The Rehabilitation and Captive Care of Insectivorous Bats

Amanda Lollar

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Revised Edition

Illustrated by David Chapman

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For the love of Sunshine

The Bat

by Ruth Pitter, 1897

Lightless, unholy, eldritch thing,
Whose murky and erratic wing
Swoops so sickeningly, and whose
Aspect to the female Muse

Is a demon's, made of stuff
Like tattered, sooty waterproof,
Looking dirty, clammy, cold.
Wicked, poisonous, and old;

I have maligned thee! . . . for the cat
Lately caught a little bat,
Seized it softly, bore it in.
On the carpet, dark as sin
In the lamplight, painfully
It limped about, and could not fly.

Even fear must yield to love,
And pity make the depths to move.
Though sick with horror, I must stoop,
Grasp it gently, take it up,
And carry it, and place it where
It could resume the twilight air.

Strange revelation! Warm as milk,
Clean as a flower, smooth as silk!
O what a piteous face appears,
What great fine thin translucent ears
What chestnut down and crepey wings,
Finer than any lady's things —
And O a little one that clings!

Warm, clean, and lovely, though not fair,
And burdened with a mother's care;
Go hunt the hurtful fly, and bear
My Blessing to your kind in air.

Forward

In 1988, I found an injured Mexican free-tailed bat (*T. brasiliensis*) on a hot sidewalk in Texas. At that time most people thought bats were vermin and rabid. Regardless, my heart went out to her, and I could not leave her there to bake alive in the sun. So, I scooted her onto a newspaper with my shoe and took her home to "die in peace". I was fascinated by her from the start. The Internet did not exist then, so I went to a library to get information. All the books, except one, said that all bats were rabid and should be killed. That one book saved "Sunshine's" life.

Sunshine, 1988

I took Sunshine home and attempted to heal her injured wing and set her free, but her injuries were permanent. She lived with me for the next year and a half, and during that time I fell completely in love. Sunshine is the inspiration behind the many medical treatments that are now being used to save her kind around the world.

In 1992, I had an opportunity to purchase a 100-year-old sandstone building that housed 30,000 Mexican free-tailed bats. The owner of the building wanted the bats killed so he could sell the building, so I purchased it to save them. For the next 20 years I made improvements to the roost and to the building, preformed daily clean-up and rescued bats daily. This allowed me to observe behavior, identify ailments and discover remedies that otherwise may have taken decades to recognize.

The treatments recommended in this manual were not developed because of controlled clinical studies on bats. Instead, they are based on my experiences in caring for several bat species, sometimes utilizing treatments based on clinical studies of other mammals. Without the help and guidance of my wonderful veterinarian, Tad Jarrett, DVM, many of the treatments in this manual would never have been developed. Dr. Jarrett has worked side-by-side with me helping bats since the founding of Bat World Sanctuary in 1994.

Fast forward to 2023. The bat rehabilitation world has changed drastically, in large part to the internet. This has allowed bat rehabilitators from around the globe to connect and share information for the betterment of bats in rehab and in permanent care. I am so thankful to see insectivorous bat rehabilitation continually evolving and improving, paving an even brighter future for bats in the decades to come.

–Amanda Lollar

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Bat World Sanctuary's Ethics for Bat Rehabilitation

1. **Prison or Paradise**

   Bats and other wild animals do not want to be taken into captivity. Regardless of why a bat is in your care, you are its captor. You control everything about a caged bat's life, whether it has fresh water, nutritious and tasty food, enrichment, the company of its kind, and medication for ailments and pain. A barren enclosure is a prison, it leaves a caged bat nothing to look forward to and nothing to occupy its intelligent mind. As a captor, it is YOUR responsibility to create paradise for a bat that you have chosen to cage. Silk foliage, roosting pouches and fleece cloths, foam rocks and rubber netting, bark, proper floor padding and fresh food and water daily are critical items that brighten a bat's life. Enrichment also eases stress and promotes healing, resulting in a faster release time.

2. **Respect verses Nurturing**

   Most people get involved in wildlife rehabilitation not just for the good it does for the animal but also the good it does for oneself. Providing nurture and watching an animal thrive under your care is a wonderful feeling, however, that feeling should never overpower the proper respect an animal deserves. Every captive bat deserves a peaceful existence, free from stress of being over-handled or over-bothered by constant intrusions. Provide just what they need to be happy and not what YOU need for a warm-fuzzy.

3. **Over-Confidence Kills**

   A good wildlife rehabilitator always second-guesses himself or herself and usually blames themselves over the loss of an animal. Every mistake or loss needs to be an opportunity to learn so that animal did not die in vain. Ask yourself what could have been done differently, or what did you miss? If there was nothing that could have been done, what knowledge did you gain that can be used to help the next bat? Learning from mistakes will make you a better rehabber. Being overly confident ruins your ability to learn from your mistakes and will cause more bats to die in your care.

4. **Know Your Limits**

   Wildlife rehabilitation is time-consuming, expensive, and it requires significant space. You must be able to provide the time, housing, food, medications, veterinary care, and the room it takes to properly care for bats. It also takes a tremendous amount of knowledge to properly care for one species of animal. Attempting to take on multiple species (such as bats as well as raccoons, opossums, squirrels, etc) is a recipe for disaster. Critical details will be missed and all the animals in your care will suffer as a result. Knowing your limitations is essential to being a successful rehabilitator.

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CHAPTER ONE

INTRODUCTION

The Natural History of Bats

Bats are among the most beautiful and agile creatures to grace our night skies, yet they remain one of the most mythical and secretive animals on Earth. They are the only flying mammals in the world, with over 1200 species worldwide. Bats have been represented symbolically in ancient cultures, ranging from Egyptian and Mayan ruins to Chinese art. Although revered in some cultures, they are feared in others, and many species have been persecuted to the brink of extinction. Bats are both an ecologically and economically valuable component of our natural environment.

Approximately 20% of all bats are frugivorous (i.e., fruit and nectar feeders). Frugivorous bats are vital pollinators and seed dispersers and play a major role in the reforestation of the world's rain forests. Most of the remaining 80% are insectivorous (i.e., insect feeders). These bats are important in controlling insect populations, including many significant agricultural pests. A few species are specialized in catching and eating fish (i.e., piscivorous). About 1% of all bats are carnivorous, feeding on small vertebrates such as frogs, lizards, birds, or other bats. There are also three species of vampire bats. These bats are sanguivorous (i.e., feed on the blood of birds or mammals) and are found only in Mexico, and Central and South America. Forty-two of the 46 bat species found in North America eat insects, feeding on a tremendous diversity of insects. Some, such as big brown bats (*Eptesicus fuscus*), are beetle specialists; others, such as Brazilian free-tailed bats (*Tadarida brasiliensis*), feed mainly on moths. Because beetles and moths lay eggs that develop into larvae that feed on vegetation, including many domestic crops, bats are critical to agricultural interests in the United States and Canada. For example, Brazilian free-tailed bats feed on the moth *Helicoverpa zea*. The larva of this moth is the corn earworm, a severe pest that causes significant damage to a wide range of crops. Bats have also been observed feeding directly on insect larvae in the wild. Pallid bats (*Antrozous pallidus*) have been observed feeding on tomato hornworms (*Manduca quinquemaculata*) which they had carried back to their roost. Tomato hornworms are a severe pest on tomato, tobacco, potato, and other solanaceous (i.e., belonging to the family Solanaceae) crops in the southern U.S. Three species of bats in the United States feed on nectar. These three species are the long-nosed bat (*Leptonycteris nivalis*), the lesser long-nosed bat (*Leptonycteris yerbabuenae*), and the Mexican long-tongued bat (*Choeronycteris mexicana*). All three of these species are found in the Southwest and are important pollinators of cacti and agave.

Most bats are nocturnal feeders, roosting during the day in a variety of places. Some are crevice bats that roost in places such as caves, abandoned mines, rock crevices, old cisterns or wells, hollow trees, under bridges, or beneath tree bark. Crevice bats may also roost during the day in human dwellings, often in the attics of homes or old buildings, under shingles, or behind window shutters. Others, such as the lasiurine bats (i.e., yellow, red, Seminole, and hoary bats), roost more openly in the foliage of trees or other vegetation. Many of these bats resemble dried leaves and are well-camouflaged in this setting.

Most bats in North America either migrate to warmer climates during the colder winter months or hibernate in caves or underground networks such as mines. Only a few species remain active year round. Some species, such as big brown bats (*E. fuscus*), occasionally hibernate in the attics of homes. Although hibernating bats may arouse during the winter, each arousal leads to the expenditure of almost 30 days of body fat when the bat is in deep torpor. Unnecessary arousals can cause a bat to use up so much of its fat reserves that it might not survive the remainder of the winter. Hibernating bats are thus extremely sensitive to disturbance. In addition, because some species of bats come from multi-state regions and congregate in great numbers (as many as several hundred individuals), disruption or disturbance of any kind to these hibernacula may result in the loss of large numbers of bats which can impact agricultural interests in many states or provinces.

