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Abstract

Since June 1982 we have studied various aspects of red bat ecology in Arkansas with emphasis on field work in the Ouachita Mountains and examination of specimens submitted to the Arkansas Department of Health Rabies Laboratory (ADHRL). This study reports on continued field work in the Ouachita Mountains using radiotelemetry and updates information regarding red bats submitted to the ADHRL through December 1996. In addition, we revisited a cave previously reported to contain a large number of red bat skull and skeletal remains. We also report remains from another cave system in north-central Arkansas. These investigations have yielded additional information on distribution, growth and development of young, litter size, use of atypical roosts, active period and hibernation roost site selection, copulation, and incidence of rabies.

Introduction

The red bat, *Lasiurus borealis*, is one of Arkansas's most common woodland bats, yet relatively little information is available regarding its natural history in Arkansas or elsewhere. For example, the *Proceedings* of the Bats and Forests Symposium held in Victoria, British Columbia, Canada (Barclay and Brigham, 1996) contains twenty-two papers, yet none pertain to red bats, and Nagorsen and Brigham (1993) allow that "scanty information" is available concerning the red bat in Canada. The secretive behavior of this solitary species probably accounts for the paucity of observations. Red bats do not form colonies; they roost individually in trees where they are rarely visible and infrequently encountered and almost never utilize buildings, mines or caves. Therefore, locating sufficient numbers of these bats on a regular basis for protracted and continuous study is extremely difficult. The result of all of these contributing factors is that most information regarding this species is of a fragmented nature and typically consists of records of individuals or females with offspring, providing researchers limited glimpses into the annual cycle of this beautiful tree bat.

Sealander and Heidt (1990) considered the red bat to be abundant and occur state-wide. They reported specimens from 34 counties. Baker and Ward (1967) regarded the red bat as the most common bat in southeastern Arkansas after they captured 177 in six nights during August. Gardner (1978) reported red bats as the most commonly encountered species in the Delta region of northeast Arkansas. They constituted 85 percent (81/95) of all bats captured during his study, and Paige (1981) reported red bats constituted 63 percent of bats captured in the Salem Plateau of northcentral Arkansas. Red bats represented 29 percent of bats captured in an urban park setting in Hot Springs, Arkansas (Saugey et al., 1988), and Saugey et al.(1989) reported red bats as the most frequently mist-netted bat in forested areas of the Ouachita Mountains where 386 individuals were captured. Steward (1988) found red bats to be one of the most common bat species in southwest Arkansas having captured 53 specimens, and Caire (1986) reported red bats comprised 35 percent of bats captured during his study in southeast Oklahoma. Clearly, these studies support the contention red bats are abundant and widespread in all regions of Arkansas. And because of their abundance, red bats undoubtedly play an important role in the ecology of Arkansas at the ecosystem level as predators of night-flying insects. The purpose of this study was to provide additional distribution, natural history and incidence of rabies data concerning the red bat in Arkansas.

Materials and Methods

The majority of data reported here was derived from the study of red bats submitted to the Arkansas Department of Health Rabies Lab (ADHRL) between June 1982 and December 1996. During this period a total of 521 specimens (Table 1) from 59 counties were recorded. Red bats represented 40 percent (521/1294) of all bat specimens submitted to the ADHRL during this 15 year period. This sample included juveniles and adults of both sexes, pregnant speci-

Table 1. Red bats submitted to the Arkansas Department of Health Rabies Laboratory, 1982 - 1996.

MONTH	# SUBMITTED	MALE	FEMALE	UNKNOWN
JANUARY	3	2	1	0
FEBRUARY	2	2	0	0
MARCH	16	13	3	0
APRIL	38	11	26	1
MAY	29	10	17	2
JUNE	168	56	111	1
JULY	124	43	76	5
AUGUST	58	18	35	5
SEPTEMBER	38	18	17	3
OCTOBER	28	15	13	0
NOVEMBER	14	11	1	2
DECEMBER	3	2	1	0
TOTAL	521	201	301	19
PERCENT		38.6	57.8	3.6

mens, adult females with litters, and litters without adult females. Nineteen specimens were submitted as "heads only" for identification purposes, and sex could not be determined: the collection localties of seven specimens were not available. As expected, the greatest number of submissions were from densely populated urban areas where bats are much more likely to be encountered by humans and their pets.

