	Snag	P	9	55	23	50	0-81 (9)
	<i>P. echinata</i>	Snag	A	1	35	19	10	1 (1)
	<i>P. echinata</i>	Snag	A	1	46	10	45	
	<i>Q. rubra</i>	Snag	A	2	33	21	5	---

Table 2. Characteristics of Indiana bat maternity habitat in a 0.02 ha plot surrounding primary and alternate roost trees. Data have been standardized to a 1-ha plot to facilitate comparisons with other studies. Means \pm 1 standard error are presented.

Habitat Characteristics	Primary Roosts (n = 3)	Alternate Roosts (n = 5)
Total number of trees (live & dead)	467 \pm 142	330 \pm 25.5
Number of conifers	133 \pm 109	140 \pm 36.7
Number of hardwoods	333 \pm 44.1	190 \pm 24.5
Number of live trees	383 \pm 60.1	280 \pm 33.9
Number of snags	83.3 \pm 83.3	50 \pm 27.4
Number of trees above top of roost tree	33.3 \pm 33.3	210 \pm 64
Number of trees below top of roost tree	433 \pm 164	12056.1
Proportion of trees above top of roost tree	0.07	0.64
DBH of all trees (cm)	21.6 \pm 3.0	22.1 \pm 3.5
DBH of conifers (cm)	21.6 \pm 7.3	23.5 \pm 4.6
DBH of hardwoods (cm)	21.6 \pm 3.2	21.0 \pm 5.1
DBH of live trees (cm)	23.5 \pm 3.6	21.2 \pm 4.0
DBH of snags (cm)	13.0 \pm 0.8	27.2 \pm 4.8

hardwood; dominant trees were eastern hemlock (*Tsuga canadensis*), Fraser magnolia (*Magnolia fraseri*), and sweet birch (*Betula lenta*). The stand containing the GSMNPI primary roost was classified as a pine stand. However, the stand had experienced a recent blow-down and contained few remaining standing pines. The roost tree was on the edge of the stand next to a mixed mesic oak stand. Dominant trees in the vicinity of the roost were eastern hemlock and red maple (*Acer rubrum*). The stand containing the GSMNPI alternate roost was classified as a pine stand; dominant trees were shortleaf pine (*P. echinata*), eastern hemlock, and sourwood (*Oxydendrum arhoreum*). The primary roost for GSMNP2 was in a stand classified as pine; dominant species were pitch pine (*P. rigida*), chestnut oak (*Q. prinus*), Virginia pine (*P. virginiana*), and black tupelo (*Nyssa sylvatica*). The two pines used as alternate roosts were also in stands classified as pine; dominant trees were shortleaf pine in one stand and white pine (*P. strobus*) in the other stand. The red oak alternate roost was in a stand dominated by yellow poplar (*Liriodendron tulipifera*) and white pine.

DISCUSSION

Most roost trees (6/8) located in this study were in conifer snags, including all three primary roosts. Although male Indiana bats have been found roosting in pine snags during summer (Gumbert 2001), this study documents the first use of conifers by Indiana bat maternity colonies. The use of pine/hardwood habitats is markedly different than habitat use reported in other studies of Indiana bat maternity colonies (Callahan et al. 1997, Gardner et al. 1991, Humphrey et al. 1977, Kurta et al. 1996). Unlike areas considered to be in the more typical maternity range (Iowa, Missouri, Indiana, etc.), this region of eastern Tennessee and western North Carolina is > 99% forested and is categorized as temperate rain forest (Harvey in press). The presence of Indiana bat maternity colonies in this area and in these types of habitats expands the distribution of potential maternity habitat.

Exit counts revealed that colonies roosted in locations above the surrounding canopy. Thus, measurement of canopy cover taken from the ground can grossly overestimate actual canopy cover at the roost site. Primary roost trees were generally taller than surrounding trees (Table 2), consistent with other studies that have found female Indiana bat roosts are often exposed to direct sunlight (e.g., Callahan et al. 1997, Kurta et al. 1993a, 1993b). Increased temperature inside roosts has been shown to speed development of young bats (Racey 1982). Sun exposure may have been particularly significant at the NNF site, as the colony was located at an elevation of 1158 m, significantly higher than reported elsewhere throughout the species' range (Harvey, in press). In addition

to increased solar exposure, taller trees provide relatively unobstructed flight paths to the roost site, which may be particularly important as young become volant.

While the habitat surrounding roost trees was different than other reported maternity habitat, characteristics of roost trees were similar. As in this study, a majority of roosts used by this species were under exfoliating bark of dead or dying trees (Callahan et al. 1997, Gardner et al. 1991, Kurta et al. 1996, US Fish and Wildlife Service 1999). Thus, maternity colonies in western North Carolina and eastern Tennessee were utilizing roosts with similar characteristics to maternity colonies in other portions of the species' range, despite the differences in habitat type used. These similarities serve to de-emphasize the importance of tree species or habitat type, while emphasizing the importance of structural characteristics of roost trees.

Radio-tracking revealed few roost switches for tagged bats (switch every 5.7 days). Five of the six bats tracked spent a large percentage of time in primary roost trees (Table 1), thereby demonstrating more loyalty to primary roosts than previously reported (Callahan et al. 1997, Gardner et al. 1991, Kurta et al. 1996). Frequent roost switching has been proposed to benefit females by allowing them to locate suitable roost sites in an area, should the primary roost become uninhabitable (Kurta et al. 1996). Roost fidelity has been shown to be negatively correlated with availability (Lewis 1995). Brigham (1991) found that when roost sites were limited, big brown bats rarely switched roosts, while in areas with numerous roosting options, they switched roosts every 2.5 days. Thus, one possible explanation for the lack of movement in our study was a limited availability of roost sites. However, observations of the study area suggest that there were numerous potential roost trees, although their suitability is unknown. Further study is needed to determine the causes of low roost switching in this area.

Since this was a multi-year project we were able to track the condition of some of the roost trees used in previous years. In 2000, the eastern hemlock (NNF) was still standing, but had decayed extensively during the previous year. The tree was monitored on more than 10 occasions between 22 May and 8 July, but no bats were observed emerging. An extensive survey effort within 2 km of the roost tree using mist nets and acoustic sampling with the Anabat II bat detector system (Titley Electronics, www.titley.com.au) in the vicinity of this roost failed to verify the presence of Indiana bats in the area. Both the primary roost tree used by GSMNP 1 in 2001 and the red oak alternate roost associated with GSMNP 2 fell during the winter of 2000-2001. Extensive use of capture and acoustic techniques during the summer of 2001 failed to locate a maternity colony in the area of

GSMNP 1. Additionally, the primary roost for GSMNP 2 had fallen during the winter of 2001-2002. These data emphasize the ephemeral nature of roost trees used by Indiana bats (Gardner et al. 1991, Humphrey et al. 1977).

This study provides the first descriptions of Indiana bat maternity habitat in the southern United States, and is the first to document the common use of conifers by maternity colonies. This study was conducted outside the previously identified maternity range and habitats used by Indiana bats. Thus, further efforts should be made to locate maternity colonies in areas previously thought to be outside the known maternity range of this species.

ACKNOWLEDGMENTS

This study was funded by the U.S. Forest Service, National Forests in North Carolina; National Park Service, Great Smoky Mountains National Park; Tennessee Wildlife Resources Agency, under Section 6 of the Endangered Species Act of 1973 (PL93-205); and the Center for the Management, Utilization, and Protection of Water Resources, Tennessee Technological University. We thank the numerous individuals who assisted in fieldwork, especially R. Currie, R. McClanahan, and B. Stiver.

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