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SHORT NOTES

Rediscovery of the Mexican flat-headed bat *Myotis planiceps* (Vespertilionidae)

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INTRODUCTION

The insectivorous flat-headed bat *Myotis planiceps* (Vespertilionidae) is an endemic species apparently restricted to a very small area, known only from three specimens collected between 1952 and 1970 in Madrean pine-oak woodland in three adjacent states in north-central Mexico: Coahuila, Nuevo León, and Zacatecas (Matson, 1975).

Myotis planiceps was once considered extinct by IUCN (Baillie and Groombridge, 1996), but more recently its status was changed to Critically Endangered (IUCN, 2004). The first objective of our study was to determine if we could find a living population or populations of this species. If extant populations were discovered, then further investigations were warranted, including detailed distribution, habitat requirements, dietary habits, and roosting behavior, to define the species' current conservation status in accordance with standards proposed by IUCN (2004).

MATERIALS AND METHODS

The project was initiated in 1998. All of the available written documents regarding the species were examined, including original field-notes from the collectors of two of the three known specimens. Then, in March 2000, a field team visited the localities where the three specimens were collected, to evaluate current habitat conditions. We decided that the most likely habitat for mist-netting *M. planiceps* would be the transition zone between the xeric scrubland and the upper pine forest. We also decided to attempt captures of live specimens during June and July, when the existing specimens were collected.

Capture localities (all in the Municipality of Arteaga) were as follows: Los Pinos — 10.6 km S, 2.6 km E Bella Unión, 2,103 m. The netting site was on the edge of a small patch of pińon pine (*Pinus*

TABLE 1. Somatic and cranial and mandibular data for the newly collected specimens of *M. planiceps* from southeastern Coahuila, México. The abbreviations for skull measurements are: GLS — greatest length of skull; CBL — condylobasal length; ZW — zygomatic width; BCW — braincase width; MW — mastoid width; LPAL — length of palate; HEI — skull height; MAX — maxillary toothrow length; M^1M^3 — length from the anterior border of M^1 to the posterior border of M^3; LD — dentary length; MAN — mandibulary toothrow length; and M_1M_3 — length from the anterior border of M_1 to the posterior border of M_3

Locality	Field No.	Sex	Body mass	Length				
				Total	Tail	Foot	Ear	Forearm
Los Pinos	1400	♀	3.0	81	32	7	11	27.4
Los Pinos	1401	♀	3.5	76	32	8	11	27.7
Los Pinos	1402	♀	3.5	82	33	8	11	27.8
Los Pinos	1403*	♀	3.5	85	37	8	11	–
Los Pinos	1404	♀	3.5	80	32	8	11	27.9
Armerías	1405	♂	4.0	80	31	8	11	27.1
Lontananza	1406	♀	4.0	80	31	8	11	26.9
$\bar{x}$	–	–	3.57	80.6	32.6	7.9	11.0	27.46

* — frozen specimen, not skinned

pseudostrobus), where the pine gives way to what was once desert scrub, today mostly converted to potato fields and apple orchards. Low hills surrounding the valley are covered with pine forest and rock outcrops. For three nights, two 12-m small mesh size nets were set over a clear, deep 25 × 15 m man-made pond Las Armenias — 0.9 km N, 9.95 km E San Antonio de las Alazanas, 3,198 m. This locality is situated within Madrean pine-oak (*Pinus-Quercus*) woodland. Two 12 m and one 6 m small mesh nets were set over a muddy stock tank. Lontananza — 4.6 km S, 18.4 km E San Antonio de las Alazanas, 2,879 m. The locality contains several species of pines, as well as other conifers. Four 12 m small mesh size nets were set over a small roadside pond.

Tissue samples (liver, kidney, heart, muscle) of voucher specimens were obtained and preserved in liquid nitrogen; ectoparasites were collected and preserved in alcohol. Skin and body skeleton or complete skeletons were preserved and catalogued in the collections of the Instituto Nacional de Antropología e Historia de México (acronym DP).

