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Source: The American Midland Naturalist, 185(2) : 241-248

Published By: University of Notre Dame

URL: <https://doi.org/10.1674/0003-0031-185.2.241>

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Roost Use and Movements of Northern Long-Eared Bats in a Southeast Nebraska Agricultural Landscape

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ABSTRACT.—Bats are important bio-indicators of ecosystem health and provide a number of ecosystem services. White-nose Syndrome and habitat loss have led to the decline of many bat species in eastern North America, including the federally threatened northern long-eared bat, *Myotis septentrionalis*. White-nose Syndrome was only recently found in Nebraska, which lies on the western extent of this species geographic range. To better understand how this forest-dependent species persists in an agriculturally dominated landscape amid a growing number of pressures, we investigated the roosting habits of this bat at the Homestead National Monument of America, located in southeast Nebraska. We mist-netted bats on eight nights in 2019 (16 August–26 August) and caught 55 bats across five species, including five juvenile northern long-eared bats. We located five unique roosts between two juvenile radio-tracked bats; most of the female roosts were in anthropogenic structures and tree cavities within 0.23 km of capture, while most of the male roosts were in snags and tree cavities as far as 2.73 km from the capture site. Fence cavities were also used by other undocumented northern long-eared bats. We recorded three radio-tagged bats that commuted between roosting sites and capture sites within hours after sunset. Our results provide evidence that at the distributional edge for this species, wooded areas, riparian zones, and human-built structures in an intensively managed agricultural landscape are used by this imperiled species.

INTRODUCTION

Destruction of habitat is a primary cause for biodiversity loss (Tilman *et al.*, 2001; Prescott *et al.*, 2015). To feed increasing human populations, conversion of land to agriculture is likely to increase. Consequently, it is important to understand how wildlife exploits available resources to allow continued persistence in these human-modified landscapes.

The northern long-eared bat (*Myotis septentrionalis*) is a small, insectivorous species found throughout much of the eastern United States and Canada (Caceres and Barclay, 2000). These bats glean prey from surfaces and capture it airborne, allowing them to hunt within the complex structure of interior forest habitats to which they are mostly constrained (Patriquin and Barclay, 2003; Ratcliffe and Dawson, 2003; Henderson and Broders, 2008). Northern long-eared bats roost primarily in trees of a variety of types and stages, where females form maternity colonies and males tend to remain solitary (Foster and Kurta, 1999; Broders and Forbes, 2004; Carter and Feldhamer, 2005). Northern long-eared bats are particularly susceptible to White-nose Syndrome (WNS) (Blehert *et al.*, 2015; Frick *et al.*,

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2015) and no longer common throughout much of their range. Consequently, this species was listed as Threatened under the Endangered Species Act by the US Fish and Wildlife Service (FWS) in 2015 (US Fish and Wildlife Service, 2015).

Nebraska lies on the western periphery of the species' range and the fungus that causes WNS was recently detected in Nebraska (White-nosesyndrome.org, 2020). Our objective was to describe late-summer roosting habits in the state's intensively farmed landscape at the Homestead National Monument of America preserve and surrounding areas. Eastern Nebraska is unique in that this is the western limit of the species range, WNS was only documented recently in the region, and most available habitat is due to afforestation following European colonization (Geluso, 2006; Anderson *et al.*, 2017). Because relatively little is known about the ecology of this species in the Great Plains, examination of how these forest-dependent bats use an extremely fragmented agricultural environment will contribute to an understanding of the habitat needs for this species in peril.

STUDY AREA AND METHODS

Created in 1936, Homestead National Monument, a Unit of the National Park Service, is located in Gage County in southeast Nebraska's glacial Drift Hill Region, 40°17'16.8857"N, 96°50'1.9601"W. The park covers roughly 79 ha, about two-thirds of which is restored native tallgrass prairie, and one-third mature lowland forest along Cub Creek in the western portion of the park. The woodland consists mainly of cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), and oak (*Quercus* spp.). The restored prairie is primarily big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indiangrass (*Sorghastrum nutans*) (Robbins, 2005). Private agricultural lands surround the park, and are heavily managed for the production of corn and soybean.

