Long Distance Commutes by Lesser Long-Nosed Bats (*Leptonycteris yerbabuenae*) to Visit Residential Hummingbird Feeders

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Abstract—*Each spring, thousands of female lesser long-nosed bats (Leptonycteris yerbabuenae) migrate from southern Mexico to northern Sonora and southern Arizona to have their young and take advantage of seasonably available forage resources, including nectar, pollen, and fruit of columnar cacti. Once the pups are volant, the population begins to disperse across the grasslands of southeastern Arizona, foraging on flowering paniculate agaves (Agave palmeri) and day-roosting in Madrean Sky Islands during their seasonal migration back to southern Mexico. Although the grasslands surrounding Arivaca, Arizona, have very low densities of naturally occurring agaves, nectar bats are documented visiting area hummingbird feeders to obtain sugar water. To better understand foraging patterns by these bats in an area with few natural food plants, we radio-tracked 28 L. yerbabuenae during 2010 and 2011. We captured bats at area hummingbird feeders and tracked them to a previously unknown day-roost in the Santa Rita Mountains, approximately 40 km away. We discovered that bats nightly performed a long-distance commute from the Santa Rita Mountains to Arivaca, bypassing hummingbird feeders and naturally occurring agaves closer to their day-roost. It may be that the large colony size in the day-roost necessitates long-distance dispersal as a mechanism to reduce competition for limited food resources.*

Introduction

The lesser long-nosed bat (*Leptonycteris yerbabuenae*) was listed as endangered in the United States by the U.S. Fish and Wildlife Service (USFWS) in 1988 (Shull 1988). The northernmost population of this species is migratory, while a southern population near Jalisco, Mexico, appears to be present year-round (Ceballos and others 1997; Cole and Wilson 2006). Female *L. yerbabuenae* are pregnant when they arrive in southern Arizona from central Mexico during April and May. These bats are highly gregarious and use a limited number of roosts with colonies numbering in tens of thousands of individuals. They give birth (typically in May) at large maternity roosts in Sonoran desertscrub habitat (Cockrum and Petryszyn 1991), feeding nightly on the nectar, pollen, and fruit of columnar cacti, including saguaro (*Carnegia gigantea*) and organ pipe (*Stenocereus thurberi*) (Fleming and others 1993). During July and August, once the young are volant (able to fly), maternity colonies begin to disperse. Wilkinson and Fleming (1996) suggested two distinct migratory routes for the species, one along the west coast of Mexico and the other along the Sierra Madre Occidental with little genetic mixing between the groups. However, more recent DNA analysis determined that there is general genetic mixing across southern Arizona and, for conservation efforts, the two groups should be considered one population (Ramirez 2011). The bats begin a gradual migratory path eastward, moving up in elevation and shifting to grassland communities where they feed on nectar and pollen of flowering paniculate agaves, primarily Palmer agaves ([Family Agavaceae, *Agave palmeri*]; USFWS 1997). Ober and others (2005) radio tracked *L. yerbabuenae* in the Huachuca Mountains of southeastern Arizona and determined that these bats used home ranges with a greater density of flowering agaves (3.6 flowering agaves/ha) than the general landscape (1.8 flowering agaves/ha). In addition, nectar bats have discovered that hummingbird feeders offer energy resources during their migration across southern Arizona. Some researchers have speculated that nectar bats visit artificial food resources in greater numbers during years of reduced agave flowering, particularly after periods of below average winter rainfall (Krebbs 2007, unpublished paper). Both *L. yerbabuenae* and Mexican long-tongued bats (*Choeronycteris mexicana*) are documented using hummingbird feeders near Portal, Arizona, (Chiricahua Mountains) and in the Santa Rita Mountains since the 1970s (Cockrum and Petryszyn 1991). Recently, urban homes well within Tucson, Arizona, city limits have multiple feeders drained each evening between mid-August and late September (D. Buecher, personal observation 2011; Lowery and others 2009).

