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NATURAL HISTORY OF THE LONG-SNOUTED BAT, *Platalina genovensium* (PHYLLOSTOMIDAE: GLOSSOPHAGINAE) IN SOUTHWESTERN PERU

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ABSTRACT

Field observations, fecal pellet analysis and δ^{13} carbon isotope ratios of toe-muscle tissue indicated that long-snouted bats, *Platalina genovensium*, depend primarily on the columnar cactus, *Weberbauerocereus weberbaueri*, for food at a 2500 m site in Arequipa, Peru. In late 1991 we estimated a total of 87 bats at roost sites occurring within a 20 km search radius. In 1992, during a severe drought caused by an El Niño event, cactus flower and fruit production decreased as did bat numbers. In late 1993, after usual rains resumed, flower and fruit production increased, but bat numbers were still 60% lower than in 1991. Long-snouted bats may have emigrated from Arequipa in response to decreased fruit and flower production because of drought conditions associated with an El Niño event. By altering cactus phenology and bat abundance, El Niño events may have significant influence on the ecology of bat-plant mutualisms in southwestern Peru. Habitat destruction and harvesting of bats for folkloric medicinal purposes may negatively impact bat populations, and persistence of bat populations in Arequipa may be threatened.

KEY WORDS: Andes, bats, Cactaceae, CAM plants, El Niño, nectar production, carrying capacity, Peru, *Platalina genovensium*

RESUMEN

Observaciones de campo, análisis de muestras fecales y la proporción del isótopo carbono δ^{13} en muestras de tejidos musculares, indicaron que *Platalina genovensium* depende principalmente de la cactácea columnar *Weberbauerocereus weberbaueri*, para su alimentación en un sitio de estudio a los 2500 msnm en Arequipa, Perú. A finales de 1991 estimamos que el número de murciélagos dentro de nuestro radio de estudio de 20 km era de 87 individuos. En 1992, durante una sequía causada por el fenómeno de El Niño, hubo una disminución en la producción de flores y frutos en las cactáceas, y el número de murciélagos disminuyó. A finales de 1993, después de que se normalizaron los patrones pluviales, la producción de flores y frutos se reestableció pero nuestros censos revelaron que el número de murciélagos era 60% menor en comparación con el número en 1991. Quizás *P. genovensium* emigró de Arequipa como respuesta a la disminución de frutos y flores causada por las condiciones de sequía durante el fenómeno de El Niño. Consideramos que los cambios de fenología de *W. weberbaueri* y la consecuente disminución en el número de murciélagos causados por el fenómeno del Niño pueden tener una influencia significativa en la ecología de mutualismos entre murciélagos y plantas en el suroeste del Perú. Destrucción de hábitat y la extracción de murciélagos con fines de uso medicinal pueden tener una influencia negativa sobre la población, por lo que la persistencia de poblaciones de murciélagos en Arequipa puede ser amenazada.

PALABRAS CLAVE: Andes, Cactaceae, capacidad de carga, El Niño, murciélagos, Perú, plantas CAM, *Platalina genovensium*, producción de nectar

RESUMO

Observações de campo, análise de amostras fecais e a proporção de carvão δ^{13} em amostras de tecidos musculares de los dígitos, indicam que *Platalina genoversium* depende primariamente de cactos colunares, *Weberbauerocereus weberbaueri*, para a sua alimentação, em un sítio en Arequipa, Peru. No final de 1991, estimamos que o número de morcegos dentro no nosso raio de estudo de 20 km era de 87 indivíduos. Em 1992, durante uma seca causada pelo fenômeno El Niño, houve uma diminuição da produção de flores e de frutas nas cactáceas e o número de morcegos diminuiu. No final de 1993, depois que se normalizaram os padrões pluviais e a produção de flores e frutas se restabeleceu, os nossos censos revelaram que o número de morcegos era 60% menor que em comparação ao número que encontramos em 1991. Propomos que as mudanças de fenologia e a conseqüente diminuição do número de morcegos causados pelo fenômeno El Niño podem ter uma influência significativa na ecologia de mutualismos entre morcegos e plantas no sudoeste do Peru. Destruição de habitat e a extração de morcegos com fins de uso medicinal podem ter uma influência negativa sobre a população, e a persistência de populações de morcegos em Arequipa pode ser ameaçada.