Under FWS federal recovery permit TE02373A-14, we mist-netted for bats on eight nights from 16–24 August 2019 at four sites in forested areas. Each site consisted of 2–4 nets, placed along forest edges, park buildings, waterways, trails, or other spaces used as travel corridors by bats, and sampled one to three nights (Fig. 1). We assembled 2.6-m high black nylon 38-mm mesh bat nets (Avinet Research Supplies, Portland, ME, U.S.A.) that were 6–18 m long, in various stacked setups, depending on the flyway.

We netted each night for at least 5 h beginning at sunset. We checked nets at approximately 10 min intervals and recorded weight, right forearm length, age (degree of epiphyseal fusion), sex, reproductive condition (nipple hair for females, testes position for males), and wing damage index (Anthony, 1988; Haarsma, 2008; Reichard and Kunz, 2009) for each bat captured. Following the < 5% body weight rule for transmitters (Aldridge and Brigham, 1988), a permitted biologist radio tagged each northern long-eared bat with a Holohil radio transmitter (Holohil Systems Ltd., Carp, Ontario, Canada) with Perma-type adhesive (The Perma-Type Company Inc., Plainville, CT, U.S.A.) to track movements and locate daytime roosts. We searched for tagged bats primarily during the daytime using Lotek wireless Biotracker units (Lotek Wireless, Newmarket, Ontario, Canada) and a five-element Yagi antenna, mounted on a truck, driving roads within 4.8 km of the park boundary. After capturing three northern long-eared bats, we followed this same search procedure for two nights between sunset and 0300, using bi-angulation to approximate flying bat positions. For bats we did not detect, we continued searching at sunset and used a stationary antenna while netting to detect tagged bats. We terminated daily searches for bats undocumented after 1 wk and conducted an emergence count on the first night at each roost, lasting from 30 min before sunset until dark.

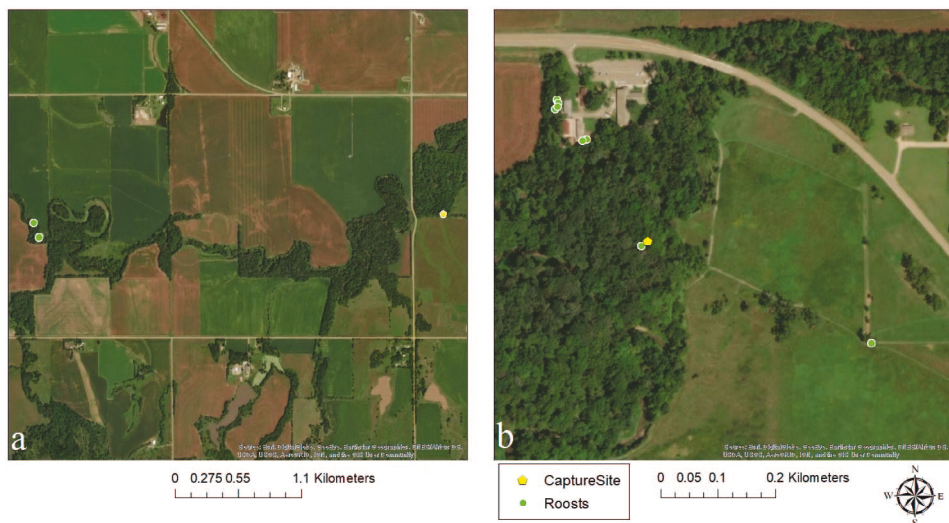


FIG. 1.—Capture and roost locations of northern long-eared bats at Homestead National Monument, Nebraska in August 2019: (1A) male capture and roost locations and (1B) female capture and roost locations. Roosts for the male were located on 18 and 19 August, and from 22 August to 2 September for the female.

RESULTS

We caught 55 bats across five species, including five northern long-eared bats. We radio tagged four female and one male non-reproductive, volant juveniles with nearly fused joints and no wing tissue damage. Of these, we tracked the male and one female to diurnal roosts. We failed to detect movement by two females within our search area, and were unable to locate any roosts for another female.

ROOSTS

We found two roosts used by the male. It first used a large slippery elm (*Ulmus rubra*) about 2.7 km west of the park, and the following day roosted under a raised slab of bark on a downed limb 0.1 km east of the elm roost (Table 1, Fig. 1A). This limb was charred by fire in a burned clearing between a corn field and the creek (Fig. 2A). This bat was in the same area the following day, but due to landowner access and personnel constraints, we did not identify additional specific roosts.

