

# POPULATION DYNAMICS OF *LEPTONYCTERIS CURASOAE* (CHIROPTERA: PHYLLOSTOMIDAE) IN JALISCO, MEXICO

GERARDO CEBALLOS, THEODORE H. FLEMING, CUAUHTEMOC CHÁVEZ, AND JAFFET NASSAR

*Centro de Ecología, Universidad Nacional Autónoma de México, Apartado Postal 70-275,*

*Ciudad Universitaria 04510, México, Distrito Federal (GC, CC)*

*Department of Biology, University of Miami, Coral Gables, FL 33124 (THF, JN)*

We estimated population size and sex ratio, and recorded mass, levels of fat, and reproductive condition of adults of *Leptonycteris curasoae* living in a sea cave in Chamela Bay, Jalisco, Mexico, 10 times between October 1992 and February 1994. We used carbon and nitrogen stable-isotope techniques to determine the general diet of this plant-visiting bat in 1993 and 1994. Size of roost in 1993 varied from ca. 5,000 individuals in March to ca. 75,000 in November. Females were absent from, or uncommon in, the roost from March through September. Beginning in July or August, many males and females migrated to the roost; bats left the roost in December. Some of these females migrate north to the Sonoran Desert to form maternity colonies in spring. Size of testis increased markedly from October through December, which we postulate is a mating period in this roost. Bats were lean in April and June (dry season) and fat in October and November (end of wet season). Stable-isotope analysis revealed that bats fed primarily at nonsucculent (C3) plants throughout the year; values for nitrogen were higher in the wet season than in the dry season. From a review of data on other roosts of *L. curasoae*, we conclude that most roosts have a seasonal fluctuation in size and sexual composition. We also postulate that two reproductive populations of females exist in Mexico; a spring-birth population and a winter-birth population. Seasonal fluctuations in size of roost mean that the timing of visits to the roost is critical for assessing the population status of this federally listed endangered bat.

**Key words:** *Leptonycteris curasoae*, Mexico, migration, reproduction, roost dynamics, stable isotopes

Compared with temperate bats (Gaisler, 1979; Tuttle and Stevenson, 1982), little is known about the population dynamics of tropical bats. Seasonal changes in sizes of roosts and sex ratios have been described for few species (Brosset, 1966, 1976). Seasonal migrations are known to occur in several species of pteropodid bats in Africa and Australia (Eby, 1991; Nelson, 1965; Thomas, 1983). In the New World tropics, Wilson (1971) described the population dynamics of *Myotis nigricans* on Barro Colorado Island, Panama, and Bradbury and Emmons (1974) and Bradbury and Vehrencamp (1976) reported on seasonal changes in populations of three species of emballonurids on Trinidad and in Costa Rica. In the large and ecologically diverse family Phyl-

lostomidae, the dynamics of only four species, *Artibeus jamaicensis*, *Carollia perspicillata*, *Desmodus rotundus*, and *Phyllostomus hastatus*, have been described (Fleming, 1988; Handley et al., 1991; McCracken and Bradbury, 1981; Turner, 1975). Seasonal migrations, primarily by females, result in changes in sizes of roosts and sex ratios in *C. perspicillata* in western Costa Rica. In contrast, neither sizes of roosts nor sex ratios change appreciably during the year in populations of *P. hastatus*, *A. jamaicensis*, and *D. rotundus*.

In this paper, we describe the annual population dynamics of the lesser long-nosed bat, *Leptonycteris curasoae* (Phyllostomidae, Glossophaginae), in a roost located in Chamela Bay, Jalisco, Mexico. *L. curasoae*

is a flower-visiting bat that lives in arid and semi-arid regions of Mexico and, seasonally, the southwestern United States (Arita, 1991; Cockrum, 1991; Koopman, 1981). Its diet includes nectar and pollen from a variety of night-blooming flowers in the Agavaceae, Bombacaceae, Cactaceae, Convolvulaceae, and Leguminosae (Alvarez and Gonzalez, 1970; Hayward and Cockrum, 1971; Howell, 1974; Quiroz et al., 1986). Each spring, thousands of females migrate from southcentral Mexico to the Sonoran Desert, where they form maternity colonies containing several thousand to >100,000 adults that are scattered over a wide area (Cockrum and Petryszyn, 1991; Wilkinson and Fleming, 1996). While in the Sonoran Desert, they feed nearly exclusively on nectar and pollen and fruits of columnar cacti (Fleming et al., 1993).