PALAVRAS-CHAVE: Andes, Cactaceae, El Niño, morcegos, Peru, plantas CAM, *Platalina genovensium*, produção de néctar

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The long-snouted bat (Phyllostomidae, Glossophaginae) is a rare nectar-feeding bat endemic to the arid regions of western Peru. This monotypic genus was first described by Thomas (1928) from a single individual collected in the department of Lima. Collection localities include the departments of Piura, Lima and Arequipa (Aellen 1965, Jiménez and Pefaur 1982, Ortiz de la Puente, 1951), as well as one location east of the Andes, in the arid valleys of the department of Huanuco (Sanborn 1936). Recent capture of long-snouted bats near the city of Tacna, Peru (Department

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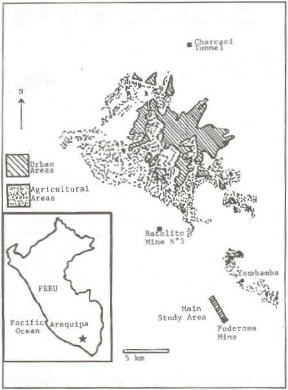

Figure 1. Map depicting the city of Arequipa and surrounding area. Locations of the three consistently censused roost sites are shown as squares.

of Tacna), extends this bat's range to the southernmost tip of Peru. Collection sites range in elevation from near sea-level (Lima) to 2500 m (Arequipa and Huanuco), and all are known arid habitats.

Nectar-feeding bat species that share part of the long-snouted bat's range include *Lonchophylla hesperia*, *Anoura geoffroyi*, and *Glossophaga soricina*. *Lonchophylla hesperia* is restricted to northwestern Peru; *A. geoffroyi* is not found south of the department of Lima west of the Andes; and *G. soricina* does not occur above 1400 m (Koopman 1978, Tuttle 1970). Thus, the long-snouted bat is the only nectar-feeding bat species present at mid- to high elevation sites in southwestern Peru and is the only potential bat pollinator and seed disperser of plants in this region.

Despite its probable role as an important pollinator and seed disperser in arid habitats and its high degree of morphological specialization for nectar-feeding (Winkelman 1971), prior to this study little was known about the natural history, population status, and ecological importance of this bat.

STUDY AREA AND SPECIES

The study site is located in the department of Arequipa, Peru, 20 km south of the city of Arequipa (16.27°S, 71.30° W; Fig. 1) on the western slope of the Andes, at approximately 2500 m above sea level. At our main study site we observed bat visitation of cacti flowers, and recorded cactus phenology and density. We recorded additional bat census data at various locations within a 20 km radius of Arequipa. Within the 1257 km^2 area searched, at least 314 km^2 is under residential or agricultural use. Also, because of heterogeneous topography, areas without cactus occurred within our search radius. Thus, suitable foraging habitat for the long-snouted bat was much less than the actual area searched. Sites that supported bat colonies all corresponded to the subtropical, low-montane, desert scrub life zone as classified by the Holdridge system (ONERN 1976). In Peru, this life zone occurs from 7°30' to 18°10' and can occur in two areas: along the coast from 500-1000 m, and along the western slopes of the Andes, generally between 2000 and 2900 m. Mean annual rainfall for this life zone is 222 mm (ONERN 1976). Between 1991 and 1993, however, a drought associated with an El Niño event resulted in a substantial decrease in rainfall in Arequipa (see Fig. 2).

Three species of columnar cacti occur at the study site: *Weberbauerocereus weberbaueri*, *Browningia candelaris*, and *Coryocactus brevistylus*. Of these, only *Browningia* and *Weberbauerocereus* have long, tubular, nocturnal flowers that can be visited by bats. The most abundant columnar cactus at the study site is *W. weberbaueri*, and around Arequipa (Aragón 1982, pers. obs.), is visited and pollinated by the long-snouted bat, two species of hummingbirds, *Patagona gigas* and *Rhodopis vesper*, and possibly diurnal insects (Sahley 1996). This cactus exhibits floral morphological characteristics consistent with both bat and hummingbird pollination syndromes of columnar cacti. For example, flowers are long, narrow, and tubular, and flower color ranges from white to red. Flowers open in the afternoon, remain open during the night and close late the following morning. Nectar production is continuous while the flower is open (Sahley 1995).

