Influence of investigator disturbance and temporal variation on surveys of bats roosting under bridges

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Abstract Given the importance of roost sites to bats, monitoring roost use is an important tool for assessing the local status of some species. We surveyed bridges for day-roosting bats in the Kisatchie National Forest of Louisiana to assess how temporal patterns of bridge use and disturbance from surveyors might affect survey results. We found no support for the hypothesis that surveys of day-roosts affected bat use of bridges. The 3 most common species roosting under bridges, Rafinesque's big-eared bats (*Corynorhinus rafinesquii),* eastern pipistrelles (*Pipistrellus subflavus*), and big brown bats (*Eptesicus fuscus*), exhibited strikingly different patterns of seasonal use. Because of seasonal variation in bridge use, a monitoring program would need to involve a minimum of a summer and a winter survey to document all common species that use bridges. Surveys during the day detected many more bats than surveys conducted at night. Although individuals tended to return to the same roosts over long periods of time, tagged bats often were absent during intervening surveys. Because individuals used multiple roosts, at least 3 surveys within a season will be necessary if an objective is to determine which specific bridges are used as roosts by locally abundant species.

Key words bridges, day-roost, disturbance, *Corynorhinus rafinesquii,* eastern pipistrelle, monitoring, *Pipistrellus subflavus*, Rafinesque's big-eared bat, seasonal trends, surveys

There is a need to monitor bats to achieve conservation and management goals. Surveying roosts provides valuable information concerning the status of some species (Sherwin et al. 2003). Many species have been documented roosting in man-made structures such as bridges (Davis and Cockrum 1963, Fraze and Wilkins 1990, Lewis 1995, Riskin and Pybus 1998). Due to their permanence and accessibility relative to other roosts in southern forests (Lance et al. 2001), bridges provide opportunities for monitoring and understanding seasonal trends in roost use.

Bridges and culverts are used as day-roosts (Lance et al. 2001), hibernacula (Sandel et al. 2001), and maternity colonies (Perlmeter 1996). Some evidence suggests that bridges are more frequently used as night-roosts than as day-roosts (Perlmeter 1996, Pierson et al. 1996, Keeley and Tuttle 1999, Adam and Hayes 2000). Bridge use also might be highly seasonal (Walker et al. 1996, Sandel et al. 2001, Trousdale and Beckett 2004). Understanding temporal and interspecific variation in the ways bats use bridge roosts is necessary for designing effective monitoring programs.

Due to the limited information available regarding bats using bridges as roosts in forested habitats of the southern United States, it was not clear when or how often bridge roost surveys should be conducted. Understanding seasonal use of structures such as bridges, as well as fidelity, would be helpful for designing monitoring programs (Chung-MacCoubrey 2003, Sherwin et al. 2003). Determining which bridges are used as roosts has conservation implications because some bridge

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replacement programs are reducing the number of suitable roost structures (Lance et al. 2001).

Counting bats at roosts creates the possibility of surveyor-induced disturbance altering patterns of roost use. Concern about bat conservation has led to the recommendation that bat roosts be protected from human disturbance (Fenton 1997). Disturbance may alter activity patterns of breeding colonies (Shirley et al. 2001, Mann et al. 2002) or force hibernating bats to use critical energy supplies (Speakman et al. 1991, Thomas 1995, Fenton 1997, Johnson et al. 1998). Also, bats may abandon traditional roosts when disturbed (Pearson et al. 1952, Kunz 1982). Most of these reports relate to harassment of bats; there is little information available regarding the sensitivity of bats using bridge roosts to human visitation associated with survey activities. If frequent visits by survey workers affect use of bridges as roosts, surveys might have negative consequences for some species or provide misleading information.

Our study had 6 objectives aimed at obtaining information on temporal use of bridges, and on the effects of investigator disturbance, to develop sampling approaches for surveys of bridge roosts. First, we evaluated the hypothesis that frequent surveys would cause bats to alter patterns of bridge roost use. Second, we quantified seasonal variation in use of bridge roosts to help determine when and how many surveys would need to be conducted to adequately sample the different species using bridges. Third, we examined whether the number of bats using bridges was likely to change rapidly over a period of a few weeks or days to provide information on how important it is to constrain surveys to a short time period. Fourth, we assessed the hypothesis that night-roosting activity was greater than day-roosting; high levels of night-roosting would suggest that night surveys be considered when assessing the importance of bridge roosts. Fifth, we used data from multiple visits to known bridge roosts to estimate how many visits would be necessary to have confidence that a bridge was not used as a roost. Finally, we used recoveries of banded bats to provide insight into patterns of roost fidelity and switching; high levels of roost switching would increase the number of surveys necessary to evaluate whether specific bridges were being used as roosts.

