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SEASONAL ACTIVITY AND REPRODUCTION IN BATS OF EAST-CENTRAL NEBRASKA

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ABSTRACT

Information on seasonal activity and reproduction is presented for seven species of bats inhabiting east-central Nebraska (*Eptesicus fuscus*, *Myotis septentrionalis*, *Nycticeius humeralis*, *Lasionycteris noctivagans*, *Lasiurus borealis*, *L. cinereus*, and *Pipistrellus subflavus*). Early and late dates of capture show five species active in the state for longer periods than previously reported. During some years, *E. fuscus* and *M. septentrionalis* emerge from winter torpor in March and feed on insects. Some *E. fuscus* inhabiting a floodplain forest in summer use houses in nearby towns as hibernacula, and year-round use of buildings by *E. fuscus* is substantial compared to other species of bats. Captures of *P. subflavus* in May and September are the first records from Nebraska not associated with mines or buildings. New reproductive information includes number of offspring, timing of lactation, and presence of volant young. Lactating females of *L. noctivagans* provide the first evidence of a reproducing population in Nebraska, and they also confirm that this species is a summer resident of eastern Nebraska.

† † †

In Nebraska, information is limited or lacking on seasonal activity and reproduction in many species of bats. The most comprehensive paper reviewing the biology of Nebraskan bats was published more than 20 years ago (Czaplewski et al. 1979). Although these authors summarized all available information known at that time, to a large extent, the natural history of Nebraska's bats was still poorly understood. Since then, only a few papers have published information on

seasonal occurrence and reproductive activity of bats in Nebraska, and these papers provide only incidental information (Benedict et al. 2000, Grube 1979, Manning and Geluso 1989, Saunders 1985). Herein we report new information on seasonal activity and reproduction in seven species of bats occurring in eastern Nebraska. For these species, we also summarize all known information on seasonal activity and reproduction in Nebraska.

STUDY SITE

We periodically netted bats at a single locality in east-central Nebraska. Our study was conducted at Fontenelle Forest Nature Center, a 526-ha private wildlife preserve situated between the Missouri River and the town of Bellevue in Sarpy County. Elevations in the preserve range from 294 to 367 m above sea level. Annual precipitation in the nearby city of Omaha averages 75.8 cm (based on 1961–1990, Owenby and Ezell 1992). Although the preserve is located in Nebraska, Iowa lies directly on the opposite side of the Missouri River.

Bats were captured in mist nets placed over a stream in a forested portion of the Missouri River floodplain. The width of the stream varied from 0.4 to 9.1 m throughout the study, and the flyway between the stream and forest canopy always remained uncluttered (Fig. 1). Our nets were set within 50 m of where the stream went under a gravel road (41°10.504'N,



Fig. 1. Our netting site in a floodplain forest of the Missouri River in east-central Nebraska. The south edge of Gifford Road in lowlands of Fontenelle Forest is shown in the foreground. Occasionally, we also netted along the stream on the north side of the road. The photograph was taken 3 January 1992.

95°53.573' W). The netting site was 1.05 km from the Missouri River.

Roughly half of the preserve is a lowland, floodplain forest dominated by cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), hackberry (*Celtis occidentalis*), rough-leaved dogwood (*Cornus drummondii*), box elder (*Acer negundo*), and white mulberry (*Morus alba*). The lowlands also contain several marshy areas, two lakes, and several streams. The remaining property is primarily an upland forest dominated by bur oak (*Quercus macrocarpa*), red oak (*Q. rubra*), shagbark hickory (*Carya ovata*), American linden (*Tilia americana*), green ash (*Fraxinus pennsylvanica*), hackberry, and ironwood (*Ostrya virginiana*). Additional information on plant diversity in the preserve is provided by Garabrandt (1988).

METHODS AND MATERIALS

At Fontenelle Forest Nature Center, we netted bats 60 nights from 1986 to 1999. Some netting was done each year. Our earliest date of netting was 21 March and latest, 18 November. Before evening twilight, one to five mist nets were placed across the stream and tended from 1.3 to 4.3 h after sunset. After bats were captured and removed from nets, each was placed individually in a 0.35-liter (12-ounce) drinking cup. Next, the cup was covered with a plastic lid and marked with time of capture. After nets were closed at night, we examined each bat and recorded time of capture, species, sex, reproductive condition (e.g., lactating, pregnant, non-reproductive), and age (young of the year or adult). Occasionally we processed bats the following morning. Females were recorded as lactating if milk was squeezed from nipples. Individuals were considered young of the year if cartilaginous epiphyseal plates in finger joints were visible to the unaided eye when the wing was transilluminated (Anthony 1988). Using this trait, all bats could be aged through early August, but starting in mid-August, it became difficult to age some individuals because cartilage in finger joints became no longer visible. Some individuals were aged by other traits (see accounts of species).