Except for Hayward and Cockrum's (1971) study of a maternity colony located near Tucson, Arizona, little is known about the population dynamics of this species. Such information is needed because *L. curasoae* has been classified as endangered in the United States (Shull, 1988). It also is included on Mexico's list of endangered and threatened species (Sedesol, 1994). Based on surveys of roosts in Mexico and Arizona in 1983-1985, Wilson (1985) reported finding ca. 15,500 individuals located in only two roosts; ca. 15,000 were found in a roost in Chamela Bay, Jalisco, and ca. 500 were in Bat Cave, near Patagonia, Arizona. Wilson's (1985) status report was instrumental in having *L. curasoae* declared an endangered species. Cockrum and Petryszyn (1991) subsequently disputed the endangered status of *L. curasoae*, at least in the southwestern United States, and reported recent (i.e., post-1985) counts of this species totalling  $\geq 3,000$  individuals in at least four roosts in Arizona.

In addition to describing seasonal changes in size of roosts and sexual composition, we report on seasonal changes in body mass, fat content, and size of testis in males and use stable isotopes to examine

the general diet of *L. curasoae* throughout the year. To place our results in the context of the overall population biology of this species, we review current data on dynamics of roosts and reproduction in this species. Our results indicate that substantial seasonal changes in size and composition of roosts occur regularly in this species. Thus, the timing of visits to roosts is critical for determining the population status of this bat.

#### STUDY AREA AND METHODS

Field portions of this study were conducted October 1992-February 1994 at a sea cave on Isla San Andrés, Bahía Chamela, Jalisco, Mexico (ca. 19°30'N, 105°03'W; site 7 in Fig. 1). Located 1.5 km from the mainland, the San Andrés cave contains three chambers with the following dimensions (length by width by height): 16 by 2.5 by 5.5 m; 7 by 0.8 by 4 m; 10 by 0.8 by 5 m. The cave is humid, and its floor regularly is covered with seawater. Vegetation on the mainland near the cave is predominantly tropical deciduous forest with bands of tropical semideciduous forest in arroyos (Bullock, 1985). Annual rainfall at Chamela averages ca. 700 mm and 80% falls in July through October (Bullock and Solís-Magallanes, 1990). The dry season is November-June and the wet season is July-October.

Fleming and Chávez initially visited the cave on 29 October 1992 to estimate the size of the population of *L. curasoae* and to obtain tissue samples for a genetic study (Wilkinson and Fleming, 1996). Ceballos and Chávez subsequently visited the cave nine times between 24 March 1993 and 15 February 1994. At each visit, the size of the population of *L. curasoae* was estimated by counting the number of bats in five randomly chosen square meters scattered throughout the roost and multiplying the average number of bats per square meter by the estimated areal coverage (in m<sup>2</sup>) of the population of *Leptonycteris* on the sides and ceiling of the cave. The presence of other species of bats also was noted.

At each visit, we netted by hand 10-25 adult bats to estimate sex ratio and to obtain morphological data. We attempted to avoid a bias in the sexual composition of our sample by obtaining bats throughout the lower portions of the cave.

