

## CHARACTERISTICS OF POSITIONS SELECTED BY DAY-ROOSTING BATS UNDER BRIDGES IN LOUISIANA

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We evaluated hypotheses that the positions of day-roosting bats on the undersurface of bridges were governed by considerations related to predator avoidance and thermoregulation. From January 2002 to January 2003, we characterized bridge roosts in the Kisatchie National Forest located in north-central Louisiana, United States. Bats, predominately *Corynorhinus rafinesquii*, *Pipistrellus subflavus*, and *Eptesicus fuscus*, tended to roost in the darkest portions of the bridge and in the narrowest available spaces. They also roosted closer to the abutment, farther from the side edge, and closer to the ground than predicted; however, bats were never found roosting less than 0.4 m off the ground or against the abutments. Roost sites were warmer than other parts of the bridge and this difference was greatest in warm months. The small difference in temperatures between roost sites and other portions of the bridge is not consistent with predictions that day-roosting bats would choose the coolest possible locations. Tendency of actual roost sites to be slightly warmer than potential roost sites is best explained by the correlation of temperature with distance from the edge of the bridge. Our observations are most consistent with the hypothesis that bats roosted in areas that minimized their visibility and accessibility to predators.

Key words: bridges, microclimate, roost-site selection

The choice of a roost site has large potential consequences for survival and reproduction of small bats. Complex interactions involving many factors govern the roosting ecology of bats (Findley and Wilson 1974; Medway and Marshall 1970, 1972; Riskin and Fenton 2001). The availability of food, risks of predation, social organization, energetic limits imposed by body size, as well as roost availability and abundance all influence roosting habits to varying degrees. Of primary importance in determining range and abundance of bat species is availability of roost sites (Kunz 1982).

Many species of bats use bridges as day-roosts (Davis and Cockrum 1963; Keeley and Tuttle 1999; Lance et al. 2001). Although most previous research has examined the attributes of bridges used as roosts compared with those not used as roosts (Adam and Hayes 2000; Keeley and Tuttle 1999; Lance et al. 2001), few studies have focused on roost-site selection within a preferred bridge type. Relatively open roosts, such as those found under bridges in forests of the southern United States (see Lance et al. 2001), create the potential for gradients in roost microclimates (Lewis 1995). If bats are distributed across

the undersurface of a bridge in a nonrandom fashion, it is possible that roost positions are selected by bats to provide thermoregulatory benefits. Keeley and Tuttle (1999) suggest that bats might be using bridges to gain warmth from the structures; however, it is likely that this benefit is more important for maternity colonies than for day-roosting bats. At other types of roosts, lactating females are thought to seek out warm sites to promote the growth of the young (Callahan et al. 1997; Sedgely 2001; Willams and Brittingham 1997; Zahn 1999). Unlike lactating females, males and nonreproductive females often appear to select cool sites as day-roosts (Kerth et al. 2001; Riskin and Pybus 1998). Cool temperatures lead to energy savings in day-roosting bats by facilitating torpor (Kerth et al. 2001; Riskin and Pybus 1998). Furthermore, in the southern United States, ambient temperatures during summers often reach levels that are stressful for bats. In these conditions, Lance et al. (2001) speculated that roosting on cool portions of bridge undersurfaces may reduce costs of thermoregulation. At other types of roosts, cooler sites are used preferentially during periods of very warm ambient temperatures (Callahan et al. 1997; Hutchinson and Lacki 2001; Vohnhof and Barclay 1997).

Bats also may select roost sites to aid in predator avoidance. Avoidance of some predators could be achieved by roosting high enough above the ground (Hutchinson and Lacki 2000; Riskin and Pybus 1998). Roosting in narrow spaces may offer some protection from predators (Riskin and Pybus 1998;

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Vonhof and Barclay 1997). Roosting in darker portions of a roost also may make solitary bats less visible to day-roosting predators (Riskin and Pybus 1998).

