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# DAY-ROOST SELECTION BY RAFINESQUE'S BIG-EARED BATS (*CORYNORHINUS RAFINESQUII*) IN LOUISIANA FORESTS

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Availability of bridge roosts is a poorly understood but possibly important component underlying abundance and distribution of the potentially threatened bat *Corynorhinus rafinesquii.* We analyzed structural characteristics and surrounding habitat of 81 bridges in west-central Louisiana forests to determine which attributes of bridges influenced the selection of roosts by *C. rafinesquii.* Type of support structure under bridges, material with which bridges were built, proportion of surrounding habitat composed of mature deciduous forest, and road surface of bridges were significantly associated with selection of roost sites. On average, bats tagged with radiotransmitters roosted under bridges 50% of the time and in black gum trees (*Nyssa sylvatica*) 50% of the time. Preservation of bridges with beam supports and conservation of mature deciduous forest are likely to be important for maintaining populations of *C. rafinesquii.*

Key words: bridges, *Corynorhinus rafinesquii,* day roost, roost selection, tree hollows

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Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) is an insectivorous vespertilionid that is indigenous to the southern United States. Although widespread in this region, *C. rafinesquii* is considered uncommon or rare throughout most of its range. Because availability of adequate roost sites may in large part determine abundance and distribution of many species of bats (Humphrey 1975; Kunz 1982; Lowery 1974), studies of roost-structure utilization by *C. rafinesquii* likely will be important to future conservation actions. Although records of roosts used by *C. rafinesquii* are scarce, these bats are known to roost in caves, hollow trees, and man-made structures such as barns and old homes (Clark 1990; Jones 1977; P. Horner and R. Maxey, in litt.). Anecdotal accounts indicate that *C. rafinesquii* prefers roosts that are spacious and partly lit (Barbour and Davis 1969).

Lance and Garrett (1997) reported the previously undescribed use of the undersides of bridges as day roosts by *C. rafinesquii.* However, many bridges they examined were not used as roosts. Furthermore, little information was available on what other structures might serve as roosts for *C. rafinesquii* in its study area, and hence little indication was available about the relative importance of bridge roosts to local populations of *C. rafinesquii.* To better understand use of bridges as day roosts, we expanded on the survey of bridges of Lance and Garrett (1997) and compared attributes of bridges that did and did not serve as roosts for *C. rafinesquii.* We also used miniature radiotransmitters to track daily movements of individual *C. rafinesquii* for the dual purposes of locating alternate day roosts and obtaining data on roost fidelity.

## MATERIALS AND METHODS

*Study area.*—Our study was conducted in the Kisatchie (Kisatchie Parish), Winn (Winn Par-

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ish), and Calcasieu (Vernon Parish and Rapides Parish) Ranger districts of the Kisatchie National Forest of west-central Louisiana. Data on bridges were collected in July–October, 1996–1998. Vegetation in the area consisted primarily of pine stands (*Pinus palustris* and *P. taeda*) in uplands and deciduous stands (e.g., *Quercus, Nyssa, Taxodium distichum*) along creek bottoms.

*Structural characteristics of bridges.*—Upon locating a bridge, we immediately surveyed the underside for presence of bats or bat feces. Most bridges were located within national forest boundaries, although some were in peripheral areas. Bridges were considered inaccessible when we could not view the entire underside of a bridge. Such situations occurred when, for example, no dry bank was present along the waterway as it passed under the bridge and water levels were too deep for wading. Culverts were located at some road and creek intersections; neither bats nor fecal droppings were ever observed inside those structures.

We categorized bridges according to whether they were made primarily of concrete (some bridges with concrete decks were supported with wooden piers) or creosote-treated wood. All wooden bridges were similar in structure and had road decks underlaid with longitudinal beams, with cross-beam supports at the piers. Two general styles of concrete bridges were recognized based on the type of structural support underlying the road deck. Decks of girder bridges were underlaid by narrow longitudinal beams, with cross-beams at the piers. Those longitudinal beams, known as T-beams or double T-beams, generally were shaped like the letter T, or like 2 connected letter Ts. The confluence of neighboring T-beams formed a longitudinal space or recess along the underside of the bridge and the underside of each girder bridge was characterized by numerous rows of those lengthwise recesses. Depending on size of the beam used in building a bridge, those recesses varied from 50 to 70 cm in width and from 50 to 75 cm in depth. The other general style of concrete bridge in the study area, known as a slab bridge, had road decks underlaid by rectangular, flat slabs, with cross-beams at the piers (Libby and Perkins 1976). Slab bridges, therefore, lacked recesses characteristic of girder bridges.