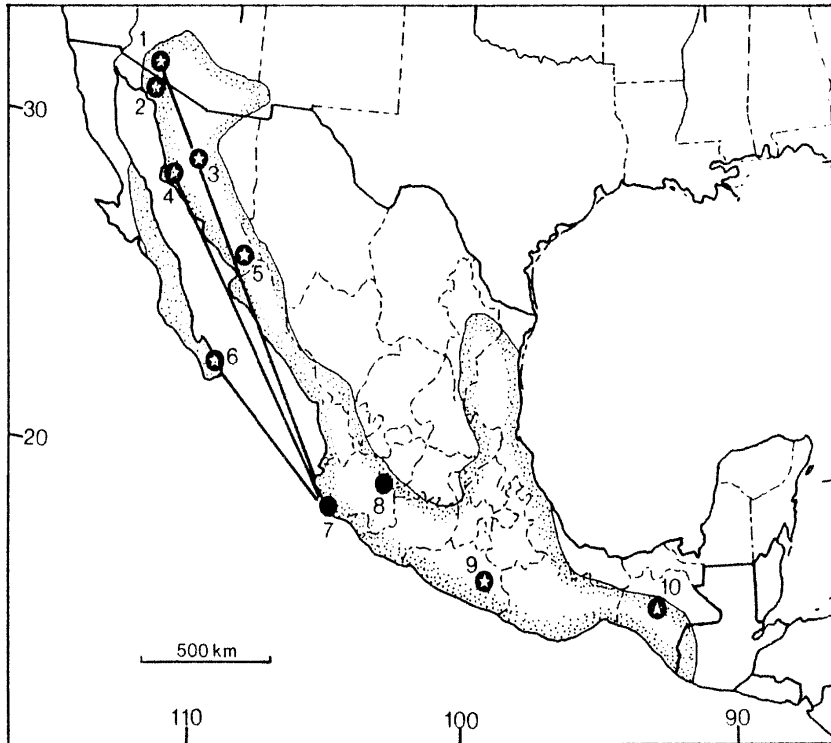


FIG. 1.—Map showing the location of 10 roosts of *Leptonycteris curasoae* in Mexico and Arizona. The geographic range of *L. curasoae* (stippled) follows Arita (1991). The Chamela roost is number 7. Starred circles represent maternity roosts; solid circles represent non-maternity roosts. The lines show genetic connections between the Chamela roost and four other roosts as reported by Wilkinson and Fleming (1996). Roosts are: 1, Mine in Organ Pipe Cactus National Monument, Arizona; 2, Pinacate Cave, Pinacate Biosphere Reserve, Sonora; 3, Cueva del Tigre, Carbo, Sonora; 4, Sierra Kino Cave, Bahía Kino, Sonora; 5, Santo Domingo Mine, Aduana, Sonora; 6, Cueva La Capilla, Buenavista, Baja California Sur; 7, Cueva San Andres, Chamela, Jalisco; 8, Cueva La Mina, Ajijic, Jalisco; 9, Gruta Juxtluhuaca, Guerrero; 10, Cueva Tempisque, Ocozocoautla, Chiapas.

We weighed each individual to the nearest 1.0 g, measured its forearm to the nearest 1.0 mm, and, for males, measured the length and width of one testis to the nearest 1.0 mm. We examined females macroscopically to determine their reproductive condition. Finally, we sacrificed a small sample of bats to determine the relative amount of superficial fat on their bodies and to obtain muscle tissue for stable-isotope analyses. After removing its skin, we scored the fat condition of each bat as: 0, no fat visible on the back or pectoral region; 1, fat covering only the lower part of the back; 2, fat covering the entire back; 3, fat covering the back and part of the pectoral region; 4, back and pectoral region completely covered with fat.

We used dried pectoral muscle for the analysis of stable isotopes of carbon and nitrogen. We

followed the techniques of Fleming et al. (1993) to determine the relative contributions of CAM and C3 carbon to the composition of each bat. *L. curasoae* ingests CAM carbon when it feeds at plants of the Cactaceae and Agavaceae; it ingests C3 carbon when feeding at species of non-succulent plants. To obtain samples of CO<sub>2</sub> and N<sub>2</sub>, we combusted tissue samples at 800°C for 3 h in Vycor ampules with 1 g of cupric oxide and copper and a small amount of silver foil. Purified samples of CO<sub>2</sub> and N<sub>2</sub> were obtained cryogenically from combustion products in a vacuum system. Concentrations of stable isotopes are expressed in delta (δ) notation as parts per thousand according to the equation:

$$\delta X = [(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 1,000$$

where X is <sup>13</sup>C or <sup>15</sup>N and R is the corresponding

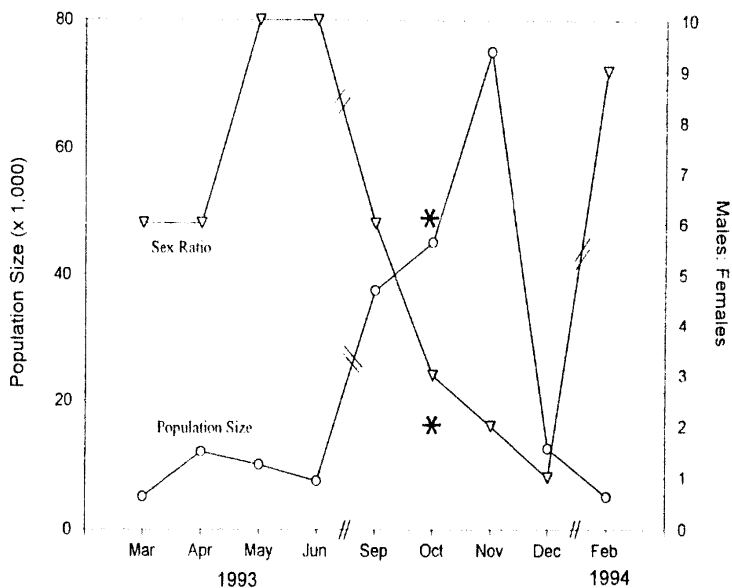


FIG. 2.—Population size and sex ratio (males:females) of *Leptonycteris curasoae* at the Chamela cave, 1993-1994. Sex ratios in May and June were arbitrarily set at 10, but actually should be  $\infty$  because no females were present. Asterisks indicate values for October 1992.