Although most individuals were released at night at the site of capture, a few were kept as voucher specimens and deposited at the University of Nebraska State Museum in Lincoln or at the University of Nebraska at Omaha. For pregnant individuals kept as specimens, we recorded crown-to-rump lengths of embryos or fetuses; in some cases however, we only measured the diameter of the largest uterine swelling. Additional information on reproduction also was determined by histological examination of some reproductive tracts. Lastly, stomachs of several bats were sent away for analysis to determine if bats captured in March were feeding on insects at that time of year or if stomach contents were of insects eaten the previous autumn (Whitaker and Rissler 1993).

Because big brown bats (*Eptesicus fuscus*) commonly roost in buildings in Bellevue and Omaha (RAB and KNG personal experience), we banded big brown bats to determine if individuals captured in Fontenelle Forest in summer were using nearby homes in winter. From 1990 to 1994, we banded *E. fuscus* with plastic split-bands (L and M Bird Leg Bands, San Bernardino, CA). Bands were yellow and uniquely numbered, and to make them different from bands of other investigators, we burned a single pin hole through the plastic adjacent to the number. Several *E. fuscus* were marked with red bands without numbers; these individuals

Table 1. Species of bats known from eastern Nebraska (Czaplewski et al. 1979), and number of individuals captured in Fontenelle Forest from 1986 to 1999.

Species	Number of individuals captured	Number of years captured	Years represented
<i>Eptesicus fuscus</i>	336	10	1986–1995
<i>Myotis septentrionalis</i>	163	12	1986–1995, 1997, 1998
<i>Nycticeius humeralis</i>	35	5	1988–1991, 1993
<i>Lasiurus borealis</i>	33	7	1988–1993, 1995
<i>Lasionycteris noctivagans</i>	12	6	1986, 1988–1991, 1993
<i>Lasiurus cinereus</i>	4	4	1989, 1990, 1992, 1995
<i>Pipistrellus subflavus</i>	2	2	1988, 1989
<i>Myotis lucifugus</i>	0	0	—
<i>Tadarida brasiliensis</i>	0	0	—
TOTAL	585 individuals		

represented 2.1% (4 out of 191) of the total number of banded bats. We banded the right forearm of males and left forearm of females.

In conjunction with our banding program, one of us (RAB) obtained bats from the Nebraska Humane Society in Omaha from 1989 to 1993. RAB visited the humane society every 1–3 weeks throughout the year and picked up bats that had been removed from buildings. All bats were identified by RAB and most were released 9.7 km from Fontenelle Forest.

RESULTS

From 1986 to 1999, we captured 585 bats representing seven species during 60 nights of netting (Table 1). Bats were captured each year except 1996 and 1999 (Table 2). Most bats (339 out of 585; 58%) were captured in 1989 and 1990, the two years netted most often. The only species documented from eastern Nebraska but not captured in Fontenelle Forest were *Myotis lucifugus* and *Tadarida brasiliensis* (Table 1).

Early and late dates of capture at Fontenelle Forest show five species active in Nebraska for longer periods than previously reported (Table 3). For *Eptesicus fuscus* and *Myotis septentrionalis*, earlier dates were obtained for spring and later dates for autumn. For *Nycticeius humeralis* and *Lasionycteris noctivagans*, new seasonal records were obtained only in spring and for *Lasiurus borealis*, only in autumn.

We kept three pregnant females of *E. fuscus* and two each of *M. septentrionalis* and *N. humeralis*. Based on our small sample size, it appears that in eastern Nebraska, *E. fuscus* and *N. humeralis* give birth to

more than one young per pregnancy, while *M. septentrionalis* bears only one young at a time (Table 4).

Through the years, we captured 91 lactating females representing six species; the only species not represented was *Pipistrellus subflavus* (Table 5). We also captured 52 individuals with cartilaginous epiphyseal plates in their finger joints. These young individuals represent five species (Table 6). Based on lack of tooth wear, we suspect that we also captured volant young of *L. noctivagans* and *P. subflavus* (see individual accounts). Further details regarding seasonal activity and reproduction are presented in the following individual accounts:

Eptesicus fuscus (Big Brown Bat)

Big brown bats are year-round residents of Nebraska, occur statewide, and probably are the most abundant species of bat in the state (Czaplewski et al. 1979). At Fontenelle Forest, they represented 57% of captures during our study. Based on captures from March to early August, adult males and females were present in the forest in roughly equal numbers (83 males, 99 females).