L. yerbabuenae require caves and mine tunnels with specific temperature and relative humidity for day-roosts, as well as bridges and various abandoned man-made structures, for night roosts (Cockrum and Petryszyn 1991). Appropriate day roosts may be a limiting factor

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for the distribution of *L. yerbabuenae* because they are documented flying 24 to 40 km nightly from a day roost to suitable foraging habitat (Horner and others 1998; Sahley and others 1993). Ober and others (2005) found that this species has large home ranges (505 ha), which allows them to access food resources across vast landscapes. Disturbance and/or loss of roost sites, combined with a gradual decrease in foraging habitat from increasing land development, are the most serious issues *L. yerbabuenae* face in Arizona (USFWS 1997). Roosts in abandoned mine tunnels, caves, or old abandoned buildings in remote areas provide refuge for bats unless disturbance occurs. Increased presence of cross border violators (CBVs) along the border between the United States and Mexico, who use these same structures for shelter, contributes to disturbance to colonial bats (USFWS 2008). *L. yerbabuenae* are also at risk when they frequent human structures for roosting purposes or to feed at hummingbird feeders because they are at risk of predation by domestic cats, being harmed by humans, or killed or injured through collisions with urban structures.

Visual surveys during our study indicated no large fields of agave plants (≥1.8 flowering agaves/ha) in the vicinity of Arivaca, Arizona, but *L. yerbabuenae* had been documented using area hummingbird feeders in late summer. Therefore, we were interested in (1) which nectar bat species were using feeders; (2) how they used a landscape with few natural food resources, and (3) where they were day-roosting. Because bats are nocturnal it is often difficult to monitor nightly feeding behavior. However, radio telemetry helps elucidate the foraging behavior of *L. yerbabuenae* (Ober and Steidl 2004; Ober and others 2005), and allows researchers to track bats across both temporal and spatial scales and identify flight corridors between day and night roosts (Amelon and others 2009).

Study Area

This study was conducted near the town of Arivaca, Pima County, in southeastern Arizona, USA (31°34'N, 111°19'W), an area surrounded by the Las Guijas Mountains, Cobre Ridge, Tumacacori Mountains, and Cerro Colorado Mountains. Arivaca is approximately 29 km west of the Santa Cruz River, 45 km west of the Santa Rita Mountains, and about 19 km north of the international border with Mexico. Although there is little natural foraging habitat for nectarivorous bats in the area, there are significant stands of flowering agaves during the summer months in the Santa Rita Mountains to the east. That range has at least four documented lesser long-nosed bat post-maternity roosts. Despite a scarcity of natural food plants near Arivaca, local residents have reported that their hummingbird feeders are often visited by bats in late summer. Arivaca is a small community (~ 900 residents according to the 2000 census), located at approximately 1100 m in elevation with homes concentrated on small lots in the historic town site and homes east of Arivaca on 0.5 ha lots to larger (≥4 ha) lots. The habitat surrounding Arivaca is semidesert grassland (Brown 1994) characterized by low rolling hills and ephemeral streams. Arivaca Creek, which contains dense cottonwood galleries, generally flows from east to west and is located less than 0.40 km south of Arivaca. The low undulating terrain of the study area made constant monitoring of telemetered bats sometimes difficult to achieve so radio-tracking stations were located on high points whenever possible, with views overlooking Arivaca and nearby canyons.

Methods

We captured up to 15 *L. yerbabuenae* per year ($n_{2010} = 13$ and $n_{2012} = 15$) during post-maternity migration (five each in August, September, and October). We radio tracked the bats during three sessions, each lasting 2 weeks per month for a total of 6 weeks per year. Bats were captured at residential hummingbird feeders both in Arivaca and approximately 6.4 km east of Arivaca. Protocols outlined by the American Society of Mammalogists (Sikes and others 2011) were followed while handling all bats, and appropriate scientific collecting permits were maintained during this study. Because of the potential threat of White Nose Syndrome being spread between bats by humans, USFWS decontamination protocols outlined for bat researchers were followed during the capture and handling process (USFWS 2011). Radio transmitters (#LB-2N from Holohil Systems Ltd., Ontario) weighing 0.42g were attached to *L. yerbabuenae* using colostomy adhesive. Prior to attachment of a transmitter, it was confirmed that the mass of the transmitter was less than 5% of the bat's total body mass (Aldridge and Brigham 1988).