Six standard skin measurements, and 18 cranial and mandibular measurements, following Owen (1987), were taken (see Table 1). A digital caliper Ultra-Call II and a stereoscopic microscope were utilized.

Sound Recording and Analysis

Recordings were made of adult females while flying in a large room and during a hand-release at the capture site. We used a Petterson D980 detector with time-expansion (10×) and a 3 s digital memory. The detector microphone makes high-quality recordings up to 100–120 kHz. Slowed-down signals were recorded on a Sony Walkman professional WM DC6. Calls were digitised at a sampling rate of 2,2050 Hz and analysed with Avisoft software (Specht, Berlin). We applied a Fast Fourier Transformation (FFT; 512 points) with a Hamming window and a time overlap of 87.5%. This setting gave a frequency resolution of 0.56 kHz and a temporal resolution of 0.92 ms including extrapolation on the screen. For each behavioural situation we selected the sequence with the best signal-to-noise ratio for analysis. We measured starting and terminal frequency (kHz), sound duration (ms), and pulse interval (from the beginning of one call to the next; ms) — for measurement points see Kalko and Schnitzler (1993).

RESULTS

In June 2004, six specimens of *M. planiceps* were captured at Los Pinos, near the type locality (Table 1), and two others at new localities in Coahuila: Las Armenias and Lontananza. All of the specimens were collected in Madrean pine-oak woodland supporting previous observations that this species may be restricted to this habitat in northeastern Mexico.

In total, eight adult *M. planiceps* were captured, all in nets over standing water. Of these eight, one was a male, which had 4 mm long abdominal testes. Seven females appeared to be lactating with no embryos;

TABLE 1. Extended

Field No.	GLS	CBL	ZW	BCW	MW	LPAL	HEI	MAX	M^1M^3	LD	MAN	M_1M_3
1400	14.52	13.69	8.24	7.31	7.35	5.91	4.60	5.06	2.80	9.88	5.27	2.95
1401	14.38	13.86	8.11	7.42	7.44	5.55	5.03	4.95	2.82	9.53	5.10	2.87
1402	14.29	13.79	8.19	7.28	7.26	5.73	4.56	5.07	2.53	9.75	5.20	2.91
1403*	–	–	–	–	–	–	–	–	–	–	–	–
1404	14.34	13.25		7.23	7.22	6.14	4.84	4.90	2.77	9.77	5.29	2.95
1405	13.52	12.90	7.74	6.99	7.02	5.74	4.74	4.78	2.71	9.11	5.13	2.91
1406	14.31	13.56		7.29	7.11	5.88	4.85	5.08	2.85	9.59	5.05	2.95
$\bar{x}$	14.23	13.51	8.07	7.25	7.23	5.83	4.77	4.97	2.75	9.61	5.17	2.92

one was released at the site of capture. Other bats captured were: *Antrozous pallidus*, *Corynorhinus mexicanus*, *Eptesicus fuscus*, *Idionycteris phyllotis*, *Lasiurus cinereus*, *Myotis californicus*, and *M. thysanodes*.

Standard external and cranial measurements (Table 1) fall within the range of those published by Matson (1975). The dental formula is the same for the entire genus: 2/2-1/1-3/3-3/3. All upper premolars are in line with molars and not crowded, but well spaced; P^3 is very similar to P^2. The skull is flattened (Fig. 1), and as such it is very distinct from other species of the same genus.

Echolocation calls of *M. planiceps* flying indoors were short (2–3 ms), broadband (40–45 kHz) and steep frequency-modulated (FM) (Fig. 2A, Table 2). They swept from 80–90 kHz at the beginning of the call to 40–42 kHz at the end of the call (Fig. 3A). The pulse interval was around 60–70 ms. During release, terminal frequency tended to decrease slightly about 1 kHz, whereas sound duration and pulse interval increased from 2–3 ms to 4 ms and from 60–70 ms to 90 ms, respectively, in comparison to the indoor recording (Fig. 2B, Table 2). Bandwidth remained similar (40–45 kHz). A short, shallow-modulated component (QCF) was added although this component was barely detectable in most calls (Fig. 3B).

