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Internal Cavity Characteristics of Northern Long-eared Bat (*Myotis septentrionalis*) Maternity Day-roosts

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Abstract

We report characteristics of seven tree cavities used as day-roosts by female northern long-eared bats (*Myotis septentrionalis*) during the maternity season in a deciduous forest in north-central Kentucky. Understanding the characteristics of cavities selected by bats will help us better understand the ecology of cavity roosting bats and the tree species and condition necessary for providing day-roost habitat. Cavity openings were created by either fungal decay or primary excavators. Length and volume of cavities were positively related to number of entrances. Mean area of entrances was positively related to the proportion of entrances created by primary excavators.

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Cover Photo

A white oak (*Quercus alba*) snag provides roosting opportunities for female northern long-eared bats on the Fort Knox Military Reservation, Kentucky, USA. Photo by Alexander Silvis, Virginia Tech, used with permission.

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INTRODUCTION

Preservation of day-roosting habitat has been a focus of bat conservation in forested ecosystems and considerable effort has been undertaken to understand habitat selection at scales ranging from individual trees to whole landscapes (Brooks and Ford 2006, Kalcounis-Rüppell et al. 2005, Perry et al. 2007). Bats select roosts based upon environmental constraints that affect physiology, and habitats used by tree-roosting bats vary widely among species and types of forests (Grindal et al. 1992, Lourenço and Palmeirim 2004) and sociality (Chaverri et al. 2007). Most studies on selection of day-roosts by myotine bats have focused on characteristics of the external (tree) and surrounding forest (Kalcounis-Rüppell et al. 2005, Miller et al. 2003). Although such metrics may be useful for understanding selection of habitat and for identifying suitable roost trees, they likely may not address the full set of characteristics bats may use to select roosts, particularly for cavity roosting species (Boyles 2007).

Many species of bats roost in cavities in live trees and snags (Kunz and Lumsden 2003). However, such cavities generally are not easily accessible to researchers, so data on their characteristics are limited (Parsons et al. 2003, Ruczyński and Bogdanowicz 2005, Sedgeley and O'Donnell 1999, Sedgeley 2001). In eastern North America, only the cavities used by Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) and the southeastern myotis (*Myotis austroriparius*) have been described in appreciable detail; both of these species roost in large bald cypress (*Taxodium distichum*) or water tupelo (*Nyssa aquatica*) trees with hollow boles that are relatively accessible by researchers (Gooding et al. 2004, Trousdale et al. 2008). Similarly, relationships between bats and fungi that decompose wood and primary excavators are poorly understood (Parsons et al. 2003). Although the sources of cavities used by bats have been recorded (Il'in 1998, Kalcounis and Brigham 1998, Psyllakis and Brigham 2006, Vonhof and Gwilliam 2007), it is unclear how primary excavators and fungal decay interact to create potential roosts for bats (Jackson and Jackson 2004).

As part of a larger study on the social ecology of northern long-eared bats (*Myotis septentrionalis*) in deciduous forests of central Kentucky (Silvis et al. 2012, 2014), we had the opportunity to remove and examine day-roosts that were used during the previous maternity season. In this report, we describe cavity characteristics and document cavity origin and volume.

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MATERIALS AND METHODS

The study was conducted on the Fort Knox military reservation in Meade, Bullitt, and Hardin Counties, Kentucky. The forest cover on the reservation is predominantly a western mixed-mesophytic association (Braun 1950), with second-growth and third-growth forests dominated by white oak (*Quercus alba*), black oak (*Q. velutina*), chinkapin oak (*Q. muehlenbergii*), shagbark hickory (*Carya ovata*), yellow-poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), and American beech (*Fagus grandifolia*) in the overstory. Sassafras (*Sassafras albidum*), redbud (*Cercis canadensis*), and sugar maple (*Acer saccharum*) dominate the understory (Cranfill 1991). We captured northern long-eared bats between May and August 2011. We attached LB-2 radiotransmitters (0.31 g; Holohil Systems Ltd., Woodlawn, ON, Canada) between the scapulae of female northern bats using Perma-Type surgical cement (Perma-Type Company Inc., Plainville, CT, USA). Bats were released at net sites after a few minutes of capture. Methods followed the guidelines of Virginia Polytechnic Institute and State University Institutional Animal Care and Use Committee permit 11-040-FIW.