During each session of radio tracking, three to five radio-tracking stations were maintained to monitor telemetered bats. Each station had a scanning radio receiver (R1000, Communications Specialists, Inc., Orange, California) and a three or five element Yagi antenna, a compass, and a long-range radio to maintain communication between stations. Each telemetry station was manned prior to sunset unless personnel were mobile and actively following a signal. To ensure that the radio receivers were functioning properly, test beacons were placed along undisclosed bearings and personnel took sightings on these prior to the evening's activities.

Each night, personnel constantly monitored all radio frequencies of bats telemetered during each month. If a signal was detected, the frequency and general bearing was communicated to all stations, and these stations attempted to monitor the frequency until the signal was lost. For each signal detected, the frequency, time of detection, bearing, and strength of the signal were recorded on data sheets. Personnel were able to continue scanning all frequencies while monitoring a particular frequency. If a new frequency was detected, the monitor would obtain a bearing for the newly detected frequency and coordinate with other stations. In order to better define foraging areas, both stationary radio tracking stations and mobile stations were used to monitor *L. yerbabuenae* behaviors and habitat use. The program LOAS 4.0.3.8 (Ecological Software Solutions, LLC) was used to determine intersections from telemetry station bearings. Because of the low rolling terrain of the area, three simultaneous points were not always achieved on bat detections so 'Best Biangulation' was used to determine bat locations. We conducted statistical analysis on the radio tracking data using the software package JMP 4.0 (SAS Institute Inc. 1996).

Results

During the 2-year study, we tracked 28 *L. yerbabuenae*, including 17 adult females, 7 subadult females, 1 adult male, and 3 subadult males. The first session of radio tracking each year was conducted in mid-August, when nectar bats are documented in southeastern Arizona grasslands; the last session was conducted in early October (USFWS 2007; Sidner 2010). During each study month in 2010 and 2011, three to five *L. yerbabuenae* were each affixed with a radio transmitter that was approximately 3% of their body mass and released. Upon release of a bat, radio telemetry stations immediately began monitoring its movements. During 2010-2011, we captured 134 bats of seven different species while mist netting for *L. yerbabuenae* on the patios of homes and at two flowering agaves (table 1). All species captured were expected to occur in semidesert grasslands of southeastern Arizona (Hoffmeister 1986). The diversity of bats was higher than expected at hummingbird feeders because two residences used for

Table 1—Mist netting results from the 2010-2011 radio telemetry survey near Arivaca, Arizona.

Scientific name	Common name	Number Caught
Antrozous pallidus[a]	Pallid bat	1
Eptesicus fuscus[a]	Big brown bat	4
Choeronycteris mexicana[b]	Mexican long-tongued bat	86
Leptonycteris yerbabuenae[b]	Lesser long-nosed bat	33
Myotis auriculus[a]	Southwestern myotis	2
Myotis velifer[a]	Cave myotis	7
Tadarida brasiliensis[c]	Brazilian free-tailed bat	2

[a]Vespertilionidae
[b]Phyllostomidae
[c]Molossidae

netting had large porches that offered night roosting opportunities for many bat species. Despite the lack of food plants for nectarivorous bats within the study area, we captured a surprising number of both *L. yerbabuenae* (n = 33) and *C. mexicana* (n = 86) over the course of the study. In 2010, despite radio tracking for 14 nights per month, we were unable to continuously track bats over multiple consecutive nights. During August, we tracked five *L. yerbabuenae* for only one night each; in September we tracked five bats for one to three nights each; and in October we tracked three bats for one to two nights each. Because the 2010 radio tracking had such limited results, no statistical analyses were conducted. However, signals from telemetered bats were detected in the vicinity of the Santa Rita Mountains to the east, so we suspected the bats might be using a day-roost in that mountain range.