Prior to our study, the earliest mention of *E. fuscus* emerging from hibernation in Nebraska was April (Table 3). In March however, we caught *E. fuscus* twice on warm days—five individuals on 21 March 1990 and two on 25 March 1991. On these days, temperatures reached 22.8 and 27.8°C, respectively, in Omaha. Maximum temperatures for these days in Omaha normally average 10.0 and 11.1°C (based on readings from Eppley Airfield). Of five *E. fuscus* captured on 21 March, we

Table 2. Total number of bats captured each year at Fontenelle Forest from 1986 to 1999.

Year	Number of individuals captured	Number of nights netted	Months sampled
1986	5	1	May
1987	4	2	May and September
1988	29	2	May and September
1989	163	9	April–October
1990	176	19	March–November
1991	69	7	March–May and July–September
1992	33	4	July, August, and October
1993	64	6	April and June–August
1994	9	1	August
1995	30	4	June, August, and September
1996	0	2	August and September
1997	1	1	September
1998	2	1	August
1999	0	1	August
TOTAL	585 individuals	60 nights	

kept one male and one female. The stomach of both individuals contained recently eaten insects, including coleopterans (Scarabaeidae and Carabidae), lepidopterans, hemipterans, and dipterans (Culicidae and others). Besides these mild days in March, our other early captures of *E. fuscus* occurred on 21 April 1989, 15 and 22 April 1990, and 23 April 1993. Our latest capture of *E. fuscus* occurred on 1 November; the previous late date for active *E. fuscus* in Nebraska was 23 October (Table 3).

In temperate North America, number of young born to *E. fuscus* varies geographically. Females west of Nebraska usually bear a single offspring (Armstrong 1972), while those east normally have two (Kunz 1971). In western Nebraska, females bear either single offspring or twins; this part of the state is considered a "zone of transition" (Czaplewski et al. 1979, Jones et al. 1983). Three pregnant females that we kept from Fontenelle Forest each contained at least two embryos (Table 4). Thus, females from eastern Nebraska appear similar to females living east of the state.

Lactating females from Fontenelle Forest were captured 31 May–29 July (Table 5). Prior to our study, the earliest date of lactation for *E. fuscus* in Nebraska was in July (date not specified; Czaplewski et al. 1979). Although we captured no lactating females later than July, Jones (1964) reported a lactating female with two large young on 5 September. At Fontenelle Forest, we

captured volant young from 6 July to 21 September (Table 6). Previously, the earliest date of capture for volant young in Nebraska was 20 July 1959 (Czaplewski et al. 1979).

Of 191 *E. fuscus* banded by us at Fontenelle Forest, seven individuals (4%) were recaptured. A male banded on 22 June 1990 was discovered alive in a cool, insulated attic on 27 January 1995 (time span of 4.6 years). Another male banded on 31 August 1990 was discovered in a house on 27 April 1992 (time span of 1.7 years). Buildings were 11.5 and 2.3 km from our study site, respectively; one was located in Omaha and the other in Bellevue.

These recoveries of *E. fuscus* from Fontenelle Forest indicate that some individuals use houses in nearby towns as hibernacula. Use of houses as hibernacula by *E. fuscus* in this region of Nebraska appears to be large (Table 7). Of 327 bats removed from buildings by the Nebraska Humane Society in Omaha, 99% were *E. fuscus*. Most *E. fuscus* were obtained in August, the time of year when maternity colonies break up and bats begin to search for shelters to spend winter (Kurta 1999).

Of the remaining five individuals recaptured at Fontenelle Forest, only one of the band numbers was readable. A male banded on 27 June 1993 was recaptured 32 days later on 29 July 1993.

Table 3. Earliest and latest dates of capture for seven species of bats living in Fontenelle Forest from 1986 to 1999. Previously published dates of active bats (= not hibernating) in Nebraska also are presented.

Species	Fontenelle Forest		Previous dates	
	Early	Late	Early	Late
<i>Eptesicus fuscus</i>	21 March 1990	1 November 1990	April ^a	23 October 1955 ^b
<i>Myotis septentrionalis</i>	21 March 1990	16 October 1990	25 May 1975 ^a	21 September 1993 ^c
<i>Nycticeius humeralis</i>	10 May 1988	21 September 1990	1 June 1957 ^b	21 September ^a
<i>Lasiurus borealis</i>	1 June 1989	1 November 1990	26 April 1951 ^b	16 October 1982 ^d
<i>Lasionycteris noctivagans</i>	21 April 1989	2 September 1988	5 June 1988 ^d	2 October 1945 ^b
<i>Lasiurus cinereus</i>	16 June 1989	4 October 1992	May ^a	October ^a
<i>Pipistrellus subflavus</i>	19 May 1989	2 September 1988	—	—

^aCzaplewski et al. (1979).