Using TRX-1000S receivers and folding three-element Yagi antennas (Wildlife Materials Inc., Carbondale, IL), we located day-roosts daily for the life of the transmitter, or until the unit dropped from the bat. We uniquely marked each female northern long-eared bat day-roost and recorded species of tree; diameter at breast height (d.b.h.); height; and crown class (Nyland 1996; i.e., 1 = suppressed, 2 = intermediate, 3 = codominant, 4 = dominant), and decay class (Cline et al. 1980; e.g., 1 = live, 2 = declining, 3 = recent dead, 4 = loose bark, 5 = no bark, 6 = broken top, 7 = broken bole). We also visually estimated percent of remaining bark.

During the winter of 2011-2012 when bats were hibernating and trees were not occupied by bats, we felled 14 day-roosts from the previous maternity season and selectively extracted the portion of the bole that contained cavities. Day-roosts were selected to meet the needs of a concurrent study on sociality and represent highly used roosts. We restricted our analyses to descriptive statistics because of our small sample size. Cavities used as roosts were classified following the method of Sedgeley and O'Donnell (1999) as knothole in large branch, knothole in trunk, trunk hollow, or basal hollow. Day-roost cavities were accessed by splitting boles along their axis using a band saw. We measured cavity entrance area using the formula for the area of an ellipse, $A = \pi dh$. We measured cavity volume by incrementally adding known quantities of water to each side of the bole and recording the total final volume added to the cavity. To prevent water from being absorbed into the tree bole or escaping through exterior entrances, cavities were first lined with a thin, conformable plastic sheet. We also measured cavity length and derived cavity diameter from volume and length measurements using the equation for the volume of a cylinder, $V = \pi r^2 h$. We visually assessed the relationships among sets of cavity characteristics by plotting variable pairs. All analyses were performed using the R statistical program (R. Development Core Team 2013).

RESULTS

We captured 58 female northern long-eared bats and located 108 day-roosts. Of the 14 maternity day-roosts that were felled, only 7 had boles (6 sassafras and 1 black locust [*Robinia pseudoacacia*]) that remained intact after felling. Mean roost d.b.h. was 19.8 (± 1.5) cm; mean height was 13.1 (± 3.5) m. Bark covered an average of 61.1 (± 42.3) percent of roost surfaces. All roosts were in suppressed canopy positions and were between decay stages 2 and 5. Overall, cavities had a mean (± standard deviation) volume of 1,069 (± 672) cm^3 and a mean length of 29.11 (± 16.7) cm. Average cavity diameter was 6.90 (± 1.5) cm. Felled day-roosts contained a mean of 3.43 (± 2.0) entrances with a mean entrance area of 61.5 (± 63.9) cm^2 (Table 1). All cavity entrances were created by woodpeckers (54.6 ± 40.4%) or decay (45.4 ± 40.4%) at knotholes.

Several cavity characteristics appeared to be related among themselves. Length and volume of cavity increased with the number of entrances (Fig.1). Mean entrance area increased with the proportion of entrances created by woodpeckers (Fig. 2). All cavities showed

Table 1.—Measurements of day-roost cavities used by female northern long-eared bat (*Myotis septentrionalis*) on the Fort Knox military reservation in Hardin, Bullitt, and Meade Counties, Kentucky, during 2011. All day-roosts contained only one cavity and were overtopped by larger trees in more dominant canopy positions. Sassafras (*Sassafras albidum*) = SAAL. Black locust (*Robinia pseudoacacia*) = ROPS. Mean entrance area reported is across all roost entrances.