The radio tracking sessions in 2011 were more successful and we had sufficient numbers of bearing intersections for statistical analysis. In August 2011, we captured five *L. yerbabuenae* at a residence approximately 6.4 km east of Arivaca. Two of the bats had modest to abundant plant pollen on their heads and face, indicating that they were successful in finding pollen-bearing flowers, most likely agaves, before visiting the hummingbird feeders. We tracked these animals for 3 to 10 nights ($\chi = 6$, SE = 1.18) before the signals were lost. August bearings on telemetered bats were used to calculate location intercepts using LOAS (2011) (fig. 1). One bat disappeared from the area after one night so the behaviors of the remaining four were analyzed statistically. These bats behaved as a group and the latitudes and longitudes of their bearing intersections were similar (ANOVA $_{latitude}$ $F_{3,79} = 1.38$, $P = 0.26$, ANOVA $_{longitude}$ $F_{3,79} = 0.71$, $P = 0.55$). As a group, these animals concentrated their foraging efforts east of Arivaca. In August 2011, we were able to track telemetered bats to an abandoned mine in the Santa Rita Mountians where we found five of our radio transmitters on the floor (four from 2011 and one from 2010). A subsequent exit count documented approximately 7,000 *L. yerbabuenae* emerging from the mine at sunset. After the bats were gone, a trip into the site found five additional transmitters (one from 2011 and four from 2010).

In September, we captured five *L. yerbabuenae* at a residence in Arivaca, where the homes are located closer together. We tracked these animals for two to nine nights ($\chi = 4.2$, SE = 1.72) until the signals were lost. September bearings on telemetered bats were used to calculate location intercepts using LOAS (2011) (fig. 2). The September bats flew more directly to Arivaca, the area where they were captured, and foraged around homes closer to town. Statistical analysis of the five bats shows that they behaved as a distinct group within latitude (ANOVA $_{latitude}$ $F_{4,146} = 0.88$, $P = 0.48$), but not strongly within longitude (ANOVA $_{longitude}$ $F_{4,146} = 5.88$, $P < 0.001$). Statistical