We tested the hypothesis that, in southern forests, bats choose locations in bridge roosts based on temperature and predator avoidance. If bats are selecting roost positions to avoid predators, we predicted they should choose to roost in the narrowest spaces available, in the darkest portions of the bridge, and as far above the ground as possible. If temperature was motivating roost-site selection, we predicted that bats would selectively roost in cooler areas of the surface. Furthermore, we predicted that the affinity for cooler portions of the bridge roosts may be the greatest during summer when ambient temperatures were highest. We compared the attributes of a bat's day-roost to other locations under the same bridge to understand whether or not bats are selecting a particular area to roost. Preferences of bats for certain microhabitat features could be useful knowledge when modifying bridges to provide desirable day-roost sites.

## MATERIALS AND METHODS

Research was conducted in the Winn Ranger District (664 km<sup>2</sup>) of Kisatchie National Forest, located in Winn, Natchitoches, and Grant parishes in north-central Louisiana, United States (approximately 31°56'N, 92°38'W). Dominant vegetation in the study area varied from mature pine forest (*Pinus palustris* and *P. taeda*) to riparian zones consisting of oak (*Quercus*), black gum (*Nyssa sylvatica*), and bald cypress (*Taxodium distichum*).

Previous research (Lance et al. 2001) and preliminary surveys indicated that bats used concrete bridges with understructure (double-T bridges) rather than other types of bridges (flat concrete or wooden creosote) in our study area. Accordingly, we monitored double-T concrete bridges monthly from January 2002 through January 2003. Bridges were considered inaccessible if we were unable to view the entire underside of the bridge. We compared attributes of a bat's roost site underneath a double-T bridge to other potential roost sites underneath the same bridge. Double-T bridges consist of adjoining pieces of preformed U-shaped concrete (Lance et al. 2001). When assembled into a bridge, the longitudinal beams create alternating wide channels (approximately 55 cm wide) and narrow channels (approximately 17 cm wide).

Upon discovery of day-roosting bats, we recorded species, number of bats in the group, distance from ground (m), direction and distance from closest abutment (m), direction and distance from closest side of the bridge (m), and channel type (wide or narrow). Light-meter readings were recorded in lux, a unit of illumination equal to 1 lumen/m<sup>2</sup>. Surface temperature measurements (°C) at the bat's location were recorded by using a Raytek Raynger ST noncontact thermometer (Santa Cruz, California).

Light, temperature, and height measurements were recorded at 2-m intervals under the bridge, starting at the abutment. These measurements extended 4 m from either abutment resulting in 3 measurements (0, 2, and 4 m) along the length of each end of the bridge. Measurements were made on both edges of the bridge as well as in the center of the span and were repeated on both ends of the bridge for a total of 18 measurements. Ambient light measurements were taken at the initiation and completion of measurement of light under the bridge. Ambient temperature, adjacent to the bridge, also was recorded at the time of data collection.

Using data collected systematically underneath each bridge, we calculated the mean surface temperature and light under a bridge each time a roosting bat was observed. We used paired *t*-tests to evaluate the null hypothesis that the temperature and light measurements taken at the bat's location were not different from the mean measurements for the bridge. Paired *t*-tests also were used to compare the temperature of the bat's roost to ambient temperature. Use of paired comparisons allowed us to remove the effects of temporal and interbridge variation in light and temperature from the analysis.

To evaluate the role of seasonal changes in ambient temperature on how bats might select a roost based on temperature or light, we divided the year into warm months (April–October) and cool months (November–March). The relationship between mean light and temperature of a bat roost site and systematic measurements of the bridge was assessed for both the warm and cool months. We used 2-sample *t*-tests to test the null hypothesis that the difference between light and temperature conditions of bat roost sites and those of the rest of the bridge did not differ between warm and cool months.

The proximity of each roosting position under a bridge to the closest abutment was compared to the null hypothesis of a random distribution under a bridge. If the distribution was random, the mean distance from the nearest abutment would be one-half the distance between an abutment and the middle of a bridge. We used a paired *t*-test to compare this expectation to the bat's distance from the nearest abutment. Using the same approach, we compared the bat's distance from the nearest edge of a bridge to the null expectation that, on average, bats would be located halfway between the middle and nearest edge of a bridge.