Unfortunately, many of the pregnant specimens were not examined internally to determine numbers and sexes of fetuses due to their advanced states of deterioration or their battered conditions. Early in the study, forearm lengths and written descriptions of newborns and juveniles were not incorporated into the database because our goals at that time were to determine identity, sex, and geographic distribution within the state for ADHRL records.

Other specimens were collected by mist netting as described by Kunz (1988). Nets of different lengths (5.5, 12.8 and 18.3 meters[m]) were erected and opened into the capture position prior to dusk and checked at frequent intervals. Netting primarily occurred over shallow pools of streams and across abandoned roads in the Ouachita National Forest, Arkansas. Few mist-netted red bats were retained as museum voucher specimens. Instead, these bats were banded using yellow plastic split-ring bird leg-bands from A.C. Hughes, Middlesex, England. Thirteen red bats were fitted with .71 gram(g), 21-day battery-life radiotransmitters manufactured by Holohil Systems, Ltd. of Carp, Ontario, Canada. Radio-tagged bats were tracked using CE-12 and Merlin-12 receivers and five-element Yagi antennaes manufactured by Wildlife Materials, Inc. of Carbondale, Illinois. Distances between roost sites were determined using a *Trimble* Navigation Scout Global Positioning System receiver. Skeletal remains were collected by hand from caves and buildings. Voucher specimens were deposited in the Museum of Zoology Collections at the University of Arkansas at Little Rock and Arkansas State University, Jonesboro.

Results

Atypical Roost Sites.--Red bats are considered tree bats and are rarely encountered in caves, mines or buildings. However, on occasion this species has been found to utilize what are considered to be atypical roosts. In 1977 McDaniel and Gardner reported red bat remains from Blanchard Springs caverns and Hell Creek cave in Stone County. Saugey et al. (1978) reported the remains of 140 red bats in a side passage of Rowland Cave also in Stone County. In January 1993, 15 years after the original report of red bat remains in Rowland, the cave was revisited. Scattered about this same passage were the remains of only 10 red bats, all in an advanced state of deterioration that precluded determination of sex. Although the rate at which red bats enter this chamber is unknown, the low number encountered suggests significant accumulations may occur over a long period of time. We also report the discovery of three red bat skulls collected from Cushman cave in Independence County on 5 October 1991.

The occurrence of red bat remains in Arkansas cave systems should not be surprising. Cassidy et al. (1978) reported 18 red bats collected during mist netting activities during late summer and early autumn swarming activity at two Arkansas Ozark caves. Saugey (1978) reported the capture of 77 red bats in mist nets during swarming activity at Rowland cave between 14 July and 27 October of 1977.

Saugey and England (unpublished data) have recovered the intact carcasses of two male red bats from the attic of an abandoned house in Columbia County. One specimen was collected during each October of 1990 and 1991. The attic was regularly used as a daytime roost by Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and was accessible only by entering the lower portion of the house and then passing through a 1 x 1.3 m opening in the ceiling. Considering the time of the year these specimens were encountered and their lack of deterioration, one may speculate that the fall aggregation activities of *Corynorhinus* or other bat species at this structure may have attracted these red bats who were unable to locate the exit and perished. The presence of red bats during swarming activities of other bat species in Arkansas and elsewhere may be the result of their apparent attraction to the vocalizations of conspecifics and other species (Baker and Ward, 1967; Barbour and Davis, 1969; Downes, 1964; Mumford and Whitaker, 1975; Saugey at al., 1988; Saugey et al., 1989).