Methods

We surveyed bridges for roosting bats in the Winn Ranger District (664 km^2) of Kisatchie National Forest (NF), located in Winn, Natchitoches, and Grant parishes in north-central Louisiana (approximately 31°N 56', 92°W 38'). Previous research in the study area (Lance et al. 2001) established that bats often roost under concrete bridges with understructure (double-T bridges), but rarely under other types of bridges (flat concrete or wooden creosote). Our own observations supported these findings, so we only considered double-T bridges in this study.

Investigator disturbance

To assess the effects of investigator disturbance on roost use, we chose 13 double-T bridges to be monitored daily for roosting bats for two 7-day periods. We treated another 13 bridges as controls and surveyed twice, once at the beginning and once at the end of each 7-day trial period. These bridges were all being actively used by bats and were randomly assigned to the 2 treatments. We conducted this comparison for one 7-day period in May 2002 and another in August 2002. We could easily see roosting bats, so typically we required only a brief visual inspection of the underside of each bridge to document the presence and number of roosting bats. We made no attempt to capture or disturb roosting bats during the survey period, but we approached some closely to confirm species identification. Because we did not mark or handle these bats, we do not know whether bats found in different surveys represented the same or different individuals.

We used logistic regression analysis to test the hypothesis that, relative to the control group, the number of frequently visited bridges with roosting bats did not decrease with frequent human visits; we blocked this analysis by month. The response variable was binary with bridges assigned to 1 of 2 groups: those that had bats on the first day but not on the last survey day, suggesting abandonment, and those that had bats on both the first and last days or just on the last day. We used PROC GLM (SAS Institute 2001), blocking by month, to assess differences in number of bats roosting under bridges at the beginning and end of the trial period.

Seasonal variation

We monitored bridges monthly from January 2002–January 2003 to assess seasonal variation in numbers and species composition of roosting bats. Initially, we surveyed only subsamples of bridges while they were being located and characterized. After April we attempted to survey all double-T bridges each month, although access was sometimes limited by water levels. We combined data from the January surveys in most analyses.

We compared proportions of occupied bridges among sampling periods using chi-square analysis. In some comparisons the expected numbers of observations were small; therefore we estimated P-values based on Monte Carlo resampling (10,000 repetitions; EXACT OPTION, PROC FREQ, SAS Institute 2001). We conducted this analysis for the 3 most commonly detected species including Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), eastern pipistrelle (*Pipistrellus subflavus),* and big brown bat (*Eptesicus fuscus)*.

To determine whether the number of bats observed per bridge differed during monthly surveys, we used a Kruskal-Wallis test (PROC NPAR1WAY, SAS Institute 2001); a nonparametric test was used because we observed skewed distributions for some species. We used Spearman's correlation coefficient to determine whether a significant relationship existed between the proportion of occupied bridges and number of bats observed for monthly surveys. A strong relationship would indicate that different surveys would not be needed to quantify which bridges are occupied and how many bats were occupying them. We considered each species separately for analysis of monthly samples. If we visited a bridge multiple times in a month, we only used the first survey in the analysis of seasonal variation in bridge use.

Short-term temporal variation

We conducted 3 surveys in July 2002 (3–6 July, 16–19 July, and 27–30 July) to assess temporal variation within a month. We selected July for weekly surveys because previous research (R. Lance, United States Army Corp of Engineers, personal communication) suggested that bat occupancy of bridges was higher during the summer than other times of the year. To assess daily variation in roost use, we used data obtained from the surveys conducted to assess the effects of investigator disturbance. We used contingency table chi-square analysis to determine whether bridge occupancy differed between weekly or daily samples. We used the Kruskal-Wallis test to determine whether the number of bats per bridge varied among the 3 weekly surveys. Because the same bridges were examined for each of the daily surveys, we used Friedman's test, blocked by bridge, to determine whether the number of bats changed among the 7 days for both the May and August surveys.

