

*Tadarida brasiliensis*. By Kenneth T. Wilkins

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***Tadarida brasiliensis* (Geoffroy Saint-Hilaire, 1824)**

Brazilian Free-tailed Bat

- Nyctinomus brasiliensis* Geoffroy Saint-Hilaire, 1824:343. Type locality "Curityba, Paraná, Brazil" (Shamel, 1931:4).  
*Dysopes nasutus* Temminck, 1827:234. Type locality "Le Brésil" (Brazil).  
*Nyctinomus murinus* Gray, in Griffith, 1827:66. Type locality "Jamaica."  
*Nycticea cynocephala* Le Conte, in M'Murtrie, 1831:432. Type locality "Georgia, probably in neighborhood of Le Conte Plantation, Liberty Co."  
*Molossus fuliginosus* Cooper 1837:67. Type locality "Milledgeville, Georgia."  
*Molossus rugosus* D'Orbigny, 1837:plate 10. Type locality "Corientes, Argentina" (probably Tucumán).  
*Dysopes naso* Wagner, in Schreber, 1840:475. Type locality Brazil.  
*Molossus mexicanus* Saussure, 1860:283. Type locality "Cofre de Perote, 13,000 feet, state of Veracruz, Mexico" (Benson, 1944).  
*Dysopes multispinosus* Burmeister, 1861:391. Type locality "Tucumán, Argentina."  
*Nyctinomus musculus* Gundlach, 1861:149. Paratypes from Cuba.  
*Nyctinomus mohavensis* Merriam, 1889:25. Type locality "Fort Mojave, Arizona."  
*Nyctinomus antillarum* Miller, 1902:398. Type locality "Roseau, Dominica," West Indies.  
*Nyctinomus bahamensis* Rehn, 1902:641. Type locality "Governor's Harbor, Eleuthera, Bahamas."  
*Tadarida brasiliensis*: Thomas, 1920:222. First use of current name combination.  
*Tadarida intermedia* Shamel, 1931:7. Type locality "Valley of Comitán, Chiapas, Mexico."  
*Tadarida constanzae* Shamel, 1931:10. Type locality "Constanza, Dominican Republic."  
*Tadarida texana* Stager, 1942:49. Type locality "Ney Cave, 20 miles north of Hondo, Medina County, Texas."

**CONTEXT AND CONTENT.** Order Chiroptera, Family Molossidae. Currently nine subspecies of *T. brasiliensis* are recognized (Hall, 1981; Schwartz, 1955):

- T. b. antillarum* (Miller, 1902:398), see above.  
*T. b. bahamensis* (Rehn, 1902:641), see above.  
*T. b. brasiliensis* (Geoffroy Saint-Hilaire, 1824:343), see above (*nasutus* Temminck, *rugosus* D'Orbigny, *naso* Wagner, and *multispinosus* Burmeister are synonyms).  
*T. b. constanzae* Shamel, 1931:10, see above.  
*T. b. cynocephala* (Le Conte, 1831:432), see above (*fuliginosus* Cooper a synonym).  
*T. b. intermedia* Shamel, 1931:7, see above.  
*T. b. mexicana* (Saussure, 1860:283), see above (*californicus* Allen, 1894:166, *mohavensis* Merriam, and *texana* Stager are synonyms).  
*T. b. murina* (Gray, 1827:66), see above.  
*T. b. muscula* (Gundlach, 1861:149), see above.

**DIAGNOSIS.** *Tadarida brasiliensis* is the only member of its genus in North America having deep vertical grooves or wrinkles on the upper lip, with a Z-shaped upper third molar, in which there is a separation of the premaxillae between the incisors, in which length of the second phalanx of the fourth digit exceeds 5.0 mm, and in which the ears when laid forward do not extend appreciably beyond the muzzle (Hall, 1981). Of the three species of *Tadarida* occurring in the United States, *T. brasiliensis* is the smallest and is the only one in which the ears are not joined at the midline and in which the hair is of uniform color (Barbour and Davis, 1969). *T.*

*femosacca* is the only North American molossid with which *T. brasiliensis* might be confused; the bases of the ears of *T. femosacca* clearly unite at the midline (Barbour and Davis, 1969).

**GENERAL CHARACTERS.** *Tadarida brasiliensis* is a relatively small bat with the distal half of the tail extending freely beyond the uropatagium (Fig. 1). The calcar is not keeled. Long, bristly hairs extend from the feet. The large rounded ears project anterodorsally to or only slightly beyond the muzzle. The leading edges of the ears bear a series of small papillae. The tragus is blunt and short. The upper lip is marked by vertically-oriented wrinkles (Lowery, 1974).

The pelage of the trunk and head is short (2 to 3 mm) and dense. Although apparently naked, the dark brown flight membranes are covered with hair much shorter than that on the trunk. Ventral hairs, especially in the neck region, are slightly longer (3 to 4 mm) than dorsal hairs. The dorsal hairs are uniformly brown from tip to base. Ventral pelage is slightly lighter in color than that of the dorsum because ventral hairs are whitish at the tip and base and dark brown only in the central segment of the shaft. Paler brown pelage of many individuals inhabiting caves results from bleaching by ammonia fumes. Deviations from solid coloration include true albinos, white-coated individuals with normal eyes, patches of white fur, and white hairs scattered among brown hairs (Barbour and Davis, 1969). Cuticular scales are coronal and dentate for the entire length of the hair. Least hair diameter is found at the tip (2 to 4  $\mu$ m) and basal diameter is 8  $\mu$ m. Sexual dimorphism is not apparent in pelage features (Nason, 1948).

In dorsal view, the relatively robust skull is triangular with the occiput as base and the rostrum as a blunt apex (Fig. 2). The permanent dentition consists of 30 or 32 sectorial teeth: i 1/2 or i 1/3, c 1/1, p 2/2, m 3/3 (Hall, 1981). The upper third premolar is much smaller than the upper fourth premolar, whose protocone is taller than any cusp on other upper cheekteeth. The parastyle, paracone, mesostyle, metacone, and metastyle of the first and second upper molars are connected by a W-shaped loph pattern. Premolars are not molariform. Lower incisors are minute. Canines of males are larger than those of females (Herreid, 1959).

Means and ranges of external measurements (in mm) for 23 male and for 46 female (in parentheses) *T. b. cynocephala* from Louisiana are: total length, 102, 90 to 109 (95, 90 to 100); length of tail, 35, 29 to 44 (33, 29 to 42); length of hind foot, 8, 7 to 14 (8, 7 to 12); length of ear, 15, 10 to 20 (16, 14 to 19); length of forearm, 42.2, 40.0 to 45.0 (42.8, 38.2 to 45.6); and length of third metacarpal, 42.1, 40.2 to 44.9 (41.6, 39.1 to 43.5). Means



FIG. 1. Brazilian free-tailed bat, *Tadarida brasiliensis mexicana*, from ZH Canyon, Sierra Viejas, Presidio Co., Texas. Photographed 29 July 1985 by J. L. Tveten.