Roost	Species	d.b.h. (cm)	Height (m)	Decay Class	Percent Bark	Cavity Type	Cavity Volume (mL)	Cavity Length (cm)	Cavity Diameter (cm)	Ant Activity Level	Total Entrances	Woodpecker Entrances	Decay Entrances	Mean Entrance Area (cm^2)
1	SAAL	28.9	15.3	4	45	trunk hollow	650	13.5	7.8	medium	2	1	1	11.3
2	SAAL	14.6	9.1	3	90	trunk hollow	540	29.5	4.8	high	4	0	4	14.6
3	SAAL	17.1	10.2	2	95	trunk hollow	405	15.5	5.8	low	2	2	0	171.0
4	SAAL	17.8	17.9	5	5	trunk hollow	1850	57	6.4	medium	5	4	1	59.3
5	ROPS	18.9	13.7	2	98	trunk hollow	2150	45	7.8	medium	7	6	1	129.8
6	SAAL	24.9	15.8	3	90	trunk hollow	910	29	6.3	medium	3	2	1	19.8
7	SAAL	16.2	9.6	5	5	knot hole in trunk	975	14.2	9.3	high	1	0	1	25.0

evidence of ant (family: Formicidae) activity through presence of serpentine galleries, usually within the bottom portion of the cavity (Fig. 3). Volume of cavity exhibited no apparent relationship with stage of roost decay or percent remaining bark.

DISCUSSION

Similar to the patterns of decay observed in other wildlife cavity trees (Zahner et al. 2012), the decay that we observed was confined largely to central and outer portions of the bole. However, because we were able to examine only those trees that did not break when felled, our results may be biased toward confinement of decay in the central portion of the bole. For all trees examined, the remaining sapwood was remarkably sound and free of decay, despite the obvious presence of serpentine galleries created by ants. Contrary to our expectations, the relative level of ant activity did not appear to be related to volume of cavity. Although our use of plastic as a cavity liner prevented us from accounting for the volume of serpentine galleries created by ants, these galleries did not constitute "usable" space by bats. Usable space appeared to be unrelated to ant activity; however, the additional volume in these ant galleries may affect the thermal properties of the cavity (Burcham et al. 2012). Additionally, it is possible that presence of ants may affect bats directly; antagonistic behavior between evening bats (*Nycticeius humeralis*) and carpenter ants (*Camponotus floridanus*) has been documented (Bender et al. 2009) although the direct interaction between bats and ants is largely unknown.

Of the cavity entrances we examined, approximately half were created by primary excavators, i.e., woodpeckers. Across forested ecosystems, the percentage of excavated cavities is indicative of the number of cavity trees within a forest stand. The percentage of excavated cavities versus cavities from other origins generally is high when the total number of cavities per hectare is small, and low when the number of cavities is high (Remm and Lõhmus 2011). Used with current methods of estimating roost availability, recording the proportions of entrances of bat roosts created by primary excavators may help us better understand the availability of roosts for bats that roost in tree cavities.