Night-roost use

To test the hypothesis that bridges may be more important as night-roosts than as day-roosts, we conducted nocturnal surveys of bridges in July–August 2002. We visited bridges after sunset and inspected their undersurfaces with flashlights. A contingency chi-square test was used to compare the occupancy of bridges, as determined through nocturnal surveys, to the occupancy of bridges surveyed during the day as part of our monthly surveys. We compared the number of bats observed per bridge between these night and daylight surveys with a Kruskal-Wallis test.

Absence from known roosts

The undersurfaces of double-T bridges were easily searched and contained no places for bats to hide (such as expansion joints), so failure to find bats at known roosts was evidence of roost switching. Therefore, we created an index of the probability of absence (p_A) of bats at bridges known to be used as roosts, where $p_A = n_A/(n_T - 1)$ and $n_A =$ the number of surveys of a bridge in which a species was absent, and $n_T =$ the total number of surveys of the bridge. We subtracted 1 from n_T to remove the bias associated with the survey that identified the bridge as a roost. We averaged this index across all bridges known to be used as roosts. A value approaching 1 represented a high probability of absence of a species at known roost sites, indicating a large number of surveys would be necessary to be confident that the bridge was not used as a roost. From this, the minimum number of times a bridge needed to be surveyed in order to determine with 90% confidence that it was not used as a roost could be estimated. For species that had marked differences in seasonal use of bridges, we estimated the probability of absence from known roosts for both summer (May–August) and winter (November–March) surveys. For species that had no seasonal variation in bridge occupancy, all surveys were used. To be included in this analysis, a bridge had to be surveyed at least 4 times within the summer or winter survey periods.

Roost fidelity and switching

We collected data on individual roost fidelity by tagging. Most bats were not handled, but we ini-

Table 1. Numbers of bats detected roosting during 902 bridges surveys between January 2002–January 2003 in the Winn District of the Kisatchie National Forest, Louisiana.

Species	Number of bats detected	% of total detected
Rafinesque's big-eared bat	1,811	90.9
Eastern pipistrelle	79	4.0
Big brown bat	95	4.8
Northern long-eared myotis	7	0.4
Total	1,992	

tially tagged 49 bats with an individually numbered aluminum band placed around the forearm. To confirm individual identification, we attempted to recapture all banded bats we subsequently observed, with the exception that no bats were handled during the investigator disturbance experiments.

Results

Four species of bats were observed roosting under bridges during this study (Table 1). Rafinesque's big-eared bats were most common, followed by big brown bats, eastern pipistrelles, and northern long-eared myotis (*Myotis septentrionalis*).

Investigator disturbance

We documented both Rafinesque's big-eared and big brown bats day-roosting under bridges used to assess investigator disturbance. However, we observed only big brown bats at 2 bridges, accounting for 14% of the 160 bats observed. Because there were insufficient observations of big brown bats for a separate statistical analysis, we combined the 2 species for the analysis of the effects of disturbance on the use of bridges by bats.

The number of bridges occupied by bats on the first but not the last day of our surveys did not differ between bridges experiencing different levels of visitation (χ^2_1=3.24, P=0.072, Figure 1). If there was any response, it appeared that the control bridges experienced more of a decrease in use than did the frequently visited bridges (Figure 1). This result was opposite the prediction that frequently surveyed bridges would experience decreased use by bats.

Differences in mean number of bats roosting under the bridges between May and August were not significant ($F_{1, 49}$=0.36, P=0.553, Figure 2), so

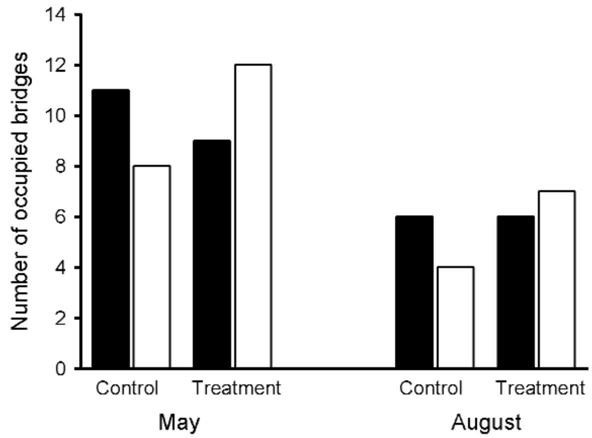

Figure 1. Number of control (n = 13) and frequently visited treatment (n = 13) bridges occupied by bats on the first (solid) and last (open) day of roost surveys conducted in Kisatchie National Forest, north-central Louisiana, May and August 2002.