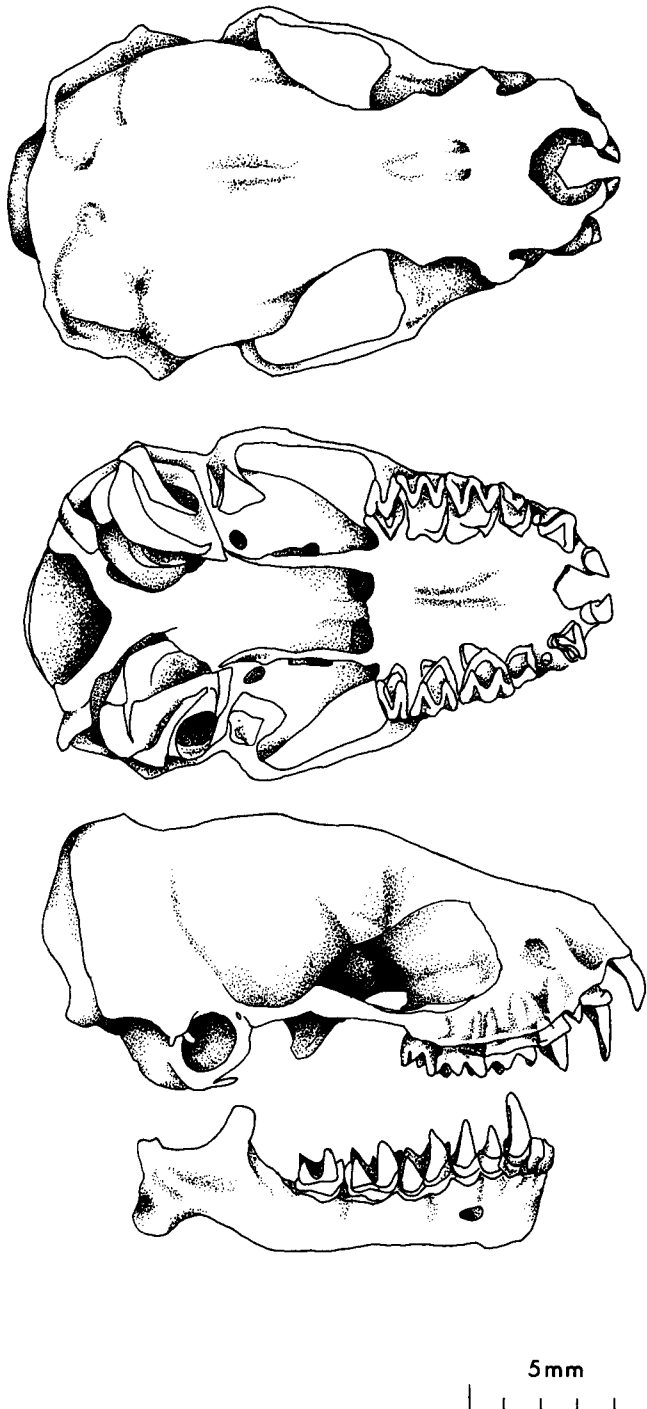


FIG. 2. Dorsal, ventral, and lateral views of the cranium and mandible of a male *Tadarida brasiliensis* (Texas Cooperative Wildlife Collection 30315) from Longview, Gregg Co., Texas. Drawings by E. Guelker.

and ranges of skull dimensions (in mm) for 32 males and 49 females (in parentheses) from Louisiana are: greatest length of skull, 16.9, 16.5 to 17.4 (16.6, 16.0 to 17.5); height of cranium, 6.2, 5.7 to 6.8 (6.2, 5.9 to 6.9); breadth of cranium, 9.7, 9.3 to 10.1 (9.5, 9.1 to 9.9); zygomatic breadth, 10.2, 9.3 to 10.1 (10.0, 9.7 to 10.8); interorbital breadth, 4.1, 4.0 to 4.5 (4.1, 3.9 to 4.3); palatal breadth, 7.1, 6.8 to 7.5 (7.1, 6.9 to 7.7); palatilar length, 5.7, 5.4 to 6.1 (5.4, 5.1 to 6.0); postpalatal length, 6.8, 5.7 to 7.3 (6.6, 6.3 to 7.2); and length of maxillary toothrow, 6.0, 5.6 to 6.6 (5.5, 5.2 to 6.3). Males and females differ significantly in some measurements (Lowery, 1974). Schmidly et al. (1977) demonstrated a clinal decrease in size of various cranial dimensions from east (Geor-

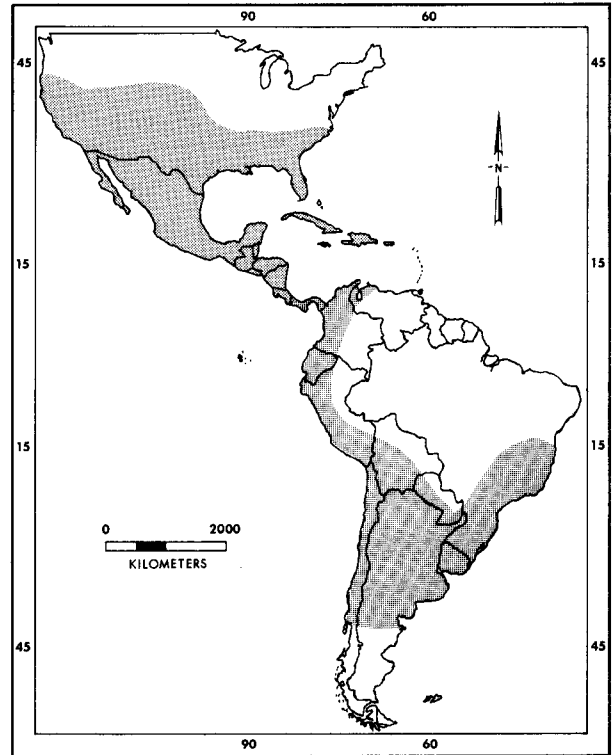


FIG. 3. Distribution of *Tadarida brasiliensis* (after Hall, 1981, and Koopman, 1982).

gia) to west (central Texas). Mean body mass (in g) for 16 females from Louisiana (12.9, 11.5 to 14.7) was greater than for a sample of 10 males (11.7, 9.6 to 14.4; Lowery, 1974).

**DISTRIBUTION.** *Tadarida brasiliensis* is one of the most widely distributed mammalian species in the Western Hemisphere (Fig. 3). Northern limits (Hall, 1981 unless noted otherwise) extend from southern Oregon to Nevada to northern Utah to northern Nebraska to Arkansas to northern Alabama, Mississippi, and Georgia to southern North Carolina (Lee and Marsh, 1978). Lee and Marsh (1978) contend that *T. brasiliensis* from North Carolina are residents, rather than post-breeding vagrants, that recently have invaded the coastal plain, perhaps in response to general climatic warming. Extralimital northern records include *T. b. mexicana* from DeKalb Co., Illinois, Iowa, and South Dakota (Glass, 1982) and *T. b. cynocephala* from Ohio in Scioto Co. and Montgomery Co. Banding studies traced *T. b. mexicana* from Oklahoma southeastward into Louisiana, an area normally inhabited by *T. b. cynocephala* (Glass, 1982). From these northern limits, *T. brasiliensis* ranges southward through most of Central America. Villa-R. (1966) depicted the range of the species to include all of Mexico except for the southern two-thirds of Baja California, whereas Hall (1981) included all of Baja California, but excluded most of the Yucatan Peninsula from the range.