^bJones (1964).

^cBenedict et al. (2000) and RAB (unpublished data).

^dManning and Geluso (1989 and unpublished data).

Myotis septentrionalis (Northern Myotis)

The northern myotis occurs in eastern Nebraska and westward along the Niobrara and Republican rivers (Benedict et al. 2000, Czaplewski et al. 1979). Prior to our study, most published records of *M. septentrionalis* in Nebraska (77 out of 129; 60%) came from limestone mines near the town of Louisville, 28–31 km southwest of our netting site. *M. septentrionalis* uses these mines on a year-round basis (Czaplewski et al. 1979, Jones 1964).

Previously, May was the earliest month documented with active *M. septentrionalis* in Nebraska; however, our earliest month of capture was March. Similar to *E. fuscus*, individuals of *M. septentrionalis* fed during nights of mild temperatures on 21 March 1990 (Table 3). The single *M. septentrionalis* captured on 21 March contained recently eaten insects (lepidopterans and dipterans). Excluding this capture, our other early captures of *M. septentrionalis* occurred on 21 April 1989, 15 and 22 April 1990, 27 April 1991, and 23 April 1993. Prior to our study, the latest published date for active *M. septentrionalis* in Nebraska was 21 September (Table 3). Our latest capture of this species at Fontenelle Forest was 16 October, thus extending its period of activity in autumn.

Adults of both sexes inhabited the forest—34 males and 57 females were captured from March to early August. We kept two pregnant females, and each contained one embryo (Table 4). The pregnant female collected on 31 May also was lactating. Other lactating females were captured in June and July (Table 5).

Earliest and latest dates of capture for volant young were 3 July and 5 September (Table 6).

Prior to our study, reproductive data for *M. septentrionalis* in Nebraska consisted of four pregnant females taken on 25–26 May; each female contained a single fetus measuring 15–17 mm in crown-to-rump length (Czaplewski et al. 1979). Additionally, two lactating females are known from 22 July and volant young from 22 July and 2 August (Benedict et al. 2000, RAB unpublished data).

Nycticeius humeralis (Evening Bat)

The evening bat occurs throughout most of the eastern United States and reaches its northwestern limit in eastern Nebraska (Benedict et al. 2000, Hall 1981). Here populations consist solely of adult females and volant young (Czaplewski et al. 1979). In fact, adult males also are not reported from adjacent areas including Iowa, Kansas, and northwestern Missouri (Bowles 1975, Clark et al. 1987, Jones et al. 1967, Sparks and Choate 2000, Watkins 1970). Our 35 captures of *N. humeralis* consisted entirely of adult females and young of the year, further suggesting that adult males do not occur or are rare in the northwestern part of their range.

Evening bats have not been discovered overwintering in Nebraska, Iowa, Kansas, or northern Missouri (Bee et al. 1981, Bowles 1975, Boyles et al. 2003, Czaplewski et al. 1979, Schwartz and Schwartz 2001, Sparks and Choate 2000, this study), supporting the conclusion that this species, at least in part, is migra-

Table 4. Number of embryos or fetuses in pregnant females captured in Fontenelle Forest. Measurements indicate crown-to-rump length of the largest embryo or fetus, or diameter of the largest uterine swelling.

Species	Date captured	Number of embryos or fetuses	Largest embryo, fetus, or swelling in mm
<i>Eptesicus fuscus</i>	4 May 1989	5	3.0 (embryo)
	4 May 1989	2	4.5 (embryo)
	10 May 1988	2	11.0 (swelling)
<i>Myotis septentrionalis</i>	19 May 1989	1	9.0 (embryo)
	31 May 1991	1	18.0 (fetus ^a)
<i>Nycticeius humeralis</i>	10 May 1988	2	7.0 (swelling)
	19 May 1989	3	4.0 (embryo)

^aForearm length of fetus was 9.5 mm.

tory (Kunz 1999, Watkins 1972). We are uncertain why Czaplewski et al. (1979) stated that there is "no doubt" that evening bats hibernate in Nebraska because their records showed evening bats in the state only from 1 June to 21 September (Table 3). Our earliest seasonal record at Fontenelle Forest was 10 May 1988. We also captured *N. humeralis* in May during other years (19 May 1989 and 14 May 1991). Our latest seasonal record was the same date as the previous record, the 21 September. Seasonal records of *N. humeralis* for Nebraska now extend from 10 May to 21 September (Table 3).