METHODS

We searched all known mines and tunnels within a 20 km radius of Arequipa. We used topographic maps as well as interviews with local people and biologists to locate sites and in 1991 we censused five sites. We consistently monitored three roost sites from one to five times a year from 1990 until early 1994. These three colonies included the two sites with the largest bat aggregations (Charcani tunnel, at a hydroelectric facility, and Batolito mine #3) as

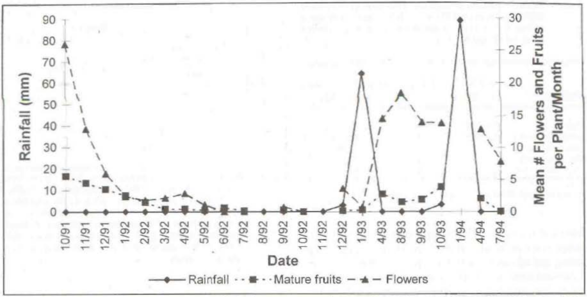

Figure 2. Flower and mature fruit production of *Weberbauerocereus weberbaueri* in relation to rainfall, October 1991- July 1994.

well as one abandoned mine that housed a smaller group of bats (Poderosa mine). We did not capture any bats from the Poderosa mine, nor did we enter the mine to conduct counts. Visual counts at the Charcani tunnel and Batolito #3 were made by either entering the mines during the day or waiting outside until bats exited in the evening. Captures were made using mist nets at one colony site in 1990 (Batolito mine #3) and at two sites (Charcani and Batolito mine #3) in 1991-93. In 1990, we recorded relative age, forearm length, and reproductive condition of captured individuals; in 1991-93 we also recorded body mass. For three adult males and three adult females, we measured and recorded wingspan and wing area according to Norberg and Rayner (1987). Wing loading was calculated separately for adult males and females by dividing mean body weight by mean wing area.

Phenological data for *W. weberbaueri* were obtained at the main study site by counting the numbers of buds, flowers, developing fruits, and mature fruits, for 40 mature, marked individuals between October 1991 and July 1994. These cacti were located ≈40 km from the Charcani roost, ≈15 km from the Batolito mine #3 roost, and <1 km from the Poderosa mine roost. Plants were censused weekly or monthly whenever possible when only LEB was present (see Fig. 2 for census dates). Mean flower and fruit production/plant/month and per day were calculated from phenology data. The relative density of adult *B. candelaris* and *W. weberbaueri* cacti at the main study site was determined by counting the number of cacti >1 m in height in ten 600 m^2 quadrats. From this data we estimated the number of adult cacti/ha. Nectar production of *W. weberbaueri* flowers was measured by bagging 29 flowers on 29 randomly selected plants prior to opening and measuring the amount of nectar produced at 2-hr intervals until the flowers closed the following morning. Sucrose concentration was measured using a Reichert-Jung refractometer. The values obtained, in mg sugar/mg solution, were converted to mg sugar/ml nectar as described in Bolten *et al.* (1979). Mean sugar content was calculated per flower/night and converted to kilojoules. We used mean number of flowers produced per night/plant/ha to estimate nectar production/ha. Estimates of carrying capacity based on nectar availability per hectare for bats were obtained from Nagy's (1987) equations for field metabolic rates of eutherian mammals and passerine birds. Estimates for mammals and birds were both used because bats may have field metabolic rates approaching those of birds (Petit 1995, Petit and Pors 1996, von Helversen and Reyer 1984). The equations used to calculate energetic requirements were: a) kJ required/individual/d = 3.35 x effective mass.$^{0.813}$ (eutherian mammals); and b) kJ required/individual/d = 8.88 x effective mass$^{0.749}$ (passerine birds). Effective mass was defined as the mean mass of adult, non-reproductive individuals (19.7 g).