The distribution of *T. brasiliensis* in South America is not well-known. This species occurs in four of seven South American faunal provinces: Patagonian subregion, eastern Brazilian highlands and coast, eastern slopes of northern Andes, and Pacific coast of Peru and northern Chile (Koopman, 1982). South American countries occupied are northern and western Colombia (Aellen, 1970), Ecuador, Peru (Koopman, 1978), southern and western Bolivia, Chile south to Temuco (Greer, 1965), Argentina north from the Gulf of San Matias (Rio Negro province; Cabrera, 1957), Paraguay (Myers, 1982), Uruguay (Ximénez et al., 1972), and coastal provinces of southeastern Brazil (Hall, 1981; Silva, 1975). *T. brasiliensis* apparently does not occur in much of Amazonia, but ranges widely in the Caribbean, occupying all of the Greater Antilles and 11 of the Lesser Antillean islands including Tobago (Baker and Genoways, 1978).

**FOSSIL RECORD.** Despite its expansive modern distribution, *T. brasiliensis* is not widely known in fossil deposits (Martin,

1972). Specimens from Mammoth Cave, Kentucky, dated at 38,000 years, are the only fossils of *T. brasiliensis* known from outside of the modern range of the species (Jegla and Hall, 1962). Three Pleistocene sites in Florida contain this species: Reddick IA, Nichol's Hammock, and Vero (Morgan, 1985; Webb, 1974). Other North American sites yielding *T. brasiliensis* are the late Rancholabrean Papago Springs Cave, Santa Cruz Co., Arizona (Skinner, 1942), Lost Valley localities of Dry Cave, Eddy Co., New Mexico (Harris, 1977) and Lower Sloth Cave, Culberson Co., Texas (Logan, 1983). Pleistocene collection sites in the West Indies include Cueva de Clara and Cueva del Perro in Puerto Rico (Choate and Birney, 1968) and Camaguey, Cuba (Koopman and Ruibal, 1955). *T. brasiliensis* was a member of the Holocene Burma Quarry fauna in Antigua, Lesser Antilles (Steadman et al., 1984). Fossils of *T. brasiliensis* are unknown from Central or South America.

**FORM.** The gular (hedonic) gland, present in both sexes, is well developed only in sexually mature males (Gutierrez and Aoki, 1973). This hemispherical organ of 2 to 4 mm diameter is located in the dermis of the suprasternal region. Hair covering the glandular area is shorter and less dense than in adjacent areas. The ducts of this gland open directly to the skin surface. This gland undergoes an annual cycle in which increased secretion accompanies hypertrophy of sebaceous cells. Greatest secretion occurs slightly before and during the breeding season. Male *T. brasiliensis* from Texas have glandular odors that are sweeter and stronger than the duller, muskier fragrance of females (Herreid, 1960a). Activity of the gular gland may be involved in sexual activity, social dominance, or territoriality (Davis et al., 1962; Quay, 1970). Glands of the facial region of *T. brasiliensis* include sebaceous glands and three pairs of salivary glands (Werner et al., 1950).

Female *T. brasiliensis* possess a pectoral pair of mammae. Milk collected in Arizona has the following characteristics (Huibregtse, 1966); specific gravity, 1.019; Kjeldahl protein, 11.07; mean carbohydrates, 3.7%; total solids, 34.4%; ash, 0.73%; pH, 6.3. Fatty acid content included molecules having 10, 12, 14, 16, and 18 carbon atoms in the chain (Stull et al., 1966).

The pelvic skeleton of *T. brasiliensis* is sexually dimorphic (Crelin and Newton, 1969). Males have a bony projection bordering the pubic joint and a convexity along the caudal border of the ischiopubic ramus. The male pubic joint is a symphysis; females possess an interpubic ligament having an abundance of elastic fibers. This ligament stretches to more than 15 times its original length to allow passage of the embryo. Length of the unstretched ligament averages 1.75 mm, and mean of the widest diameter of newborn bats is 16.0 mm.

Polydactyly was reported for a specimen of *T. brasiliensis* from Berkeley, California (Koford and Krutzsch, 1948). This specimen possessed six digits on each limb. The extra fingers projected forward free of the wing membrane for about 2.5 mm and were not under voluntary control. All toes functioned normally.

Several morphological features of *T. brasiliensis* represent adaptations for rapid flight in open areas (Vaughan, 1966). Short, broad ears that lie against the head do not directly face the airstream. The anterior and ventral borders of the pinnae are braced by connective tissue to form airfoils that probably contribute lift. The mass of the head is shifted towards the body's center of gravity by carrying the occipital region of the skull against the interscapular depression. The loose, wrinkled lips around the closed mouth seem to embody tissue that stretches when the mouth opens widely during flight; an enlarged mouth opening produces a greater effective area for gathering insects in partial compensation for the lack of maneuverability accompanying high-speed flight.

The wings have relatively low camber and are long and narrow. Wing aspect ratio (8.60) and wing loading (0.165 g/cm<sup>2</sup>) are high (Vaughan, 1966). Similar values for wing aspect ratio (8.57) and wing loading (0.111 g/cm<sup>2</sup>) were computed from the following measurements: wing span, mean of 300.6 mm; wing area, 104.9 cm<sup>2</sup>; and tail area, 8.1 cm<sup>2</sup> (Farney and Fleharty, 1969). Flight membranes of *T. brasiliensis* are leathery, elastic, and stronger than in non-molossids. Muscles that tense portions of the wing membranes (occipito-pollicalis, tensor plagiopatagii, humeropatagialis) are well developed. Molossids lack the coracobrachialis muscle; the coracoid head of the biceps brachii is larger than the glenoid head. These musculoskeletal adaptations yield very efficient wing adduction and division of labor among several muscles. The calculated value for the minimum speed a *T. brasiliensis* must fly to sustain level flight

is 18.5 km/h. Short, velvety fur is probably an adaptation for reducing drag (Vaughan, 1966).

The rounded tympanic membrane of *T. brasiliensis* measures 2.8 mm and 2.3 mm in its long and short axes. Surface area is about 5 mm<sup>2</sup>; thickness ranges from 0.002 mm peripherally to 0.008 mm centrally. The neck of the malleus is similar to that in other bats except for being extremely thin and delicate. The anterior process of the malleus possesses an inner lamella that ends abruptly, rather than by tapering. No suspensory ligaments or folds are associated with the ear ossicles (Henson, 1961).

The tensor tympani originates from the sphenoid and inserts via two separate tendons onto two processes of the malleus (Henson, 1970). The multipennate stapedius originates from the stapedial fossa and inserts on the posterior portion of the head of the stapes. In *T. brasiliensis* the cochlea is insulated from the cranium by blood sinuses, fat deposits, or connective tissue. Insulation of the lateral semicircular canal from the squamosal bone is achieved by the squamosal being fibrous at the contact area (Henson, 1961).

Middle ear muscle activity associated with echolocation indicates that the stapedius contracts maximally just before or at the beginning of the pulse. The stapedius begins relaxing at the onset of the pulse, continues relaxation for the rest of the pulse and achieves full relaxation within 10 msec. The stapedius apparently remains contracted during an entire series of pulses at rapid pulse rates of about 140/sec. The tensor tympani seems not to be involved in the attenuation of pulse-sound pressures (Henson, 1965).