we combined the data to compare the frequently visited and control bridges. There were no differences in mean number of bats roosting under control and frequently visited bridges ($F_{1, 49}$=0.89, P= 0.375, Figure 2). Based on a posteriori power analysis (Sokal and Rohlf 1990), an average reduction of 0.5 bats per bridge would have been detected 80% of the time when using an alpha level of 0.05 to determine statistical significance. Therefore, the sample sizes were sufficient to detect large changes in bat abundance due to disturbance.

Seasonal variation

The proportion of bridges occupied and mean number of bats were highly correlated for

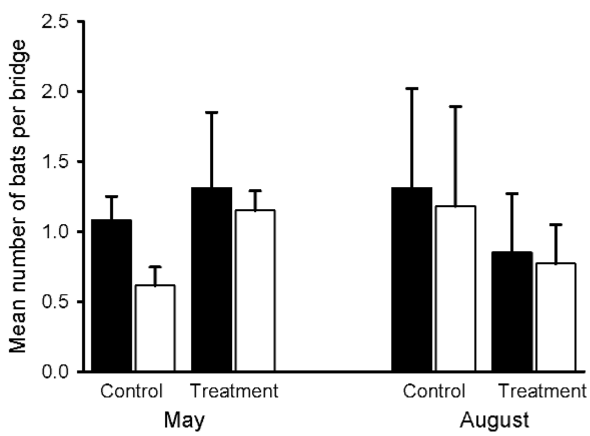

Figure 2. Mean number of roosting bats observed per control (n = 13) and frequently visited treatment (n = 13) bridge on the first day (solid) and last day (open) of surveys conducted in Kisatchie National Forest, north-central Louisiana, May and August 2002. Vertical bars represent one standard error.

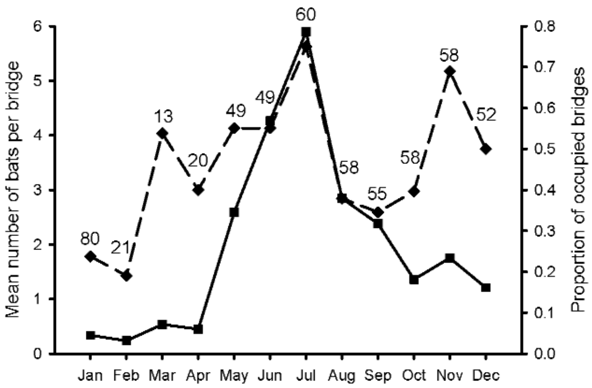

Figure 3. Proportion of occupied bridges (dashed line) and mean number of Rafinesque's big-eared bats per bridge (solid line) during monthly surveys conducted January 2002–January 2003 in Kisatchie National Forest in Louisiana. Numbers above points represent sample sizes of bridges.

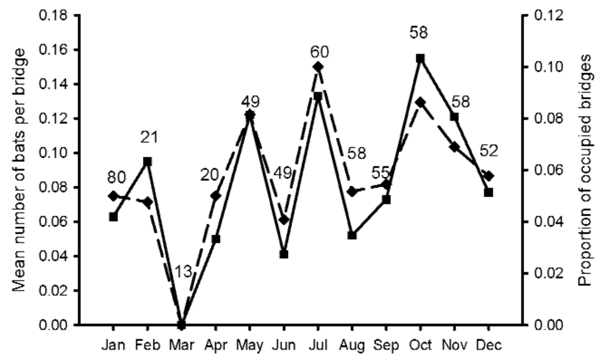

Figure 5. Proportion of occupied bridges (dashed line) and mean number of big brown bats per bridge (solid line) during monthly surveys conducted January 2002–January 2003 in Kisatchie National Forest in Louisiana. Numbers above points represent sample sizes of bridges.