Given that bridge width influences the number of channels, we analyzed 1-lane and 2-lane bridges separately to evaluate the null hypothesis that bats did not differentially roost in narrow or wide channels. One-lane bridges are approximately 4.5 m wide and have 6 wide and 5 narrow channels. Two-lane bridges are approximately 7 m wide and have 9 wide and 8 narrow channels. We used the ratio of wide and narrow channels to generate null expectations for goodness-of-fit tests to determine if differences occurred between expected and observed distribution of roosting bats in narrow and wide channels. In some comparisons the expected numbers of observations were small; therefore, *P*-values were estimated based on Monte Carlo resampling of the data (10,000 repetitions; EXACT OPTION, PROC FREQ—SAS Institute Inc. 2001). Using a paired *t*-test, we also compared the height of the bat's roost from the ground or water surface to the mean height of the bridge from the ground or water surface.

To understand how the microhabitat variables of temperature and light may covary with position under the bridge, we examined the relationships among these variables by using the systematic measurements taken at fixed points under each bridge. Because temperature and light measurements at different bridges were under a variety of ambient conditions, we created relative measures by dividing light or temperature under the bridge by ambient light or temperature above the bridge. We examined the correlations of relative temperature and light with distance from the edge of bridge and from the abutment.

## RESULTS

Of the 99 bridges initially evaluated in the Winn Ranger District, 63 were double-T concrete bridges. Roosting bats were observed at least once under 90.6% of double-T bridges. Four species of bats and approximately 1,992 individuals were documented under bridges (Ferrara and Leberg, in press). Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) made up the majority of bats encountered ( $n = 1,811$ ). This was the only

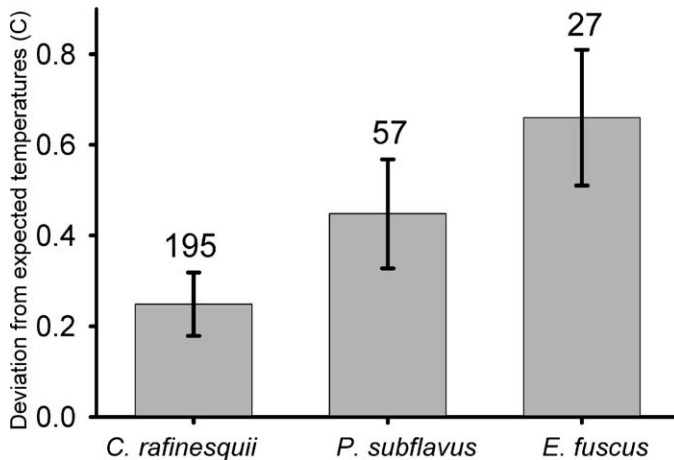


FIG. 1.—Mean differences in surface temperature at roost locations and mean surface bridge temperature for 3 species of bats in Louisiana. Positive values indicate that the bat roost locations were warmer than the average location under the bridge. Bars represent 1 SE; numbers represent sample sizes.

species common enough throughout the year to test differences in roost characteristics between warm and cool months. A number of eastern pipistrelles (*Pipistrellus subflavus*,  $n = 79$ ) and big brown bats (*Eptesicus fuscus*,  $n = 97$ ) also were detected. Insufficient numbers of northern myotis (*Myotis septentrionalis*;  $n = 7$ ) were observed to allow for statistical tests. The majority of roosts had single bats (77%); the remaining roosts consisted of groups of 2–90 bats.

Microclimate measurements and location information ( $n = 289$ ) were collected on solitary bats (90.1%) or small groups consisting of 2–11 bats (9.9%); groups were treated as 1 observation. Larger groups ( $>15$  bats) consisted primarily of summer maternity colonies of *C. rafinesquii*. Because colonies were highly active, it was difficult to document specific details about original locations and roost microclimate. We wished to avoid unnecessarily disturbing the maternity colonies; therefore, no microclimate or location data measurements were recorded.