Health Precautions

Bats, like many other mammals, are susceptible to the rabies virus; however, they are not considered to be asymptomatic carriers of the disease. Rabies is nearly always transmitted through a bite. Although extremely rare, exposures can also occur from contact between a bat's infected saliva or nervous tissues and a person's open wounds or mucous membranes of the eyes, nose, or mouth. The principal source of rabies exposure from bats is through careless handling.

According to the Centers for Disease Control and Prevention (CDC) people cannot get rabies just from seeing a bat in an attic, in a cave, or at a distance. In addition, people cannot contract rabies from having contact with bat guano, blood, or urine, or from touching a bat's fur. The rabies virus has never been isolated from bat blood, urine or feces, and there is no evidence of air-borne transmission in buildings. Two cases of aerosol transmission were reported in the 1950s in Texas caves that support very unusual environments. No similar cases have occurred since, even though many thousands of people explore bat caves each year. No such transmission has ever occurred outside, in buildings, or from captive bats.

All personnel considering the captive care of bats should receive pre-exposure rabies vaccinations. Although it has been this author's experience that infected insectivorous bats demonstrating signs of disease usually die within a few days to a few weeks after they are taken in, this may not be the case with animals still incubating the virus. In fact, one incubation period reported in the literature involved a bat taken into captivity that lived 209 days before the onset of clinical signs. Other researchers have mentioned instances in which an incubation period of over one year was reported. Bat World Sanctuary has been routinely vaccinating insectivorous bats since 1990, and we recommend that all captive bats be vaccinated on intake as well as annually (see Quarantine).

Histoplasmosis is a fungal disease which frequently manifests with respiratory symptoms and is contracted by inhalation of *Histoplasma capsulatum* spores, a naturally occurring soil fungus. Like most fungi, it requires warm, humid conditions for growth and is known primarily from the Mississippi and Ohio River Valleys and adjacent areas, especially in large quantities of bird droppings. Conditions necessary for growth are also found in some cave environments where the fungus may be found in accumulations of bat droppings. For this reason, caves containing large bat populations should be avoided (for the protection of the bats as well as humans).

Disturbance of dry fecal deposits causes the aerosolization of histoplasmosis spores which may then be inhaled by humans. A small percentage of people become seriously, even fatally ill with this disease. Organic respirators capable of filtering out small fungal spores (i.e., particles as small as 2 microns in diameter) should be worn when in the presence of large deposits of bat guano to minimize possible exposure. In areas where histoplasmosis is a concern, it is also recommended that guano deposits be dampened with water before removal in order to minimize aerosolization of fungal spores.

Identification

Because different species of bats have different natural histories, captive care routines including caging, feeding, and roostmates may vary significantly from one species to another. Differences in roosting habits in particular will determine the manner in which a bat is temporarily or permanently housed, or subsequently released.

Bat species are identified by a variety of characteristics including the length of various body parts (e.g., forearm, ear, foot, tail), presence or absence of various anatomical features (e.g., keeled calcar, nose leaf, tail), the shape of certain anatomical structures (e.g., ears, tragus), distinctive areas of fur on different parts of the body (e.g., the tail), weight, and coloring, as well as various dental and skeletal (e.g., cranial) characteristics. Measurements often vary by only millimeters from one species to another. The color of the fur frequently varies from one individual to another, making it impossible to identify many species based on color alone. In truth, most species, particularly Myotis, look very much alike. Bat World Sanctuary frequently receives requests for assistance in species identification. The individual specimen in question is oftentimes described as "very small with big ears and brown fur," a description that could be used for most North American bats.

The way bats roost in the wild is the primary factor dictating how that species should be housed in captivity. Regardless of the species, bats should be categorized primarily by their natural roosting preferences, which is typically either in a crevice or in foliage.

Crevice bats are generally social and prefer to roost in cracks and crevices such as under the bark of old trees (Figure 1-1), in tree hollows, caves, mines, behind shutters, rock crevices and in attics. Some species, such as *Tadarida* and *Antrozous* (Figure 1-2A and B) roost within small cracks or crevices, while others roost openly in natural or man-made structures, such as *Corynorhinus, Perimyotis* and *Parastrellus* (Figure 1-2D). Crevice bats should always be housed as a group. Tree bats prefer to roost on the branches of trees, in clumps of leaves, in Spanish moss, and under large leaves such as palm fronds and banana leaves. Except when rearing young, tree bats are a solitary species and prefer to roost alone or in small groups, but somewhat separated from one another. However, when sharing a large enclosure with crevice bats, tree bats have frequently been found to choose roosting spots that are in very close proximity to crevice bats, and crevice bats will occasionally choose to roost directly against a tree bat without protest from the tree bat.

Each chapter of this manual describes procedures appropriate for both crevice and tree bats. For the purposes of this manual, crevice and tree species are identified as follows:

Crevice Bats

The fur of crevice bats includes colors that blend well with their roosts, such as gray, tan, brown, or black. The following genera are considered crevice bats: *Mormoops*, *Eumops*, *Mollosus, Nyctinomops*, *Tadarida*, *Antrozous*, *Euderma*, *Eptesicus*, *Idionycteris*, *Myotis*, *Nycticeius*, *Lasionycteris*, *Perimyotis, Corynorhinus, and Parastrellus.*

Figure1-1. Evening bat in caregivers hand. *N. humeralis. Photo by A. McCool*

Tree Bats

Tree bats commonly roost in the open in trees leaves or other vegetation. They often hang by one foot attached to a small twig or stem of a leaf. The leaf cover protects them from predators that may approach from above. Tree species are well camouflaged, ranging in shades from gray, brown, and yellow, to orange or bright reds (Figure 1-2C), colors resembling dried leaves or fruit. In addition, they may have white patches or contrasting shades that help break up body outlines and further mask them from diurnal predators (Figure 1-2E). The following species are included as tree bats: red bats (*Lasiurus borealis*), Seminole bats (*Lasiurus seminolus*), desert red bats (*Lasiurus blossivilli*), northern yellow bats (*Lasiurus intermedius*), southern yellow bats (*Lasiurus ega*), Arizona or western yellow bats (*Lasiurus xanthinus*), and hoary bats (*Lasiurus cinereus).* Note: Although tri-colored bats and canyon bats (*Perimyotis subflavus* and *Parastrellus hesperus*) are classified as crevice bats, both species occasionally roost in foliage.

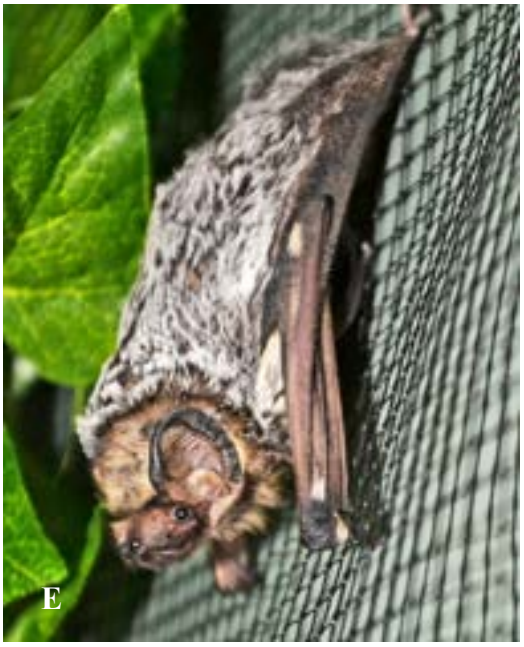


Figure 1-2. A: *Tadarida brasiliensis*, a crevice bat. **B**: *Antrozous pallidus*, another crevice bat. **C:** *Lasiurus borealis* and *Lasiurus seminolus* , orphaned tree bat pups. Note the red bat male in the center is more brightly colored and smaller than the female red bat pup on the right, while the Seminole pup on the left is deeper red in color, making it easy to distinguish between the species. **D:** *Parastrellus hesperus* and *Perimyotis subflavus,* crevice species who occasionally roost in foliage. **E**: *Lasiurus cinerus*, a tree bat. *Bat World facility. Photos by A. Lollar.*

Table 1
Roosting and Hibernating Patterns

Family	Hibernates	Roosting Pattern
Family Mormoopidae		
Mormoops megalophylla	No	Do not tightly cluster. Individuals roost about 6" apart in groups of up to hundreds of thousands. Roost in caves, mines, and occasionally buildings.
Family Phyllostomidae		
Artibeus jamaicensis	No	Tightly cluster. Roost in small bachelor groups or groups that include one male and several females. Several of these groups of males and their harems may roost in the same cave. Roost in tree hollows, foliage, and caves.
Choeronycteris mexicana	No	Do not tightly cluster. Individuals roost about 1" to 2" apart. Roost in groups of up to several dozen in caves and mines and occasionally in other shelters such as buildings.
Leptonycteris yerbabuenae	No	Tightly cluster. Roost in groups of up to thousands. Generally found during the day in mines and caves but may rest during the night in open buildings such as barns.
Leptonycteris nivalis	No	Tightly cluster. Roost in groups of up to thousands in mines and caves.
Macrotus californicus	No	Do not tightly cluster. Roost in groups of up to a hundred in abandoned mines and rock shelters during the day but may also roost during the night in open buildings, bridges, and mines.
Family Vespertilionidae		
Antrozous pallidus	Yes	Tightly cluster. Roost in groups of up to hundreds. Roost during the day in rock crevices and buildings, may also be found in mines, caves, and hollow trees, and during the night in rock shelters, open buildings, bridges, and mines.
Corynorhinus townsendii	Yes	Do not tightly cluster. Roost in groups of up to 1,000, although generally found in fewer numbers. Roosts in caves and mines, but can also be found in buildings in the west where they roost in open buildings during the night.
Corynorhinus rafinesquii	Yes	Tightly cluster. Roost in groups of up to 100. Roost in buildings, behind loose bark, and in hollow trees, caves, and mines.
Eptesicus fuscus	Yes	Tightly cluster. Roost in groups of up to hundreds in buildings, bridges, and behind shutters. Have also been found roosting in rock crevices, swallow nests, hollow trees, and saguaro cacti. In winter can be found roosting in caves, mines, quarries, and storm sewers.
Euderma maculatum	Yes	*Clustering information not available. Believed to roost in cracks and crevices of high cliffs and canyons.