To obtain a preliminary assessment of the dietary habits of long-snouted bats, in 1992 we collected all fecal pellets in a 0.5 m^2 plot underneath an area where a cluster of bats regularly roosted in Batolito mine #3. The pellets were air

Table 1. Mean morphological measurements for *P. genovensium* captured between 1991 and 1993. Mann-Whitney U comparison of forearm length and body mass between adult males and females.

Variable	Subadults			Adult females			Adult males		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Mass (g)	16.9	1.38	25	19.9	1.4	41	19.5	1.3	44
Forearm length (mm)	49.2	0.93	27	50.5[a]	1.2	48	50.0	1.17	52
Wing span (cm)				0.351		3	0.356		3
Wing area, S (m^2)				0.0188		3	0.0203		3
Wing loading[b] (N/m^2)				10.4		3	9.4		3

[a] $P<0.05$

[b] N stands for Newton, the unit used to designate weight (weight = mass x 9.81 m/s)

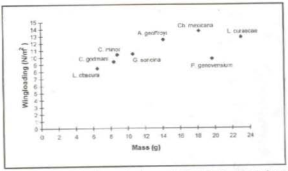

Figure 3. **Wing loadings of glossophagine bats. Data from Norberg and Rayner (1987) and Sahley *et al.* (1993). L.=*Lichonycteris*, C.=*Choeroniscus*, G.=*Glossophaga*, A.=*Anoura*, Ch.=*Choeronycteris*, P.=*Platalina*, and L.=*Leptonycteris*. For purposes of comparison, mean wing loading for *P. genovensium* was calculated from mean wing measurements and body mass of both sexes combined.**

dried and stored in a plastic bag. One hundred and two pellets were randomly selected, placed in separate petri dishes, and rehydrated with water prior to observation with a stereomicroscope. Pellets were teased apart with dissecting probes, and frequency of occurrence of pollen, fruit pulp, seeds, and insects per pellet was scored. Pollen, fruit pulp and seeds found in fecal samples were compared to reference samples of *W. weberbaueri* collected in the field.

Carbon isotope analysis of bat toe-muscle tissue was performed to determine this species' dependence on CAM cacti for food. Because columnar cacti use crassulacean acid metabolism (CAM) as a photosynthetic adaptation to arid conditions (Gibson and Nobel 1986), the proportion of ^{12}C *vs.* ^{13}C (δ^{13} ratio) that is fixed into cactus tissues varies substantially from that of plants that undergo the more common C_3 photosynthetic pathway. When animals feed from CAM plants or on herbivores that feed on CAM plants, the carbon isotopic composition of the CAM plant tissue is conserved and fixed into animal tissue. Therefore, analysis of the carbon isotopic composition of animal tissue can offer important insights into animal diets. Muscle tissue from one toe per individual was obtained from three live bats captured in January 1991 and from three preserved specimens in the collection of the Universidad Nacional de San Agustín (no collection date was available for these). Carbon turnover in gerbil muscle tissue has a half-life of approximately 27.6 days (Tiezsen *et al.* 1983), thus analysis of carbon stable isotope composition of bat muscle tissue probably integrated isotopic composition of dietary carbon ingested during the preceding year. Analysis of tissues was performed according to methods outlined in Herrera *et al.* (1993) and Buchanon and Corcoran (1959). Tissue samples were not collected in 1992 through 1994 because of low bat numbers.

Statistical analysis was performed using SYSTAT version 5.3 (Wilkinson 1991). We conducted Mann-Whitney U tests on forearm lengths and body mass to estimate significant differences between adults of both sexes.

RESULTS

Morphology

The long-snouted bat is a relatively large nectar-feeding bat, third in size to *Leptonycteris curasoe* and *L. nivalis* (Table 1; see Norberg and Rayner 1987 for comparative morphological data on glossophagine species discussed in this paper). Adult females have a slightly longer forearm (U=1541, n=85, P=0.037) than adult males. The long-snouted bat has a large wingspan and forearm, second to *L. nivalis*. Wing area of *Platalina* is the largest of any glossophagine recorded, although wing area measurements for the largest nectar-feeding bat, *L. nivalis*, are unavailable for comparison. The long-snouted bat has a low wing loading relative to most other glossophagine bats for which measurements are available, especially when compared to glossophagines with a similar body mass (Fig. 3).