Rabies.--In Arkansas, red bats test positive for rabies more frequently than any other bat species based upon the

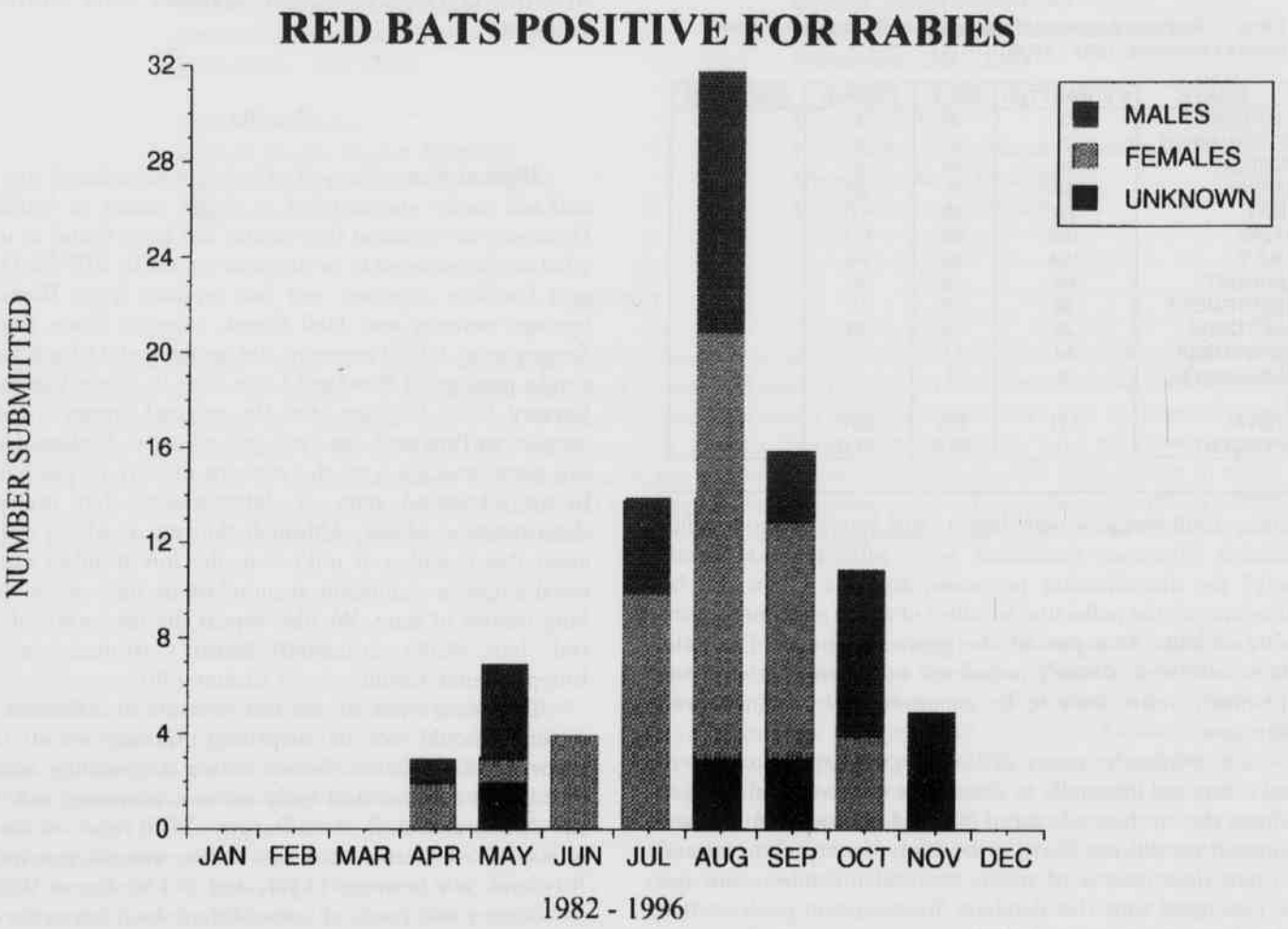

Fig. 1. Red bats reported positive for rabies in Arkansas, 1982 - 1996.