Family	Hibernates	Roosting Pattern
Idionycteris phyllotis	*	Tightly cluster. Can roost in groups of up to 100. Roost in caves, rock shelters, and mines.
Lasionycteris noctivagans	Yes	Tightly cluster in small groups. Roost behind loose tree bark, but have also been found in buildings, mines, woodpecker holes, and a bird's nest. During migration, have also been found in open buildings, lumber piles, and fence posts.
Lasiurus blossevillii	Yes	Solitary. Roost in tree foliage.
Lasiurus borealis	Yes	Solitary. Roost in tree foliage. May hibernate in leaf litter.
Lasiurus cinereus	Yes	Solitary. Roost in the foliage of trees.
Lasiurus ega	*	Solitary. Roost in leafy vegetation.
Lasiurus intermedius	*	Do not tightly cluster although females appear to be somewhat colonial. Several individuals may roost in the same tree. Roost in Spanish moss and dead palm leaves.
Lasiurus seminolus	Yes	Solitary. Roost in Spanish moss.
Lasiurus xanthinus	Yes	Solitary. Roost in leafy vegetation.
Myotis auriculus	*	Do not tightly cluster. No more than two or three have been found roosting together. Roost in buildings and caves. Known to also roost in tree hollows.
Myotis austroriparius	Yes	Tightly cluster. Have been found roosting in groups of up to thousands. Roost in caves, buildings, and hollow trees, although in winter they are also found in bridges, storm sewers, road culverts, and drainpipes.
Myotis californicus	Yes	Tightly cluster in small groups. Roost in mines, caves, rock crevices, hollow trees, beneath loose bark, bridges, and in open shelters such as garages, barns, houses, sheds, and porches.
Myotis ciliolabrum	Yes	Tightly cluster. Roost in groups of up to 50. Roost in mines, caves, buildings, and sometimes beneath tree bark.
Myotis evotis	Yes	Do not tightly cluster. Roost in groups of up to 30. Roost in sheds, cabins, and beneath tree bark. Also roost in caves at night.
Myotis grisescens	Yes	Tightly cluster in groups of up to thousands of individuals. Roost mainly in caves, although a maternity colony was found in a storm sewer.
Myotis keenii	Yes	Do not tightly cluster. Solitary. Roost in tree cavities and cliff crevices.
Myotis leibii	Yes	Tightly cluster. Roost in groups of up to 50 individuals. Maternity colonies of up to 20 bats have been found in buildings. Roost in mines, caves, and buildings; have also been found beneath quarry rock slabs.
Myotis lucifugus	Yes	Tightly cluster. Roost in groups of up to thousands. Roost in mines and caves. In the summer may also be found in buildings, bridges, and under tree bark.
Myotis sodalis	Yes	Tightly cluster. Roost in groups of up to 100,000. Roost in caves, although maternity colonies use hollow trees. Also sometimes found in bridges and beneath loose tree bark.

Family	Hibernates	Roosting Pattern
Myotis septentrionalis	Yes	Tightly cluster. Relatively solitary although clusters of up to 30 individuals have been found in small maternity colonies. Roosts in mines, caves, and buildings.
Myotis thysanodes	Yes	Tightly cluster. Roost in groups of up to 300. Roost in caves, mines, rock crevices, and buildings.
Myotis velifer	Yes	Tightly cluster. Roost in groups of up to hundreds. Roost in buildings, rock crevices, and trees. Also found in mines and caves at night.
Myotis volans	Yes	Tightly cluster. Roosts in groups of up to hundreds. Roost in buildings, rock crevices, and trees. Also found in mines and caves at night.
Myotis yumanensis	Yes	Tightly cluster. Roosts in groups up to thousands in maternity colonies, although adult males are typically solitary during this time. Roost in buildings, under bridges, and in caves and mines.
Nycticeius humeralis	Yes	Tightly cluster. Roosts in groups of up to several hundred. Roost in buildings, tree cavities, and behind loose tree bark.
Parastrellus hesperus	Yes	Tightly cluster. Relatively solitary although small maternity colonies of up to a dozen bats have been found in rock crevices and behind window shutters. Roosts in rock crevices, buildings, mines, and caves.
Perimyotis subflavus	Yes	Tightly cluster. Relatively solitary, although small maternity colonies of up to 30 individuals have been found. Roosts in Spanish moss, caves, mines, rock crevices, and occasionally buildings.
Family Molossidae		
Eumops floridanus	No	Tightly cluster. Have been found roosting in groups of up to eight individuals. Found in Spanish tile roofs and palms.
Eumops perotis	No	Tightly cluster. Roost in groups of less than 100. Roost in the crevices of cliffs and rocky canyons. Also roost in buildings.
Eumops underwoodi	No	Tightly cluster. Have been found roosting in small groups in the U.S. in buildings and roofing tiles.
Molossus molossus	No	Tightly cluster. Roost in groups of up to hundreds. Roost in tree hollows, rock piles, and buildings.
Nyctinomops femorosaccus	No	Tightly cluster. Roost in groups of up to 100. Roost in the crevices of rocky outcroppings. Have also been found roosting in tile roofs.
Nyctinomops macrotis	No	Tightly cluster. Roost in rock crevices.
Tadarida brasiliensis	No	Tightly cluster. Roost in groups of up to several million. Roost in mines, caves, bridges, and buildings.

This table is intended only as a very general guideline. The original source was Barbour and Davis, 1969. Additional information was obtained from Emmon, 1990, and communications with various researchers. *Information not available from reference sources used.

Behavior

Emotion

Like other mammals, bats express themselves through actions and behaviors and even facial expression. An understanding of the emotional lives of bats is critically important in successfully caring for these animals.

Figure 1-3. A short-tailed fruit bat displays fear by hiding its head beneath its wings, a behavior also observed in frightened insectivorous bats. *Carollia perspicillata. Bat World facility. Photo by A. Lollar.*

In the last few decades, scientific study of animal emotions has gained momentum. The vast majority of people believe that all animals have emotional lives and are capable of suffering because of their emotions. Masson and McCarthy (1995) note that different species experience different emotions based on their surroundings. The author has also found that when people believe that animals have emotions, they are more likely to believe that they have negative emotions, such as fear and anger, and are less likely to suggest that animals feel love, joy or compassion. Balcombe (2010) wrote "The important thing for humans to recognize is that animals do have feelings, and that to the animals these are every bit as important as our own feelings are to us." He went on to state that six universally recognized and biologically determined facial expressions of emotion have been demonstrated in humans: anger, distrust, fear, happiness, sadness, and surprise. These so-called primary emotions are widely expressed in other mammals. Fear is perhaps the most instinctive emotions to this argument, as most animals respond to danger by exhibiting behaviors that are easily understood by humans, such as aggression, fleeing, or cowering (Figure 1-3).

Good animal welfare is not just the absence of negative experiences. Instead, it is the presence of positive experiences that promote pleasure (Boissy, et al., 2007). A research project proved that rats exhibited “laughter" when tickled by humans, and even sought further contact in response to being tickled (Planksepp & Burgdorf, 2003). Temple Grandin (2009) also describes the importance of promoting positive animal emotion by stating, “I believe that the best way to create good living conditions for any animal, whether it's a captive animal living in a zoo, a farm animal, or a pet, is to base animal welfare programs on the core emotion systems in the brain. My theory is that the environment animals live in should activate their positive emotions as much as possible, and not activate their negative emotions any more than necessary. If we get the animal's emotions right, we will have fewer problem behaviors.”

One of the earliest proponents of the idea that animals have conscious emotional experiences was Jeremy Bentham (1789) who wrote the famous lines: “The question is not, Can they reason? Or, can they talk, but, can they suffer?” In 2007, an investigative subcommittee was formed by the Animal Care and Use Committee to review allegations of cruelty to pallid bats (*A. pallidus*) which were part of a research project at Texas A&M University. During the investigation, the question was asked as to whether or not the bats were "happy", to which a panel member replied, "They are hanging upside-down, aren't they?" (M. Singleton, pers. comm.). It is absolutely crucial that we have a clear understanding of what constitutes animal suffering in captivity. The notion that a bat is happy because it is hanging upside-down is equivalent to the notion that a prisoner of war is happy because he/she is standing upright. Perhaps John Webster (2006) professor of animal husbandry at Bristol, Great Britain, put it best: “People have assumed that intelligence is linked to the ability to suffer, and that because animals have smaller brains they suffer less than humans. That is a pathetic piece of logic.” The ability to suffer is the greatest of all cross-species levelers. We should never intentionally inflict pain on or purposefully cause fear in an animal that we wouldn't be willing to experience ourselves.