Diet

Cactus pollen was the most frequent item found in fecal samples (99%), followed by unidentified insect parts (59.8%), seeds and/or fruit pulp (17.6%), and anther parts (14.7%). Of 102 pellets examined, we found nine whole *W. weberbaueri* seeds, and 6 large pieces of *W. weberbaueri* seed husks. We found a total of 52 *W. weberbaueri* seeds in the same area where fecal pellets were collected. Presumably these separated from fecal pellets during defecation or upon striking the ground.

Table 2. Census data and roost sites for long-snouted bats used to estimate total population size within our study radius in late 1991 and early 1992.

Roost Site	Census Date	No. of Bats
Batolito mine #2	April 1990	5
Batolito mine #3	January 1992	10
Poderosa mine	December 1991	5
Rescate mine	January 1992	2
Coricancha mine	January 1992	10
Charcani tunnel	December 1991	50
Batolito tunnel #1 (flooded 1991)	March 1990	5

We obtained $\delta^{13}C$ ratios of -10.29, -10.52, -10.90, -9.40, and -10.48 from tissue samples of five long-snouted bats. A previous study found tissues of CAM cactus and agave plants from Mexico to have $\delta^{13}C$ values of -12.6 whereas bat-visited C_3 plants have a mean $\delta^{13}C$ of -26.4 (Fleming *et al.* 1993). These data, along with our observations, indicated that in Arequipa long-snouted bats feed almost exclusively from cactus flowers, fruits and insects that feed on CAM plants. Estimates of density indicate that *W. weberbaueri* (98 plants/ha) is much more abundant than *B. candelaris* (4 plants/ha) at our site. Observations of flower visitation behavior and of bat droppings collected at day roosts indicated bats feed from flowers and fruits of *W. weberbaueri*. Phenology data indicated year-round fruit and flower production of *W. weberbaueri* (see below).

Bat Populations

Seven roost sites containing long-snouted bats were located (Table 2). All potential roost sites searched contained bats. Four sites were located in 1990 and three additional sites in 1991 (Table 2). All occurred between 2200 and 2600 m above sea level, and all were located within *Weberbauerocereus* habitat. Five roost sites were abandoned copper mines and two were man-made tunnels excavated into ridges. Both tunnels were unused by humans and had only one opening. Visual counts of bats indicated that colony sizes ranged from a minimum of one to a maximum of 50 individuals; prior to the 1992 drought, the median colony size was five. Within a roost, groups of 5-7 bats were found at different roost microsites. In late 1991, a census of five of seven roost sites revealed the presence of approximately 77 individuals. Due to logistical constraints in late 1991 to 1994, we did not census the remaining two sites (Batolito mine #2 y tunnel #1) we had found in 1990. If we assume these two sites contained a total of 10 individuals (the maximum number of bats found there in 1990), we estimate a total number of 87 individuals present in tunnels and mines within a 20 km radius of the city of Arequipa in late 1991.

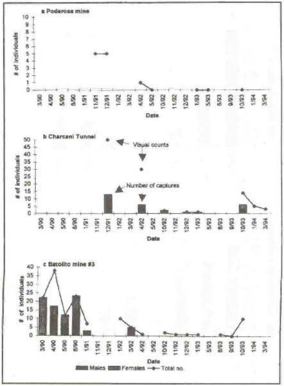

Figure 4. a) Census data for Poderosa mine. b) Census and sex composition data for Charcani tunnel. Bars represent number of individuals captured by sex and age. Diamonds indicate visual counts. Months with only visual counts lack sex composition data. c) Census and sex composition data for Batolito mine #3 from 1990-1993.

In 1990, prior to the El Niño drought, groups containing males, females, and subadults were present during every census period at Batolito mine #3 (only mine censused in 1990). Subsequent censuses of Batolito mine #3, Charcani tunnel, and Poderosa mine showed that long-snouted bat abundance declined substantially during the onset of the severest part of the El Niño drought in April 1992 (Figs. 4a, b, and c). In late 1991 and early 1992 we found a total of 65 bats during our census of these three mines, but in January 1993 we found only two bats. In late 1993 after the drought ended, bat numbers increased slightly but did not approach pre-drought levels. Only 24 individuals were found at the two largest colony sites (Charcani and Batolito #3) in October 1993, a 60% decrease compared with late December 1991 and early January 1992 when 60 individuals were found. Numbers remained low in 1994 relative to 1991, although two rainy seasons had occurred since the drought (Fig. 4). No bats were found in the Poderosa mine