We also recorded if the surface of the road that crossed each bridge was gravel or pavement. In 1997, we classified bridges as having a north–south (315°–45°, 135°–225°) or east–west (45°–135°, 225°–315°) orientation. Several quantitative measurements were taken at each bridge, including total length of the bridge between abutments, greatest width of the bridge, and density of cover along the sides of the bridge. Width of the waterway was measured on both sides of the bridge and averaged. Amount of dry bank under a bridge was estimated by subtracting the average width of the waterway from the length of the bridge.

*Habitat characteristics.*—Density of cover was estimated using a 1-$m^2$ density board (Gysel and Lyon 1980) divided into one hundred 10-$cm^2$ squares. For estimation, the density board was placed about halfway between the abutment of the bridge and the stream and about 1 m away from the side of the bridge. An observer situated under the bridge and about 2 m directly in front of the board made a visual count of all squares that were completely or partially obstructed by vegetation or debris. One estimate was made for each side of the bridge and on each side of the creek for a total of 4 estimates. Those 4 estimates were averaged to obtain a mean density of cover for each bridge.

We quantified proportions of different habitat types within a 0.25-km radius of each bridge. Our data on habitat were based on information provided by United States Forest Service stand maps, which list dominant species of trees within each stand in the national forest and the year each stand was last replanted. We grouped stands into 4 general habitat types: mature deciduous (e.g., *Quercus, Liquidambar styraciflua, Nyssa sylvatica, T. distichum*), immature deciduous, mature coniferous (primarily *P. palustris* and *P. taeda*), and immature coniferous forest. Stands classified as mature by the United States Forest Service consisted of trees with an average diameter at breast height $\geq$ 28 cm.

To quantify the proportion of each habitat type within a 0.25-km radius (19.6 ha) of each bridge, we superimposed a circle containing 100 evenly spaced points over a stand map. With the bridge at the center of the circle, the number of points within each stand was counted and converted to a proportion of the total number of points. Points over streams and roads were assigned to the stand in which they were located. Points that fell on private land were not used in calculation of habitat types because no habitat information was available. Our decision to limit the scale of this analysis to a 0.25-km radius was based on the judgment that homogeneity of upland pine tracts at larger scales would statistically obscure associations between roost selection and habitat.

*Data analyses.*—Associations between roosting and qualitative characteristics of bridges (composition, structure, roadway surface, and orientation) were assessed with log-likelihood ratio tests (Sokal and Rohlf 1995). Differences in quantitative attributes of bridges (width, length, width of waterway, amount of dry bank, mean density of cover, and proportions of habitat types) with and without bats were evaluated using Wilcoxon 2-sample tests (Sokal and Rohlf 1995). To detect nonindependent variables, we conducted log-likelihood ratio tests of independence and Pearson correlation analyses to assess associations between those qualitative and quantitative attributes of bridges that were significantly associated with roosting. All statistical analyses were conducted using SAS (SAS Institute Inc. 1990).

The same analyses used to evaluate associations between bridge attributes and presence of bats under bridges were used to evaluate associations between bridge attributes and presence of feces under bridges. However, because we could not definitively ascertain which species had left the feces, and because results based on presence of feces were similar to results based on the presence of bats, we report only the latter.

Effects of various bridge attributes on the probability that a bridge would be used as a day roost were assessed with logistic regression analysis (Sokal and Rohlf 1995). The coefficient of determination that resulted from our logistic regression ($r^2_{adj}$) was adjusted so that its maximum value would equal 1, thereby placing it on the same scale as $r^2$-values from least-squares regression (Nagelkerke 1991). The goodness of fit of the logistic regression was evaluated by the method of Hosmer and Lemeshow (1989). Influences of different variables on the likelihood of bat roosting were expressed as odds-ratios (Sokal and Rohlf 1995). We employed a backward selection ($P = 0.05$) of all variables for the regression but excluded orientation because it was recorded for only a subset of bridges.