DISCUSSION

The finding of *M. planiceps* was the result of a successful effort by a team of concerned scientists. This rediscovery of a species presumed to be extinct offered us an opportunity to study its biology and behaviour. For example, the echolocation recordings available of an individual *M. planiceps* reflect the typical call design of a *Myotis* species flying in confined space (indoors) and in more open habitat (hand-release). Sound duration and pulse interval increased whereas bandwidth decreased (Schnitzler and Kalko, 2001). Interestingly, *M. planiceps* has a surprisingly low terminal frequency (38–42 kHz) given its very small body size and mass (3.5 g). Small Neotropical *Myotis* such as *M. keaysi* and *M. nigricans* (body mass, 5–6 g) produce higher pitched echolocation calls with

TABLE 2. Echolocation call parameters of *M. planiceps* flying indoors and during release

Parameter	Indoors				Release			
	n	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range
Starting frequency (kHz)	11	85.4	4.6	77.0–92.1	14	82.3	4.5	69.3–87.8
Terminal frequency (kHz)	11	40.6	1.0	39.1–42.6	14	39.5	0.8	38.0–40.9
Sound duration (ms)	11	2.4	0.3	2.0–2.9	14	4.0	0.5	3.3–4.7
Pulse interval (ms)	14	64.0	12.8	50.5–90.1	12	89.9	5.9	79.5–96.9