We located the one female in cavities beneath the trimmed top of a shadow box fence about 0.2 km from her capture site (Fig. 1B, Fig. 2B) on 6 of 8 d following capture. Once she shared a cavity with an unbanded, untagged northern long-eared bat (Fig. 2C), and twice we found only an unbanded, untagged northern long-eared bat in the fence as late as 10 September. For 1 d this female used a small cavity near the base of a young common hackberry 1 m from her capture site (Fig. 2D). She shed her transmitter 2 d later in the cavity of a large cottonwood 0.3 km east in the prairie portion of the park.

At each roost, we recorded habitat features including tree roost species, diameter at breast height (DBH), tree height, roost height, and percent canopy cover (Table 1). The four roost

TABLE 1.—Characteristics of roosts used by two volant young northern long-eared bats in Homestead National Monument, Nebraska, U.S.A., from 16 to 24 August 2019, including two roosts for a male and eight for a female. For fence roosts, bats occupied a new cavity each day

Roost species	Structure ht. (m)	Roost type	Roost ht. (m)	DBH (cm)	Canopy cover (%)	Days per roost	Tracked bat
<i>Ulmus rubra</i>	45	Unknown	25	74.8	25	1	Male
Burned snag	1.75	Bark	1.75	18.3	0	1	Male
Fence	1.82	Cavity	1.74	—	20	4	Female
<i>Celtis occidentalis</i>	6	Cavity	1	7.0	80	1	Female
Fence	1.67	Cavity	1.61	—	5	2	Female
<i>Populus deltoides</i>	30	Cavity/Unknown	12	65.3	25	Unknown*	Female

DBH = diameter at breast height; — = value not available; * = transmitter shed overnight

trees varied from 7–74.8 cm DBH ($\bar{X}$ = 41.4 cm) and each was a different species (Table 1). Roost heights were 1–25 m, and included live trees, downed material, and a synthetic fence. Both bats appeared to switch roosts almost every night, with the male and female using two and three structures, respectively. The female also occupied a different cavity on six occasions we found her in the fence.

EMERGENCE COUNTS AND MOVEMENTS

Emergence counts ranged from one to three bats. Larger trees typically had more counts. Except for one instance in the fence, we counted one emergence each survey at the fence and burnt snag. Due to the length of the fence, we were unable to view the entire structure each survey attempt.

On the day following capture, the male roosted 2.7 km west of the capture site. We detected the faint signal of a female further west, but did not locate her roost. After emergence that night, we failed to detect either of these bats until midnight, when both had returned to the park. By morning the following day, we found the male in a second roost 0.1 km east of the first roost, and bi-angulated him flying near the second roost at 0230 h.

After tagging, we tracked the last captured female throughout the remainder of the night until she roosted for the day in a fence 0.2 km from her capture site, where she also roosted the next night. For each of the next 3 d, she roosted no further than 0.2 km from the capture site and dropped the transmitter overnight in a tree 0.3 km away.

DISCUSSION

These data provide evidence that wooded areas, riparian zones, and human-built structures are used by this imperiled species in a Great Plains agricultural landscape. Eastern Nebraska is currently at the western edge of the spread of WNS, a disease known to cause steep recruitment declines of northern long-eared bats in areas following its arrival (Francl *et al.*, 2012; Reynolds *et al.*, 2016). Despite this, the presence of juveniles during our short study indicates successful reproduction in this area of Nebraska.

Although we captured no adult northern long-eared bats, it is possible adults already migrated from the area to hibernacula, where they gather for swarming in late August and September (Caceres and Barclay, 2000). In neighboring Otoe County, Stein and White (2016) documented a maternity colony from 21 June–8 October 2014, from which members began disbanding mid-August. However, White *et al.* (2017) documented northern long-



FIG. 2.—Roost sites of northern long-eared bats at Homestead National Monument, Nebraska in August 2019: (2A) burned snag, (2B) shadowbox fence, (2C) two northern long-eared bats in box fence, and (2D) hackberry cavity.

eared bats in nearby Sarpy County through early November, suggesting later migration. While known caves and mines in southeastern Nebraska are in Cass and Sarpy counties, where this species has been found year-round (Czaplewski *et al.*, 1979; White *et al.*, 2016), northern long-eared bats also use crevices in cliff and rock faces during winter, which are slightly more common and widespread in eastern Nebraska (Lemen *et al.*, 2016; White *et al.*, 2020).