In August and September 1997, we used radiotelemetry to monitor use of roosts by *C. rafinesquii* on the western part of the Calcasieu Ranger District (Vernon Parish). We captured 9 adult female bats (average mass = 7.5 g) under 4 bridges using handheld hoop nets and attached LB-2 radio transmitters (≈0.45 g; Holohil Systems Ltd., Woodlawn, Ontario) to their dorsal surfaces using surgical glue. Bats were released a few hours later at the capture site. When possible, bats were located each day. The study was conducted in late summer, after juvenile bats had been weaned, so that stress to females would be minimal. However, because female bats without dependent young may exhibit patterns of roost fidelity different from those with dependent young, application of our results to pregnant and nursing females should be made with caution.

## RESULTS

We located 95 bridges and were able to access undersides of 81. We found feces under 51 of those bridges and observed bats roosting under 32. Bats roosted primarily over dry bank, usually in proximity to bridge abutments, and often in recesses that were centrally located relative to width of the bridge. Number of bats found under a bridge ranged from 1 to about 50, with bats often roosting in tight clusters. Although solitary *Pipistrellus subflavus, Myotis austroriparius,* and *Eptesicus fuscus* were at times found roosting under bridges, *C. rafinesquii* constituted >95% of observations.

*Corynorhinus rafinesquii* was never observed roosting under any of the 15 wooden bridges we surveyed but was observed under 32 of 66 concrete bridges, indicating an association between roost selection and the material with which bridges were built ($G = 17.260$, $d.f. = 1$, $P < 0.001$, $n = 81$). Because no bats were observed under wooden bridges, those bridges were excluded from subsequent analyses. Subsequent analyses, then, specifically addressed which factors affected selection of concrete bridges as roosts.

*Corynorhinus rafinesquii* was observed roosting under 31 of 52 girder bridges but was observed roosting under only 1 of 14 flat slab bridges, indicating an association between structure of bridges and roosting ($G = 14.078$, $d.f. = 1$, $P < 0.001$, $n = 66$).

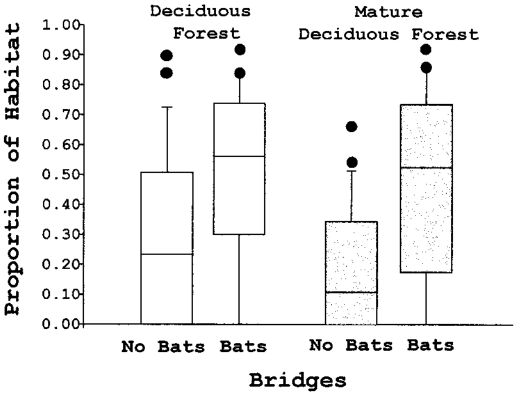

FIG. 1.—Box and whisker plots of proportions of deciduous forest (mature and immature stands) and mature deciduous forest in the habitat surrounding bridges where *Corynorhinus rafinesquii* was and was not observed to roost. Filled circles represent outliers (values beyond 90% of total distribution).

However, we found no associations between presence of *C. rafinesquii* and road surface ($G = 0.006$, *d.f.* = 1, $P = 0.938$, $n = 66$) or orientation of bridge ($G = 1.312$, *d.f.* = 1, $P = 0.252$, $n = 47$). We also found no differences in width ($T_{0.025} = 1{,}005.000$; *d.f.* = 32, 34; $P = 0.393$; $n = 66$), length ($T_{0.025} = 1{,}014.50$; *d.f.* = 32, 34; $P = 0.465$; $n = 66$), width of waterway ($T_{0.025} = 1{,}051.000$; *d.f.* = 32, 34; $P = 0.797$; $n = 66$), amount of dry bank ($T_{0.25} = 627.500$; *d.f.* = 28, 24; $P = 0.883$; $n = 52$), or density of cover ($T_{0.025} = 794.000$; *d.f.* = 33, 25; $P = 0.378$; $n = 58$) between bridges with and without bats.