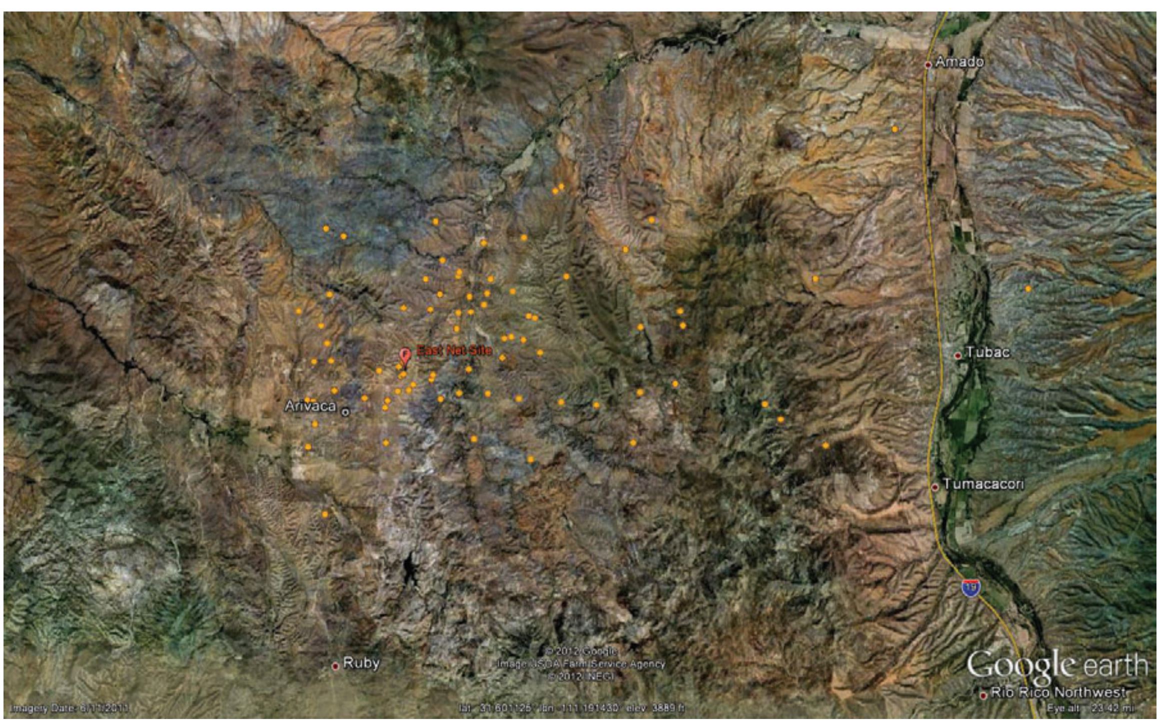

Figure 1—Gold circles indicate intersection locations from LOAS for five telemetered bats during August, 2011. These points indicate where *L. yerbabuenae* were flying in relation the capture site east of Arivaca

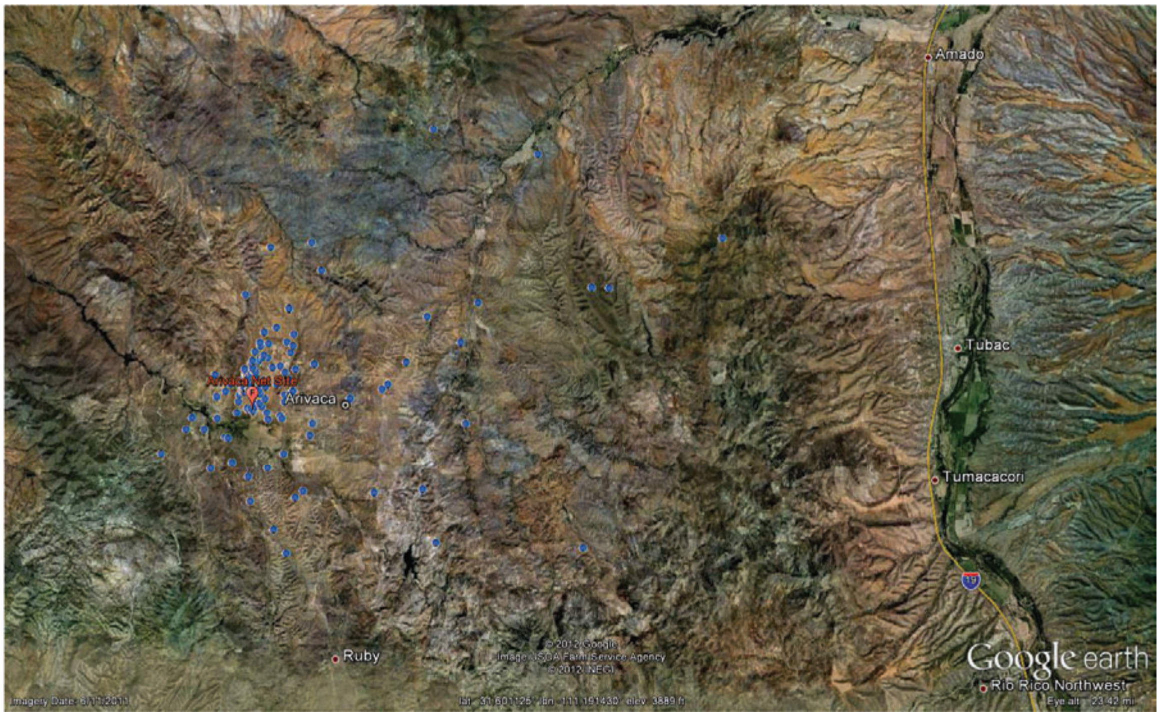

Figure 2—Blue circles indicate intersection locations from LOAS for five telemetered bats during September, 2011. These points indicate where *L. yerbabuenae* were flying in relation to the capture site in Arivaca.