available sample size. Heidt et al. (1987) summarized bat rabies in Arkansas for the period 1982-1986 during which time red bats positive for rabies were reported from 23 counties. In 1991 Heidt et al. updated animal, including bats, rabies data for the state, but did not specifically address additional county occurrences for the red bat. Since 1986, 14 additional counties have had red bats test positive for rabies, and a number of previously reported counties have had additional cases confirmed bringing the total to 92 positive specimens (17.7%) of 521 red bats submitted (Fig. 1). County affiliation of two of these positive specimens is unknown. These 37 counties and the number of positive specimens are Arkansas (2), Ashley (1), Benton (3), Clark (3), Cleburne (2), Cleveland (1), Conway (3), Crawford (2), Dallas (1), Faulkner (8), Franklin (1), Garland (4), Hot Spring (1) Jefferson (5), Johnson (1), Logan (1), Lonoke (2), Miller (2), Mississippi (3), Ouachita (1), Perry (2), Phillips (1), Pike (1), Polk (1), Pope (4), Pulaski (11), Randolph (1), Saline (4), Scott (2), Sebastion (3), Sevier (1), Stone (1), Union (5), Van Buren (1), Washington (1), White (2), and Yell (2).

Copulation.--Saugey et al. (1989) observed fall copulation of red bats on two separate occasions, both of which were apparently initiated in flight. On 28 March 1993 an adult female was captured at 1920 hours in a mist net over a pool of the North Fork of the Ouachita River. Within seconds, an adult scrotal male entered the net and mounted the female. The male mounted dorsally and intermittently clenched the nape of the female's neck and upper back in his mouth maintaining some degree of tension. The male extended his legs and uropatagium around and beneath the caudal aspect of the female and attempted copulation (Fig. 2). The female remained calm during the entire episode.

Both bats were wing banded and released.

Two additional observations of red bats copulating occurred during the fall of 1997. On two occasions in September and October, high school football games were stopped while officials and coaches removed copulating red bats from the field. In both instances, bats had initiated copulation in flight and had fluttered to the ground (Coach James Sutton, Jessieville, Arkansas, pers. comm.).

Fig. 2. Copulatiing red bats

Fetuses.--There are few data regarding gender, rump-crown length or forearm lengths of fetuses due to poor condition of females submitted to ADHRL. On 19 May 1987 a female was examined that contained four very small fetuses (implanted 2L-2R) with left forearm lengths (LFA) of 6.2, 6.2, 6.4 and 6.7 millimeters [mm]. Sexes could not be determined with certainty. A female collected on 7 June 1989 contained two male fetuses. One fetus had been damaged so as to make a determination of forearm length impossible and the other had a LFA of 8 mm. On 8 June 1995, a female contained three small fetuses with LFA lengths that averaged 8.3 mm, and on 16 June 1986 a female contained four fetuses with average LFA lengths of 7 mm. Interestingly, even though all of these fetuses had similar LFA measurements, there was as much as 29 days between the dates of their collection in different years. Variance such as this suggests considerable fluctuation in dates of fertilization, parturition, lactation and postlaction from year to year and is most likely the result of environmental conditions, particularly temperature. Temperature affects the activity and availability of night flying insect prey and has a major effect upon active and dormant periods of this bat.

Saugey et al. (1988) mist-netted pregnant red bats on 16 and 23 May and 1 June in Hot Springs National Park. Caire (1986) reported the first palpable pregnancy on 22 May from the Ouachita Mountains of southeast Oklahoma, and on 18 May Gardner (1978) captured a female containing three embryos (2 males and 1 female) with average crown-rump lengths of 15 mm.

Lactation.---Fifty females were determined to have been lactating (45) or postlactating (5) at the time they were tested for rabies. Females were classified as lactating when submitted with one or more young-of-year and/or exhibited hair worn away from teats as the result of suckling by pups. Lactating females were submitted from 1 June through 16 July. Seventy-eight percent (35) of those lactating were submitted within the 19-day period between 12-30 June. The high percentage of lactating females submitted at this time may have been the result of the advanced sizes and weights of their pups and the difficulty females may have experienced in remaining attached to roost sites during inclement weather and windy conditions. Examination of Table 2 shows mean LFA lengths of pups to be 50-97 percent of

Table 2. Mean left forearm lengths for 47 juvenile red bats submitted to the ADHRL in June (1982-1996) and percent of adult male (38.7 mm) and adult female (41.1 mm) mean left forearm lengths.