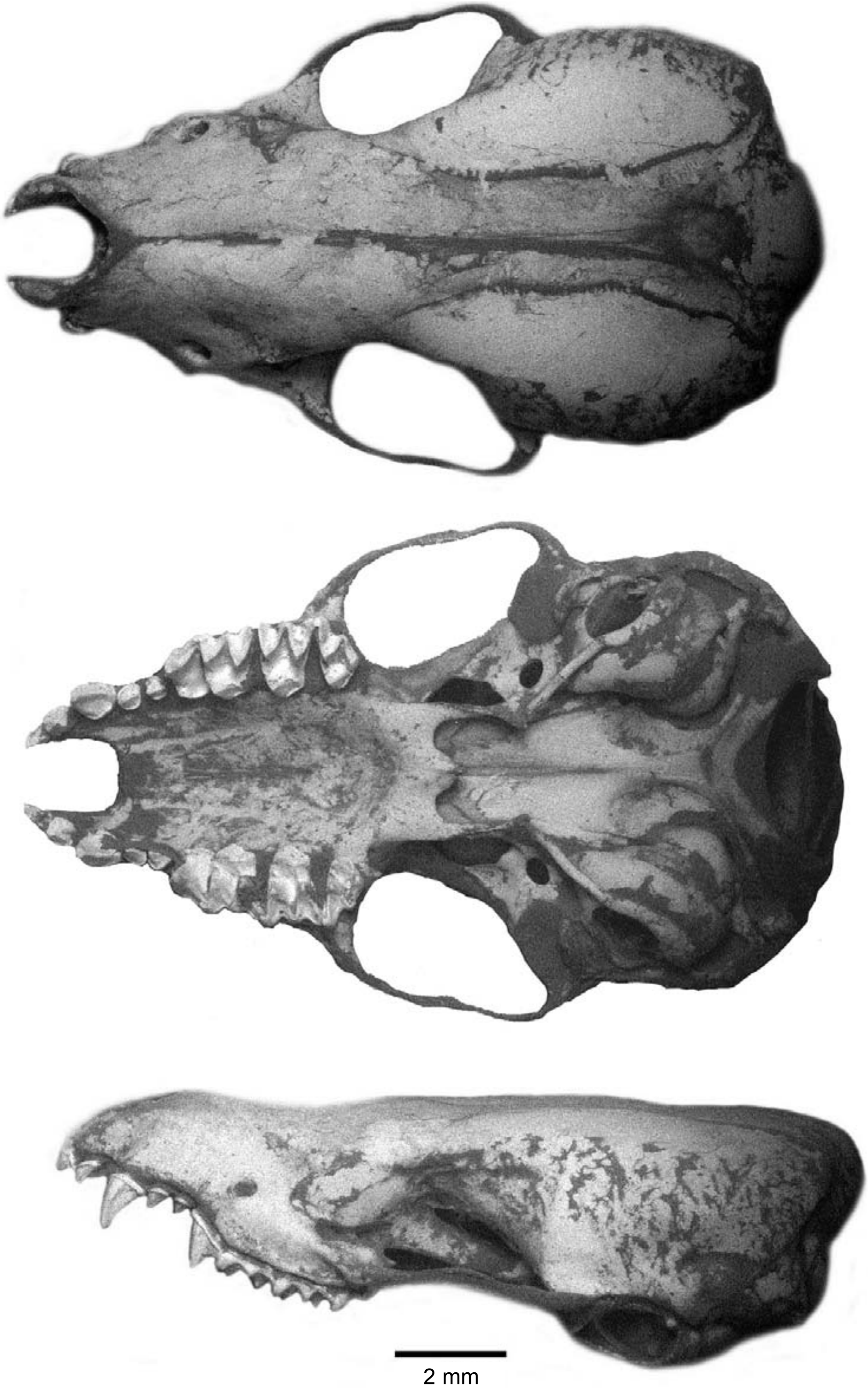

FIG. 1. Ventral, lateral, and dorsal views of the skull of *M. planiceps* (♀, field no. 1401). Photographs were taken under a SEM at 20 kV, 8× by J. Antonio Alva-Medina

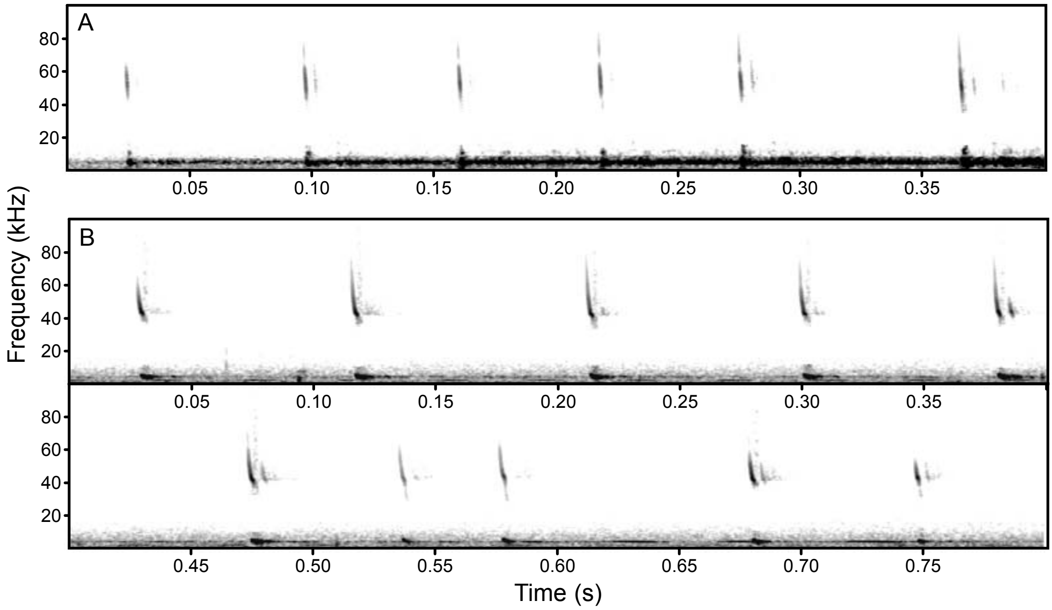

FIG. 2. Echolocation sequence of *M. planiceps*: A — indoors; B — during release

terminal frequencies around 59–63 kHz and 50–52 kHz, respectively (Rydell *et al*., 2002; Siemers e*t al*., 2001) in spite of their larger size and body mass. Sympatric *M. californicus* is barely larger than *M. planiceps* and also has higher terminal frequencies. As pattern and design of echolocation calls are shaped by a variety of factors, in particular ecological conditions, body size and phylogenetic relationships (Denzinger *et al*., 2003), a detailed study of *M. planiceps* echolocation behaviour will permit a broad-scale comparison with other species foraging under similar conditions. Further, echolocation call recordings will be very useful for determining habitat use, provided its call design is sufficiently unique to allow *M. planiceps* to be correctly identified among the other, co-existing species.