We kept two pregnant females; one contained two embryos and the other three (Table 4). Two embryos is the usual number for this species, although 1–4 have been reported (Watkins 1972). Lactating females were captured from 16 June to 14 July and volant young from 6 July to 10 August (Tables 5 and 6). The only other reproductive information available for *N. humeralis* in Nebraska includes two pregnant females (two fetuses each) on 1 June; lactating females on 9 and 24 July; and volant young on 30 June, 9 July, and late July (Benedict et al. 2000, Czaplewski et al. 1979).

Lasiurus borealis (Eastern Red Bat)

Eastern red bats are migratory in Nebraska and arrive in spring from southern and eastern wintering areas (Cryan 2003). The earliest date of capture in the state is 26 April (Czaplewski et al. 1979, Jones 1964). Of 33 *L. borealis* caught in Fontenelle Forest, our earliest capture was 1 June; however, a red bat caught on 1 November in the forest represents the latest seasonal record for the state (Table 3). No winter record of *L. borealis* is known from Nebraska. Although eastern red bats appear to be migratory at the latitude of Nebraska, some *L. borealis* may hibernate as far north as

the Ohio River Valley (Davis and Lidicker 1956, Jones et al. 1983).

Although Czaplewski et al. (1979) noted that adult males of *L. borealis* are rare in Nebraska in spring and early summer, we captured four adult males in Fontenelle Forest during this period (16 June 1989; 17 June 1990; 22 June 1990, $n = 2$). Six other adult males were captured in the forest; one each on 3 July 1990, 14 July 1989, 28 August 1992, 6 September 1991, 21 September 1990, and 1 November 1990.

At Fontenelle Forest, we captured two lactating females on 16 June and one on 27 June (Table 5). Another adult female captured on 16 June was not lactating nor was one taken on 1 June. We documented volant young ($n = 9$) from 10 August to 5 September (Table 6), but we were uncertain of the age of nine individuals captured from 20 August to 14 September.

Additional reproductive information for *L. borealis* in Nebraska includes one pregnant female with four fetuses (31 May), lactating females (21 June and 15 July), and eight females accompanied by young (females with four young on 14, 22, 24, 25, and 29 June and on 5 and 24 July; females with three young on 24 June; Czaplewski et al. 1979, Saunders 1985). Benedict et al. (2000) also reported a juvenile female and adult female (with four nursing young) from Nebraska, but specific dates of capture were not given.

Lasionycteris noctivagans (Silver-haired Bat)

Silver-haired bats are migratory but apparently also hibernate at latitudes of Nebraska and farther north (Jones et al. 1983). Evidence of hibernation exists in Michigan (Sherwood and Kurta 1999), Minnesota (Beer 1956), northern Illinois (Izor 1979), and

Table 5. Dates of capture of lactating females at Fontenelle Forest during our study. Total number of lactating females captured is given in parentheses. Asterisks indicate new records for earliest and latest dates of capture of lactating females in Nebraska. Years correspond to earliest date and latest date of capture.

Species	May	June	July	Earliest date	Latest date
<i>Eptesicus fuscus</i> (57)	31*	16, 17, 22, 27	3, 6, 20, 23, 29	1991	1993
<i>Myotis septentrionalis</i> (19)	31*	16, 17, 22, 27	3, 6, 7, 14, 20	1991	1990
<i>Nycticeius humeralis</i> (3)	—	16*	6, 14	1989	1989
<i>Lasiurus borealis</i> (3)	—	16, 27	—	1989	1993
<i>Lasionycteris noctivagans</i> (7)	—	16*, 17, 27	3, 6*	1989	1991
<i>Lasiurus cinereus</i> (2)	—	16, 22	—	1989	1990

South Dakota (Turner and Jones 1968). Although winter records of *L. noctivagans* from Nebraska are unknown, winter residents are a possibility. Our earliest date of capture of *L. noctivagans* in Fontenelle Forest was 21 April and latest, 2 September; however, the latest published date for Nebraska is 2 October (Table 3).

After arriving in mid-spring, some females remained in Fontenelle Forest to bear and raise young. We captured 11 adult females of which seven were lactating—two on 16 June 1989, one on 17 June 1990, two on 3 July 1990, one on 6 July 1991, and one on 27 June 1993 (Table 5). These females provide the first evidence of reproduction of *L. noctivagans* in Nebraska and confirm that in the east-central part of the state, silver-haired bats are summer residents. Lactating females also are known from adjacent Iowa (Clark et al. 1987, Easterla and Watkins 1967), but females of *L. noctivagans* have not been reported from Kansas in June, July, or August (Sparks et al. 1999, Sparks and Choate 2000). The remaining four females from Fontenelle Forest were not lactating and were captured on 4 May 1986 ($n = 2$), 21 April 1989, and 12 May 1990. Our first captures of *L. noctivagans* in the forest (the two females captured on 4 May) were previously reported by Roebuck (1986).