DATE	SEX	LFA Range mm	Mean LFA mm	% Adult
1-Jun	Male(1)	11.6	11.6	29.9
2-Jun	Female(1)	13.8	13.8	33.5
5-Jun	Male(1)	18.2	18.2	47.0
	Female(3)	16.3-17.4	16.9	41.0
18-Jun	Male(1)	26.0	26.0	67.1
20-Jun	Male(1)	25.7	25.7	66.4
	Female(1)	31.6	31.6	76.7
21-Jun	Male(2)	28.8-29.8	29.3	75.7
	Female(5)	30.5-35.7	32.3	78.3
22-Jun	Male(2)	22.3-24.0	23.1	59.6
	Female(2)	24.7-26.3	25.5	61.9
23-Jun	Female(3)	20.8-32.9	28.1	68.2
24-Jun	Male(3)	26.0-34.8	31.3	80.8
26-Jun	Male(4)	18.8-37.8	28.4	73.3
27-Jun	Male(4)	25.6-36.7	29.7	76.7
	Female(2)	26.8-27.3	27.0	65.5
28-Jun	Male(2)	33.4-34.2	33.8	87.3
	Female(4)	34.8-39.6	36.3	88.1
29-Jun	Female(2)	38.8-39.7	39.3	95.4
30-Jun	Male(1)	39.1	39.1	100.1
	Female(2)	38.2-41.0	39.6	96.1