Communication

Bats communicate with each other in many ways including vocal calls, displays, and physical interactions. Even odors play a role in the recognition of roost mates. Colonial bats often communicate with one another in their roost as well as in flight. Researchers have documented bats using distress calls and group foraging calls, and some have recorded calls exchanged by mothers and their infants. Brazilian free-tailed bats (*T. brasiliensis*) use calls that are unique to individuals so mothers and their babies can find and identify one another (Balcombe, 1992). Solitary tree bats also communicate with their pups vocally, although they may not be using calls that are unique to an individual like some of the colonial species. Infant sac-winged bats (*Saccopteryx bilineata*) have been recorded "babbling," that is, uttering long strings of adult-like noises that appear to be precursors of the well-defined social calls they use as adults (Knörnschild, 2006).

Figure 1-4. Two free-tailed bats engage in a mild territorial dispute. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

The secretive white-winged vampire bats (*Diaemus youngi*) exchange rapid social calls (Carter, 2007). One third of a second after the first bat calls, others chime in. They appear to be using these vocalizations as "contact calls" to find and identify one another, and they make these calls not only when they are in the roost, but also when they are stalking their prey. Social calls are known to be used by some bats in relation to mating activity. For example, males of some bat species sing courtship songs to attract females. Some bat species use a diversity of social calls. The author has described multiple calls of the Brazilian free-tailed bat (*T. brasiliensis*) that were associated with different behaviors and found that the bats appeared to use a variety of vocalizations to locate, greet, argue (Figure 1-4) and even play with one another (Lollar, 1994). Bohn (2007) documented many of these calls acoustically and demonstrated that the bats' behaviors varied depending not only on the individual notes and called syllables that were used, but also by sequence and timing between syllables. These interesting findings hint at the use of syntax. In other words, the bats may be using specific sounds or phrases that can be put together in different ways to convey different meanings. The possibility that some bats may be using rules to guide their use of social calls is reminiscent of human language, a characteristic often used to distinguish humans from other animals.

Being Individual

Balcombe (2006), states "…the danger of viewing animals only as a species is that we may lose touch with their individuality and their sensory experience of life. Understanding how and why an individual insectivorous bat behaves the way it does is one of the most important aspects of successfully maintaining that bat in captivity. Behavior and personality, and the handler's responses to both, play an enormous role in a bat's ability to adapt to and survive a captive life.

Figure 1-5. Two pallid bats exhibit entirely different reactions upon having their roosting pouch disturbed. The bat on the right appears curious and somewhat apprehensive, while the bat in the left appears visibly disturbed. *A. pallidus. Bat World facility. Photo by A. Lollar.*

There are considerable differences in the behaviors of different species as well as the behavior of individual bats (Figure 1-5). The following list provides observations on behavior and personality traits from bat care specialists with decades of experience. These guidelines offer insight to overall bat behavior according to the species; however, it is important to note that as individuals, every bat has the capacity to have his/her own personality traits.

Big Brown Bats

In captivity, some *E. fuscus* become quite amenable while others remain fearful or defensive. Males tend to be more aggressive than females, particularly during fall and winter months. Some males prefer to roost alone and will defend their territory from both males and females to the point of injuring other bats. Females tend to form close bonds with one another but will squabble on a regular basis. Females have been observed displaying empathy for injured and dejected roostmates by positioning themselves over a debilitated roostmate and under a folded wing. Big browns readily roost with other species in captivity.

E. fuscus prefer to be held in a closed hand or wrapped in a cloth during handling. Nervous or extremely timid individuals will visibly relax with soothing tones and will also benefit from being handled in a soft cloth. Healthy, wild, newly volant juveniles are highly prone to stress and panic and, therefore, should be handled as little as possible. *E. fuscus* generally learns to self-feed within one to five days, although some individuals may take longer. Housing reluctant feeders with reliable self-feeders will speed the process. Bats that are particularly hungry, such as those that are newly rescued and underweight, may latch on to anything in front of their mouths, such as the cloth that enfolds them, and subsequently bite down and chew. Training these individuals to self-feed takes time and patience, as they must be encouraged to focus on the food rather than instinctively biting down on whatever is near their mouth. Long term captives and hand-reared juveniles tend to be lazy, flying infrequently and selecting a feeding station close to their day roost. *E. fuscus* sometimes exhibit a vibration of the body (purring) when being held or rubbed behind the ears, or when receiving hand-fed treats such as mealworm viscera. These bats emit a musky odor when under extreme stress.

Myotis Bats

M. septentrionalis, M. californicus and *M. velifer* are relatively calm bats while *M. lucifugus, M. yumanensis* and *M. sodalis* are reported to be nervous. Both *M. yumanensis* and *M. californicus* are prone to capture myothapy, therefore caution should be used when handling these species. Most myotis will often calm when soothing tones are used (Figure 1-6). Myotis bats can be difficult to treat as they do not sit still for physical manipulation. They can be very vocal when in distress. All Myotis bats dislike excess handling and should be handled as little as possible. They also do not react well to sudden changes of their environment, which can cause refusal to self-feed. Therefore, major changes such as moving from a familiar enclosure to an entirely new enclosure, should be done gradually over a period of time. Myotis bats are extremely curious and investigative, as evidenced by copious amounts of guano that is deposited on new items gradually added to their enclosure.

Figure 1-6. A frightened Northern long-eared bat. The body is rigid, the wrists are tucked against the face, and the ears are somewhat lowered. Myotis bats visibly calm when soothing tones are used. *M. septentrionalis. Photo by G. Victor-Dorr.*

All Myotis bats are highly intelligent. Most learn to eat from a dish in only a day or two. Over time, these bats may become somewhat trusting of their handler. Males seem to be calmer and more manageable than females, but are reported to be slower at learning to self-feed than females. Myotis readily roost with other species in captivity.

Evening Bats

These bats can be highly stressed when entering captivity, baring their teeth and vocalizing nonstop. When held, extremely frightened *N. humeralis* will lower their ears over their eyes, or place slightly opened wings in front of their face in an attempt to shield their face. Soothing tones and gentle handling in a soft cloth can help these bats relax. Evening bats emit a musky odor when under extreme stress.

N. humeralis typically learn to self-feed in three to five days, although some may take longer. Males are reported to be slower at learning to self-feed than females. Captive evening bats are prone to stop self-feeding on occasion and therefore require hand-feeding the soft food diet for extended periods of time. Once *N. humeralis* have adjusted to captivity they rarely vocalize. These bats appear to have a preference for certain roostmates, but will readily roost with *T. brasiliensis* in captivity. Evening bats seem inclined to fly throughout their time in captivity. Long-term captives exhibit a vibration of the body that resembles purring when being held and being hand-fed treats such as mealworm viscera.

Silver Haired Bats

L. noctivagans appear to be very independent bats; and may struggle violently and can appear fierce when initially restrained. Sometimes this behavior includes symptoms resembling rabies such as biting, snapping, and chewing with unfocused eyes, biting at meal worms but not swallowing them, spitting out or not swallowing fluids, and/or twitching of the head and extremities. It is critical to observe panicked individuals closely, without handling, to appropriately determine if actual clinical signs are present. These bats prefer to be held loosely on a cloth or glove (holding them too tightly causes refusal to eat and possible panic). Most individuals visibly calm when soothing tones are used. Food, such as mealworm viscera or soft food, is a good tool for gaining trust.

Figure 1-7. A silver-haired bat exhibiting displeasure about being held. The mouth is open, teeth are bared and the wings are positioned to open and take flight. *L. noctivagans. Bat World NoVa facility. Photo by R. Sturges.*

Silver-haired bats are very intelligent and often learn to self-feed after only one training session; however, some tend to be messy eaters. *L. noctivagans* appear to suffer from depression when unable to fly. Solitary *L. noctivagans* require personal attention and interaction with their caretaker. They develop recognition of their caretakers and associations between sounds and activities, providing the handler maintains consistency. These bats rarely vocalize when handled, and instead exhibit emotional cues through the position of their ears, their physical posture, and their facial expressions (Figure 1-7). Long-term captives exhibit a vibration of the body that resembles purring when being held or when receiving hand-fed treats such as mealworm viscera. Males do not seem prone to aggression when housed together, although they rarely seem to roost in close proximity to one another. Confrontations are solved with posturing, hissing, and screeching. These bats readily roost with other species in captivity including *E. fuscus* and *T. brasiliensis*.

Pipistrelle Bats

Tri-color bats (formerly known as the eastern pipistrelle) appear to be relatively calm bats. *P. subflavus* can be very social in captivity while *P. hesperus* tends to remain solitary. Both will bond with other species of bats. These bats are agile on foot and will fly even in extremely tight quarters. These bats have been known to fly to favored caretakers, and will readily roost with *T. brasiliensis* in captivity. They do not like to be restrained when held and will struggle if enclosed in a cloth or hand. Therefore, they should be allowed to sit in a slightly open hand or cloth for examination or hand-feeding. When frightened or irritated, tri-color bats can be quite vocal and emit a faint skunk-like odor.