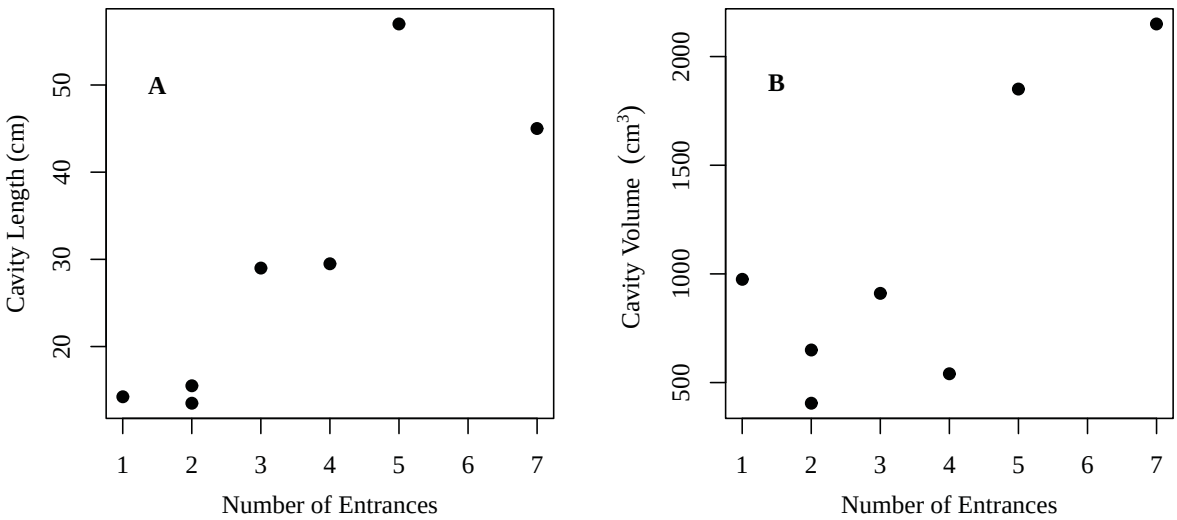

Figure 1.—Relationship between the characteristics of seven cavities used as maternity day-roosts by northern long-eared bats (*Myotis septentrionalis*) in 2011on the Fort Knox military reservation in Hardin, Bullitt, and Meade Counties, Kentucky. **A** shows the relationship between cavity length and number of entrances. **B** shows the relationship between the number of entrances and cavity volume.

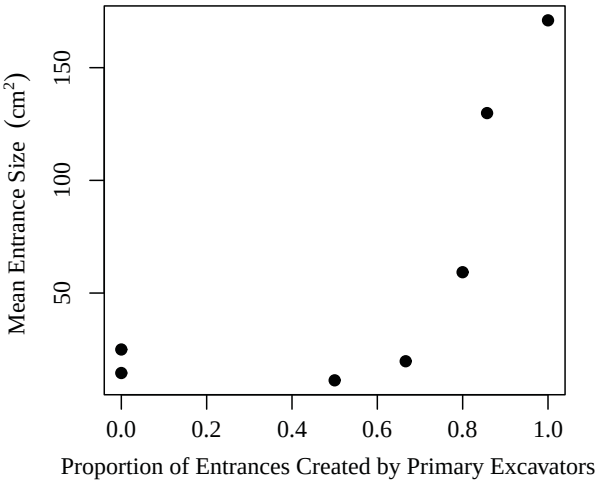

Figure 2.—Relationship between mean size of entrance and the proportion of entrances created by primary excavators for seven cavities used as maternity day-roosts by northern long-eared bats (*Myotis septentrionalis*) in 2011 on the Fort Knox military reservation in Hardin, Bullitt, and Meade Counties, Kentucky.

Figure 3.—Representative cavity in a sassafras (*Sassafras albidum*) bole used as a maternity day-roost by northern long-eared bats (*Myotis septentrionalis*) on the Fort Knox military reservation in Hardin, Bullitt, and Meade Counties, Kentucky, during 2011. Each side of the scale on left is 66.5 cm.

We observed a trend of increased area of entrances with increased previous activity by primary excavators. Whether increased entrance area benefits northern long-eared bats or not is unclear, but increased entrance area may increase susceptibility to predators (Sparks et al. 2003) and roost competitors such as the southern flying squirrel (*Glaucomys volans*). Furthermore, area of entrances affects thermal conditions in the cavity (Coombs et al. 2010). Both factors have been observed to affect roost selection by other bat species (Lourenço and Palmeirim 2004, Sedgeley 2001, White and Jones 2004).

For cavity roosting bats, merely quantifying the external metrics of day-roosts fails to describe the total variation in day-roost resources used (Boyles 2007). Although tree cavities used by bats are difficult to measure, a better understanding of cavity microclimatic and physical characteristics is needed. Furthermore, increased understanding of the criteria bats use to select roosts, by improving efforts to distinguish node and primary day-roosts (Johnson et al. 2012), may offer greater insight into non-random social assortment by bats (Kerth 2008, Rhodes 2007). If influences of cavity characteristics on suitability of day-roosts could be adequately described, it also may be possible to create artificial cavities in standing trees for species that rarely use bat boxes, such as the northern long-eared bat. Manual cavity creation is a management technique that has been used successfully with the endangered red-cockaded woodpecker (*Picoides borealis*) (Copeyon 1990). Additionally, it also may be possible to achieve similar results using less intensive arboricultural techniques by strategically wounding live trees (Smith 2006).

Our data provide the first description of the characteristics of cavities used by northern long-eared bats, but should be interpreted cautiously because of our small sample size and variability among samples. Additionally, it is unclear how well our study sites on the Fort Knox military reservation represent forest conditions off base. We encourage further investigation of the characteristics of cavities used by bats.

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KEY WORDS: *Myotis septentrionalis*, cavity, roost characteristics, day-roost, northern long-eared bat, maternity, decay, roost formation, roost persistence

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