Rafinesque's big-eared bats (Spearman's $r=0.61$, $P=0.036$, Figure 3), eastern pipistrelles ($r=1$, $P<0.001$, Figure 4), and big brown bats ($r=0.88$, $P<0.001$, Figure 5).

There were differences among months for both proportion of bridges occupied by Rafinesque's big-eared bats ($\chi^2_{11}=66.7$, $P<0.001$, Figure 3) and the numbers of bats per bridge (Kruskal-Wallis $\chi^2_{11}=78.43$, $P<0.001$, Figure 3). Rafinesque's big-eared bats roosted under bridges throughout the year, but roost use was lowest in winter. Numbers of Rafinesque's big-eared bats increased in spring and summer (Figure 3) due to more bridges being used as roosts and the formation of several large maternity colonies. Eleven bridges served as roosts for aggregations of 5–85 Rafinesque's big-eared bats from May through August; most of these were obvious maternity colonies. The other 40 bridges used by big-eared bats during the summer typically sheltered 1–2 individuals that were often solitary males.

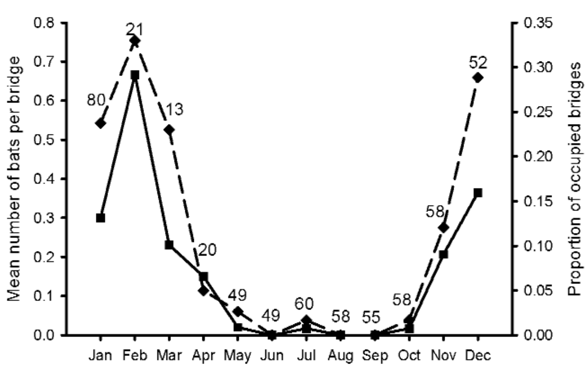

Figure 4. Proportion of occupied bridges (dashed line) and mean number of eastern pipistrelles per bridge (solid line) during monthly surveys conducted January 2002–January 2003 in Kisatchie National Forest in Louisiana. Numbers above points represent sample sizes of bridges.

Eastern pipistrelles (Figure 4) were rarely observed during the summer, but represented nearly 25% of the bats observed from November to March. The proportion of bridges occupied by eastern pipistrelles ($\chi^2_{11}=86.8$, $P<0.001$, Figure 4) and numbers of individuals per bridge (Kruskal-Wallis $\chi^2_{11}=86.66$, $P<0.001$, Figure 4) differed among months.

There were no differences in the proportion of bridges occupied by big brown bats ($\chi^2_{11}=4.12$, $P=0.973$, Figure 5) or numbers of bats per bridge (Kruskal-Wallis $\chi^2_{11}=4.17$, $P=0.964$, Figure 5) among months. We observed big brown bats roosting in low numbers throughout the year with no strong seasonal trends (Figure 5).

The low number of myotis observed ($n=8$) precluded an analysis of seasonal variation. In monthly surveys, we observed 1 individual in June, September, October, and December and detected 4 in July.

Short-term temporal variation

Almost all individuals observed in July were Rafinesque's big-eared bats (98% of 635 bats); therefore, differences in bat numbers among weeks were not assessed by species. There were large changes in the number of bats detected per bridge between the 3 weekly surveys (Kruskal-Wallis $\chi^2_2=17.21$, $P<0.001$). The number of bats observed per bridge declined over the 3 weekly surveys (mean number per bridge $=5.9\pm1.8$ SE [$n=60$], 3.8 ± 1.6 [$n=53$], and 2.9 ± 1.3 [$n=56$], respectively). The proportion of occupied bridges also declined significantly during the weekly surveys (χ^2_2=12.2, P=0.002). During week 1, 75% of bridges were occupied; in following weeks occupancy declined to 51% and 45%, respectively.

On any given day, approximately 55% of the 15 bridges surveyed daily were typically occupied and occupancy did not vary significantly among the 7 daily surveys in either May or August (May: χ^2_6 =6.2, P=0.447; August: χ^2_6=1.8, P=0.963). The number of bats remained relatively constant throughout both 1-week survey periods (May: Mean = 1.9 bats, Friedman's Test = 5.98, df = 6, P = 0.43; August: Mean = 2.1, Friedman's Test = 4.19, df = 6, P = 0.65). While average numbers of bats and the proportions of bridges used by bats did not vary significantly among days, bats occupied different bridges on each day and the number of bats of each species under individual bridges changed frequently during the 7-day sampling periods. Only 5 of the 13 occupied bridges in May and 6 of the 13 occupied bridges in August were used all 7 days. Furthermore, the number of bats under some individual bridges varied from as few as no bats to as many as 8 over a single 7-day period.