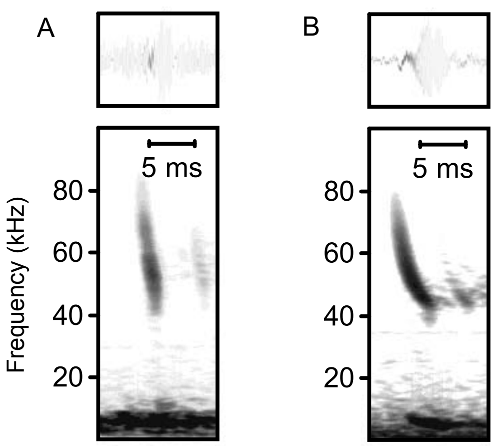

FIG. 3. Individual search calls (sonagram and oscillogram) of *M. planiceps*: A — indoors; B — during release

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Literature Cited

Baillie, J., and B. Groombridge. 1996. IUCN red list of threatened animals. The IUCN Special Survival Commission, Gland, 341 pp.

Denzinger, A., E. K. V. Kalko, and H.-U. Schnitzler. 2003. Ecological and evolutionary aspects of echolocation in bats. Pp. 311–326, *in* Echolocation in bats and dolphins (J. A. Thomas, C. Moss, and M. Vater, eds.). University of Chicago Press, Chicago, 631 pp.

IUCN. 2004. 2004 IUCN red list of threatened species. [http://www.redlist.org/search/details.php?species=14191].

Kalko, E. K. V., and H.-U. Schnitzler. 1993. Plasticity in echolocation signals of European pipistrelle bats in search flight: implications for prey detection and habitat use. Behavioral Ecology and Sociobiology, 33: 415–428.

Matson, J. O. 1975. Myotis planiceps. Mammalian Species, 60: 1–2.

Owen, R. D. 1987. Phylogenetic analyses of the bat Subfamily Stenodermatinae (Mammalia, Chiroptera). Special Publications, The Museum of Texas Tech University, 26: 1–65.

Rydell J, H. T. Arita, M. Santos, and J. Granados. 2002. Acoustic identification of insectivorous bats (order Chiroptera) of Yucatan, Mexico. Journal of Zoology (London), 257: 27–36.

Schnitzler, H.-U., and E. K. V. Kalko. 2001. Echolocation behavior of insect-eating bats. BioScience, 51: 557–569.

Siemers, B. M., E. K. V. Kalko, and H.-U. Schnitzler. 2001. Echolocation behavior and signal plasticity in foraging Neotropical *Myotis nigricans* (Schinz, 1821) (Vespertilionidae): a convergent case with European species of pipistrelles? Behavioral Ecology and Sociobiology, 50: 317–328.

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Acquisition of foraging behavior and insect preferences by naive juvenile red bats (*Lasiurus borealis*)

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Key words: *Lasiurus borealis*, foraging, diet, juveniles

Introduction

Little is known about how young insectivorous bats make the transition from a diet of mother's milk to flying insects. It has been hypothesized that young bats need time to acquire the skills necessary for successful flight and to capture flying insects (Davis and Hitchcock, 1965), and that they may learn these techniques by spending time foraging with their mothers (Brigham and Brigham, 1989).

The red bat (*Lasiurus borealis*) is a solitary, foliage-roosting species that ranges from Canada to Central America (Shump and Shump, 1982). Females typically give birth from two to four pups. In the wild, young *L. borealis* weigh 4–5 g by 3–4 weeks of age and fly at 4–5 weeks of age (Jackson, 1961). In captivity, pups generally weigh ca. 1.7 g within 24 hours of birth but do not open their eyes until day 10 or 11. Captive-born young are well furred dorsally by one week and are fully furred within 15 days (Lollar and Schmidt-French, 2002).