analysis of behavior differences between bats telemetered in August (6 km east of Arivaca) to bats telemetered during September (in Arivaca) showed a significant difference between the latitude where these bats foraged ($t_{228} = -12.49$, $P < 0.001$). Some of the bats captured 6.4 km east of Arivaca did fly as far as Arivaca; however, they consistently used more areas east of town than those bats captured in Arivaca itself. Bats originally captured at feeders in Arivaca flew more directly to that area before settling down to forage most of the night. Differences in longitude are not as pronounced, but still significant ($t_{228} = -2.73$, $P = 0.01$), with bats captured east of Arivaca flying more to the north than bats that were captured in Arivaca.

In October, we captured eight *L. yerbabuenae*: five at the same Arivaca residence as in September and three at the same residence as in August east of Arivaca. The plan for this last month was to radio track five *L. yerbabuenae* captured at two different sites. It was hoped that this could elucidate if bats acted as distinct groups and used different foraging patterns, depending on their capture site. We tracked the telemetered bats for four to eight nights ($\chi = 5.8$, SE = 0.63) until signals were lost. October bearings on telemetered bats were used to calculate location intercepts using LOAS (2011) (fig. 3). The October bats did not forage with a distinct configuration, but appeared to combine both the behaviors of August bats and September bats. When these five bats are analyzed statistically they behaved significantly differently across latitude ($\text{ANOVA}_{\text{latitude}}\ F_{4,76} = 0.23$, $P < 0.001$), distributed from east to west between the two capture sites. However, longitudinally they behaved as a group ($\text{ANOVA}_{\text{longitude}}\ F_{4,76} = 1.24$, $P = 0.30$), staying within a limited north to south range.

Once the day roost was found, we were able to estimate average flight speed for telemetered bats by using a telemetry station along I-19 to document exit times from the roost, while one or two stations in the Arivaca Valley detected the bats once they crossed the Tumacacori Mountains. Eleven bats were documented traversing this distance for an estimated average speed of 28.3 kph. Sahley and others (1993) found similar speeds (27.2 kph) by *L. yerbabuenae* commuting from a day-roost in Sonora, Mexico, to forage on flowering columnar cacti. *L. yerbabuenae* visiting hummingbird feeders in the Tucson basin (table 2) travelled to foraging areas a bit faster (32.8 kph) although these animals were commuting from multiple day-roosts (Lowery and others 2009). All nectar bat flight speeds are significantly faster than documented for many regional insectivorous bat species (Hayward and Davis 1964). Sahley and others (1993) suggested that the large body size and high wing loading of *L. yerbabuenae* may be an adaptation for long-distance commutes to food resources across naturally heterogeneous landscapes.

Discussion

We were unable to consistently track telemetered bats in 2010 because of issues related to losing the radio signals almost immediately after bats were telemetered. Unfortunately, when a transmitter is not detected once affixed, there are three possible reasons: (1) the bat continued its migration to another foraging area in southeastern Arizona; (2) the bat migrated towards its winter site in Mexico; or (3) the transmitter was groomed off at a day- or night-roost. In 2010, we assumed that these bats were continuing their migration from west to east across southeastern Arizona to Madrean Sky Islands where there were good stands of flowering agaves. The fact that nectar bats were captured in semidesert grassland that lacked stands of agaves was attributed to their learned knowledge that hummingbird feeders offered sugar-water to 'power' them across inhospitable landscapes (Cockrum and Petryszyn 1991; Lowery and others 2009). However, in 2011 we were more successful in continually monitoring telemetered bats and we were able to document bats commuting between their day-roost in the Santa Rita Mountains to hummingbird feeders