ratio  $^{13}\text{C}:^{12}\text{C}$  or  $^{15}\text{N}:^{14}\text{N}$ .  $R_{\text{standard}}$  for  $^{13}\text{C}$  and  $^{15}\text{N}$  are the PDB standard and atmospheric  $\text{N}_2$ , respectively. Analytical precision of these measurements was  $\pm 0.1\text{‰}$  for both isotopes. We used a mass-balance equation and a 1‰ trophic correction of monthly mean  $\delta^{13}\text{C}$ -values (Fleming, 1995) to estimate the proportional contribution of CAM and C3 carbon to the diet of *L. curasoae* each month.

## RESULTS

### *Size and composition of populations.*—

Size of the population of *L. curasoae* at Chamela Bay in 1993 varied from ca. 5,000 bats in March to ca. 75,000 in November; numbers decreased precipitously in December (Fig. 2). The roost contained mostly or exclusively males from March through September in 1993 (Fig. 2). The sex ratio (males:females) decreased to 1:1 during October-December before increasing again in February 1994. Estimates of size of population and sex ratio in October 1992 and 1993 were in close agreement.

*Leptonycteris curasoae* shared the roost with large numbers of *Pteronotus davyi* in October 1992, and with *P. davyi* and *P. parnellii* in March through May 1993; *Mor-*

*oops megalophylla* was present in the cave in April 1993.

*Size and fat condition.*—Length of forearm was larger in males sampled in June and September than for males sampled in other months (Kruskal-Wallis ANOVA,  $\chi^2 = 41.0$ ,  $d.f. = 8$ ,  $P < 0.001$ ; Fig. 3a). Length of forearm in females was larger in February than in other months (Kruskal-Wallis ANOVA,  $\chi^2 = 15.8$ ,  $d.f. = 6$ ,  $P = 0.022$ ). In our dataset, adult males and females did not differ in average length of forearm (males:  $\bar{X} = 54.3 \pm 1.5$  SD mm,  $n = 102$ ; females:  $\bar{X} = 54.0 \pm 1.6$  mm,  $n = 32$ ;  $t = 0.95$ ,  $d.f. = 132$ ,  $P = 0.35$ ), but males were significantly heavier than non-pregnant females (males:  $\bar{X} = 26.4 \pm 3.4$  SD g,  $n = 102$ ; females:  $\bar{X} = 24.9 \pm 2.4$  g,  $n = 32$ ;  $t = 2.28$ ,  $d.f. = 132$ ,  $P = 0.024$ ).

Masses of males and females were lowest during the dry season and highest in October and November (Fig. 3b). Monthly changes in the mass of males were significant (Kruskal-Wallis ANOVA,  $\chi^2 = 58.8$ ,  $d.f. = 8$ ,  $P < 0.001$ ); those in females were marginally significant (Kruskal-Wallis ANOVA,  $\chi^2 = 13.2$ ,  $d.f. = 6$ ,  $P = 0.056$ ).