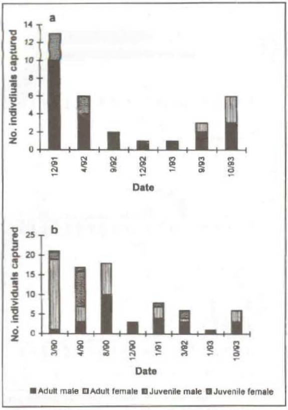

Figure 5. Age and sex composition of captured bats at Charcani roost and b) age and sex composition of captured bats at Batolito mine #3.

after April 1992. The Charcani tunnel, site of the largest colony that contained 50 bats in 1991, contained only three individuals in March 1994.

Social Structure

Roosts consisted of only males or mixed-sex aggregations, and sex composition of the roosts varied over time (Figs. 5a and b). For example, at the Charcani tunnel (Fig. 5a), which contained approximately 50 individuals in 1991, we captured only adult and subadult males from 1991 until late 1993, but thereafter also captured females. Subadult males occurred in all male and mixed-sex colonies, but subadult females occurred only in mixed sex aggregations (Figs. 5a and b). We never found all-female colonies and pregnant females were always found in mixed-sex colonies. Although capture data indicated that overall the adult male and female sex ratio was almost exactly 1:1, we captured more subadult males than subadult females.

Reproduction

After March 1992, during the height of the drought, we caught no subadults or juveniles. We caught no pregnant females from January 1991 through September 1993. This two-year span corresponds with the drought period and low fruit and flower production by *W. weberbaueri*. In 1993, three out of eight females captured in October were pregnant or post-lactating. Adult males, however, were found year-round in Arequipa, although at very low numbers, in all years from 1990 through 1993 (Fig. 5).

Cactus Phenology and Carrying Capacity Estimate for Bats

Mean density for adult (>1m) *W. weberbaueri* cacti per sampling quadrant was 4.5 cacti (n=10, SD=4.1, 95% C.I.=2.9) which allowed us to estimate adult cactus density at 9.8/ha. Flower density at the main study site dropped from 86/ha/d in October 1991 to 9.3/ha/d by April 1992. Mature fruit production decreased from 19.3/ha/d to 1.4/ha/d during this same time period, although flower and fruit production never stopped completely. After rains returned in 1993, fruit and flower production in *W. weberbaueri* increased to a level comparable to that observed in late 1991 (Fig. 2). Because flowers produced an average 2.173 kJ of nectar per night, energy from nectar available to the bats decreased 89% between October 1991 and April 1992, from 186.8 kJ/ha/night to 20.2 kJ/ha/night. Daily energy requirements for non-reproductive long-snouted bats, as calculated from Nagy's (1987) equation for eutherian mammals, indicate a need of 37.8 kJ/d per individual. Thus, estimated carrying capacity for bats based on nectar availability ranged from 4.93 bats/ha in October 1991 to 0.53 bats/ha in April 1992. Estimates obtained from the equation for passerine birds indicate bats may need up to 82.78 kJ/d. If this were the case, carrying capacity would have ranged from 2.6 bats/ha in October 1991 to 0.24 bats/ha in April 1992.

DISCUSSION

Morphology

The long-snouted bat has a large wing area and wingspan relative to most other glossophagine bats for which measurements are available. Since air density decreases with altitude above sea level, power required for hovering and forward flight also increases with altitude (Norberg 1990). A large wingspan and low wing loading, as found in long-snouted bats, will reduce power required for flight at high altitudes and may also increase flight maneuverability (Norberg and Rayner 1987). Wing loading of the long-snouted bat is lower than that of two other relatively large glossophagines that inhabit arid zones, *Choeronycteris mexicana* (13.7 N/m^2, Norberg and Rayner 1987) and *Leptonycteris curasoae* (12.8 N/m^2, Sahley *et al.* 1993). Feinsinger *et al.* (1979) found that mean wing disc loading decreased with increasing elevation for hummingbirds occurring on the eastern Andean slopes of Peru. They suggested that low wing loading found in hummingbirds at high elevations is a potential adaptation to reduce energetic expenditure during hovering and forward flight. Wing morphology of long-snouted bats may also represent adaptation to flight in montane desert habitats, although more detailed information on its altitudinal range and morphological comparisons with other glossophagine bats with similar altitudinal ranges are necessary to test this hypothesis.