Besides the 11 females, we also captured a young male on 2 September 1988. Although cartilaginous epiphyseal plates were not visible in finger joints, its unworn teeth indicate that it was probably a young of the year (we compared tooth wear with teeth of a known volant young of *L. noctivagans* housed at the University of Nebraska State Museum, UNSM). Although our data suggest that summer populations of *L. noctivagans* in Nebraska are composed solely of females and young, presence of adult males in summer is a possibility. In fact, an adult male captured in western Nebraska on 19 June may have been a resident (Czaplewski et al. 1979). Moreover, adult males captured in summer (3 July and 6 August) are known from south-central Iowa, 225 km from the border of Nebraska (Clark et al. 1987). Thus far, adult males have not been reported from Kansas in summer (Sparks and Choate 2000).

Lasiurus cinereus (Hoary Bat)

In Nebraska, this migratory species arrives in May and remains in the state until October (Table 3). Adult males are known only from Pine Ridge and Wildcat Hills in western Nebraska, but adult females raise young throughout the state (Czaplewski et al. 1979).

Table 6. Dates of capture of volant young at Fontenelle Forest during our study. Total number of volant young captured is given in parentheses. Young are listed only if cartilaginous epiphyseal plates were observed in finger joints. Asterisks indicate new records for earliest date of appearance of volant young in Nebraska. Year corresponds to earliest date of capture.

Species	July	August	September	Year
<i>Eptesicus fuscus</i> (29)	6*, 29	10, 31	5, 21	1991
<i>Myotis septentrionalis</i> (7)	3*	10, 17	5	1990
<i>Nycticeius humeralis</i> (6)	6	4, 10	—	1991
<i>Lasiurus borealis</i> (9)	—	10*, 17	5	1989
<i>Lasiurus cinereus</i> (1)	—	4	—	1995

Table 7. Number of *Eptesicus fuscus*, *Myotis septentrionalis*, *Myotis lucifugus*, and *Nycticeius humeralis* removed from buildings (mostly in Omaha) by the Nebraska Humane Society of Omaha from 1989 to 1993. Numbers in parentheses indicate total number of individuals removed.

Time period	<i>Eptesicus fuscus</i> (324)	<i>Myotis septentrionalis</i> (1)	<i>Myotis lucifugus</i> (1)	<i>Nycticeius humeralis</i> (1)
April–May	7	—	—	—
June–July	38	—	—	1
August	140	—	—	—
September–October	13	1 ^a	—	—
November–March	126	—	—	—
date unknown	—	—	1	—

^aCollected in late October.

We captured four hoary bats at Fontenelle Forest, and all were females. Individuals captured on 16 June 1989 and 22 June 1990 were lactating, and one captured on 4 August 1995 was a volant young (Tables 5 and 6). The fourth female of unknown age was caught on 4 October 1992.

Additional reproductive information for *L. cinereus* in Nebraska includes three pregnant females with two fetuses each (5, 6, and 16 June), three lactating females (6, 16, and 30 July), seven females accompanied by young (females with two young on 6, 8, 17, 19, and 30 June and 6 July; a female with one young on 25 June), and several volant young during the last week of June (Czaplewski et al. 1979, Grube 1979, Jones 1964, Manning and Geluso 1989, Saunders 1985).

Pipistrellus subflavus (Eastern Pipistrelle)

Based on published records, eastern pipistrelles are known in Nebraska only from limestone mines along the Platte River in Cass and Sarpy counties (Czaplewski et al. 1979). They regularly hibernate in these mines, and a few have been discovered in them during summer. We also are aware of an unpublished record of an individual discovered in a garage in Weeping Water, Cass Co., Nebraska in July 1991 (UNSM 19925).

Although we only captured two *P. subflavus* at Fontenelle Forest, they are the first records from Nebraska not associated with mines or buildings. A female was captured on 19 May 1989 and a male on 2 September 1988 (Table 3). Our two captures indicate that during some years, *P. subflavus* is active in Nebraska as early as mid-May and as late as early September. In adjacent Kansas, *P. subflavus* emerges

from winter torpor in May and early June and enters hibernation in September (Jones et al. 1983).