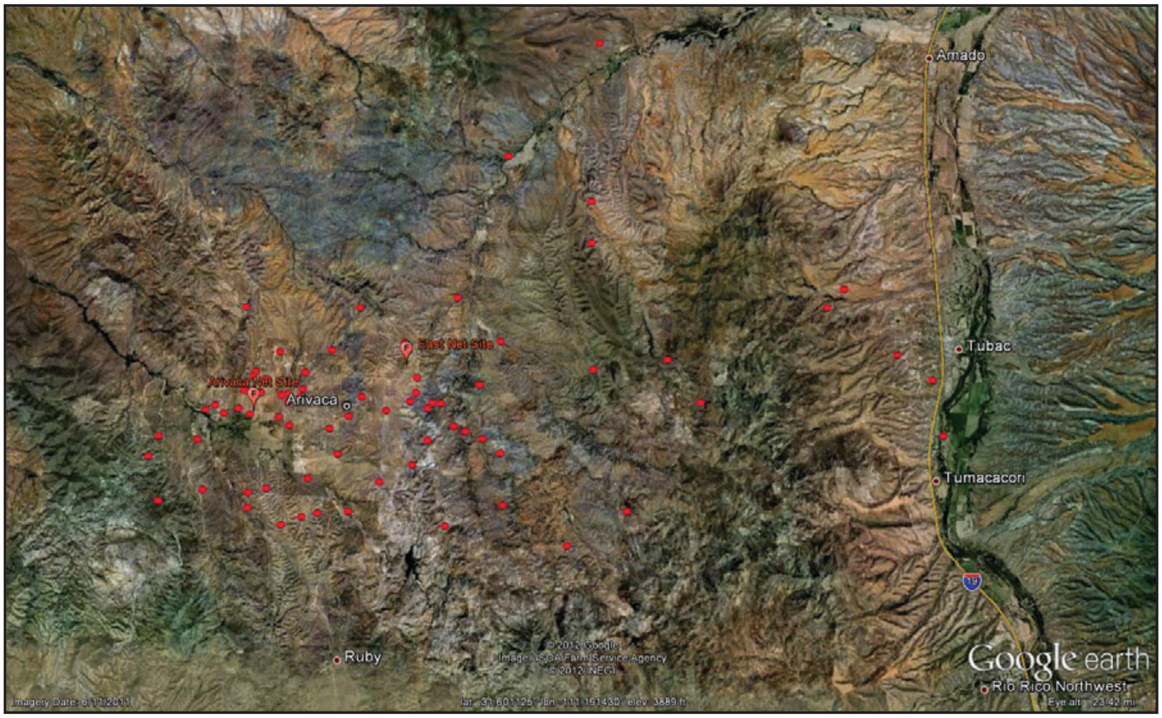

Figure 3—Red circles indicate intersection locations from LOAS for five telemetered bats during October, 2011. These points indicate where *L. yerbabuenae* were flying in relation to the two capture sites, one in Arivaca and one east of Arivaca.

Table 2—Flight distances and speeds recorded for lesser long-nosed bats reported by various researchers.

Source	Year	Location	Distance	Avg. Speed	Food Resources
Buecher/Sidner	2011	Pima Co., AZ	35.4 km	28.3 kph	sugar water
Horner et al.	1998	Sonora, Mexico	32.5 km	15.5 kmh	columnar cacti
Lowery et al.	2009	Pima Co., AZ	28.8 km	32.8 kph	sugar water
Ober et al.	2004	Cochise Co., AZ	19.2 km	unknown	paniculate agaves
Sahley et al.	1998	Sonora, Mexico	27.2 km	27.2 kph	columnar cacti
Sidner	1995	Cochise Co., AZ	27.4 km	unknown	paniculate agaves