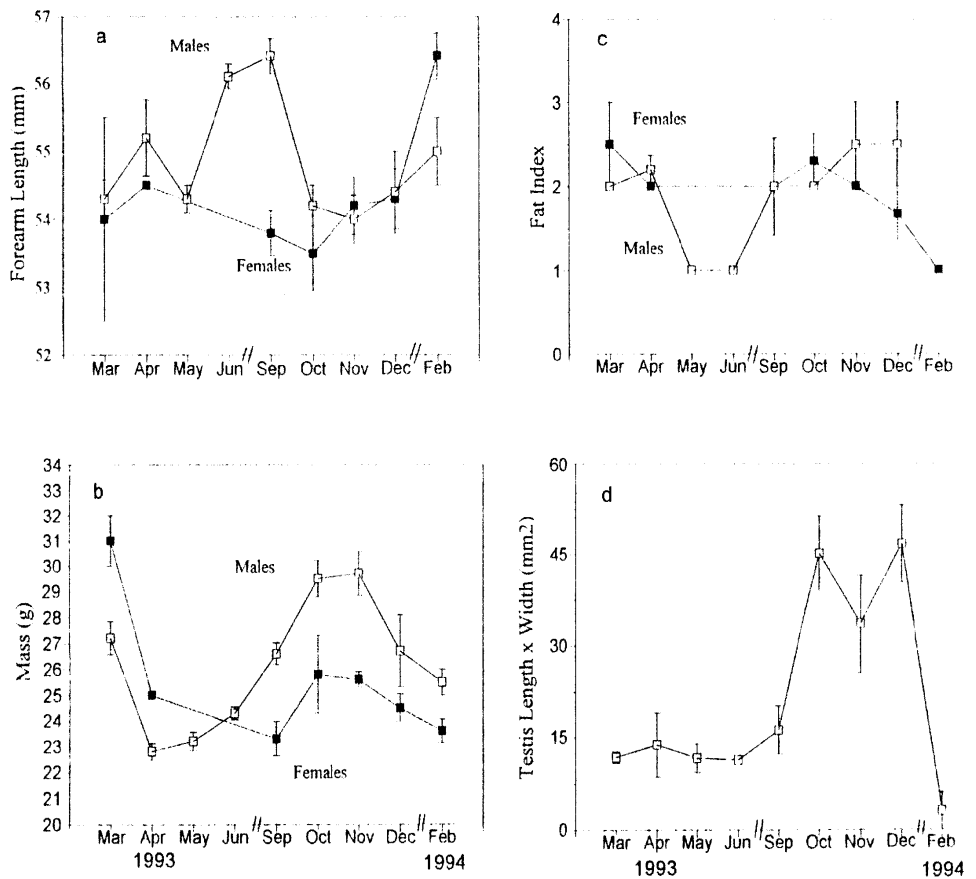


FIG. 3.—Monthly changes in a) length of forearm, b) mass, c) fat index, and d) size of testis (length by width) in *Leptonycteris curasoae* roosting in the Chamela cave, 1993-1994. Data are  $\bar{X} \pm 1$  SE.

Visible fat was present in all individuals we examined, and males had larger amounts of fat during the wet season than in the dry season (Kruskal-Wallis ANOVA,  $\chi^2 = 23.0$ ,  $d.f. = 7$ ,  $P = 0.007$ ; Fig. 3c). The absence of samples of females during May-September precluded a seasonal analysis of fat condition, but females were especially fat in March and October. Fat index was significantly correlated with mass in males ( $r = 0.52$ ,  $F_{1,33} = 12.3$ ,  $P = 0.001$ ), but not in females ( $r = 0.22$ ,  $F_{1,14} = 0.69$ ,  $P = 0.42$ ), probably because of the absence of samples of females collected during the dry season.

**Reproductive condition.**—Size of testis (length by width) was small from March through September, but increased substantially in October through December (Fig.

3d). We infer from this increase in size that production of sperm in males is maximal during the late wet season. Size of testis was significantly correlated with mass ( $r = 0.48$ ,  $F_{1,101} = 29.9$ ,  $P < 0.001$ ). Only three of 32 females showed signs of reproductive activity; two females (of two examined) were lactating in March 1993, and one (of eight examined) was pregnant in February 1994. Two of five females examined in October 1992 were postlactating.

**Carbon and nitrogen stable isotopes.**— $\delta^{13}\text{C}$ -values showed no seasonal variation and averaged  $-21.90 \pm 0.30$  SE (Kruskal-Wallis ANOVA,  $\chi^2 = 10.77$ ,  $d.f. = 8$ ,  $P = 0.22$ ; Fig. 4). Proportional contribution of CAM carbon to the diet of *L. curasoae* ranged from 0.18 (December 1993) to 0.35 (March and April 1993) and averaged 0.25