Bridges where bats were observed to roost had a higher proportion of deciduous forest within the 0.25-km radius than bridges without bats ($T_{0.025} = 718.500$; *d.f.* = 29, 30; $P = 0.021$; $n = 59$; Fig. 1). Proportion of mature forest (coniferous and deciduous combined) surrounding a bridge was not associated with roosting ($T_{0.025} = 830.500$; *d.f.* = 29, 30; $P = 0.550$; $n = 59$). However, proportion of mature deciduous forest in the surrounding habitat was greater at bridges with bats than at bridges where no bats were observed ($T_{0.025} = 683.000$; *d.f.* = 29, 30; $P = 0.004$; $n = 59$; Fig. 1). Proportion of immature deciduous forest was not different for bridges with and without bats ($T_{0.025} = 864.000$; *d.f.* = 29, 30; $P = 0.915$; $n = 59$).

No association was found between structure of bridges and proportion of deciduous forest ($Z = -0.146$, $P = 0.6773$, $n = 59$) or mature deciduous forest ($Z = 0.280$, $P = 0.780$, $n = 59$) in areas surrounding bridges. Proportion of deciduous forest and proportion of mature deciduous forest were correlated ($r = 0.871$, $P < 0.001$, $n = 46$). That strong correlation, in concert with lack of significant association between roosting and immature deciduous forest, suggested that proportion of deciduous forest surrounding a bridge was a redundant measure and could be excluded from our logistic regression analysis.

Results of the logistic regression analysis indicated that probability of a concrete bridge being used as a roost by *C. rafinesquii* was influenced by bridge structure, road surface, and proportion of mature deciduous forest in the surrounding habitat ($r^2_{adj} = 0.399$, $n = 52$). The Hosmer and Lemeshow (1989) test did not indicate a lack of fit between the regression and data ($\chi^2 = 5.259$, *d.f.* = 7, $P = 0.628$). Based on odds ratios estimated from the logistic regression, girder bridges were 35 times more likely to serve as a roost than slab bridges and bridges crossed by gravel roads were 7 times more likely to be roosts than bridges crossed by paved roads. For every percent increase in surrounding mature deciduous forest, a bridge was 1.03 times more likely to be a used as a roost.

We were able to track radiotagged females to roost sites on 56 occasions (range = 2–10 observations/bat; Table 1). A majority of those occasions ($n = 45$) resulted from following 5 individuals, each located 7–10 times. We were able to identify 9 day roosts, including 5 bridge roosts (4 were sites where individuals originally were captured) and 4 roosts in tree hollows. All 4 tree roosts were in *N. sylvatica* (diameter at

TABLE 1.—Number of days that an individual *Corynorhinus rafinesquii* was located in tree roosts and bridge roosts.

| Bat number | Days at tree roosts | Days at bridge roosts | Proportion of days at bridge roosts |
|---|---|---|---|
| 246 | 4 | 7 | 0.64 |
| 264 | 0 | 11 | 1.00 |
| 304 | 0 | 2 | 1.00 |
| 344 | 6 | 2 | 0.25 |
| 368 | 8 | 2 | 0.20 |
| 387 | 3 | 2 | 0.40 |
| 409 | 1 | 1 | 0.50 |
| 425 | 0 | 2 | 1.00 |
| 465 | 0 | 8 | 1.00 |
| $\bar{X}$ | | | 0.63 |

breast height, 59–103 mm) in creek bottoms. Distance between any 2 roost sites used by a single individual varied from about 70 m to about 2.5 km. Of 17 occasions that bats captured together were both relocated, individuals were roosting at separate sites on 9 occasions. Overall, bats roosted under bridges a majority of the time (Table 1). Use of trees and bridges by individual bats varied widely, with some individuals roosting solely under bridges (Table 1).

## DISCUSSION

Use of bridges as day roosts by bats may be a common occurrence (Davis and Cockrum 1963, Pierson 1998). Davis and Cockrum (1963) observed that bats in the southwestern United States roosted in expansion joints, narrow slots between beams under wooden bridges, and in hollow areas behind abutments. However, neither use of relatively exposed interbeam spaces under concrete girder bridges as day roosts, nor the occurrence of this behavior in *C. rafinesquii,* had been reported previously.