in Arivaca. The discovery of both 2010 and 2011 radio transmitters groomed off in the roost documents bats from both years using the mine for day-roosting. All bats captured in Arivaca during 2011 were found day-roosting a majority of the time in the Santa Rita roost, approximately 32-38 km east of the capture sites. What is interesting about this behavior is that these *L. yerbabuenae* appear to nightly bypass naturally occurring agaves in the Santa Rita Mountains and closer hummingbird feeders along the more urbanized I-19 corridor. Hummingbird feeders in Tubac, Green Valley, and even Patagonia and Sonoita were closer to the day-roost than the Arivaca feeders (table 3). This seemingly unusual behavior may be an effort by individuals in a large colony to partition available food resources. The Santa Rita Mountains have at least four known lesser long-nosed day-roosts with an approximate regional population of 16,000 bats. Because the newly discovered Santa Rita roost has approximately 7,000 bats, these animals might be required to disperse across a broad landscape in order to find sufficient food resources. The telemetered animals were all captured in or near Arivaca, which may bias the results towards those individuals that have already chosen this area to feed, whereas other *L. yerbabuenae* in the day-roost may forage at closer feeders. Despite a lack of flowering agaves in the Arivaca area, nectar bats are actually present in good numbers, presumably because they have 'learned' to utilize sugar water resources at urban homes to maintain their energetic needs during migration across southern Arizona. Overall, these animals were highly loyal to this artificial food source (sugar water) and some bats returned many nights to the area after capture.

When the telemetered bats are evaluated as a group, the bats captured 6.4 km east of Arivaca behaved as a unit and did not forage differently when measured spatially. Bats captured in Arivaca also behaved as a unit and travelled farther towards Arivaca to feed. Howell (1979) hypothesized that *L. yerbabuenae* foraged in groups as a benefit for locating food resources in a heterogeneous landscape. Our results support this hypothesis by showing that bats captured at specific sites behaved strongly as a group on subsequent nights. When the 2 months (August and September) are compared there is a significant difference in the foraging areas the bats used. However, during October, when the sampling for bats was conducted from two residences 6.4 km apart, the combined group foraged across all latitudes and longitudes reflected by the August and September bats. Since these

Table 3—Distances from the Santa Rita day-roost to area hummingbird feeders. Bold italic entries indicate feeders definitely used by the telemetered bats during 2010-2011 radio tracking. Note that five urban areas where feeders are closer to the day-roost than Arivaca, Arizona.

Feeder locations	Santa Rita roost
	miles (km)
Tubac	7 (11.2)
Patagonia	13 (20.8)
Continental	14 (22.4)
Sonoita	16 (25.6)
Green Valley	18 (28.8)
East Arivaca	***20*** **(*32*)**
Sahuarita	22 (35.2)
Arivaca	***24*** **(*38.2*)**
West Arivaca	27 (44.8)

bats behave so cohesively on the landscape, it would be interesting to understand how they initially segregate themselves into foraging groups. Three possibilities might be (1) kin groups; (2) members of summer maternity colony cohorts; or (3) winter colony cohorts.

The results of our radio tracking study provide important information on activity patterns and foraging behaviors of *L. yerbabuenae* on artificial food resources near Arivaca, Arizona. While this area was not previously documented for having regular visitation at urban hummingbird feeders by nectar bats, our high capture rates show that feeders are used by both *L. yerbabuenae* and *C. mexicana*. However, one question, still to be determined, is how much do these animals benefit physiologically from this highly artificial food? The flowers of columnar cacti and paniculate agave offer nectar, but also large amounts of pollen, which have amino acids that the bats convert to proteins (Howell 1974). Horner and others (1998) estimated that the energy budget of *L. yerbabuenae* was ~40 kJ/day and it took 80-100 visits to columnar cacti flowers to obtain this energy. It is currently unknown how many visits would be needed to artificial food resources to obtain an equal amount of energy. Another concern is how hummingbird feeders impact the natural foraging behaviors and migration patterns of nectar bats. Without the availability of urban hummingbird feeders, there is very little reason for nectar bats to be foraging in the grasslands surrounding Arivaca. There has been work to quantify how many agave plants are needed to maintain *L. yerbabuenae* populations (Ober and others 2005). Although the grasslands surrounding Arivaca appear to have few agaves, fortunately there are naturally occurring stands of agaves in many of the Sky Islands to the east of Arivaca. This allows nectar bat populations to persist in the region and offers resources required during energetically costly migration for *L. yerbabuenae* migrating to winter roosts in Mexico.

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