Diet

Our data indicate that the long-snouted bat is a cactus specialist at our study site in southwestern Peru. Flower visitation observations, flower availability, analysis of fecal pellets and $\delta^{13}C$ values indicate that at Arequipa, the long-snouted bat subsists almost entirely on CAM plants and insects that feed from CAM plants. Our observations and analysis of fecal pellets suggest that in our study area, the long-snouted bat obtains most of its nourishment from *W. weberbaueri*. Pollinator exclusion experiments conducted on *W. weberbaueri* flowers indicated that the long-snouted bat is an important pollinator of this cactus (Sahley 1996). Although this bat probably visits *Browningia candelaris* flowers, the other co-occurring nocturnally flowering columnar cactus, this plant occurs at extremely low densities and flowers only 2 months of the year whereas *W. weberbaueri* produces at least some flowers and fruits year-round (Fig. 2). Thus, *B. candelaris* flowers and fruits probably comprise only a fraction of the diet of the long-snouted bat. No other night-blooming plants such as agaves occurred near any of the roosts we censused, nor did any occur at our main study site.

Despite its exceptionally elongated skull and its hypothesized high degree of specialization for nectar-feeding (Winkelman 1971), the long-snouted bat feeds on insects and fruits as well as nectar and pollen. The low $\delta^{13}C$ values found in bat muscle tissue and the fact that insects co-occurred with pollen and anther parts in fecal pellets suggest that the long-snouted bat probably feeds on insects found within cactus flowers, most likely small coleopterans belonging to the family Nitidulidae. Other studies have shown that nectar-feeding bats eat insects and cactus fruit pulp as well as nectar and pollen. For example, in Sonora, Mexico, *Leptonycteris curasoae* feeds from both flowers and fruits of three species of columnar cactus (T. H. Fleming, pers. comm.) and in Curaçao also consumes insects (Petit 1995). In arid Venezuelan habitats, *Glossophaga longirostris* consumes cactus fruits, insects, flower nectar, and pollen (Soriano *et al.* 1991, Sosa 1991).

Census Data

Tuttle (1970) referred to the long-snouted bat as "extremely rare" and our data agree. Long-snouted bat abundance is low at Arequipa; collection records for the department of Arequipa indicate this species has never been collected at altitudes below 2200 m, even though isolated cactus communities exist near the coast. We estimate that prior to the drought, a total of 87 bats were present within a 20 kilometer radius of Arequipa. However, we may have missed some mines or small tunnels, because we used topographic maps, visual searches and interviews with local people to locate potential colony sites. Because no natural caves occur within our study area, bats may be adapted to roosting in rocky crevices or shallow depressions along ridges. We never observed bats emerging from these types of roosts, although we walked transects near the main study site at sunset and sunrise, and checked shallow crevices when possible for bat presence. If long-snouted bats are using crevices as roost sites, then our censuses may have underestimated bat numbers. Bats may have shifted their roosting habits since the advent of mining in Arequipa and at present primarily use abandoned mines.

The pattern of low bat density we found contrasts with that of the arid-dwelling *Leptonycteris curasoae*, a highly social, relatively abundant, and widespread nectar feeding bat (Arita 1993, Cockrum and Petryszyn 1991, Howell 1979) and with the common *Glossophaga longirostris* and *G. soricina*, (Arita 1993, Soriano *et al.* 1991). The long-snouted bat's habit of roosting in relatively small groups may be most similar to that of the arid-dwelling *Choeronycteris mexicana* (Arita 1993). Unfortunately, little comparative information exists on the abundance of other species of arid-dwelling nectar-feeding bats.