Locations of *C. rafinesquii* were significantly warmer than the rest of the bridge (paired  $t = 3.62$ ,  $df. = 194$ ,  $P = 0.0004$ ; Fig. 1). The difference in mean bridge temperature and the temperature of a bat's location was greater (unpaired  $t = 2.33$ ,  $df. = 191$ ,  $P = 0.021$ ) in April–October (mean difference =  $0.35^{\circ}\text{C} \pm 0.1$  SE) than in November–March (mean difference =  $0.07 \pm 0.07^{\circ}\text{C}$ ). Temperature at a bat's location was warmer than mean bridge surface temperature in April–October (paired  $t = 3.52$ ,  $df. = 123$ ,  $P = 0.001$ ) but not in November–March (paired  $t = 1.03$ ,  $df. = 70$ ,  $P = 0.31$ ). Roost sites of *P. subflavus* (paired  $t = 3.69$ ,  $df. = 58$ ,  $P = 0.001$ ) and *E. fuscus* (paired  $t = 4.29$ ,  $df. = 26$ ,  $P < 0.001$ ) also were warmer than mean bridge temperature (Fig. 1).

The temperatures of roosts of *C. rafinesquii* were consistently about  $5^{\circ}\text{C}$  cooler than the ambient temperatures (paired  $t = 19.28$ ,  $df. = 168$ ,  $P < 0.001$ ; Fig. 2) and no seasonal effects were found on the difference between roost and ambient temperatures (unpaired  $t = -0.21$ ,  $df. = 167$ ,  $P = 0.837$ ). This difference between roost and ambient temperatures was ob-

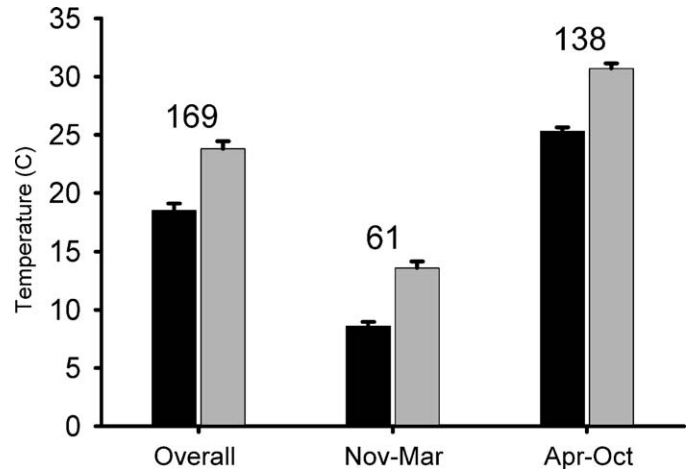


FIG. 2.—Mean ambient air temperature (black) and surface temperature at roost locations (gray) for *Corynorhinus rafinesquii* roosting under bridges in Louisiana. Bars represent 1 SE; numbers represent sample sizes.

served in the other species (*P. subflavus*,  $t = 7.21$ ,  $df. = 36$ ,  $P < 0.001$ ; *E. fuscus*,  $t = 7.50$ ,  $df. = 19$ ,  $P < 0.001$ ).

In general, bats tended to roost in the darkest portions of bridges throughout the year. *C. rafinesquii* roosted in locations that were darker than the rest of a bridge (paired  $t = -7.51$ ,  $df. = 193$ ,  $P < 0.001$ ; Fig. 3). Significant seasonal differences also were found in light at roosts of *C. rafinesquii* (unpaired  $t = -2.15$ ,  $df. = 180$ ,  $P = 0.033$ ). Relative to mean light under a bridge, roost sites of *C. rafinesquii* in April–October (mean difference =  $-36.3$  lux  $\pm 5.49$  SE,  $n = 123$ ) were darker than roost sites in November–March (mean difference =  $-19.8 \pm 5.37$  lux,  $n = 71$ , unpaired  $t = -2.15$ ,  $df. = 180$ ,  $P = 0.033$ ). *P. subflavus* (paired  $t = -4.95$ ,  $df. = 51$ ,  $P < 0.001$ ) and *E. fuscus* (paired  $t = -2.70$ ,  $df. = 24$ ,  $P = 0.013$ ) also had roost sites that were darker than the rest of the bridge (Fig. 3).