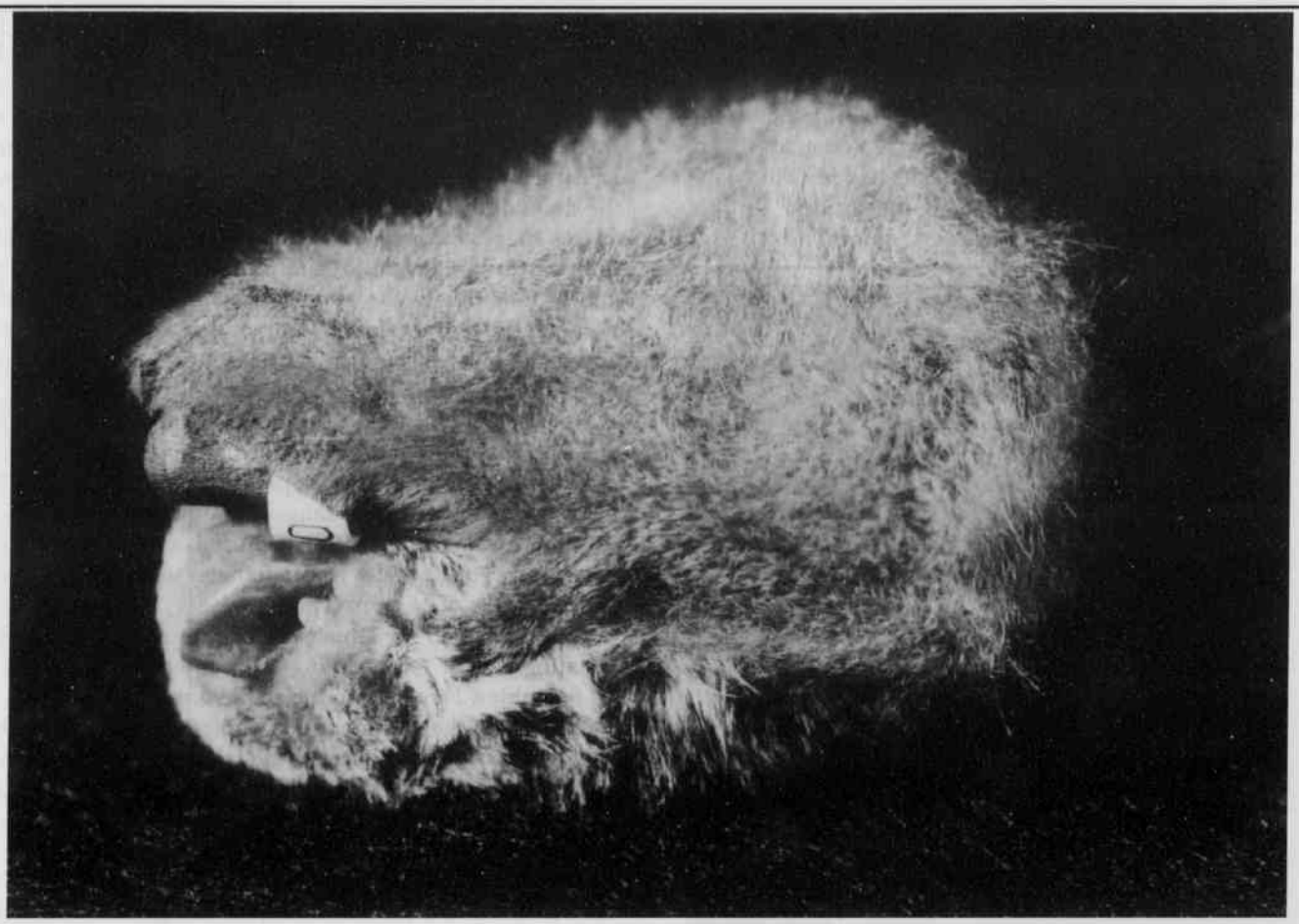

Fig. 3. Female red bat during induced hibernation. The bat is lying on her back with her uropatagium extended beyond the top of her head.

adult female mean forearm lengths during this period. In several litters, pups were observed to have forearm lengths longer than their mothers. It was also interesting to note that even though pups in many litters had forearm lengths of sufficient size to be volant, the family unit remained together.

Females were classified as postlactating when submitted without young and when they exhibited re-growth of hair around teats indicating suckling had ended prior to their collection. Postlactating females were submitted 2 July through 9 August.

Other studies have reported similar dates. In northeast Arkansas, Gardner (1978) reported lactating females on 13, 16, 23, 25 and 26 June. Saugey et al. (1988) mist-netted lactating females on 30 June, 8 and 18 July and postlactating specimens on 1 and 8 July in Hot Springs National Park. In southeast Oklahoma, Caire (1986) reported the first lactating female on 18 June, the first post-lactating female on 2 July and the last postlactating female 9 August.

Litter Size.--A total of 131 young-of-year consisting of 63 females and 68 males was examined for the months of June and July. Of this number, 98 were collected with lactating females, and the remaining 33 were collected with siblings only. These bats were contained within thirty-eight litters. Of these litters, 8 consisted of two young; 14 consisted of three young, and 10 consisted of four young. The overall ratio of males to females within these litters was 1.08:1. Litters were typically composed of a combination of male and female pups, but on several occasions litters were composed entirely of males or females. Six females were accompanied by only one young which is not considered typical litter size but which has been reported in the literature (Barbour and Davis, 1969). These single-young litters may have resulted from predation, other mishaps, or failure of the collector to secure all siblings. Left forearm lengths were noted for 47 of these pups (Table 2), but weights were not recorded. There were no lactating females, females with

young, or young without females submitted to the ADHRL during the month of May of any year. Elsewhere in Arkansas, Gardner (1978) reported one litter of 4, three litters of 3, and one litter of 2 totaling eight females, five males and two of unknown sex from northeast Arkansas. Saugey et al (1988) captured a juvenile female that had a mass of 5 g on 30 June 1982 and Caire (1986) captured the first flying young in southeast Oklahoma on 18 June.