In laboratory experiments where bats flew towards an object that was removed as the bat approached, the general pattern of echolocation signals in *T. b. mexicana* was approximately 17 single pulses (mean duration 3.1 msec with gaps averaging 93.2 msec) followed by a crescendo of six paired pulses as the bat came to within 1 m of the obstacle (Vernon and Peterson, 1965). Apparently, crescendo pulsing indicates that the bat has detected the obstacle. After removal of the obstacle, the bat emitted a single pulse, a double pulse, and then a series of single pulses until the end of the flight run. Further study of acoustic physiology in *T. brasiliensis* is reported in Simmons and Stein (1980).

The brain of *T. brasiliensis* is compressed to the point that it forms nearly a right angle middorsally. Fissures are shallow and indistinct. Ventricles are small and flattened into slits. The disproportionately small olfactory bulbs lack accessory olfactory bulbs. The nucleus olfactorius anterior is relatively smaller and less well differentiated than in most mammals; it possesses a small pars externa, but lacks a pars posterior (Crosby and Humphrey, 1939). The corpus callosum is small and receives fibers from only a small portion of the neopallial cortex; lacking the splenium and genu, it is positioned frontalward. Nervus terminalis, absent from adult *T. brasiliensis*, is present transiently during embryonic stages measuring from 7 to 13 mm crown-to-rump length. Ganglion cells associated with this nerve arise as clusters from epithelium of the nasal septum, with the greatest number of cell clusters present at the 10.5 mm stage. Nerve 0 possesses two or three branches that pierce the hemispheric wall (Brown, 1980).

The stomach of *T. brasiliensis* is very similar to those of two other insectivorous species, *Myotis velifer* and *Antrozous pallidus* (Rouk and Glass, 1970). A pyloric caecum is present. Near the middle of the greater curvature is an invagination of the stomach wall that produces a fold of tissue protruding slightly into the lumen. Several rugae run longitudinally from gastroesophageal to gastroduodenal junctions. A muscular pyloric valve is present; there is no muscular valve at the gastroesophageal junction. The gastric mucosa includes cardiac glands, oxyntic glands, transitional glands, and pyloric glands over the small region from the aboral angle to the pyloric valve.

During the approximately 11-week gestation period (Sherman, 1937), three successive placental relationships exist (Stephens and Cabral, 1971). The choriovitelline placenta ends with the enlargement of the allantois (Stephens and Cabral, 1972). Two arrangements of chorioallantoic placentae, a diffuse labyrinthine endotheliochorial placenta and one that is discoidal, labyrinthine, and hemomonochorial, follow. Maternal blood directly contacts microvilli extending from this cellular trophoblast. The placental barrier is as thin as 0.04  $\mu$ m at term (Stephens, 1969).

**FUNCTION.** The primary flight muscles (pectoralis, subscapularis, serratus ventralis) of *T. brasiliensis* are composed only of fast oxidative fibers, suggesting design for high-speed flight over

long periods of time (Foehring and Hermanson, 1984). A mixture of fast oxidative and slow oxidative fibers characterizes the accessory flight muscles (triceps brachii and biceps brachii); the deeper slow oxidative fibers probably stabilize the wings, whereas fast oxidative fibers flex or extend the humerus or assist humeral adduction during the downstroke. The primary form of lactate dehydrogenase found in the pectoralis muscle is B<sub>1</sub>. This isoenzyme, which favors the oxidative pathway, predominates in species capable of sustained flight (Gutierrez et al., 1974).

Blood pressure in *T. brasiliensis* drops about 55% from small arteries (about 100 mm Hg) to the precapillary sphincters in the patagium; much of the remaining pressure dissipates at the sphincters (Wiederhielm and Weston, 1973). Pressures in the middle of the capillary bed averaged 24 mm Hg and dropped as low as 4 mm Hg in patagial veins. Resting heart rate of about 150 beats/min rapidly jumped to 660 beats/min when the bat was startled. Mean erythrocyte density is 10,650,000/mm<sup>3</sup> (Kruttsch and Hughes, 1959).

*Tadarida brasiliensis* experiences significant seasonal variation in body fat content. In Jamaica, fat content decreased from high values in December to intermediate values in February–March to the lowest values in June–July (McNab, 1976). Greatest fat loss occurred during the dry season when the diet of insects was less abundant. During the early dry season, females carry greater fat reserves than do males; this disparity between sexes decreases as the dry season passes into summer. Autumn fat indices for *T. b. cynocephala* in Louisiana increase from September into December (Pagels, 1975).

Migratory *T. b. mexicana* reaching their summer ranges in Arizona have their greatest fat reserves upon arrival in March (O'Shea, 1976). Fat content decreases through May, increases slightly in June and July, and drops to its lowest level in September. This pre-migratory low in fats corresponds to the likelihood that the more southern locales along the migratory route offer reliable food supplies and to the uncertainty of timing of cold fronts that might prompt migration. The need for large fat reserves for the northward spring migration may be associated with more rigidly timed departure dates and an uncertainty of food resources at northern destinations. *T. brasiliensis* from Texas have considerable fat deposits during September just before the southward fall migration (Herreid, 1963). Fat indices in the non-migratory *T. b. cynocephala* are lower at all times of year than for *T. b. mexicana* in New Mexico (Pagels, 1975).

Clustering behavior of *T. b. cynocephala* varies with ambient and roost temperatures. Compactness of bat clusters in a warehouse roost in Louisiana ranged from loose and moderate during September and October, when roost temperature was 24 to 33.5°C, to dense from late October through March (roost temperature, 4 to 24°C). Clustering decreases exposed body surface area and, thereby, reduces loss of body heat. The ability of these bats to resist hypothermia when exposed to cold was least in summer, intermediate in early fall, and greatest in late fall. Greater body fat supplies in cool months correspond with greater resistance to hypothermia during cool months. In experiments wherein food and water were withheld, mean survival times ranged from 2 to 82 days. Females resist hypothermia more effectively and survive longer than males (Pagels, 1975).

The number of times a bat can arouse from torpor and warm its body temperatures to flight temperature without feeding varies by month. In October, all bats in the sample rewarmed only on the first night, with only 20% successfully rearming on the fourth night. The percentage rearming increased through fall into winter with the entire sample rearming for six nights in January. Body mass of bats that rewarmed was greater than for those that did not rearm. Amounts of interscapular brown fat were greater in rearming bats than in those that did not arouse (Pagels, 1972). *T. brasiliensis* warmed from torpor at an average rate of 0.55°C/min over 1 h (Herreid, 1967a).

The upper limit of ambient temperature selected by *T. b. mexicana* is about 35°C (Herreid, 1967a). Air temperatures in barns and some caves used by this species often exceed 40°C (Henshaw, 1960; Licht and Leitner, 1967). Because body temperature is always greater than ambient temperature, passive heat loss could occur by conduction and by radiation. Other heat loss mechanisms employed by *T. brasiliensis* include vasodilation of blood vessels in the ears and flight membranes, increased respiratory rate, and salivation onto fur and wings to facilitate evaporative cooling (Herreid, 1967a). Bats in Bracken Cave, Texas, moved from darker recesses of the roost into full sunlight near the cave entrance where ambient temperature was lower; temperatures outside the cave were always cooler

than inside (Henshaw, 1960). At high ambient temperatures, bats often increased the spacing between individuals. During the later stages of hyperthermia, decreasing heat production by decreased levels of panting and salivation allowed *T. brasiliensis* to tolerate body temperatures of 42.5 to 44°C for up to 2 h (Henshaw, 1970). Flying serves to increase the circulation of air in the roost and to expose a greater body surface for cooling. At Bracken Cave, Texas, the proportion of bats swarming in the roost increased from 1% in May to 12% in July in correlation with increases of roost temperatures from 35 to 37.2°C (Henshaw, 1960).