Though both juveniles, the male used two roosts, each approximately 2.7 km from the capture site, but the female remained in close proximity to the park. While we did not locate the specific roosts, another tagged female traveled more than 2.7 km between roosting and foraging areas. For both tracked bats, distances between day roosts were under 0.1 km to 0.5 km, which is consistent with studies in eastern North America, where mean travel distances between summer roosts are usually less than 0.8 km, and generally within 0.7 km from the

point of capture (Carter and Felhamer, 2005; Broders *et al.*, 2006; Johnson *et al.*, 2009; Silvis *et al.*, 2016). In nearby Otoe County, Brack *et al.* (2019) documented distances of 3.4 and 2.1 km between capture sites and roosts of an adult non-reproductive female and an adult male, respectively, during summer, including traversing the Missouri River by the female. However, during autumn migration, a northern long-eared bat in nearby Sarpy County covered about 41 km in 2.8 h (White *et al.*, 2017).

Northern long-eared bats often switch roosts, primarily using snags, crevices, cavities, and exfoliating bark of a variety of tree species (Cryan *et al.*, 2001; Perry and Thill, 2007; Silvis *et al.*, 2012). We found 10 different roosts used within 0.1 km of Cub Creek on average, and only twice documented re-roosting on consecutive days by either bat. Like other studies (Patriquin *et al.*, 2016; Rojas *et al.*, 2017), we found roost use to be quite variable, including exfoliating bark on a burnt snag, a tree cavity, and multiple cavities of a shadow box fence. Stein and White (2016) found a maternity colony using cabins in southeastern Nebraska, perhaps driven by limited roost availability in a largely treeless landscape (Henderson and Broders, 2008), although the species readily uses bat boxes (Whitaker *et al.*, 2006). Although our night tracking data was limited, individuals appeared to remain in close proximity to the riparian woodland corridor when foraging, a behavior documented in other agricultural studies (Henderson and Broders, 2008).

Our data shed light on the late-summer roosting habits and movements of this threatened species at the western edge of its range. The number of northern long-eared bats we caught over our sampling period is similar to that of the previous study in the Homestead National Monument (Robbins, 2005), and indicates successful reproduction, despite a landscape dominated by agriculture and the arrival of WNS to the area. Because northern long-eared bats used a variety of mature and young snags for daytime roosts, we recommend against removal of woody debris and other dead vegetation from forested areas. Before European settlement, trees were naturally restricted to riparian areas in Great Plains states, and as such, these natural woodland corridor habitats should be maintained to facilitate bat movement through the landscape (Geluso, 2006; Anderson *et al.*, 2017). Anthropogenic structures also provide additional roosting opportunities for northern long-eared bats in Nebraska, and may prove vital for the persistence of forest-dependent bat species in landscapes with fewer tree roosts. Additional research is needed to understand the use of summer roosts and habitat by this declining species, at the edge of its range, on a landscape dominated by agriculture, to conserve this species in the face of rapid global change.

Acknowledgments.—This study was funded by the Homestead National Monument of America and is based upon work supported by the National Science Foundation under Grant No. DGE-1735362. Opinions, findings, conclusions, or recommendations are those of the author(s) and do not necessarily reflect views of the National Science Foundation. We obtained study approval from the University of Nebraska-Lincoln IACUC (project 1667), National Park Service scientific research and collecting permit HOME-2018-SCI-0002, and Nebraska Game and Parks scientific and education permit 1183-1. We thank park staff, especially M. Engler, J. Bolli, and J. Korgie for support, and the Nebraska Cooperative Fish and Wildlife Research Unit. We are grateful to B. Hale, A. Oetting, and Environmental Solutions & Innovations, Inc. for assistance in conducting surveys. We thank Associate Editor Dr. K. Powers, Dr. A. Silvis, Dr. V. Brack, and anonymous reviewers for comments that improved the manuscript.

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SUBMITTED 9 SEPTEMBER 2020

ACCEPTED 8 JANUARY 2021