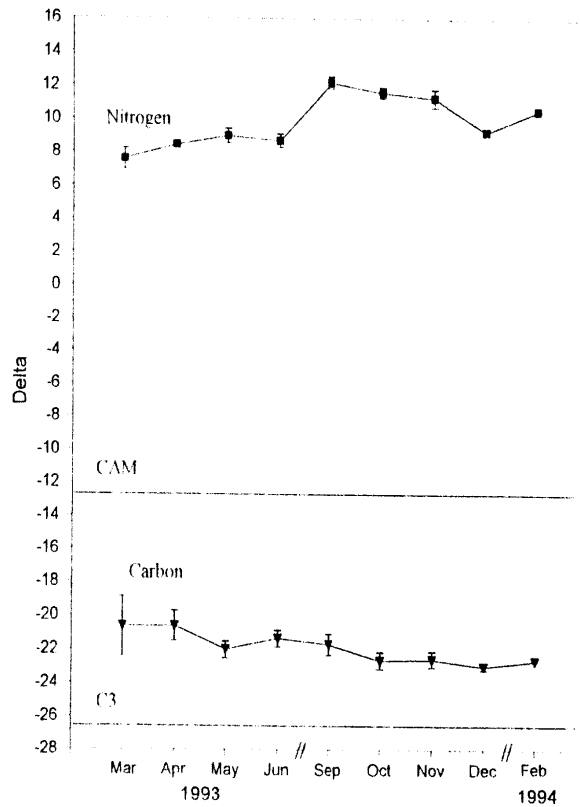


FIG. 4.—Monthly values of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in samples of muscle tissue from *Leptonycteris curasoae* from the Chamela cave, 1993-1994. Data are  $\bar{X} \pm 1 \text{ SE}$ . The horizontal lines indicate mean values of  $\delta^{13}\text{C}$  for bat-visited CAM and C3 plants in Mexico (Fleming et al., 1993).

$\pm 0.02$ . In contrast,  $\delta^{15}\text{N}$ -values changed seasonally with significantly higher values occurring in September through November 1993 than earlier in the year (Kruskal-Wallis ANOVA,  $\chi^2 = 26.0$ ,  $d.f. = 8$ ,  $P = 0.001$ ; Fig. 4).

#### DISCUSSION

The results of our study, plus other published (e.g., Cockrum and Petryszyn, 1991) and unpublished observations on the roost dynamics of *L. curasoae*, indicate that substantial seasonal changes in size and sexual composition are basic features of the population biology of this nectarivorous bat. During much of the year, the Chamela roost contained several thousand males, as observed on 30 May 1984 by Wilson (1985). Between June and September size of roost began to increase as many males and fe-

males returned to the cave. The steady decrease in sex ratio between June and November 1993 suggests that ca. 40,000 males and ca. 25,000 females joined this roost by late November.

Many males and females left the roost in December, presumably migrating to other locations in Mexico. Where these bats went is currently unknown, but the results of a mtDNA study (Wilkinson and Fleming, 1996) provides a hint about the migratory behavior of some of these bats. Wilkinson and Fleming (1996) sampled *L. curasoae* from 13 roosts in Mexico and southern Arizona and found either shared haplotypes or especially high levels of genetic similarity between four individuals from the Chamela roost and individuals from the following northern roosts: Baja California (site 6; Fig. 1); Bahia Kino, Sonora (site 4); Carbo, So-

nora (site 3); and Organ Pipe Cactus National Monument, Arizona (site 1). Close genetic similarities were not found between these bats and bats in three roosts located in Jalisco, Guerrero, and Chiapas, respectively (sites 8–10; Fig. 1). These results suggest that some bats from Chamela regularly migrate between Baja California and the Mexican mainland while others, nearly exclusively females, migrate northward to maternity roosts in the Sonoran Desert each spring.

Females do not begin to form maternity colonies in northern Sonora and Arizona until mid-to-late April, so their locations for ca. 4 months are currently unknown. They may migrate slowly north, stopping in areas between Jalisco and Sonora for various lengths of time or they may stay in south-central Mexico for several months before migrating north. Studies of the genetic composition and dynamics of other roosts in western and central Mexico in December through March will be needed to answer this question.

Seasonal changes in the sizes of maternity roosts in the northwestern part of the range of *L. curasoae* show the opposite pattern to that observed at the Chamela roost. In 1992 and 1993, for example, females arrived at the maternity roost in Organ Pipe Cactus National Monument, Arizona, in mid-April, numbers reached a peak of ca. 12,000–15,000 adults by mid-May, and the roost was empty by mid-September (V. and D. Dalton, pers. comm.). Similarly, in 1992, females began arriving at a large maternity roost located in the Pinacate Biosphere Reserve, Sonora (site 2; Fig. 1), in mid-April; adults and young numbered ca. 100,000 on 9 August, and the roost was empty by early September (W. Pechey, pers. comm.). To judge from the reproductive conditions of females (some arrive in late pregnancy and others in earlier pregnancy so that births are spread out over a month or more—Y. Petryszyn and V. Dalton, pers. comm.) and genetic composition (Wilkinson and Fleming, 1996), the northern migrants come

from several roosts rather than from a single southern source.