Metabolic rates of adults in a nursery cave ranged from 1.99 to 7.31 ml O<sub>2</sub> g<sup>-1</sup> h<sup>-1</sup>. Metabolic rates for groups of bats decreased with increasing group size, and were higher during cooler months than during summer. The yearly energy budget of 4,300 kcal for *T. brasiliensis* exceeds that of *Myotis lucifugus*, a hibernator, by eightfold (Herreid, 1967a).

Comparison of migratory *T. b. mexicana* with various hibernating vespertilionids showed that Brazilian free-tailed bats can live without food and water only one-fourth to one-third as long as hibernating species under the temperature conditions (about 5°C) normally experienced by those hibernating species. Yet, Brazilian free-tailed bats survived three to four times longer at 27°C than did the hibernators. This pattern of survival might be related to the subtropical affinities of *T. brasiliensis* and to the possibility that this species has a more efficient mechanism of body-water retention than do hibernating vespertilionids (Herreid, 1963).

*Tadarida brasiliensis* possesses physiological mechanisms for countering high atmospheric concentrations of ammonia found in many roosts. Carbon dioxide and protein content of respiratory mucous and carbon dioxide dissolved in blood plasma increase with increasing levels of dissolved ammonia, with the effect of increased buffering capacity (Studier and Fresquez, 1969). *T. brasiliensis* can filter 97.1% of the ammonia in an inhaled mixture of 1,130 ppm, 73.4% at 4,420 ppm, 72.6% at 5,040 ppm, and 77.5% at 7,200 ppm (Studier, 1969). Exposure to inhaled ammonia levels greater than 7,200 ppm is lethal within 0.5 h. These mechanisms for ammonia tolerance apparently are passive, as indicated by decreasing metabolic rate with increasing ammonia concentration (Studier et al. 1967). The swarming behavior of *T. brasiliensis* inside its roosts is probably a means of wafting ammonia-laden air out of the roost (Henshaw, 1960).

To maintain water balance, *T. brasiliensis* requires free water (Carpenter, 1969). Evaporative water loss, ranging from about 1 to 9 ml H<sub>2</sub>O g<sup>-1</sup> h<sup>-1</sup>, correlates with ambient temperature. A calculated water-deficit value of only 3.8% of body mass/day correlates with the observation that individual *T. brasiliensis* might not leave the roost each night. Maximum urine concentrations of urea and chloride were 2.27 moles/l and 489 meq/l. Daily urine volume is about 2.53 cc (22.6% of body mass). The ability of *T. brasiliensis* to conserve urinary water varies geographically with habitat aridity (Bassett, 1982). Renal structure reflects different urine concentrating abilities; values for percent medullary thickness to percent cortical thickness (89 compared to 86.5), ratio of inner medullary thickness to cortical thickness (5.83 compared to 4.58), and ratio of total medullary thickness to cortical thickness (8.13 compared to 6.46) are greater for *T. brasiliensis* from New Mexico (more arid) than for those from California (less arid; Bassett, 1982).

**ONTOGENY AND REPRODUCTION.** In Gainesville, Florida, males probably become sexually mature in their second year whereas females do so at about 9 months (Sherman, 1937). Spermatogenesis begins in September, with mature spermatozoa present in the testes and epididymides primarily in February and March. Ovulation occurs within a 3-week period in March with about 90% of females ovulating during a 1-week period. Mating occurs during an approximately 5-week interval about the time of ovulation. Normally, one embryo develops in the right uterine horn, although over half of the females in a sample from Alabama carried twins or triplets (DiSalvo et al., 1969a). Generally, sex ratio at birth is 1:1. Lengths of embryos from bats in a Gainesville, Florida, colony increased steadily from 5 to 10 mm in early April to 25 to 30 mm just before parturition, which occurs over a 2- to 3-week period, usually during June.

Parturition in *T. b. cynocephala* occurs with the mother hanging head downward (Sherman, 1937). Passage of the young through the birth canal requires about 90 sec. During passage the mother shreds the amnion with the claws of her hind feet. The mother does

not use her flight membranes to receive the young. The newborn takes about 15 min to locate a nipple and begin nursing. The placenta passes about 2 h after birth and remains attached to the young until the cord dries and breaks after 2 days.

Newborn *T. b. cynocephala* in Louisiana average 25.8 mm in crown-to-rump length. Their skin is smooth, slightly pigmented, and virtually hairless except near the toes and thumbs. By about 5 to 6 weeks of age, pelage is long, thick, and black. Some young reached adult mass by 3 weeks of age. Body length of newborns is about two-thirds that of adult, with adult length attained by about 2 months of age. Length of forearm increases at 0.7 to 0.9 mm/day, and bats gain 0.4 g/day. Some young are capable of straightline flight at 35 days; most were capable of maneuverable flight at 38 days. At birth all deciduous teeth (i 2/3, c 1/1) are erupted. The permanent incisors and canines erupt before the permanent premolars and molars (Pagels and Jones, 1974).

Reproductive biology in *T. b. mexicana* is similar to that in *T. b. cynocephala*. An essential difference corresponds to the migratory habits of *T. b. mexicana*. Few adult males return northward in spring; mating probably occurs in lower latitudes of the winter range (Davis et al., 1962). Parturition at Merrihew Cave, Oklahoma, occurred between 20 June and the first half of July in 1953 (Twente, 1956). Deciduous teeth are shed by 2 weeks of age (Short, 1961). The permanent dentition erupts completely by 6 weeks. At the time of first flight, young, which are of adult mass, experience a significant loss of mass; adult mass is regained by about 12 to 13 weeks of age. Length of forearm increases by about 1.0 mm/day (Short, 1961).

The reproductive cycle of male *T. brasiliensis* involves cyclic appearance of two lactate dehydrogenase enzymes in testes containing mature spermatozoa. In *T. brasiliensis* from Cordoba, Argentina, mature spermatozoa are present in seminiferous tubules and epididymides from June through October (Blanco et al., 1969).

McCracken (1984) refuted earlier reports (for example, Davis et al., 1962) that females randomly nurse young. Electrophoretic study of genotypes of mothers and young from caves in Texas demonstrated that females correctly identified and nursed their own young 83% of the time. Correct identification of young is facilitated by the mothers' practice of placing young into creches. Mothers enter the creche to nurse young twice daily. Although females generally do not carry their young while flying, they occasionally will do so following roost disturbance (Davis, 1970).

Methods of determining ages of Brazilian free-tailed bats include tooth wear (Davis et al., 1962), banding and recovery (Glass, 1982), and mass of the eye lens (Perry and Herreid, 1969). The greatest age reported for *T. brasiliensis* is 8 years (LaVal, 1973). Predicted adult survival rate is 70 to 80% with a lifespan of 15 years (Davis et al., 1962). Both sexes experience equivalent mortality rates (Jennings, 1958).