Orphaned or abandoned red bat pups are often brought to wildlife rehabilitators during May, June, and July in central Texas. Captive-raised males generally reach 3.5 g by one week, 5 g at two weeks, and 7 g at three weeks, while females weigh 4 g by one week, 6 g at two weeks, and 8.5 g at three weeks (Lollar and Schmidt-French, 2002).

While captive red bat pups exhibit some flight activity by 3 weeks of age, lactation continues for about 38 days under natural conditions (Kunz, 1971). The stomach contents of 33 young in Indiana revealed that 28 bats had only milk in their stomachs, three had only insects, and two had both milk and insects, an indication that some young bats still suckle after they begin independent foraging (Whitaker, 1972).

To assess whether young bats can learn to forage without their mother, we studied the behavior and diet of eight orphaned *L. borealis* raised in captivity as they began feeding on flying insects in an outdoor enclosure. Use of flight cages has proven useful in assessing bat behavior (Siemers, 2004). We hypothesized that if mothers are essential for the development of insectivory, then orphans would not develop the skill at all or develop it late, or possibly capture different prey than normally eaten by free-ranging *L. borealis*.

Materials and Methods

We used eight orphaned red bats (*L. borealis*) from central Texas, 7 ♂♂ and 1 ♀, from six different litters between 14th and 20th June 1999. All eight pups had their eyes open, were fully furred, had a mass of 4–7 g and none exhibited more than minimal flight ability. Taken together this suggests that they were less than four weeks of age.

All individuals were fed canine milk replacer formula and baby foods (meat and banana), supplemented with a vitamin paste four times per day. Mealworm larvae (*Tenebrio molitor*) were added to the diet as soon as pups accepted them, after which hand feedings were reduced to three per day. When pups were placed in an outdoor flight cage on 2nd July (10–16 days after we first received them), hand-feedings were reduced to two per day.

An outdoor flight cage was constructed from a metal tube frame covered with 0.6 cm polypropylene mesh, although a 1.8 m by 9.1 m section on one end of the enclosure was covered with 1.3 cm mesh to allow larger insects to enter. The cage was 17.2 × 6.4 m with a peak height of 3.6 m. It was located in a rural setting near Austin, Texas that included a mix of native trees, grassland, and agricultural fields. One 60-watt incandescent light bulb and two 1.0-mm black lights were suspended from the ceiling to attract insects. Small water trays were hung within foliage attached to the ceiling.

After their first flights, all eight bats had sunken abdomens prior to morning hand-feedings. Hand feedings were discontinued for individual bats when insects were first identified in feces and bats were observed to have distended abdomens in the early morning. Individuals that appeared to be feeding independently (as indicated by distended abdomens) were removed from the enclosure on 30th July, and 8th, 9th, 14th, and 15th August to minimize the possibility of competition for insect prey in the cage. To assess the type of insects consumed, feces were collected from beneath individual bats. Individuals were also weighed to the nearest 0.5 g when they first were observed to have distended abdomens in the early morning hours.

Insects that entered the flight cage were sampled using a funnel trap suspended from a black light on 30th and 31st July, and on 5th, 6th, 13th, and 14th August, and subsequently identified using a 10–30× dissecting microscope. Flight activity and echolocation calls were monitored for 10 to 30 min periods twice per week during evening flight activity with a Pettersson Mini-3 heterodyne bat detector from 2nd July through 15th August.

We compared the diet of the young *L. borealis* to our measure of insect availability even though availability is difficult to assess because bats may not be feeding in areas where insects were sampled, and insect traps may not properly sample insects. One of these variables was eliminated during this study as the insects were assessed inside the flight cage where bats foraged. Thus our results are not necessarily indicative of what juvenile *L. borealis* naturally eat. Availability is given as percent of total insects, whereas food is given as percent volume of diet. Notwithstanding, our data provide insight about the insects eaten relative to those available.