Some readily learn to self-feed, while others can take up to two weeks. Some tri-colored bats appear to enjoy being hand-fed and will sit openly on the floor of their enclosure to receive mealworms from the handler (Figure 1-8). Some long-term captives never take to mealworms and must be hand-fed a complete soft food diet.

Figure 1-8. Tri-color bats sitting on their enclosure floor, relaxed and enjoying a hand-fed meal. *P. subflavus. Bat World facility. Photo by D. Hyatt.*

Pallid Bats

Pallid bats have a wide variety of personality types. Some are very calm and non-vocal while others are high-strung and very vocal. They prefer to be held in a closed hand or cloth for examinations but will struggle if held too tightly. Frightened *A. pallidus* will bare their teeth, lower ears over their eyes, or place slightly opened wings in front of their face in an attempt to shield the face. When stressed, these bats will emit a skunk-like odor and may vibrate. Soothing tones and gentle handling will help them relax. Pallid bats appear to have a preference for certain roostmates. They readily roost with *T. brasiliensis* in captivity, although newly introduced pallid bats are sometimes ostracized for a period of time before being allowed to join a colony. Captive pallid bats have been reported to eat smaller bats in captivity (Engler, 1943); however, the author has housed pallid bats with a reproductive colony of *T. brasiliensis* without incidence, and found an infant free-tailed bat tucked under the wing of a male pallid bat on more than one occasion. Although remaining independent, these bats may become trusting of regular caretakers, and have been known to fly to favored caretakers. Pallid bats are very curious and have been known to land on a trusted caretaker to investigate something new. They appear to remember caretakers they distrust and react negatively to sounds related to unpleasant experiences (e.g., a latex glove being drawn up over the hand).

Most learn to self-feed very quickly, some after only one training session. Others may take more time to learn. Housing reluctant self-feeders with reliable self-feeders will speed the process. These bats often sit up slightly in order to tuck mealworms beneath them to better grasp the worm. Long term captives and hand-reared juveniles have a tendency to be lazy, flying infrequently and selecting a feeding station close to their day roost. Pallid bats will fly in tight quarters. Flighted pallid bats seem to suffer from depression when unable to fly. These bats may attempt to fly even with severely damaged wings and will exacerbate injuries unless safely confined. They have been known to become aggressive when recovering from anesthesia.

Free-tailed Bats

Free-tailed bats are extremely docile, although an occasional individual may be high strung. These bats have a rich social life and are very gregarious. *T. brasiliensis, N. femorosaccus, N. macrotis* and *E. perotis* readily roost with Myotis bats as well as *E. fuscus, P. hesperus, P. subflavus*, *L. noctivagans, A. pallidus and N. humeralis.* Females have been observed displaying empathy for injured and dejected roostmates by positioning themselves immediately beside the roostmate or under a folded wing. These bats appear to be quite curious and investigative, as evidenced by copious amounts of guano deposited on new items that are added to their enclosures. Free-tailed bats become very trusting of regular caretakers. When approached or hand-fed by unfamiliar caretakers they may cower, and almost always refuse to eat. They appear to remember caretakers they distrust and react negatively to sounds related to unpleasant experiences. They prefer to be held in a closed hand or cloth for examinations but will struggle if held too tightly. Frightened *T. brasiliensis* may bare their teeth and lower their ears over their eyes. Panicked free-tails will repeatedly jerk and cry out in high pitched squeaks. It is best to handle panicked individuals as little as possible until they have calmed. Mastiff bats are often referred to as “gentle giants” as they rarely bite when handled, opting instead to vocalize and open their mouths wide. Soothing tones and gentle handling help them relax. *T. brasiliensis* and *N. femorosaccus* are difficult to teach to self-feed. The process usually takes five to ten days, although a rare individual will learn in as little as two days. Housing reluctant self-feeders with reliable self-feeders will speed the process, although some bats

never learn and therefore must be hand-fed twice daily. Most *N. macrotis* and *E. perotis* reject training attempts at self-feeding and therefore must be hand-fed twice daily. Free-tailed bats readily adapt to injuries that render them flightless.

Flighted bats that are not allowed to fly appear to become depressed over time. *T. brasiliensis* have a distinctive language that includes over 25 vocalizations and associated gestures (Lollar, 1994, French and Lollar, 1998). Research has shown that *T. brasiliensis* puts chirps, buzzes, and trills together in specific ways to form phrases (Bohn et al., 2009). All free-tailed bats are exceptionally intelligent and have a rich social structure. These bats will communicate to the handler through squawks, buzzes, and chitters.

Big-eared Bats

C. townsendsii and *C. rafinesquii* are passive, calm, and generally non-vocal when handled, although some occasionally grumble and exhibit half-hearted attempts to bite. They are reported to be very tolerant and peaceable in captivity. Over time, these bats may become trusting of their handler. They develop recognition of their caretakers and associations between sounds and activities, providing the handler maintains consistency. This species may become trusting of regular caretakers while remembering caretakers they distrust.

They prefer to be held in a closed hand or cloth for examinations but will struggle if held too tightly. Nervous Townsends sometimes curl their ears back while leaving the tragus pointed upward. Soothing tones will help to relax nervous bats. These bats will fly in tight quarters. Big-eared bats generally learn to self-feed in a matter of days, although some individuals can take much longer, or never learn at all. They often sit up slightly in order to tuck mealworms beneath them to better grasp the worm.

Hoary Bats

For the most part, *L. cinereus* are generally passive, calm, and tolerant in captivity, however, they often struggle violently and can appear fierce when initially restrained. Always hold these bats loosely; confining these bats in a cloth or closed hand causes extreme distress to hoary bats. Sometimes this behavior includes symptoms resembling rabies such as biting, snapping, and chewing with unfocused eyes, biting at meal worms but not swallowing them, spitting out or not swallowing fluids and twitching of the head and extremities. When frightened, frantic hoary bats may flip onto their backs, open their wings wide and hiss and click in an attempt to appear fierce. They sometimes strike out with their wings, or even make a forward jumping movement in a mock attack. It is critical to closely observe panicked individuals without handling to appropriately determine if true clinical signs exist. Most individuals will visibly calm when soothing tones are used. Food, such as mealworm viscera or soft food, is a good tool for gaining trust.

Figure 1-9. A disturbed hoary bat being suddenly woken. *L. cinerus. Bat World facility. Photo by A. Lollar.*

Hoary bats seem to enjoy interaction with their caretaker and being in captivity in general. They develop recognition of their handler and associations between sounds and activities, providing the handler maintains consistency. These bats rarely vocalize when handled, instead exhibiting emotional cues through the position of their ears, their physical posture, and their facial expressions (Figure 1-9).

Hoary bats will sometimes try to fly even with severely damaged wings in small enclosures. These bats normally learn to self-feed in a day or two, although some individuals may take longer. Even then, they rarely find food on their own and must be placed in position over a dish of worms at feeding time, and they must be removed from the dish when they are full. Captive hoary bats with gentle dispositions will roost in close proximity to another tree bat, or even crevice bats.

Red Bats and Seminole Bats

The personalities of *L. borealis, L. blossevillii* and *L. seminolus* range from very calm to extremely frantic. Always hold these bats loosely on a cloth or hand. Confining these bats in a cloth or closed hand causes extreme distress. They typically struggle violently and can appear fierce when initially restrained. Sometimes this behavior includes symptoms resembling rabies such as biting, snapping, and chewing with unfocused eyes, biting at meal worms but not swallowing them, spitting out or not swallowing fluids, and/or twitching of the head and extremities. When frightened, frantic red bats may flip onto their backs, open their wings wide and hiss and click in an attempt to appear fierce. They sometimes strike out with their wings, or even make a forward jumping movement in a mock attack. It is critical to observe panicked individuals closely, without handling, to appropriately determine if true clinical signs are present. Most individuals visibly calm when soothing tones are used. Food, such as mealworm viscera or soft food, is a good tool for gaining trust. Captive western red bats have been seen curled up on the floor of their enclosures, hiding beneath cloths at the bottom of the enclosure. Captive red bats with gentle dispositions will roost in close proximity to another tree bat, or even crevice bats (Figure 1-10).

Figure 1-10. A non-flighted hoary bat and red bat soundly sleeping in the enclosure they share. *L. borealis and L. cinereus. Bat World facility. Photo by D. Hyatt.*

Tree bats in general appear more primitive in nature than crevice bats. They will try to fly even with severely damaged wings in small enclosures. It may take as much as a week to train these bats to self-feed, and even then, they rarely find food inside their enclosure on their own and must be placed in position over the dish of worms at feeding time, and they must be removed from the dish when they are full. Over time, these bats may become trusting of their handler. They develop recognition of their handlers and associations between sounds and activities, providing the handler maintains consistency. Juvenile red bats have been reported to vocalize and seek out caretakers at mealtime.