**ECOLOGY.** Avian predators of *T. brasiliensis* include American kestrels (*Falco sparverius*; Black, 1976), Mississippi kites (*Ictinia mississippiensis*; Taylor, 1964), red-tailed hawks (*Buteo jamaicensis*; Twente, 1956), and roadrunners (*Geococcyx californianus*; Herreid, 1960b). Great horned owls (*Bubo virginianus*) ate juvenile bats inside the bat roost in Conner's Cave, Oklahoma (Perry and Rogers, 1964). Barn owls (*Tyto alba*) took *T. brasiliensis* in flight as the bats exited Vickery Cave, Oklahoma (Caire and Ports, 1981). Skunks (*Mephitis mephitis*, *Conepatus mesoleucus*), raccoons (*Procyon lotor*), and opossums (*Didelphis marsupialis*) are among mammalian predators of *T. brasiliensis* (Constantine, 1948; Twente, 1956). A Brazilian free-tailed bat, apparently roosting in a wood duck (*Aix sponsa*) nest box, was found in the stomach of a Texas rat snake (*Elaphe obsoleta*; Ridlehuber and Silvy, 1981). Other snakes preying on *T. brasiliensis* include coachwhips (*Masticophis flagellum*), copperheads (*Agkistrodon contortrix*), and coral snakes (*Micrurus fulvius*; Davis et al., 1962). Green sunfish (*Lepomis cyanellus*) occasionally consume *T. brasiliensis* (Jones and Hettler, 1959). Some *T. brasiliensis* survive falls by crawling to and ascending the roost walls before being immobilized by beetles (Hermanson and Wilkins, 1986).

Bat species associated with *Tadarida brasiliensis* in caves and sinkholes include *Myotis velifer*, *Mormoops megalophylla*, and *Plecotus rafinesquii* (Eads et al., 1957). *Nycticeius humeralis*, *Myotis austroriparius*, and *Eptesicus fuscus* commonly occur with *T. brasiliensis* in building roosts in the southeastern United States (Jennings, 1958). Cave swallows (*Petrochelidon fulva*), rock wrens

(*Salpinctes obsoletus*), and eastern phoebes (*Sayornis saya*), frequently nest near the entrances to caves (Davis et al. 1962). *T. brasiliensis* occasionally, during spring cold snaps, takes refuge in cliff swallow (*Petrochelidon pyrrhonota*) nests located in culverts and beneath bridges (Pitts and Scharninghausen, 1986). Invertebrate species associating with *T. brasiliensis* include various species of beetles, fleas, bedbugs, flies, spiders, and scorpions (Eads et al., 1957).

Endoparasites of *T. brasiliensis* include the nematode *Seuratum cancellatum* found in the body cavity of specimens taken in Brewster Co., Texas (Specian and Ubelaker, 1976). Twelve species of helminths parasitizing *T. brasiliensis* from Bracken Cave, Bexar Co., Texas, include the trematodes *Acanthatrium nycteridis*, *Limatulum oklahomense*, *Ochoterenatrema labda*, *Urotrema scabridum*, *Plagiorchis vespertilionis*, *Dicrocoelium rileyi*, and *Conspicuum icteridorum*, the cestode *Hymenolepis gertschi*, and the nematodes *Molinostrongylus delicatus*, *Tricholeiperia* sp., *Physaloptera* sp., and *Rictularia* sp. (Martin, 1976). *T. brasiliensis* from New Orleans, Louisiana, host eight helminths: *H. gertschi*, *Physaloptera* sp., and the trematodes *Allasogonoporus marginalis*, *O. labda*, *U. scabridum*, *P. vespertilionis*, *D. rileyi*, and *C. icteridorum* (Martin, 1976). Infection rates in bats from Carlsbad Caverns, New Mexico, were 37.5% of the bats examined for *D. rileyi*, 16.6% for *H. gertschi*, and 28.1% for *M. delicatus* (Cain, 1966). *D. rileyi* resides in the gall bladder, whereas *Platynosomum beltrani*, *Paralecithodendrium carlsbadensis*, *Ochoterenatrema fraternum*, *O. labda*, and *Tremajoannes buckleyi* occur in the intestine (Caballero y C. and Caballero R., 1969). Three additional nematode endoparasites of *T. brasiliensis* are *Parallintoshius parallintoshius* from Brazil, *P. tadaridae* from Mexico (Trichostrongylidae), and *Anoplostrongylus paradoxus* (Strongylacanthinae) from Mexico (Yamaguti, 1958-1963). The protozoan *Trypanosoma cruzi* had been reported from *T. brasiliensis* from Trans-Pecos, Texas (Ubelaker, 1970).

The chigger *Microtrombicula merrihewi* (Trombiculidae), a common parasite of the nasal cavity in *T. b. mexicana* and *T. b. intermedia*, was found in 29% of the *T. b. mexicana* examined (Davis and Loomis, 1971). *T. b. mexicana* parasitized by ticks (*Ornithodoros stageri*; Argasidae) are known from California, Arizona, Oklahoma, and Texas (Randolph and Eads, 1946). *O. yumatensis* infests *T. b. mexicana* in Arizona (Dooley et al., 1976). At least six species of bat mites afflict *T. brasiliensis* as follows: *Chiroptonyssus robustipes* (Dermanyssidae) is documented from Dominica (Pence et al., 1981), California, Arizona, Texas, Oklahoma, Georgia, Florida, Alabama, Costa Rica, and Panama (Dooley et al., 1976; Radovsky, 1967; Randolph and Eads, 1946). *C. robustipes* was the causative agent of persistent dermatitis of an 18-month-old boy who lived in a house also occupied by a colony of *T. brasiliensis* (Keh, 1974). Other bat mites associated with *T. brasiliensis* are *Steatonyssus ceratognathus* and *S. occidentalis* (Mesostigmata; Radovsky, 1967), *Nycteriglyphus bifolium* (Glyciphagidae; Strandtmann, 1962), and *Dentocarpus macroctichus* and *Olavidocarpus laurencei* (Labidocarpidae; McDaniel and Coffman, 1970). Other ectoparasites known from *T. brasiliensis* are fleas (*Sternopsylla* sp.; Randolph and Eads, 1946) and the batflies *Basilia forcipata* and *B. antrozoi* (Nycteribiidae; Whitaker and Easterla, 1974).

*Tadarida brasiliensis* uses several types of roosts (Cockrum, 1969). Although they may be located in diverse situations (for example, caves, culverts, attics, bridges), maternity colonies initially include almost exclusively pregnant females. Examples include Eagle Creek Cave, Arizona, Carlsbad Caverns, New Mexico, and Bracken Cave, Texas, where bat numbers reach into the millions. Most males in a maternity colony are offspring of that birthing season. Many males do not migrate northward in spring but remain in their winter range throughout summer (Glass, 1982). Males that migrate northward (and an occasional female) might occupy summer male roosts (bachelor colonies); alternatively these males congregate with other males, but separate from females, with which they share the roost (Hermanson and Wilkins, 1986). Usually, only a few hundred males occupy such colonies. Bats of both sexes temporarily use transient roosts as stopover sites during migration. Sex ratio and group size can vary widely for transient roosts (Cockrum, 1969).