Results

With varying degrees of ability, all eight bats began flying on 2nd July, the first night they were placed in the outdoor cage. All bats had noticeably sunken abdomens in the morning each day through 7th July, and thus we judged that they were not feeding during their nightly flights. Although clear feeding buzzes were not detected until 16th July, one 10 g male apparently fed sufficiently on 8 July to have a distended abdomen in the early morning. Four other males (10 g, 10.5 g, 10.5 g, and 12 g) had distended abdomens in the early morning on 26th July. The remaining three bats did not have distended abdomens until 13th August (10 g ♂ and 11 g ♀) and 14th August (10 g ♂).

Bats were observed roosting near the incandescent light each night between bouts of flight activity. Sometimes they roosted singly, but other times in groups of 2 or 3. Although some juveniles began roosting alone by 23rd July, others continued to cluster in groups of two to three individuals periodically during their entire time in the enclosure.

Feces collected on 21st and 22nd July consisted entirely of the remains of mealworms, indicating that 20 days after flight began, most bats did not feed on their own. Other insect remains were not identified in feces until 30th July. The time required for individuals to independently forage on insects varied from 6 to 43 days after they began flying. All bats captured flying insects by the time they had attained body masses of 10–12 g.

A total of 918 insects were collected in the trap (Table 1). On 30th July, the most common insects in the trap were Hemiptera and Coleoptera. The bats, however, selected soft-bodied Diptera. On 31st July, the most abundant insects in the trap were Coleoptera but the bats fed heavily on Lepidoptera and Homoptera (cicadellids), again soft foods, although they also consumed smaller amounts of Hemiptera (lygaeids) and Coleoptera. Based on insects sampled on these two dates, the young bats appeared to avoid Coleoptera. On 5th August, the most abundant insects in the trap were Hemiptera and Homoptera, but the major foods taken by the bats were Lepidoptera, Homoptera (cicadellids), and Coleoptera (unidentified beetles). On 6th August, most insects in the trap were Coleoptera (unidentified beetles), Lepidoptera, and Homoptera (cicadellids). The bats avoided the most abundant Coleoptera (Staphylinidae — rove beetles), but did take Elateridae (click beetles). Fecal samples contained a high volume of Chironomidae (midges) on this date. On 14th August, coleopterans were the most common insects identified from the trap, but the bats selected Lepidoptera and Homoptera (cicadellids). Lepidopterans and leafhoppers are common prey of this species in natural situations and were the most abundant prey in fecal material in this study.

Discussion

In short, young *L. borealis* can learn to forage on insects without the help of their mothers. Because we were not interested in the food habits per se in this study, we do not present the data for all items eaten or in the availability sample, but rather report those that were available or eaten in larger proportions (Table 1). It is difficult to undertake a statistical analysis of these data because availability is given as percent of total insects, whereas food is given as percent volume of diet. However, if the bats are simply eating what is available, then the foods eaten should roughly be in the same

TABLE 1. Available insects (% of total insects trapped) versus insects eaten (% volume as resulted from the fecal analysis) by young captive *L. borealis* during three different periods

Insects	30th–31st July		5th–6th August		13th–14th August	
	Available	Diet	Available	Diet	Available	Diet
			Lepidoptera			
Unidentified	1.2	47.4	12.3	42.8	3.7	66.7
			Coleoptera			
Unidentified	14.8	18.3	17.5	10.6	41.5	3.0
Carabidae	0	0	2.9	3.4	0	0
Elateridae	0	0	0	0	2.4	13.9
Staphylinidae	0	0	21.7	0	24.4	0
			Homoptera			
Cicadellidae	1.2	16.1	13.6	27.5	11.0	11.8
			Hemiptera			
Lygaeidae	1.2	10.0	0	0	0	0
Unidentified	12.3	1.5	6.0	0.6	0	0
Cynidae	51.9	0	10.9	0	0	0
Pentatomidae	0	0	0	5.7	0	0
			Diptera			
	7.4	5.8	3.8	0.0	0	0
			Hymenoptera			
Ichneumonidae	9.9	0	0	0	0	0
Formicidae	0	0	0	0	17.1	0
Unidentified	0	0	11.3	0	0	0
Total insects trapped	81		755		82	

relative proportion to the available foods. It is clear (see Table 1) that the most common insects captured in the flight cage in our trap are not the most common insects the bats were consuming.