Yellow Bats

L. intermedius, L xanthinus, and *L. ega* are passive, calm, and generally non-vocal when handled, although some occasionally exhibit half-hearted attempts to bite. They are very tolerant and peaceable in captivity. Both males and females roost readily together, sharing the same roost. Females have been observed licking male yellow bats on top of the head and positioning themselves over a male and under a folded wing (Figure 1-11). Yellow bats prefer to roost inside the folds of flannel or other fabric, and appear to have an affinity for their roosts within a enclosure.

Figure 1-11. Male and female yellow bats roosting together. *L. intermedius. Bat World Lone Star facility. Photo by D. Hyatt.*

Yellow bats prefer to be held in a loosely closed glove or wrapped loosely in a cloth during handling. Like infant pups, these bats will use their teeth to grab the cloth or glove while being moved, clinging tightly to the handler with their thumbs, toes and teeth. Nervous or extremely timid individuals will visibly relax with soothing tones and will also benefit from being handled in a soft cloth. These bats generally learn to self-feed within one to five days, although some individuals may take longer. Even then, they rarely find food on their own and must be placed in position over a dish of worms at feeding time, and they must be removed from the dish when they are full. Over time, these bats may become trusting of their handler. They develop recognition of their handlers and associations between sounds and activities, providing the handler maintains consistency. Long term captives and hand-reared juveniles have a tendency to be lazy and rarely attempt to fly.

Age and Longevity

Due to the small size of North American insectivorous bats, inexperienced handlers may mistake adults for infants. Most pups are born naked. Their skin is pink for at least the first few days to the first couple of weeks of life and the skin darkens as fur begins to grow (Figure 1-12).

Figure 1-12.
A: Brazilian free-tailed pups ranging from one to four weeks old. Between two to three weeks of age the skin begins to darken as fur grows. Fur growth first appears underneath the wings, then across the chest. By four weeks of age a velvety coat covers the entire body. *T. brasiliensis*. Photo by A. Lollar.
B: A two-day old big brown pup. *E. fuscus.* Photo by C. Troiani.
C: A red bat mother and pups at approximately 10 days of age. Male red bat pups are significantly redder in color and are also smaller in size than female red bat pups. *L. borealis.* Photo by L. Sturges.

The young of some species, such as Brazilian free-tailed bats (*T. brasiliensis*), are born with their eyes open (Lollar, 1994). Red bats (*L. borealis*) are born with their eyes closed and open them around day 10 or 11. Big browns (*E. fuscus*) and evening bats (*N. humeralis*) open their eyes within hours after birth. Most species will be fully furred within a few weeks at most. Red bats (*L. borealis*) and hoary bats (*L. cinereus*) are born with a gray pelage that resembles peach fuzz and are well furred dorsally by one week of age, although their abdomens are still naked at this time. These bats are fully furred within 15 days of age. Brazilian free-tailed bats (*T. brasiliensis*) develop more slowly and are not fully furred until about four weeks of age, although their pink skin begins to darken after the first or second week.

Birth weights and growth rates vary, but many of the medium-sized bat species (adult weight of 10g to 20g) weigh just under 2g at birth. Smaller-sized bat species (adult weight of under 10g) may weigh less than a gram at birth. Most pups will attain adult weight by six to eight weeks of age. Nursing pups have tiny, sharp-hooked milk teeth which they use to cling to the mother's teat or fur. Young bats also have elongated, cartilaginous areas in the growth plates of the finger (phalanges) and hand (metacarpals) bones for the first several months of life. This growth pattern results in joints that appear cylindrical or even flattened, whereas in adults these joints appear as round, bony knobs (Figure 1-13).

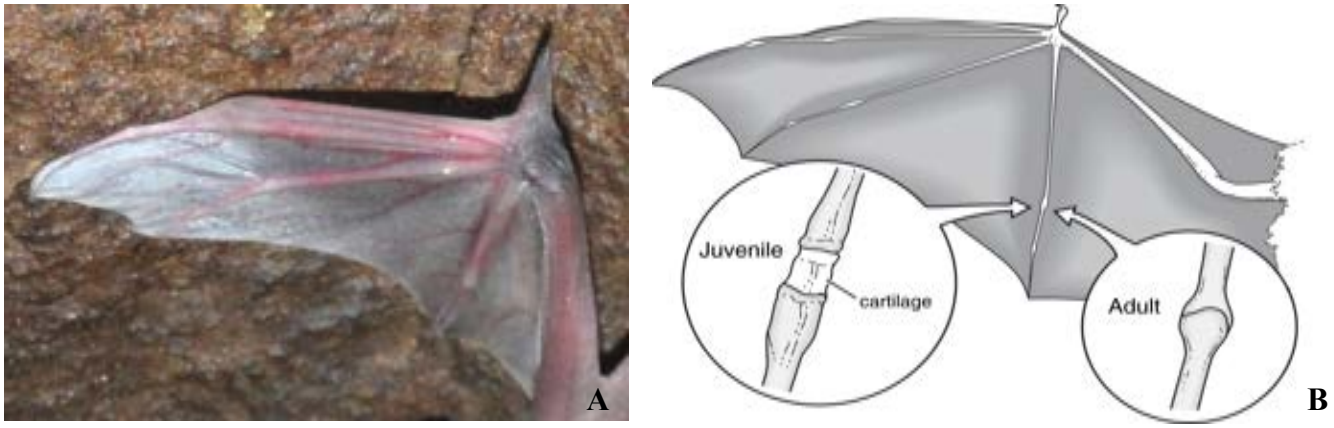


Figure 1-13. A: Finger joints of an infant bat, approximately one week of age. *Photo by A. Lollar*. **B:** Finger joints of a juvenile and adult bat. David Chapman. Modified from Schwartz and Schwartz, 1981.

Longevity

In comparison to larger mammals, insectivorous bats live an average of three times longer than predicted by their body size. Additionally, bats have other qualities that are characteristic of larger animals that are long-lived, such as bearing few offspring and a high level of intelligence.

To date, the longevity record for a captive free-tailed bat (*T. brasiliensis*) is 18 years. This bat was admitted to the Bat World facility in 1993 as a week-old emaciated orphan with a crushed wing. Insufficient calcium during starvation caused her to lose all her teeth before six months of age. She was subsequently fed Bat World Sanctuary's soft diet, supplemented with mealworm viscera from giant mealworms. This bat reproduced five times in captivity. A male offspring of hers lived to be 15 years of age. The longevity record for a captive big brown bat (*Eptesicus fuscus*) is 22.5 years. This bat's diet was supplemented with brewer's yeast sprinkled on mealworms twice a week. This bat was also allowed to hibernate naturally in a cool section of its enclosure (Michele Sims, pers. comm.). The current longevity record for a wild bat is a male Brandt's myotis (*Myotis brandtii*) that was captured in the wild at 41 years of age (Podlutsky, et al. 2005). The bat was identified through a numbered band that had been attached by researchers in the 1960s.

Bat World Sanctuary has raised a large number of free-tailed bats (*T. brasiliensis*) from birth to age ten through 18 years. There is little evidence of sensory loss; however, as with other mammals, age can alter both physical

and facial characteristics. Juvenile Molossid bats are darker in color than adult bats, and the fur also appears fluffier than the fur of an adult. The fur of Myotis juveniles is wooly and more of a dusty gray. However, it is important to note that natural color variations may result in juvenile bats being lighter or darker in color. Body mass may also be used as an indicator of age. Flighted juvenile bats that are both nursing and foraging may be fatter than adults, while juvenile bats that are both flighted and weaned are more physically slender. Additionally, the facial characteristics of a juvenile bat lack the "maturity" of older bats - the eyes appear larger and rounder, and the muzzle is slightly narrow than that of an adult bat. The teeth of a juvenile bat are bright white and exceptionally sharp at the tips (Figure 1-14).

Figure 1-14. A: A juvenile free-tailed bat (*T. brasiliensis*) showing bright white teeth and darker fur. **B**: An 18-year-old free-tailed bat (*T. brasiliensis*) showing markedly lighter fur. *Photos by A. Lollar.*

Using appearance alone, it is extremely difficult to age adult bats that are between two to ten years of age. However, by ten years of age the ventral fur typically becomes lighter in color, occasionally turning entirely white. By age 12 the fur on the sides of the neck may lighten, and lighter fur is often sprinkled throughout the entire coat (Figure 1-12). As bats age their teeth also become worn; however, tooth wear may not become obvious to the naked eye until around ten years of age, when the sharp tips of the canine teeth become somewhat rounded. Tooth breakage is common in some species, particularly big brown bats (*E. fuscus*) that have been recovered from buildings or have been grounded (L. Sturges, pers. comm.).

Older bats may become grounded in the wild due to worn teeth. Although fully flighted, extreme tooth wear will affect the ability of a bat to adequately forage, and it will become emaciated and too weak to fly. Elderly bats with worn teeth are typically unable to chew solid food such as whole mealworms in captivity, and so must be hand-fed a nutritionally complete soft diet.

As bats age they also become less mobile, only occasionally moving from a favored roosting spot, and generally they move more slowly (see Geriatric Bats). These bats can lead enriched lives in captivity and may still reproduce. Elderly female free-tailed bats (*T. brasiliensis)* cared for at the Bat World facility have reproduced on a number of occasions and have successfully reared pups to weaning.