Creosote-treated wood bridges were never used as roosts by *C. rafinesquii* in our study areas, but 48% of concrete bridges were used. Other species of bats that use human-made roosts have been shown to have preferences for stonelike substrates (concrete or brick) relative to wood substrates (Gerell 1985; Riskin and Pybus 1998). Alternatively, rather than preferring concrete bridges, *C. rafinesqii* may have avoided roosting under wood bridges. The creosote treatment of lumber used in construction of wood bridges leaves a pungent, tarlike substance on the wood.

Girder bridges were used more often as roosts than were slab bridges. Unlike slab bridges, girder bridges have interbeam recesses that may provide a protected, semienclosed area for roosting. Possible benefits of roosting in the interbeam recesses include reduced visibility to predators and microclimates that may enhance thermoregulation.

Bridges used by roosting *C. rafinesquii* tended to be in areas with higher proportions of mature deciduous forest than bridges that did not have roosting bats. This result agrees with the study by Clark (1990) of *C. rafinesquii* roosting in abandoned homes in South Carolina, which found that roosts were always located ≤1.0 km from standing water and in areas with a relatively high percentage of closed canopy bottomland forest. Potential roost sites within or near bottomland deciduous forest likely will be in the vicinity of naturally occurring *C. rafinesquii* roosts, such as hollow trees, and will have a relatively higher probability of being encountered and subsequently inhabited than roosts in other areas.

Probability of a bridge being used as a roost increased when a bridge was located along a gravel road. Undersides of bridges spanned by paved roads and gravel roads possibly have different thermal characteristics, which could explain why *C. rafinesquii* appears to prefer the latter. However, a more simple explanation is that areas with paved roads are likely to be associated with higher road traffic, more human activity, and more disturbance at roosts than areas with gravel roads.

Frequent switching of roosts is a commonly observed behavior among bat species that roost in tree cavities (Lewis 1995).

*C. rafinesquii* in our study switched roosts frequently, including switches between tree roosts and bridge roosts. Bats that were captured together at 1 roost subsequently moved to separate roost sites, indicating that groups we found together at roost sites may not have constituted permanent colonies but temporary aggregations (Lewis 1995).

Some movement of bats between bridges and trees may have been in response to disturbance by investigators. In the study by Clark (1990), a few roost sites were abandoned after visits by investigators, although the exact cause of abandonment was difficult to ascertain. We found that bridge roosts rarely were abandoned after visits that did not include handling bats. In our telemetry study, bats often returned within a few days to bridges where they had been captured.

Although size of our radiotracking sample ($n = 9$) was somewhat limited, evidence exists that concrete girder bridges and tree hollows are commonly used as roosts by *C. rafinesquii* in forests of west-central Louisiana. Because abundance of girder bridges, tree hollows, and mature deciduous forest may all factor into roost availability, they potentially limit the size of local populations of *C. rafinesquii*. Unfortunately, availability of girder bridges is threatened by the replacement of older girder bridges with slab bridges. Slab bridges are more durable and less costly to build than girder bridges (J. Pace, pers. comm.). In the Kisatchie National Forest, the United States Forest Service currently replaces about 3 older bridges per year with slab bridges (J. Pace, pers. comm.). This trend in bridge replacement also is pursued by other agencies responsible for bridge maintenance and construction in forested areas of Louisiana.

The decrease in available roosts caused by replacement of girder bridges by slab bridges may be ameliorated by modification of slab bridges to improve their adequacy as roosts (Pierson 1998; Whitaker 1995). The addition of roost structures to existing slab bridges also could provide *C. rafinesquii* with increased roosting opportunities, which could in turn stabilize or increase current abundance and distribution of *C. rafinesquii*. Bat Conservation International has designed such a structure, but it has yet to be tested (B. Keeley, pers. comm.).

Given the importance of both bridge and tree roosts to *C. rafinesquii* in our study, it is apparent that preservation of mature deciduous forest should be an important facet of management policies. In particular, those policies that preserve *N. sylvatica*, and other trees that may be prone to form hollows, could increase numbers of roosts available to *C. rafinesquii*.

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