The female from Fontenelle Forest contained swollen uteri, and histological examination of the reproductive tract showed that it had recently ovulated; however, it was not determined if any eggs were fertilized. The male contained no visible cartilaginous plates in its finger joints, but we suspect this bat was a young of the year based on lack of tooth wear. No other reproductive information for *P. subflavus* is available for Nebraska (Czaplewski et al. 1979).

DISCUSSION

Seasonal activity and reproduction

Our surveys of bats in east-central Nebraska showed five species active for longer periods than previously reported in the state (Table 3). In addition, our surveys extended the period of lactation in four species and documented the earliest date of appearance of volant young in three species (Tables 5 and 6). These records are primarily due to the limited number of chiropteran studies in Nebraska (see *Introduction*); however, timing of fieldwork and frequent sampling also helped us obtain these records.

Many of our records of seasonal activity are the result of when we sampled bats. Due to academic restraints of many researchers, most netting of bats is conducted in summer rather than spring and autumn. Because much of our netting was associated with classes and projects at the University of Nebraska at Omaha and because our study site was nearby, we netted bats regularly in spring, late summer, and autumn (Table 2). In addition, we netted bats during unseasonable climatic conditions.

Timing of migration, hibernation, and reproductive events in bats varies from year to year due to climatic factors. For example, movements of migratory species in autumn are influenced by passage of cold fronts (Constantine 1967). Cold temperatures reduce insect abundance, which results in bats moving to more favorable areas (Hill and Smith 1984). Thus, early cold fronts in some years and late ones in others help explain inter-year differences in bat activity in autumn.

In spring, climatic conditions also can influence emergence of individuals from hibernation. For example, in March 1990 and 1991, eastern Nebraska experienced unseasonably mild temperatures. Normally at this time of year, night-flying insects are rare or absent, and bats are in hibernation. However, during these years, we recorded the earliest spring records of volant *E. fuscus* and *M. septentrionalis* in Nebraska (Table 3), along with observations of many night-flying insects. Mild temperatures of 1990 and 1991 resulted in bats emerging from hibernation earlier than usual. These mild temperatures provide an example of how unusual weather conditions affect emergence of bats from hibernation.

Although our captures of *E. fuscus* and *M. septentrionalis* represent the earliest spring records for Nebraska, mid-March probably is not their average time of emergence; mid-April is probably closer to average for eastern Nebraska. We predict that if cold temperatures return after a period of unseasonably warm temperatures in early spring, bats will reenter hibernation.

In spring and summer, timing of reproductive events also is influenced by climate. For example, timing of parturition in bats is correlated with ambient temperature and precipitation (Grindal et al. 1992, Hoying and Kunz 1998). Warm, dry conditions result in earlier dates of births, lactation, and first appearance of volant young, while cool seasons with high amounts of precipitation result in later dates. Our records of reproduction in eastern Nebraska probably are linked to inter-year variation in weather patterns.

New information of seasonal activity and reproduction reported here was due to a combination of factors: (1) limited or lack of information on the natural history of many species of Nebraskan bats, (2) sampling of bats over many years, and (3) timing of surveys to include spring, autumn, and unusual weather conditions.

Species richness and abundance

Fontenelle Forest Nature Center is part of a floodplain and upland forest that extends along the Missouri River in eastern Nebraska. Here mature trees in

the forest and buildings in surrounding residential areas provide roosting sites for bats, while nearby water sources are plentiful, including marshes, streams, lakes, and the Missouri River. During our study at Fontenelle Forest, we captured all species of bats documented from eastern Nebraska, except *M. lucifugus* and *T. brasiliensis* (Table 1).

Although we did not capture *M. lucifugus* at Fontenelle Forest, this species occurs in surrounding areas. For example, individuals are known to occupy a mine 20 km southwest of our netting site, and an adult female was captured near the Missouri River, 14.7 km south of the forest (RAB unpublished data). In terms of *T. brasiliensis*, only nine records are known from Nebraska, including four from eastern Nebraska (Genoways et al. 2000, Glass 1982). The chance of us capturing this species at Fontenelle Forest was unlikely because known colonies of *T. brasiliensis* do not exist in the region (Genoways et al. 2000).

At Fontenelle Forest, the pattern of abundance of the four species of bats known to hibernate in eastern Nebraska probably is related to selection of winter roosting sites and abundance of hibernacula. We observed that *E. fuscus* and *M. septentrionalis* are common in the forest, while *P. subflavus* is rare and *M. lucifugus* absent (Table 1).