Night-roost use

The mean number of bats per bridge observed at night was 0.26 ± 0.12, compared to 4.40 ± 1.20 observed day-roosting during the same sampling period (Kruskal-Wallis χ^2_1=28.97, P<0.001). Of 53 bridges surveyed at night, only 15% were occupied, and the only species was Rafinesque's big-eared bats. This was significantly less than the proportion of bridges occupied by day-roosting bats (57%) during July and August (χ^2_1=25.84, P<0.001).

Absence from known roosts

The probability of not finding Rafinesque's big-eared bats at bridges known to be used as roosts was 0.42 during May–Aug surveys. The likelihood of absence of colonies (defined here as aggregations of >5 bats) under bridges where they existed in other surveys was also 0.42. The probability of absence from known roosts increased to 0.59 in Nov–Mar surveys, indicating a decrease in the consistency of bridge use during the winter. Based on a 0.42 probability of absence of Rafinesque's big-eared bats from known roosts, at least 3 surveys would be necessary to have <10% chance of misidentifying a roost bridge as a nonroost.

The probability of absence of eastern pipistrelles

~~Big brown bat (*Eptesicus fuscus*)~~ roosting on the undersurface of a bridge.

at known winter roosts during any single survey was 0.69. Thus, at least 7 surveys would be necessary to have <10% chance of misidentifying a bridge used by pipistrelles in the winter as one that was not a roost. Big brown bats, which showed no strong seasonal trends in occupancy, had high probabilities of being absent at known roost bridges (0.84). Because of the high probabilities of absence during surveys of known roosts, as many as 13 surveys would be needed to ensure that there was <10% chance that a bridge used by this species would be incorrectly identified as not being a roost site.

Roost fidelity and switching

Twenty of 27 banded Rafinesque's big-eared bats were recaptured 39 times; on 14 additional occasions banded bats were observed but individual identification was not made. One male was located 10 times during monthly surveys from January–December 2002. Another male was recaptured 4 times. Seven bats (5 males, 2 females) were recaptured twice and 11 were recaptured once (9 males, 2 females). We recaptured all individuals at the same bridge where they were originally banded.

During May–October 2002 we also recaptured 4 of 19 Rafinesque's big-eared bats that had been banded in the same area during 1998 (Lance 1999). One bat was recaptured at the same bridge where it was originally banded. The other 3 bats were recaptured at bridges within 1.5 km from the original banding site; one of them subsequently returned to the bridge where it was originally banded.

Five big brown bats were banded during our study, of which 1 male was recaptured on 2 occasions under the bridge where he was originally banded. Three of 17 banded eastern pipistrelles, banded in February–April 2002, were recaptured in November 2002–January 2003. Two bats were recaptured at the same bridge where they were banded; the third was recaptured 2.75 km from the original roost. The shortest time between recaptures of pipistrelles was 7 months, indicating a long absence of individuals from bridge roosts.

~~Eastern pipistrelle (*Pipistrellus subflavus*)~~ roosting on the under-surface of a bridge.

Discussion

Investigator disturbance

Surveys of bridge roosts did not cause roost abandonment in our study, so it appears that the results of bridge surveys are unlikely to be substantially biased by presence of surveyors. Neither occupancy nor the number of bats per bridge differed between our experimental treatments. The benign effect of surveys on bridge roost use may have been the result of high visibility of roosting bats. Bats were generally in open areas, aiding in rapid species' identification with minimal disturbance.

Most bridges we surveyed for this experiment were used by solitary individuals or small groups. Few bats awakened, vocalized, switched positions, or left the bridge while a surveyor was present. However, large groups were more vocal and apt to fly than solitary bats. Observations we have made at other bridges suggest that bats in colonies are more alert and agitated by human presence than the bats in our experiment. Therefore while brief inspections do not appear to affect bridge use by day-roosting bats, additional care should be taken when monitoring larger groups such as maternity colonies.