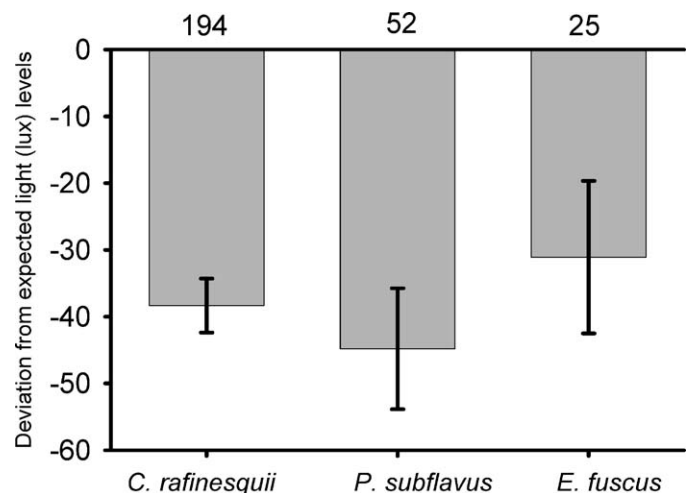


FIG. 3.—Mean difference in light at roost locations and mean light under bridges for 3 species of bats in Louisiana. Negative values indicate that bat roost locations were darker than the average location under the bridge. Bars represent 1 SE; numbers represent sample sizes.

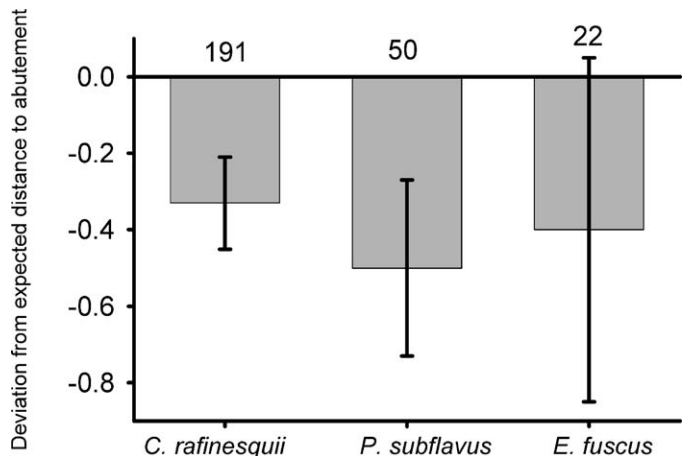


FIG. 4.—Deviation of distance (m) 3 species of bats, in Louisiana, roosted from abutment of a bridge from the null expectation that they would roost, on average, one-half the distance between an abutment and the middle of a bridge. Negative values indicate that the bats roosted closer to the abutment of the bridge than expected. Bars represent 1 SE; numbers represent sample sizes.

*Corynorhinus rafinesquii* roosted closer to an abutment than expected based on our null expectation (paired  $t = -2.70$ ,  $d.f. = 190$ ,  $P = 0.008$ ; Fig. 4). This species was found closer to an abutment in April–October ( $2.6 \text{ m} \pm 0.1 \text{ SE}$ ) than in November–March ( $3.4 \pm 0.2 \text{ m}$ , unpaired  $t = 3.47$ ,  $d.f. = 189$ ,  $P < 0.001$ ). No differences were found in the observed distance from an abutment and the null expectation for *P. subflavus* (paired  $t = -1.89$ ,  $d.f. = 49$ ,  $P = 0.065$ ) or *E. fuscus* (paired  $t = -0.73$ ,  $d.f. = 21$ ,  $P = 0.475$ ; Fig. 4). Failure to detect differences in these species may be due to smaller sample sizes than occurred for *C. rafinesquii*.

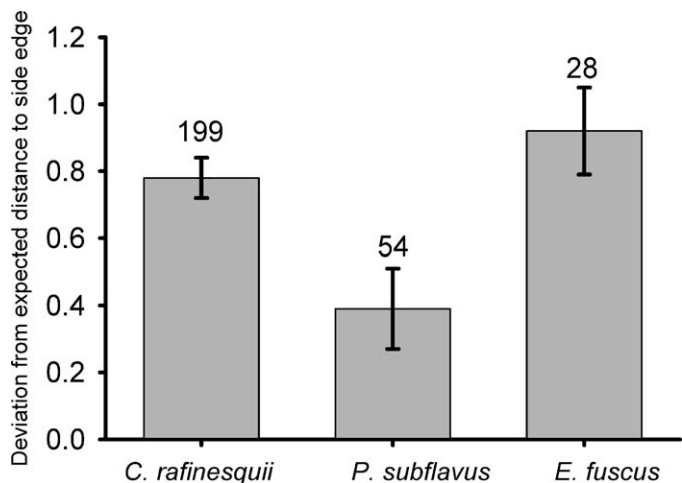


FIG. 5.—Deviation of mean distance (m) that 3 species of bats, in Louisiana, roosted from side edge of a bridge from null expectation that they would roost, on average, halfway between the side and the middle of the bridge. Positive values indicate that the bats roosted farther from the side edge of the bridge than expected. Bars represent 1 SE; numbers represent sample sizes.