Caves likely were the only type of roost inhabited by *T. b. mexicana* before construction of buildings. Virtually any type of building is suitable as a roost if openings into dark recesses in walls or ceilings are present. Factors seemingly not affecting suitability of

a building for occupation are building age, height, architecture, construction materials, occupancy by humans, and compass orientation. Not all caves, however, are suitable as *T. brasiliensis* roosts. In central Texas, caves occupied by *T. brasiliensis* share several features. They are large enough to provide adequate wall and ceiling space for millions of bats. The domed ceilings of large rooms minimally are about 20 by 20 m with about 10 m from ceiling to floor. Minimal dimensions of entrances into such rooms are about 5 m high by 10 m wide; vertical entrance shafts into sinks are about 10 by 10 m (Davis et al., 1962).

Hollows of trees, such as red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and cypress (*Taxodium*), probably were the natural roosts for Brazilian free-tailed bats in the southeastern United States (Jennings, 1958). However, most *T. b. cynocephala* in Florida have forsaken natural roosts for buildings or other man-made structures. Only rarely do they occur in caves in Florida, which instead usually are occupied by *Myotis austroriparius*. The essential difference between caves in the western United States and in Florida seems to be the presence of water on the floors of Florida caves; *Myotis austroriparius* requires a much higher relative humidity than does *T. brasiliensis*.

Populations of *T. brasiliensis* in North America exhibit two general types of seasonal movements (Cockrum 1969). Brazilian free-tailed bats ranging eastward from eastern Texas (*T. b. cynocephala*) do not migrate, although local shifts in roost usage often occur seasonally. Several bats banded in Clinton, Louisiana, were recovered at roosts located up to 135 km from the site of banding (LaVal, 1973). Similarly, a regional population of *T. b. mexicana* ranging from Oregon and California, maintains year-round residence in the region. Three other populations engage in extensive seasonal migrations: Those in southeastern Nevada, southwestern Utah, western Arizona, and southeastern California form a unit that migrates westward and southwestward into southern California and Baja California. Those in southeastern Utah, southwestern Colorado, western New Mexico, and eastern Arizona migrate into Jalisco, Sinaloa, and Sonora along the western side of the Sierra Madre Occidental. *T. b. mexicana* that summer in Kansas, Oklahoma, eastern New Mexico, and Texas migrate southward into southern Texas (Glass, 1982), and into eastern, central, and perhaps western Mexico. Springtime arrival of *T. b. mexicana* in Texas (Ney Cave) is in March or April; autumn departure is in September or October (Cagle, 1950). However, some *T. b. mexicana* in eastern and central Texas winter in Texas (Spenrath and LaVal, 1974), and Brazilian free-tailed bats have been captured in southwestern Utah during January and February (Ruffner et al., 1979). Orientation over the long migratory circuit might involve olfactory cues on odor tracks left by bats migrating earlier in the season (Glass, 1982); no evidence is available to support this contention.

Migrations are documented for distances up to 1,840 km from natal banding sites (Glass, 1982). In Oklahoma, a large proportion of these bats returns annually to natal areas (Glass, 1982). One bat flew 1,280 km from Carlsbad Caverns, New Mexico, to Las Garrochas Cave, Jalisco, in 69 days; the maximum documented rate of travel is about 32 km/day (Villa-R. and Cockrum, 1962). *T. brasiliensis* homes over distances of 525 km (Davis, 1966). In homing experiments, the proportion of bats returning decreased with increasing distance of release from the return site; 42.2% returned from 8 km, whereas 23.4% returned from about 175 km. Males and females returned in approximately equal proportions. Experiments on the effects of direction of release on return indicated that more bats returned from the southeast and northeast than from other directions (Davis, 1966).

The rabies virus (*Lyssavirus*, Rhabdoviridae) was isolated from 9 of 335 *T. brasiliensis* collected in Texas during 1954, with Negri bodies found in 5 of the 9 specimens (Enright, 1956). None of 31 *T. brasiliensis* examined in Florida during 1953 were positive for rabies (Venters et al., 1954). Only 4 of 1,129 (0.4%) Brazilian free-tailed bats collected in Florida from 1953 through 1956 were positive for rabies (Schneider et al., 1957). From 1966 to 1973, 5 of 63 (7.9%) Florida specimens tested positive; these five rabid *T. brasiliensis* composed only 4.5% of the total sample of rabid bats of nine species (Bigler et al., 1975). Transmission of the virus among bats of a colony potentially occurs by inhalation, licking, biting, and contact with infected urine or milk (Baer, 1975).

At least five other identified kinds of virus are harbored by *T. brasiliensis*. Rio Bravo virus, a group B arbovirus, has been isolated

from salivary glands (Constantine and Woodall, 1964). A study of *T. brasiliensis* collected from coastal sites in Texas yielded specimens carrying the St. Louis encephalitis virus (SLE); *T. brasiliensis* apparently can maintain the SLE virus in nature year-round and might be an important element in SLE epidemics (Allen et al., 1970). *T. brasiliensis* is a host of eastern equine encephalitis, western equine encephalitis, and Japanese B encephalitis (Constantine, 1970).

*Histoplasma capsulatum*, the fungal species causing histoplasmosis, has been recovered from soil, guano, and tissues of several species of bats. Natural infection in *T. brasiliensis* probably is by inhalation of mycelium-borne infective spores (Hoff and Bigler, 1981). Eight of 251 (3.2%) *T. brasiliensis* collected from 14 sites in Arizona harbored the pathogen, although none appeared ill at the time of capture (DiSalvo et al., 1969b). Cave-floor guano deposits can harbor the infective stage of *H. capsulatum* while the resident bats need not be infected; none of 86 *T. brasiliensis* examined at Bracken Cave, Texas, were infected (McMurray and Russell, 1982). None of 161 *T. brasiliensis* occupying building attics in Mississippi, Louisiana, and eastern Texas tested positive for the fungus (Tesh and Schneidau, 1967). Six of 50 (12%) Brazilian free-tailed bats netted in a cave near Reed, Oklahoma, yielded the fungus (Bryles et al., 1969). Intraperitoneal inoculation of *T. brasiliensis* with *H. capsulatum* produced an 80% mortality rate over a 7- to 34-day period; associated symptoms included irritability, lethargy, refusal to eat, emaciation, and diarrhea (Hoff and Bigler, 1981).

Dermestid beetles (*Dermestes carnivorus*) and larval *Tenebrio* beetles are important agents of mortality for neonate and juvenile *T. brasiliensis* that fall to the roost floor (Eads et al., 1957). Studies at Davis Blowout Cave, Texas, indicated that non-volant Brazilian free-tailed bats fell to the cave floor at rates of 4.8/h to about 20/h over a period of about 6 weeks after parturition (Herreid, 1967b). Thereafter, juveniles could fly, and mortality decreased drastically. Estimated juvenile mortality rate was 1.3%. *T. brasiliensis* was among several species of bats found dead following in-flight collisions with a television tower and its guywires in northern Florida (Crawford and Baker, 1981). Accidental death can occur also by entanglement with cactus (*Opuntia* sp.), grass burs, or other vegetation located near a roost entrance (Gillette and Kimbrough, 1970).