Seasonal variation

Rafinesque's big-eared bats and eastern pipistrelles exhibited seasonal patterns of bridge use; there were no seasonal trends in use of bridges by big brown bats. Rafinesque's big-eared bats roosted under bridges throughout the year but were found in higher numbers during the spring and summer. Similar seasonal patterns were observed for this species at bridge roosts in Mississippi (Trousdale and Beckett 2004). There is no evidence that this species is migratory, suggesting that many individuals are using alternate roosts during the winter months. Those bats remaining at bridges move at least occasionally to other roosts because they were not documented at the same locations throughout the winter.

We rarely encountered eastern pipistrelles during the summer. Mist-net surveys (Lance 1999) also rarely detected eastern pipistrelles in the summer. The increased presence of eastern pipistrelles during the winter was similar to observations of bridge roosts in Mississippi (M. Wolters, United States Army Corp of Engineers, personal communication) and box culverts in Texas (Sandel et al. 2001). These observations suggested either that eastern pipistrelles switch from natural roosts to bridges and other man-made structures in the winter months (Sandel et al. 2001), or that some portion of the population is migratory and increased encounters reflect wintering migrants.

After a summer absence, at least some eastern pipistrelles returned to bridges near where they were banded. Jones and Pagels (1968) reported reuse of winter roosts by banded pipistrelles. Similar to Rafinesque's big-eared bats, banded eastern pipistrelles often were not detected at the bridge where they were last captured, or nearby bridges, during surveys in the winter. This suggested that individuals were not sedentary during the winter and that they were using several alternate roost sites.

Short-term temporal variation

Numbers of bats per bridge and the proportion of occupied bridges decreased significantly during the 3 surveys conducted in July. This result likely was due to the time of year that the surveys were conducted. During this time, juvenile Rafinesque's big-eared bats became less dependent on their mother's care and the gradual breakup of the maternity colonies started to occur. Although colonies were decreasing in size in July, a similar series of weekly surveys in June would also have resulted in considerable temporal variation in bridge use given the large increase in bat numbers we observed between June and July. Trousdale and Beckett (2004) found that the timing of summer peaks in Rafinesque's big-eared bat activity varied considerably among years. Given that colony size is very fluid, the periods over which summer surveys are conducted should either be kept very short to minimize the effects of time on differences in counts between bridges, or multiple surveys should be conducted to quantify the influence of temporal variation on survey results.

Daily surveys revealed considerable short-term variation in which bridges were used as roosts. Coupled with the day-to-day variation in bat numbers at individual bridges, it was apparent that bats frequently switched roosts. Thus, while a single seasonal survey might be sufficient to obtain average rates of occupancy or numbers of roosting bats across bridges, a single survey was insufficient to determine that a bridge is not used as a roost.

Night-roost use

Surveys at night would be inefficient if the goal was to quantify seasonal or annual trends in numbers of roosting bats across a large number of bridges. Although we did not quantify the amount of time it took to survey a bridge, there was no question that night surveys took considerably longer than diurnal surveys. The amount of time spent underneath a particular bridge to determine presence or absence made these surveys impractical, especially given the lack of roosting bats relative to numbers observed during the day. Furthermore, night surveys only detected 1 species using bridges while diurnal surveys conducted during the same months detected 3 species. This is not to say that night-roost surveys should not be conducted, only that brief surveys are unlikely to detect the majority of bats using bridges. Night-roost surveys are quite useful if long periods of time are spent underneath a particular bridge in order to study colony dynamics, foraging patterns, or nightly energy budgets (Lewis 1994; Perlmeter 1996).

Absence from known roosts

Bat use of individual bridges was sporadic; absence of bats at known bridge roosts was <50% only for Rafinesque's big-eared bats in the summer. The decrease in absences from known roosts probably resulted from large numbers of bats using bridges during summer, rather than individual bats consistently roosting under the same bridge. Consistency of bridge occupancy in the winter was low for both Rafinesque's big-eared bats and eastern pipistrelles; individuals switched roosts throughout the winter.

The probability of absence from known roosts was particularly high for big brown bats. In all likelihood, this species was commonly using other types of roosts. The high probability of absence from a roost during a single survey means that many surveys are needed to have confidence that a bridge is not being used by this species.