Crevice bats have longer life spans than foliage bats, both in the wild and in captivity. Red bats (*L. borealis*) and hoary bats (*L. cinerus*) traditionally only survive one to four years in captivity; however, we have maintained individuals of these species up to six years using housing and feeding procedures as outlined in this manual.

Notes for the Handler

Handling

Bats must be removed from roosting surfaces gently to prevent injury to the bat's toes and thumbs. Never forcefully pull a bat off the surface to which it is clinging. Doing so will result in severe foot, toe and thumb injuries. Instead, wrap a gloved hand around the bat while using the forefinger of the same hand to gently pluck the bat's feet and thumbs clear of the roosting surface. Bats have been described as having Velcro®-like feet and thumbs and will reattach themselves to the roosting surface at every opportunity. Lifting the bat up and away from the roosting surface will help release its hold and prevent toes and thumbs from reattaching. Patience is required until the technique is perfected.

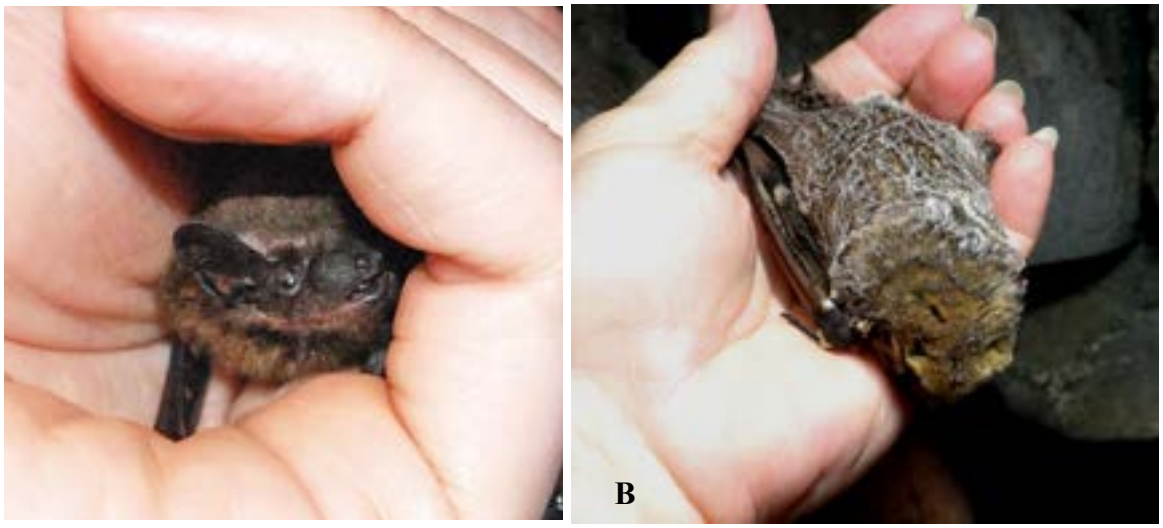


Figure 1-15. A: A crevice bat is held in a closed hand. *N. humeralis. Photo by A. Lollar.* **B:** A tree bat is held very loosely. *L. cinerus. Photo by D. Hyatt.*

Crevice bats should be gently held in a closed hand while exerting minimal pressure on the bat's body (Figure 1-15A). Tree bats prefer to be held very loosely on a cloth or in a hand (Figure 1-13B). Holding both crevice and tree bats too tightly will cause the bat to panic and attempt to escape. Efforts to constrain the bat will be fruitless and the caretaker will be unable to gain the upper hand, causing additional anxiety to both the bat and the handler. In these cases it is best to put the bat away and allow it to calm before attempting to handle it again. Holding crevice bats too loosely will also result in the bat attempting to flee. Bats trying to flee often run across the hand, prompting the handler to move one hand over the other as the bat essentially "runs in place" (Figure 1-15C). This motion leads to panic in crevice bats and should always be avoided. Rather, gently gather the bat up in a closed hand. If the bat appears panicked, put it away and allow it to calm before attempting to handle it again.

C: Never allow crevice bats to "run in place" across the hands*. T. brasiliensis. Photo by A. Lollar.*

On foot, crevice bats tend to be very fast runners while tree bats are very slow. Crevice bats are almost impossible to safely catch from behind. Rather, it is best to position oneself ahead of the bat and catch it from the front. Due to the risk of injury, it is best not to attempt to catch bats in flight. Rather, wait for the bat to land, then gently gather it up by hand. Never attempt to grab a bat that has extended its wings, even slightly, to fly. Doing so risks dislocating and/or fracturing delicate wing fingers, shoulders and knees.

As with other mammals, insectivorous bats can develop close trusting bonds with their caregiver. Because of their sensitive nature, abruptly changing handlers is very stressful, and has been reported by several bat care professionals to result in sudden death. Balcombe (2010) illustrates a condition known as emotional fever, which, describes a measurable rise in an animal's core body temperature that is attributed to a psychological rather than a physical cause. In rats, handling by an unfamiliar person elicits a rise in body temperature of 1.7 Fahrenheit or more. If the same person handles the rat over several days, the response declines and disappears as the rat develops trust for the handler. If, however, another handler is introduced, emotional fever returns.

Any change in the bats caretakers should be made gradually, over a two-to-three-day period. New handlers should work side-by-side with a primary handler so the bat can become familiar with the sight, sound and smell of an additional caretaker. For bats that must be hand-fed soft food, the primary caretaker should hand the bat to the new caretaker and remain present during the hand-feeding process, while speaking gently to reassure bats that appear overly stressed. Over the course of transitioning the bat to a new handler, the primary caretaker should decrease the amount of time spent caring for the bat as the new caretaker increases the time spent, until the adjustment is complete. Unless arising medical care dictates, the new handler must not deviate from any care routines set in place by the previous caretaker.

Additional notes:

- Never handle insectivorous bats when feeling angry or overly stressed as they will become stressed as well. Wait until you feel calm to handle bats.
- Learn the individual personalities of the bats in your care. They are just as individual as we are.
- Develop a rapport, use soothing tones.
- Always leave the bat with a positive experience at the end of a handling session through use of a treat such as mealworm viscera.
- Never used scented hand cream or soap before handling bats as they are sensitive to certain odors. Use unscented products only. Also avoid perfumes and clothing overly scented with fabric softeners.
- Never put a bat away with soiled or wet fur.
- Be consistent with cleaning and feeding times. Also be consistent in the times lights are turned on and off. Bats can detect light from inside their enclosures. Avoid the undue stress of having a light suddenly turned on at night when a bat expects it to be dark.
- Keep interruptions to a minimum during the day when bats are sleeping.
- Excluding objects intended for enrichment, always return roosting items, water, and food dishes to the same location in the enclosure. Additionally always return items to the exact position (i.e. if the opening to the roosting pouch faces the back of the enclosure, do not switch the position so the opening faces the front of the enclosure—this is the equivalent of someone moving the front door of your house to the back of your house).
- Always return a bat to its enclosure in the location from which it was removed. For example, if a crevice bat was roosting in a particular pouch, return the bat to the same pouch after handing. If a tree bat was roosting within a particular cluster of silk foliage, return the bat to the same location.
- Avoid creating high-frequency noises when in proximity to insectivorous bats. Examples of high-frequency sounds are wadding and crinkling of paper or cellophane, pulling tissue from a box, and sniffing. Noises like these are the equivalent of a shot gun blast to us. A bat detector can help to identify common high-frequency noises.

CHAPTER TWO

WILD BATS ENTERING CAPTIVITY

Collecting and Transporting

The manner in which wild bats are collected and handled directly impacts their ability to adapt to captivity. Therefore, procedures that minimize stress and potential for injury should be used. Gathering individual bats by hand is always recommended over methods that capture bats in flight, such as mist nets or harp traps, which have been known to cause obvious stress, injuries and fatalities.

Both crevice and foliage bats should be transported in bat huts or soft-sided enclosures such as mesh dog carriers with zippered doors (see Temporary Housing). Transport carriers should be ventilated and well padded and be able to be secured inside a vehicle with seat belts. The floors of enclosures should be padded with fabric or foam to prevent or reduce injuries to bats that may fall to the enclosure floor. Additionally, carriers must be covered with a dark towel or other dense fabric to provide security for the animals. Roosting pouches and surgical towels or other non-snagging fabric cloths should be draped over the inside framework of the carrier against the enclosure walls to provide hiding places for crevice bats in transport. Bats transported by automobile should be placed inside the vehicle and never in a camper shell or the bed of a truck. Avoid excess noise such as loud radios while transporting bats in a vehicle. A seat belt should be fastened to the handle of the carrier or Bat Hut or positioned around the entire carrier if necessary. Keep the interior temperature at a level that corresponds to the normal thermal requirement of the species, and never leave bats inside a parked car without appropriate heating or air conditioning. Bats have been known to overheat and die in automobiles, even in relatively cool environments. Avoid aromatic substances such as air fresheners, etc., while bats are in transport.

Adult foliage bats should be separated from one another by placing them in Bat Huts (Figure 2-1A). The individual Bat Huts should then be placed inside a larger mesh carrier. Crevice bats should be allowed to remain grouped together and not separated. Carriers should be large enough to provide room for all bats to roost simultaneously, eat, drink (when applicable) and eliminate.