In the wild, young *L. borealis* weigh 4–5 g by 3–4 weeks of age and are flying by 4–5 weeks of age (Jackson, 1961). Based on the mass of young bats at the beginning of this study and the period of time in captivity, we estimate that the female was 62–69 days old and one of the males was 64–71 days old when they began feeding independently. Based on developmental stage and body mass, the remaining six males were estimated to be between 50–82 days old when they first began feeding on flying insects. This is longer than 38 days — the time young in the wild have to learn to feed based on documented lactation periods (Kunz, 1971). This suggests the possibility that young *L. borealis* may well learn from their mothers under natural conditions. Information transfer from mothers to young about good feeding areas could account for this difference (Rossiter *et al.*, 2002). A limited flight area may also have influenced insect availability and contributed to the time it took young to acquire these skills.

Analysis of stomach contents from bats in the wild suggest that moths and beetles are important prey items for this species; June bugs (Scarabaeidae), planthoppers (Delphacidae), ants (Formicidae), leafhoppers (Cicadellidae), and ground beetles (Carabidae) are some of the specific prey items eaten (Lewis, 1940; Hamilton, 1943; Jackson, 1961; Ross, 1967; Whitaker, 1972; Mumford, 1973). Our orphaned bats also took Lepidoptera and Coleoptera. Stomach contents of one young pup in the wild (64 mm body length; 4.4 g body mass) included 60% Chironomidae (Whitaker, 1972).

Fecal samples from young bats in our study contained a high volume of Chironomidae on 6th August. Because Chironomidae are small, soft-bodied, slow-flying insects, they may be more easily captured by young bats learning to feed.

In summary, our data show that captive-raised young *L. borealis* can learn to feed on insects commonly taken by the species in the wild without the benefit of a mother when provided with supplemental feedings, an indication that foraging on certain insects is at least partly an innate behavior.

Literature Cited

Brigham, R. M., and A. C. Brigham. 1989. Evidence for association between a mother bat and its young during and after foraging. The American Midland Naturalis t, 121: 205–207.

Davis, W. H., and H. B. Hitchcock. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy, 46: 296–313.

Hamilton, W. J., Jr. 1943. The mammals of eastern United States. Comstock Publishing Associates, Ithaca, New York, 432 pp.

Jackson, H. H. T. 1961. Mammals of Wisconsin. University of Wisconsin Press, Madison, 504 pp.

Kunz, T. H. 1971. Reproduction of some vespertilionid bats in central Iowa. The American Midland Naturalist, 86: 477–486.

Lewis, J. B. 1940. Mammals of Amelia County, Virginia. Journal of Mammalogy, 21: 422–428.

Lollar, A. L., and B. Schmidt-French. 2002. Captive care and medical reference for the rehabilitation of insectivorous bats, 2nd edition. Bat World Publication, Mineral Wells, Texas, 340 pp.

Mumford, R. E. 1973. Natural history of the red bat (*Lasiurus borealis*) in Indiana. Periodicum Biologorum, 75: 155–158.

Ross, A. 1967. Ecological aspects of the food habits of insectivorous bats. Proceedings of the Western Foundation of Vertebrate Zoology, 1: 201–263.

Rossiter, S. J., G. Jones, R. D. Ransome, and E. M. Barratt. 2002. Relatedness structure and kin-based foraging in the greater horseshoe bat (*Rhinolophus ferrumequinum*). Behavioral Ecology and Sociobiology, 51: 510–518.

Shump, K. A., and A. U. Shump. 1982. Lasiurus borealis. Mammalian Species, 183: 1–6.

Siemers, B. M. 2004. Bats in the field and in a flight cage: recording and analysis of their echolocation calls and behavior. Pp. 107–113, *in* Bat echolocation and research: tools, technique and analysis (R. M. Brigham, E. K. V. Kalko, G. Jones, S. Parsons, and H. J. G. A. Limpens, eds.). Bat Conservation International, Austin, 167 pp.

Whitaker, J. O., Jr. 1972. Food habits of bats of Indiana. Canadian Journal of Zoology, 50: 877–883.

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