Changes in size of roost also have been observed in two other locations in Mexico: Santo Domingo Mine at Aduana, Sonora (site 3; Fig. 1) and Gruta Juxtlahuaca, Guerrero (site 9; T. H. Fleming, in litt; Quiroz et al., 1986). On 20 October 1992, the Santo Domingo Mine contained ca. 1,000 bats of both sexes. On 13 February 1993, it contained  $\leq 20,000$  females in early pregnancy and contained similar large numbers on 15 March and 30 April; on the latter date most females were in late pregnancy. Quiroz et al. (1986) visited the Juxtlahuaca cave three times in 1979 (June, September, and December) and twice in 1980 (February and August). *L. curasoae* was present in the cave only in December, February, and August; females were pregnant or lactating in December and lactating in February. On 14 November 1992, the population of *L. curasoae* in this cave was estimated at  $\leq 1,000$  individuals; four of five females examined were in late pregnancy (T. H. Fleming, in litt.).

Seasonal changes occurred in size, as measured by length of forearm, of individuals of *L. curasoae* in the Chamela roost. Without detailed data on the relationship between length of forearm and age, these changes are not easily interpretable, but probably reflect changes in the age composition of this roost. If size is positively correlated with age (as it is in *Carollia perspicillata*—Fleming, 1988), then males present in the roost in June through September may be somewhat older than males present later in the year. Similarly, it appears that older (larger) females migrate from the roost later (after February?) than females leaving in December and January.

Males and non-pregnant females had less mass and males carried smaller deposits of fat in the dry season than in the wet season. Similar changes also occur in other Neotropical bats such as *Artibeus jamaicensis*, *Carollia perspicillata*, and *Tadarida brasiliensis* (Fleming, 1988; McNab, 1976).

These changes probably reflect significant seasonal changes in the availability of food resources. Bullock and Solís-Magallanes (1990) report that at Chamela, peak flowering activity of canopy trees occurs at the beginning of the wet season (late June-early July) and peak fruiting occurs in mid-dry season. Flowering peaks of bat-visited plants at Chamela occur in January (*Ipomoea*), June (*Crescentia alata*, *Cephalocereus purpusii*), August (*Stenocereus chrysocarpus*), and November (*Bauhinia unguilata*, *Ceiba aesculifolia*); fruiting peaks occur in April (*Ficus mexicana*), July (*C. purpusii*), August (*Chlorophora tinctoria*), and September (*S. chrysocarpus*). Although pollen of *C. alata* and *Ceiba* has been noted on the fur of *L. curasoae* (G. Ceballos, in litt.), we lack data on which plants are important dietary items and the extent to which availability of food changes throughout the year. The fact that thousands of *Leptonycteris* depart from the Chamela cave in December only to return in the wet season strongly suggests that the carrying capacity of the forest for this species around Chamela is much lower in the dry season than in the wet season. Similar seasonal changes occur in the abundance and diversity of other bats and in the population density of *Liomys* (Rodentia: Heteromyidae) at Chamela (Ceballos, 1990; C. Chávez and G. Ceballos, in litt.).

Males apparently produce sperm only in the late wet season and, thus, have only one mating period per year at this site, in contrast to certain tropical phyllostomid males (e.g., *C. perspicillata* and *A. jamaicensis*) that have two peaks in size of testis and two mating periods each year (Fleming et al., 1972; Handley et al., 1991). Although we have not observed the behavior of *L. curasoae* in the Chamela cave, we predict that mating activity will be common there from October into December. If true, then the Chamela cave must function as a mating site for thousands of bats. After mating, many individuals of both sexes disperse to

other roosts. The Chamela cave is not a maternity roost for females.

If mating takes place in about mid-November and young are not born in northern maternity roosts until mid-May, the gestation period of *L. curasoae* must be ca. 5 months. This value is ca. 1 month longer than that of tropical phyllostomids such as *C. perspicillata*, *A. jamaicensis* (for pregnancies lacking delayed development), and *Glossophaga soricina* (Fleming, 1971; Fleming et al., 1972). A. Arends and A. Martínez (pers. comm.) have observed mating in *L. curasoae* in November in a cave on the Paraguana Peninsula of Venezuela; births occur in May. Their observations further support our suggestion of a gestation period of 5 months in *L. curasoae*. Whether or not this gestation involves delayed implantation or delayed development requires detailed histological study.