TABLE 1.—Number of bat roost sites, under bridges in Louisiana, observed in narrow channels, out of the total ( $n$ ), compared to the number expected given the availability of narrow channels.

Bridge width	Species	$n$	Observed	Expected	$\chi^2$ , $d.f. = 1$	$P$
One lane	<i>Corynorhinus rafinesquii</i>	102	67	46.4	17.64	<0.001
	<i>Pipistrellus subflavus</i>	28	19	12.7	5.91	0.015
	<i>Eptesicus fuscus</i>	17	15	7.7	12.84	<0.001
Two lanes	<i>Corynorhinus rafinesquii</i>	101	56	47.5	2.89	0.089
	<i>Pipistrellus subflavus</i>	24	14	11.3	1.24	0.266
	<i>Eptesicus fuscus</i>	13	6	6.1	>0.01	0.951

All species roosted farther from the side edge a bridge than expected (*C. rafinesquii*: paired  $t = 14.44$ ,  $d.f. = 198$ ,  $P < 0.001$ ; *P. subflavus*: paired  $t = 3.65$ ,  $d.f. = 53$ ,  $P = 0.001$ ; *E. fuscus*: paired  $t = 7.40$ ,  $d.f. = 27$ ,  $P < 0.001$ ; Fig. 5). No differences were found in the distance *C. rafinesquii* roosted from the side edge of a bridge between April–October and November–March (unpaired  $t = -0.65$ ,  $d.f. = 138$ ,  $P = 0.518$ ).

Overall, the 3 species roosted in narrow channels more frequently than in wide channels. Bats roosted in narrow channels more frequently than expected by chance for 1-lane bridges, but not for 2-lane bridges (Table 1).

*Corynorhinus rafinesquii* (paired  $t = 3.05$ ,  $d.f. = 172$ ,  $P = 0.003$ ; Fig. 6) and *P. subflavus* (paired  $t = 3.50$ ,  $d.f. = 47$ ,  $P = 0.001$ , Fig. 6) both roosted significantly closer to the ground than expected. This pattern was not observed in *E. fuscus* (paired  $t = -1.18$ ,  $d.f. = 18$ ,  $P = 0.253$ ; Fig. 6).

Relative light levels were positively correlated with distance from the abutment ( $r = 0.234$ ,  $P < 0.0001$ ); darker areas were

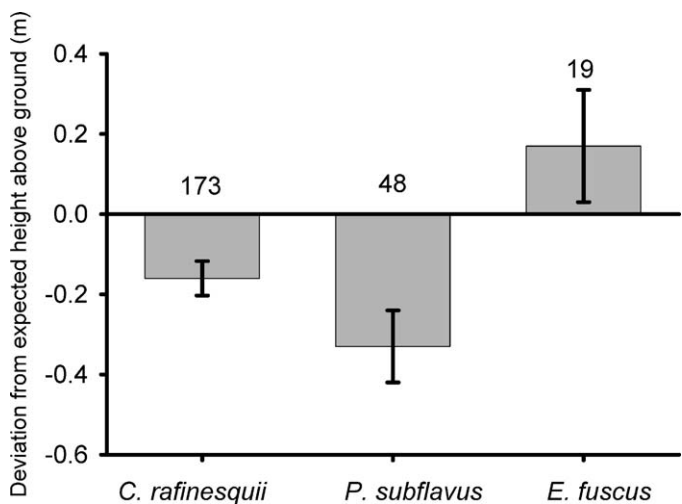


FIG. 6.—Deviation of height (m) that 3 species of bats, in Louisiana, roosted above ground from null expectation that they would roost at the average height of the bridge above the surface of the ground or water. Negative values indicate that the bats roosted closer to the ground than expected. Bars represent 1 SE; numbers represent sample sizes.

found closest to the abutment. Likewise, relative light decreased with distance from the side edge of the bridge ( $r = -0.199$ ,  $P < 0.0001$ ). Relative temperature was weakly correlated with distance from the edge of the bridge ( $r = 0.037$ ,  $P = 0.051$ ) and was unrelated to proximity to the abutment ( $r = 0.022$ ,  $P = 0.246$ ).