*Tadarida brasiliensis* is an insectivore with about 90% of its diet consisting of moths (primarily Gelechiidae) between 5 and 9 mm long (Ross, 1961; Storer, 1926). The misconception that mosquitoes composed much of the diet prompted Campbell (1925) to pursue a vigorous campaign of building bat towers to increase local bat populations and, thereby, control malarial mosquitoes.

Heavy metals, such as mercury, lead, and selenium, can be incorporated into the tissues of *Tadarida brasiliensis* (Clark, 1981). Mercury was detected in the breast muscles of these bats from Arizona (Reidinger, 1972). The trend of mercury content in annual strata of guano deposits in a cave near Morenci, Arizona, tracked the production figures of a copper smelter located 8 km away; the mercury probably entered the bats via the food chain (Petit and Altenbach, 1973). Mercury concentrations in the guano ranged from about 0.07 to 0.15 ppm. Analysis of a 1,100-year-old accumulation of guano in a *T. brasiliensis* cave roost in the Patagonia Mountains, Arizona, revealed that today's concentration is less than that of a millennium ago, but about triple that of about 116 years ago (Petit, 1977). The guano cores studied showed discontinuous occupancy of the roost; *T. brasiliensis* was absent from the site for a 120 year interval beginning about 310 years ago.

Tissues of *T. brasiliensis* collected in California, Arizona, New Mexico, and Texas contained various combinations of residues of the organochlorine compounds DDT, DDE, DDD, dieldrin, endrin, toxaphene, and the PCBs Aroclor 1254 and 1260, with DDE occurring in higher concentrations than the other contaminants (Geluso et al., 1976, 1981; Reidinger, 1976; White and Krynsky, 1986). Carcass levels of DDE were greatest in flying young from Carlsbad Caverns, New Mexico (101 ppm); means were much lower for young in Eagle Creek Cave, Arizona (9 ppm), Bracken Cave, Texas (10 ppm), and Newman Bridge, California (13 ppm; Geluso et al., 1981). The concentration of DDE in brain tissues, ranging from 0.19 to 17.0 ppm, was lower than (and highly correlated with) that in carcasses. Being lipid-soluble, DDE and these other contaminants are stored primarily in fatty tissue. Fat content in the brain is quite stable, even when body fat decreases rapidly. As body fat is depleted by the energetic demands of migration or starvation, DDE residue is mobilized and carried to the brain, where it accumulates in much higher concentrations. DDE concentrations of 260 and 330 ppm



were detected in brain tissues of two bats that died of pesticide poisoning (Geluso et al., 1976). Pesticide poisoning symptoms include hyperactivity, violent contractions of chest muscles, intermittent audiogenic seizures, and prolonged trembling (Geluso et al., 1976). Young-of-the-year are at particular risk of pesticide poisoning during their first migratory flight: the post-weaning diet includes insects carrying a pesticide burden and the diet of milk contains high concentrations of residues (Clark et al., 1975). Tissue concentrations of pesticide residues were greater for bats collected in cities and close to agricultural activities than for bats obtained in caves and canyons remote from humans (Reidinger, 1976). Pesticide poisoning is probably the primary agent responsible for drastic declines in some populations of *T. brasiliensis* (Geluso et al., 1976).

*Tadarida brasiliensis* has been maintained in captivity for over 4 years (Constantine, 1952; Orr, 1958). An effective laboratory diet is a homogenized mixture of cottage cheese, bananas, codliver oil, and mealworms (*Tenebrio molitor*; Krutzsch and Sulkin, 1958). Bats in a breeding colony eagerly ate live mealworm larvae and drank water from dishes (Baer and Holguin, 1971). Bats were held in wood frame cages lined with hardware cloth, and maintained at temperatures of 24 to 32°C and relative humidities of 50 to 70%.

The tendency of *T. brasiliensis* to aggregate in great numbers leads to accumulation of guano, often in commercially significant amounts (Constantine, 1970). Guano is used in production of fertilizer and has served as an important source of saltpeter for manufacture of gunpowder (Hutchinson, 1950). The estimated average amount of guano deposited per cave in Texas was from 22 to 99 metric tons with over 18,700 metric tons produced annually in certain caves in northern Mexico (Osborne, 1939). During World War II, the United States military investigated the use of *T. brasiliensis* to carry incendiary bombs into enemy facilities (Mohr, 1948).

**BEHAVIOR.** *Tadarida brasiliensis* exhibits two types of flight during emergence from roosts (Herreid and Davis, 1966). A diffuse flight, showing little group integrity, is the more common (88% of observations) and characterizes slow emergence, especially from sinkholes. Diffuse flights begin an average of 15.8 min after sunset. Roosts containing many individuals were exited rapidly in a winding serpentine column extending across the sky for several km. Serpentine flights, composing 12% of the observations, began an average of 23 min before sunset. The relationship between emergence time and sunset suggests the importance of light levels on flight behavior. However, bats sometimes leave Ney Cave, Texas, as early as 1630 hrs (Eads et al., 1957). Other factors influencing departure time include number of bats in the colony, size of cave openings, and climatic factors (Eads et al., 1957). For most of the flights observed by Herreid and Davis (1966) in Texas, most emerging bats exited during the first hour of flight. Reduced rates of exodus continued until around 0300 to 0400 h when bats began to return in large numbers. Average time for a bat to be away from the roost was 3 h 48 min. Both the time of the peak of return and the time of return of the last bat to the roost correlated with sunrise. On cloudy days, the last bat might return as late as 0930 h (Eads et al., 1957). Return to the roost usually involves rapid, irregular descent with the bats spiraling as they drop from great heights. Wings open and close to break their fall.

Brazilian free-tailed bats often fly 50 km or more to reach foraging areas; such flight is rapid, direct, and often involves gliding (Davis et al., 1962). Clusters of bats may cover areas as large as 400 km<sup>2</sup> and move at speeds over 40 km/h and at altitudes of 3,000 m or more (Williams et al., 1973). In flight trials, *T. brasiliensis* covered a 30.5 m course in times averaging 7.2 to 10.2 sec (Hayward and Davis, 1964). Observations of foraging behavior indicated that *T. brasiliensis* spends about 60% of its active time foraging while cruising and about 12% foraging, with lesser times spent cruising and resting (Caire et al., 1984). Most foraging and cruising was done at heights of 6 to 15 m.

**GENETICS.** Morphological intergradation in skull characters occurs between *T. b. cynocephala* and *T. b. mexicana* in eastern Texas (Schmidly et al., 1977). Electrophoretic examination of populations of *T. b. mexicana* in the southwestern United States and adjacent Mexico demonstrated no fixed allelic differences between populations even though a high degree of homozygosity exists (Svoboda et al., 1985). Despite considerable site tenacity, some intermingling of these southwestern gene pools seemingly occurs in maternity and bachelor colonies (Svoboda et al., 1985). The relationships

of the populations of *T. brasiliensis* in North America, as well as those in South America and the Caribbean, remain poorly understood (Cockrum, 1969).

The diploid number of chromosomes for *T. brasiliensis* is 48, with fundamental numbers of 58 (Painter, 1925) and 54 (Kniazeff et al., 1967). The X chromosome is submetacentric and the Y chromosome is acrocentric (Kniazeff et al., 1967).

**REMARKS.** Relatively little research has been conducted on this species outside of North America. Other common names by which *T. brasiliensis* is known are guano bat and Mexican free-tailed bat (Barbour and Davis, 1969).

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