Our data indicate that the long-snouted bat was present year-round when censused in 1990, but populations decreased during a severe drought from 1991-1993. This drought included a 17-month period with no rainfall (Fig. 2). Although in 1992 and 1993 we regularly censused only three of the original seven colony sites, we believe our censuses represent actual decreases in bat populations and not local roost shifts. If local roost shifts from censused to uncensused sites were occurring, we probably would have noticed temporal variation of bat numbers over time at roosts we censused, as occurred in 1990 for Batolito mine #3 (Fig. 3). It is unlikely that roost disturbance caused by our censuses resulted in the long-term, persistent decline of bats we observed. We never caught bats at the Poderosa mine and infrequently censused and/or captured bats at the other two roost sites. Some of our censuses occurred over 8-9 month intervals (Fig. 3). Finally, pollinator exclusion experiments on *W. weberbaueri* cacti showed a decrease in bat-pollinated flowers in 1993 relative to 1991 (Sahley 1996). This decrease in bat pollination was statistically significant, though the site where experiments took place was within 10 km of all uncensused roosts, well within foraging range of the long-snouted bat.

After flowering and fruiting of *W. weberbaueri* increased in 1993, long-snouted bat populations remained low relative to 1991. We hypothesize three factors may have played an important role in the bat population decline observed. First, bats may have emigrated from the study area. Data on reduced flower and fruit production in 1992, and thus a substantial decrease in carrying capacity, suggest that emigration from the study site is plausible. Second, drought and/or migration may have caused greater mortality in 1992 and 1993, and third, bat collecting for medicinal purposes might have played an important role in observed declines. Although we had no evidence of increased mortality in long-snouted bat colonies because of drought, it is possible that a combination of all three factors may have been responsible.

Results of pollinator exclusion experiments indicate low bat abundance in 1993 caused significantly lower fruit set from bat-pollinated flowers of *W. weberbaueri* in 1993 compared with 1991 (Sahley 1996). We propose that local decreases in long-snouted bat abundance, probably triggered by droughts that cause reductions in flower and fruit production, may have considerable influence on the ecology of this bat-cactus-hummingbird mutualism.

Conservation

Threats to continued persistence of the long-snouted bat around Arequipa include roost disturbance, collection of bats for folkloric medicinal purposes, and habitat destruction. Bats are believed to cure a variety of ailments ranging from epilepsy to heart attacks. Bats can be obtained from healers, or "curanderos," and at medicinal stands within city markets. Information we obtained from informal interviews in the central market in downtown Arequipa suggests that several hundred bats might be sold annually at this market alone. Bats sold at medicinal stands are purchased from intermediaries, and market vendors do not differentiate among species with respect to selling price or medicinal use. In 1992 we visited seven medicinal stands at the central market in Arequipa and found verspertilionid and molossid bats brought from the coast and rainforest areas, but no long-snouted bats. In 1995, during a visit to the same market we found 10 long-snouted bats, priced from \$2.40 to \$5.00 each. One of the colonies we monitored (Batolito mine #3) was visited occasionally by medicinal collectors. Unfortunately, since the locations of most mines are well known by local inhabitants, long-snouted bats are especially vulnerable to over-harvesting. However, the Charcani roost was located on the premises of a hydroelectric facility; thus access to this site was restricted and no harvesting of bats by humans occurred there.

To adequately assess whether harvesting of bats for medicinal purposes is sustainable over the long term, information on harvest rates, yearly juvenile recruitment rates, and bat immigration from outside the study radius is necessary. Nevertheless, we conclude that during the drought, harvesting of any long-snouted bats within our study radius would probably have been unsustainable because of the extremely low bat numbers, absence of juveniles (*i.e.* less than 2-3 months) or pregnant females, and apparent lack of immigration from outside our study radius.

An additional threat to long-snouted bat populations occurring near the city of Arequipa is rapid urban growth and expansion of residential areas into cactus habitat. At present, most new high density urbanization occurs north of the city where areas of extensive cactus habitat occur. Unfortunately, during the process of settlement and urbanization, native plants including columnar cacti are removed.

Currently, no data exists on the population status and ecology of long-snouted bats throughout the rest of its range. Obtaining such information is especially important because of this bat's role as a pollinator of columnar cacti, the low numbers of bats found in Arequipa, and potential over-harvesting of bats for medicinal purposes.

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