## DISCUSSION

Several characteristics appear strongly associated with bridges used as bat roosts. In Louisiana, important characteristics appear to be design of bridge and construction material, followed by proportion of mature deciduous forest and mean age of trees in surrounding habitat (Lance et al. 2001). However, before this study, little was known about factors influencing day-roost-site selection under a particular bridge.

We rejected the null hypothesis that temperature of a bat's location was not different from average temperature for the undersurface of a bridge; however, the observed pattern did not support the prediction that bats would roost at cooler sites. It is not clear why bats chose warmer positions under the bridge, or why this tendency would increase in the heat of the summer for *C. rafinesquii*. Although warm roosts can provide an energetic advantage for maternity colonies in the temperate zone, day-roosting bats often choose roosts with reduced temperatures, especially during warm weather (Hutchinson and Lacki 2001; Kerth et al. 2001; Riskin and Pybus 1998; Vonhof and Barclay 1997). Summer temperatures under bridges in Louisiana were quite high and we doubt that bats day-roosted in warmer portions of the bridge because of the benefits of additional warmth.

The difference between ambient temperature and temperature of a bat's roost site may be a more important relationship than temperature of a roost site compared to the rest of a bridge. Concrete in the shade can remain cool relative to ambient temperatures. Channels underneath the bridge provide a vertical roosting surface where bats may rest. By exposing their ventral surface to the concrete, they may be better able to take advantage of temperature-related benefits of roosts (Lance et al. 2001). Bridges may provide day-roosting bats with protection from high temperatures. This could be critically important in avoiding heat stress during the hot, humid summers of the southeastern United States. However, the possibility that bridges might be preferred roosts because they are cooler than other roosts in the summer, as speculated by Lance et al. (2001), does not explain why bats are roosting in the warmer portions of the bridges.

One possible explanation for the apparent preference for warmer roost sites is that such sites have other characteristics preferred by bats. The undersurface temperatures tended to increase toward the middle of the width of the bridge and were lowest at edges. Not surprisingly, positions near the edge of the bridge were much lighter than positions away from the edges. The roosts of all 3 species of bats were darker than the average position under the bridges. The strong tendency of bats to roost in the darkest portions of a bridge may explain why bat roosts tend to be warmer than other locations of the bridge. We also

found that bats tended to roost farther from the side edge of the bridge than expected. Thus, both the warmer temperatures of bat roost sites and the tendency to roost near the center of the bridge can be explained by a hypothesis in which bats are selecting the darkest available microhabitats as roosts.

We also rejected the null hypotheses that bats positioned themselves at random with regard to the distance of the roost site from the ground or the abutments of the bridge. Bats roosted closer to both an abutment and to the ground than expected. These trends also can be explained by the hypothesis that bats seek the darkest available roost. Areas closest to an abutment are typically darker than areas closer to the middle of the length of a bridge. Likewise, the undersurface of a bridge is typically much closer to the ground or water at the abutment than at the middle of the length of the bridge. If bats select roosts primarily based on amount of light, this may result in an apparent preference for areas closest to an abutment and closest to the ground.

Light is not the only factor that may play a role in selection of a roost location. Although bats had a tendency to roost closer to an abutment, we noticed that they were never observed right against an abutment. If roosts were selected only for light, then bats should regularly roost against abutments because these are the darkest areas under a bridge because of a support beam that runs across the width. However, the beam creates a shelf that may put bats within reach of predators. Furthermore, during post hoc examination of the data, we observed that bats never roosted in portions of bridges closer than 0.42 m above the ground. Thus, although bats tend to roost in portions of the bridge with low light levels, they may avoid the very darkest areas because these sites may put them at higher risk from terrestrial predators.