Roost fidelity and switching

Recaptures of banded bats indicated that individuals often returned to the same bridge roosts. We recaptured close to 75% of the Rafinesque's big-eared bats we banded, and all were recaptured at the same roost where they were banded. Most of individuals banded 4 years ago were recovered at other sites than where they were banded; however, they were still using bridges within 1.5 km of the original banding site.

Although band returns and daily surveys of bridges indicated that while Rafinesque's big-eared bats repeatedly roosted at the same bridges, the absence of individuals at intervening surveys indicated that they frequently used alternate roosts. Radiotelemetry indicated that the species often switches between bridge and tree roosts (Lance et al. 2001). Similar to our tag return results, the distances individuals move between roosts was short (<2.5 km) and only 1 of 9 radiotagged bats switched bridge roosts (Lance et al. 2001).

Recapture success for banded big brown bats and eastern pipistrelles was 17–20%. This was considerably lower than recaptures of Rafinesque's big-eared bats, suggesting that big brown bats and eastern pipistrelles may spend more time at nonbridge roost sites. However, when recaptures were made, they occurred either at or close to the site of initial capture.

Management implications

Frequent surveys of day-roosting bats had no negative effects on the number of bats observed or use of bridges as roosts. Thus, investigators can conduct surveys with increased confidence that they are not affecting the numbers of roosting bats observed; however, disturbance should be minimized and caution should be used in surveys of maternity colonies.

For each species bridge occupancy and mean number of roosting bats were highly correlated. Thus, timing of surveys to maximize 1 measure of bridge use would also result in high values of the other. If the purpose of the survey is to determine which bridges are being used as roosts by the different species in an area, the focus should be on conducting several diurnal surveys than on more time-consuming nocturnal surveys.

Ideally, survey schedules would optimize the chance of detecting bats (Chung-MacCoubrey 2003) while minimizing temporal variation among sampling units. For Rafinesque's big-eared bats, June and July had peak occupancy and the highest number of bats using bridges. This peak corresponded with the use of bridges as maternity colonies. Since the size of maternity colonies is probably an indicator of potential recruitment, colonies should be a focus of conservation efforts (Sherwin et al. 2003). Thus, June or July would be good times for surveying roost use by Rafinesque's big-eared bats. However, numbers of this species using bridges can change rapidly during this period of heavy use, so surveys conducted to compare bridges should be conducted over a short period. Multiple surveys during this period should also be conducted to quantify the amount of amount of temporal variation in roost use. At least 3 surveys in the summer are necessary to be confident that a bridge with no bats, or no aggregations of bats, is not being used as a big-eared bat roost or maternity colony. At least 7 surveys in the winter are needed to be confident that a bridge is not an eastern pipistrelle roost.

Surveys conducted for big brown bats could conceivably occur during any month. Because of the very high probabilities of absence of this species during surveys of known roosts, >13 surveys would be needed to ensure that a roost bridge would be not be misidentified as one that was not being used. Clearly, such intensive monitoring would only be justified if this species was of special conservation concern.

Estimates of the number of surveys needed to determine that a bridge was unlikely to be used as a roost are minimums for our study area. Such estimates are likely to differ for other regions and types of roosts (Sherwin et al. 2003). Additionally, our estimates of the number of surveys necessary to establish whether a bridge is a roost site may be underestimated given the high variance in occupancy rates among samples. Faced with high levels of roost switching resulting in variation in occupancy rates and the mean number of bats using bridges, it is important to include multiple surveys in any monitoring program.

The proportion of occupied bridges and mean numbers of roosting bats are indices of bridge use; their relationship to the total number of bats in a population is unknown. On the positive side, large numbers of bats were readily accessible under bridges, making it possible to monitor roosting; individuals using other roosts are quite difficult to study. Furthermore, mist-net surveys detected only a small fraction of the individuals observed under bridges. Used in conjunction with mist-netting and acoustical monitoring techniques (O'Farrell and Gannon 1999; O'Farrell et al. 1999; Sedlock 2001), surveys of bridge day-roosts should provide a fuller understanding of bat community composition in forested areas.

Acknowledgments. J. Larriviere, E. Smithies, and J. Szostek provided valuable field assistance. This research was funded by grants from the United States Forest Service, the J. Bennett Johnston Science Foundation, and the Louisiana Department of Wildlife and Fisheries.

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Associate editor: *Nilon*