Eptesicus fuscus is the most common and widespread bat in eastern Nebraska probably because of the wide range of hibernacula it uses. This species is known to hibernate in buildings, caves, mines, storm sewers, and may even use hollow trees (Barbour and Davis 1969, Kurta and Baker 1990, Whitaker and Gummer 1992). As shown in Table 7, the number of *E. fuscus* using buildings for hibernacula near Fontenelle Forest is large. And based on our banding efforts, we documented some individuals from the forest hibernating in nearby buildings. We suspect that most *E. fuscus* captured during our study likely hibernated in buildings in Bellevue and Omaha.

In contrast to hibernacula selected by *E. fuscus*, *M. lucifugus* and *P. subflavus* apparently do not hibernate in buildings but prefer to use caves and mines (Barbour and Davis 1969, Fenton and Barclay 1980, Fujita and Kunz 1984). Our work with the Nebraska Humane Society supports these findings. Of 327 bats taken from buildings near Fontenelle Forest, only one was a *M. lucifugus* and none *P. subflavus* (Table 7). Nearest known hibernacula for these species are mines 19–42 km southwest of Fontenelle Forest near towns of Louisville and Weeping Water (RAB and KNG unpublished data, Czaplowski et al. 1979). Although these mines are within distances traveled by these species between their winter and summer retreats (Fenton and Barclay

1980, Fujita and Kunz 1984), most of the mines are considerably farther from Fontenelle Forest than buildings occupied by *E. fuscus*. Therefore, paucity of records of *M. lucifugus* and *P. subflavus* at the forest is likely due to these species fanning out over a broad area after leaving distant hibernacula.

Explanation for the abundance of *M. septentrionalis* at Fontenelle Forest is not clear. This species is relatively common in the forest, suggesting that it may hibernate nearby. However, buildings do not appear to be important hibernacula for this species in eastern Nebraska or elsewhere (Table 7, Caceres and Barclay 2000, Hoffmeister 1989). Perhaps *M. septentrionalis* is common in the forest because of its use of nearby storm sewers as hibernacula (Goehring 1954), or perhaps it uses hollow trees. However, we have no record of *M. septentrionalis* hibernating in these types of roosts in Nebraska, and a recent review of its biology mentions no use of trees in winter (Caceres and Barclay 2000). Hibernation requirements of *M. septentrionalis* in the Great Plains and in other parts of its range are in need of study (Fenton 1999).

Myotis septentrionalis is known to hibernate with *M. lucifugus* and *P. subflavus* in mines along the Platte River, southwest of Fontenelle Forest (Czaplewski et al. 1979, Jones et al. 1983). If numbers of *M. septentrionalis* in these mines are significantly greater than *M. lucifugus* and *P. subflavus*, then this might help explain higher numbers of *M. septentrionalis* in Fontenelle Forest after spring dispersal. However, we do not know about numbers of bats at these sites in winter.

We believe that *M. lucifugus* and *P. subflavus* (and probably *M. septentrionalis*) are more abundant in eastern Nebraska today than in the past because of excavation of mines and perhaps other human-made equivalents. Limestone and sandstone mines in Cass and Sarpy counties along the Platte River and North Branch of Weeping Water Creek provide places for these species to hibernate in a region of Nebraska that otherwise contains few natural caves or rock crevices. Without these mines, numbers of *P. subflavus* and *M. lucifugus* probably would be significantly lower in eastern Nebraska because these species primarily hibernate in caves and mines throughout their range (Fenton and Barclay 1980, Fujita and Kunz 1984). Furthermore, records of *M. lucifugus*, *M. septentrionalis*, and *P. subflavus* do not exist from counties in Iowa across the Missouri River from Fontenelle Forest; absence of these species from this part of Iowa is likely due to scarcity of suitable hibernacula (Bowles 1975, Clark et al. 1987).

Eptesicus fuscus also uses mines in east-central Nebraska (Jones 1964) but has been impacted more by

construction of buildings. Before buildings appeared in eastern Nebraska, summer roosts of this species presumably were located in tree cavities and rock crevices, while hibernacula were located in natural caves and possibly hollow trees (Barbour and Davis 1969, Kurta and Baker 1990, Whitaker and Gummer 1992). Today this species frequently occupies buildings in summer and winter (Table 7, Kurta and Baker 1990). On the Great Plains, construction of buildings likely has led to a dramatic increase in population size and geographic range of *E. fuscus* (also see Sparks and Choate 2000).

Use of buildings in summer also has been implicated in the increase in geographic range of *M. lucifugus* and *M. septentrionalis* (Barclay and Cash 1985, Fenton 1970, Sparks and Choate 2000). However, we recorded little use of buildings by these species in east-central Nebraska (Table 7).

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