Keeley and Tuttle (1999) suggested that most bridge roosts are  $\geq 3$  m above ground. However, bats in our study area roosted an average of  $2.0 \text{ m} \pm 0.04 \text{ SE}$  above ground level, with a tendency to roost closer to the ground or water than the mean height of the bridge. The difference between the 2 studies may have resulted from the type of bridges examined. Only about 25% of the double-T bridges we examined were more than 3 m off the ground; however, even when bridges were higher off the ground, bats often did not select the highest point to roost. Additionally, Keeley and Tuttle (1999) examined many bridges spanning roadways, whereas all of the bridges we studied spanned streams. Keeley and Tuttle (1999) found that high traffic volume reduced roosting; bats in our study may have roosted closer to the ground because no traffic passed beneath them.

Our results are based on solitary or small groups of day-roosting bats. Because maternity colonies were rare and activity levels made it difficult to quantify microhabitats, bats in these colonies are not part of our statistical comparisons. Based on observations of several colonies, it appears that maternity roosts of *C. rafinesquii* may use bridges differently than day-roosting individuals.

Colonies were typically located under bridges that were higher off the ground and usually over permanent water. Bats were often located in the middle of a bridge in terms of distance

from the abutment. These areas had high levels of light, but were also at the highest point above ground level. These large groups also had a tendency to be more active and vocal than smaller groups or individuals. This activity could be more likely to attract predators. Because colonies would be easily detectable by predators under any light conditions, height of a roost site may be a more important factor than light in roost-site selection for maternity colonies as compared to solitary bats.

Conversely, Keeley and Tuttle (1999) found maternity colonies of *C. rafinesquii* between open beams in low bridges darkened by thick vegetation along the sides. One such colony abandoned the roost immediately after vegetation was removed (Keeley and Tuttle 1999), and anecdotal evidence suggests that day-roost abandonment after vegetation removal may occur in Louisiana as well (A. Talley, pers. comm.).

For 1-lane bridges, bats roosted in narrow channels (approximately 17 cm wide) far more frequently than in wide ones (approximately 55 cm wide). Narrow channels used in our study were much wider than the preferred crevice widths discussed by Keeley and Tuttle (1999). High use of the 17-cm channels might have been influenced by a lack of narrower spaces in double-T bridges.

The apparent preference for use of narrow channels over wide channels observed at 1-lane bridges is not strong at bridges with 2 lanes. This may be the result of the distributions of the 2 types of channels under bridges with different widths and the tendency to roost away from the sides of bridges. At 1-lane bridges, the channel farthest from the sides of the bridge is narrow, whereas at 2-lane bridges, the channel farthest from the sides is wide. Alternately with increased width, the light levels near the center of the bridge are reduced. Thus, advantages a narrow channel might offer a bat in terms of reduced detection by predators may be most important under 1-lane bridges with their higher levels of light.

Use of dark roosts and narrower spaces coupled with avoidance of portions of the undersurface close to the ground suggests that bat roost-site selection was due primarily to predator avoidance. Predator avoidance has been attributed to selection of roost sites with similar characteristics in other settings (Hutchinson and Lacki 2000; Riskin and Pybus 1998; Vonhof and Barclay 1997). The narrow temperature range under individual bridges ( $\leq 2^{\circ}\text{C}$ ) may have provided little opportunity for roost selection based on temperature. Because bridges were much cooler than the ambient temperatures in the summer, they may have been selected as preferential day-roost sites, as suggested by Lance et al. (2001). However, once a bridge was selected, we hypothesize that the location of the roosting bat was selected by the need to avoid predators; additional observation will be needed evaluate this hypothesis.

We have evaluated several possible factors that may influence a bat's selection of a roost site. Shade and narrow channels seem to be important components of day-roost microhabitat. These factors can be incorporated into management schemes. For example, vegetation removal should be discouraged because of potential increases in light. Providing bridges with shaded vertical roosting surfaces, in narrow spaces, that are out of reach of predators should encourage more bat use

(Keeley and Tuttle 1999). This is especially important in areas such as Louisiana, where many bridges used by bats are being replaced by designs that lack adequate roost habitat (Lance et al. 2001).

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