Current data suggest that in Mexico, females of *L. curasoae* give birth to a single offspring each year and that there are two distinct breeding populations. Females in the Chamela roost belong to a spring-birth population of females that form maternity colonies in northwestern Mexico and southwestern Arizona. Our record of a pregnant female at Chamela in February 1994 is consistent with this scenario. Other females located in southern Mexico, for example at Gruta Juxtlahuaca and at a cave near Ocozocoautla, Chiapas (site 10; Fig. 1), give birth in December or January (Quiroz et al., 1986; R. Medellín, pers. comm.) and hence are members of a winter-birth population. We do not believe that females give birth twice a year, once in spring and again in winter, a pattern of bimodal polyestry that is common in many tropical phyllostomids (Fleming et al., 1972; Wilson, 1979). None of the dozens of pregnant adult females examined in April 1989-1996 at Bahia Kino, Sonora (site 4; Fig. 1), have shown evidence of recent lactation (T. H. Fleming, in litt.).

Our capture of two lactating females in March 1993 in Jalisco is puzzling and does



not fit the above reproductive scenario. One possible explanation for these bats is that they were recent migrants from Baja California, where the annual birth period appears to differ from those on the Mexican mainland. On 13 April 1993, a cave near Buenavista, Baja California Sur (site 6; Fig. 1), was estimated to contain 30,000 females and their recent offspring; most of the young were judged to have been born in March, halfway between the two birth periods on the mainland (T. H. Fleming, in litt.).

Our carbon and nitrogen stable-isotope data indicate that, at Chamela, *L. curasoae* is feeding primarily at C3 plants all year. These results differ somewhat from the annual carbon cycle described for bats from the Mexican mainland by Fleming et al. (1993). Their data, which included small samples of individuals from many locations in Mexico, indicated that most bats contain substantial amounts of CAM carbon (acquired by feeding at cactus and agave plants) during summer months and a mixture of C3 and CAM carbon at other times of the year. This pattern clearly does not hold at Chamela. Our data suggest that bats at this site do not feed heavily on cactus and agave at any time of the year, probably because of the low density of columnar cacti and agaves in the Chamela region (Lott et al., 1987). Furthermore, our data suggest that *L. curasoae* is not an obligate cactus and agave visitor and that its diet is influenced strongly by the availability of local plant resources.

Unlike the carbon data, nitrogen stable-isotope values were higher in the wet season than in the dry season. Until detailed dietary studies are conducted, we will not know the source of this seasonal variation. It is possible that *L. curasoae* eats insects and, thus, occupies a higher trophic level during the wet season (Fleming, 1995) or that the plant material it eats during the wet season is enriched in nitrogen compared to its dry season plant food.

#### CONCLUSIONS AND CONSERVATION IMPLICATIONS

Our results and review of recent data from other roosts clearly indicate that the size of population and sexual composition of *L. curasoae* at any one site is dynamic and that individuals of this species undergo extensive seasonal movements. We have strong reasons to believe that some females from the Chamela region migrate >1,500 km north to the Sonoran Desert each spring, but we do not believe that the Chamela roost is the only source of northern migrants. Numbers of *L. curasoae* in Mexico and Arizona are currently much higher, perhaps by two orders of magnitude, than reported by Wilson (1985), but this does not mean that this species is not vulnerable to catastrophic losses owing to disturbance of roosts. A basic feature of the population biology of this species is its gregarious roosting behavior. This behavior will always leave *L. curasoae* extremely vulnerable to disturbance by humans. Another basic feature of its population biology is local and long-distance seasonal migrations along nectar corridors of critically important plants, including columnar cacti and paniculate agaves (Fleming et al., 1993; Wilkinson and Fleming, 1996). Protection of roosts and protection of these plants are essential for the annual population cycle of this bat. Our results also indicate that the tropical dry forest of western Mexico, which is currently endangered in Mexico and elsewhere in Central America (Ceballos and Garcia, 1995), is an extremely important habitat for this bat and needs to be protected. Finally, when monitoring the population status of this bat, timing of visits to roosts is critical. Depending on time of year, the Chamela roost contains a few thousand or tens of thousands of bats. This variation appears to be a normal part of the biology of this species, and conservation decisions must be made with this knowledge in mind.

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