Radiotelemetry.--Thirteen adult red bats were fitted with radiotransmitters in 1994 and 1995. Signals from 10 of these were not detected following the release date and are presumed to have flown beyond the search and study areas. In December 1993 an adult female was captured in a mist net over the North Fork of the Ouachita River. She was radiotracked to a large short-leaf pine tree where she roosted for three days and was subsequently tracked to a small shrub. The following day she was discovered hibernating in the hardwood-pine leaf litter on the forest floor. She remained at this location for at least eighteen days after which the battery on her transmitter was exhausted. During this period, daytime temperatures remained near 2.5 degrees C, substrate temperatures averaged 4.5 degrees C, and nighttime temperatures dropped near -2 degrees C or cooler. This bat was observed on a daily basis by gently removing enough leaf litter to verify that she was still alive. Interestingly, she would often be found lying in a different position, but always with her well-furred uropatagium pulled up near her neck (Fig. 3). The discovery of this female's choice of a hibernation site was not unexpected and confirmed observations by Saugey et al. (1989). In that study of bats ofthe Ouachita Mountains, red bats were observed to be "smoked" from hibernation sites during prescribed burning activities in the Ouachita National Forest. However, at the time these observations were made, a determination of whether those bats had come from tree roosts or from the leaf litter could not be made although most observers indicated they believed these bats were coming from the leaf litter. These observations made sense because at the time these prescribed burns occurred, deciduous trees had already shed their leaves. The color-match between the fur of red bats and the red and brown colors of fallen deciduous leaves provides an incredible degree of camouflage.

During April 1994, an adult male was radiotracked to a similar hibernation site beneath a large white oak tree in a hardwood-pine timber stand. The daytime temperatures during that time averaged 21 degrees C or higher, and this bat was alert when uncovered. Several minutes after being disturbed the bat flew from its hibernation site. Although many red bats were observed foraging at dusk that April, spring "greenup" or "leaf-out" of hardwood trees had not yet occurred, and the opportunity to roost among deciduous tree canopies was not yet available.

In May 1994 a male red bat was radiotagged and relocated in three different roost trees on three consecutive days before it left the study area. We recorded moves of 1.6 kilometers (km) from the capture/release site to the first roost tree with subsequent moves of 0.6 km and 0.3 km. In each instance this bat chose to roost in a midstory white oak tree (*Quercus alba*) even though large crowned, more mature white oaks and other hardwood species and shortleaf pine were available. At each location this bat roosted 6-7 m above the ground and chose roost sites approximately 0.5 m from the branch tip. Roost locations were on small branches at the leaf petiole/branch junction where the bat was well camouflaged among leaves and appeared as a somewhat "curled" leaf. Roost sites were also chosen on a side of the crown where an open, branch-free "flight gap" was available for easy departure and, presumably, easy access. The diameters breast high (DBH) of these trees were 10.7, 16 and 20.8 centimeters. All roost trees were located in mixed sawtimber/poletimber stands within red oak (*Quercus rubra*)/white oak/ hickory (*Carya* spp.)/shortleaf pine (*Pinus echinata*) upland forest types. Two locations were mid-slope on north and west facing areas, and one was located within a riparian zone approximately 60 m from a perennial stream. It is interesting to note that this male used three different roosts on three consecutive nights making him somewhat of a vagabond. Whether this behavior is typical cannot be deduced from these brief observations, but because red bats are not known to need or use structural habitat components (snags/cavity trees) other than tree canopies, they have an unlimited number of roost opportunites within the study area.

Discussion

Red bats may be the most common and widely distributed tree dwelling species in both rural and urban areas of Arkansas, yet only spotty information of their natural history is known. Assuming they are common and therefore numerous, the sheer magnitude of their impact upon the night flying insect populations of Arkansas's ecosystems must be staggering. Certainly, this important species deserves much more attention from researchers who at present are unable to even ascertain populations levels and whether the species is stable or in decline. Often referred to as a "weed species", red bats may prove to be extremely important to the health of timber and agricultural related industries of Arkansas. Studies designed to investigate their feeding habits and selection of prey should be intiated to help resolve their role in ecosystem dynamics.

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