If bats are being shipped by airline, the mesh carrier, complete with a cover, should be placed inside an International Air Transport Association (IATA) approved hard-sided dog crate (Figure 2-1C). Bats should only be shipped by airline when temperatures correspond to the normal thermal requirement of the species. The duration of flight may dictate that certain species of bats be provided with food and water. Bat species that are predisposed to stress should be conditioned to the shipping crate prior to shipping by airline. This can be accomplished by placing bats inside the mesh carrier and then placing the carrier on top of a running washing machine, allowing the bats inside to become accustomed to both vibrations and noise before the actual flight.

Figure 2-1. A: A Bat Hut can be used to transport individual foliage bats or several crevice bats. **B:** A mesh dog crate equipped with hiding cloths and pouches to transport crevice bats. **C:** A mesh dog crate placed inside an airline approved hard-sided dog crate. Additional padding has been placed above and below the mesh crate to provide extra cushioning and stability during flights. *Photos by A. Lollar*

Intake and Initial Exam

Figure 2-2. Gently restrain a bat by using a thumb and one finger to hold the mouth closed. (*E. fuscus*). *Photo by A. Lollar.*

General Information

It is extremely important to take note of a bat's general condition before initiating an exam or treatment to minimize the possibility of treating a bat infected with rabies. Common signs of rabies include central nervous system disorders such as uncoordinated or spastic movements, spastic paralysis of the lower body with the legs clamping against the abdomen, constant chewing on materials, and an increased sensitivity to sound. etc. If the bat does not exhibit obvious signs of rabies, the examination can continue.

It is not possible to thoroughly examine bats with heavy leather gloves; however, Nitrile gloves offer a good amount of puncture resistance while permitting a high degree of dexterity and tactile sensitivity. Although no gloves are entirely puncture resistant, these gloves do provide more resistance than disposable rubber or vinyl gloves. Note: While the author uses gloves to initially examine bats, gloves are not worn thereafter when handling presumably healthy bats that do not have a propensity to bite. While gloves may offer safety to the caretaker, they can also interfere with the ability to effectively handle the bat, perform meaningful physical exams and medical treatments, and maintain a clean hand-feeding environment.

Bats should be restrained for examination in a manner that minimizes the possibility of receiving bites or scratches but does not place undue stress or discomfort for the bat. As previously stated, crevice species can be restrained in a soft cloth or a gloved hand; however, tree species will struggle if tucked in a cloth, so simply hold them in a gloved hand for examination. If necessary, use the thumb and one finger of a gloved hand to gently hold the mouth closed (Figure 2-2). Never hold a bat dorsally at the shoulders while tenting the wings above the back. This handling technique shows little regard for the welfare of the bat; it causes undue stress and unnecessary pain to the bat, along with the possibility of exacerbating any existing injuries. It is important to avoid causing injury or increasing pain levels of any existing injuries during handling and examination. When in doubt, adhere to the veterinary profession's maxim "if it would hurt us, it hurts them."

Eyes First

A bat's eyes and respiration are excellent indicators of a bat's overall condition so always check them first. The eyes should be round, clear, and alert. Partially closed eyes can be an indication of dehydration and/or illness. A dazed expression may indicate shock. Matted eyes indicate illness such as rabies or pneumonia. Squinting eyes indicates pain. Rapid blinking indicates confusion and fear.

Respiration Second

Normal respiration is visible in the pelvic region. Labored breathing that is visible in the chest area is a sign of respiratory distress and may indicate injury or illnesses (e.g., rabies or pneumonia, see Diagnosis and Treatment of Illness).

Exam Third

Bats that are trapped or downed for any length of time are very likely to be dehydrated. The skin on the abdomen or back of a dehydrated bat may appear wrinkled and exhibit no elasticity when pulled gently away from the body, instead remaining tented or very slowly resuming its normal position. Weakness, dry wing and tail membranes, and dry, droopy eyelids (or refusing to open the eyes) are all signs of severe dehydration. (See Dehydration and Fluid Replacement Therapy).

Bats should be treated for ectoparasites upon intake. For severe infestations, dip a cotton swab into 70% isopropyl alcohol and use it to slightly dampen the fur of the head and neck first. This will force parasites away from the face and onto the torso. Use a gauze pad dampened with alcohol to remove mites from the wing membrane. After mites have been killed or removed, rinse each wing with a gauze pad soaked in warm water. Keep the bat warm and dry the fur if it becomes wet. Administer selamectin (Revolution®) topically to eliminate any remaining external parasites (see Medications). A wild bat grounded due to illness or injury is often more heavily parasitized than others. Severe endoparasitic infection (e.g., roundworms, tapeworms, flukes) can cause a bat to become grounded. Selamectin is effective against roundworms but is ineffective against hookworms, tapeworms, whipworms, and flukes. Therefore, bats that will remain in captivity for eight days or more should also be treated for endoparasites (see Medications). If the bat is debilitated, wait until it has stabilized before administering Revolution® topically or before treating for endoparasites.

Determining the sex and age of the bat will assist in diagnosis and treatment. If the bat is a female, check for abdominal distention, a possible indication of pregnancy. If not visibly pregnant, look for white, oval areas beneath the skin of the breasts (Figure 2-3). These are signs of a lactating female which has recently given birth. Also determine if the bat is a pup, juvenile, adult, or a very old (see Age and Longevity on page 15).

Figure 2-3. Oval white areas beneath the skin of a lactating pregnant bat. *T. brasiliensis. Photo by A. Lollar.*

Check the epiphyses of the finger joints by using a light source behind the wing membrane. Elongated cartilaginous finger joints in the wings indicate a bat born the previous spring or summer (see Figure 1-1B on page 15). Young bats maintain cartilaginous finger joints for the first several months of life. Adults have rounder, bony joints. Elongated sections at these joints on fully furred bats indicate a juvenile bat.

Gently running a cotton swab along the bat's jaw line causes most bats to open their mouths wide (in a defensive posture), allowing a cursory check of the teeth. Look for broken or worn teeth. Very worn teeth are an indication of an old bat. Check the color of the gums by gently raising the lip with the rounded edge of a flat toothpick. Pale gums may indicate anemia due to a variety of causes (see Parasites and Gastrointestinal Disorders). Weighing a bat at intake isn't necessary and only causes undue stress to the animal. If your state agency requires the bat be weighed, it can be wrapped in gauze and the bat placed inside. Never weigh a bat before it is fully hydrated, otherwise the reading will be false.

Broken wing bones are the most common injury observed in bats. Breaks of the humerus and radius are obvious and are normally noticed before an examination begins. One wing may droop more than the other or not close as tightly against the side of the body as the uninjured one does. This can be an indication of a fracture of the scapula, humerus, radius, or ulna. Fractures of the carpals (small bones of the wrist) often result in significant swelling at the joint. Closed fractures of the metacarpals and phalanges (hand and finger bones) are more difficult to identify visually.

The fingers and wing membranes can be examined by carefully extending each wing by the outermost metacarpals, with the bat facing down against the palm of the hand (Figure 2-4). Hold the forearm of the wing stable and close to the bat's body with the thumb and fourth finger of the other hand, and then gently grasp the outermost metacarpals and carefully pull the wing away from the bat's body.

Figure 2-4. Gently extend the wing using the outermost metacarpals. T *brasiliensis. Photo by A. Lollar.*

A light source held behind the wing will help to reveal possible fractures, bruising, or interruption of the blood supply from injuries that may have become necrotic (Figure 2-5). Examine each metacarpal and finger, from the wrist all the way down to the tip for visible breaks. Closed fractures that do not involve displaced bone will often heal on their own, although fractures involving displaced bones, whether open or closed, generally do not heal in a manner that reestablishes excellent flight capability. These bats may need to be kept in permanent captivity. However, in some cases, such fractures have been surgically corrected (see Wing Injuries). Thoroughly check wing and tail membranes. Most membrane tears, even those that are very large, will heal on their own with little intervention. Check to ensure that the tail membrane is intact. Although other animals may be able to survive in the wild without a tail, insectivorous bats need this structure to help form a "catcher's mitt" for capturing insects, and for maneuvering during flight. Therefore, the tail must be fully functional for any bat intended for release.

Figure 2-5. Use a light source to reveal bruising and other injuries. *T. brasiliensis. Photo by A. Lollar.*

Check the thumbs to see if one appears larger or more swollen than the other. If so, the bat is likely to have sustained a fracture of the thumb. Full use of the thumbs is important because bats use their thumbs for clinging, roosting, climbing, grooming, and manipulating food. However, bats are occasionally found in the wild with a healed, non-functional thumb or the distal portion of a finger missing. A bat with a foot, leg, or hip injury may not be able to roost or groom properly and should not be considered for release unless the injury has sufficiently healed to allow normal grooming and locomotion. Otherwise healthy bats that are missing a toe are occasionally seen in the wild.

A bat's body temperature can vary significantly. During flight, the body temperature is directly related to the ambient temperature. For example, the body temperature of the canyon bat (*P. hesperus*) is 71° Fahrenheit when the ambient temperature is 23° Fahrenheit. At an ambient temperature of 86° Fahrenheit, the bat's body temperature is the same as the ambient temperature (Hill and Smith, 1984). Because of the normal variation in body temperature, it is not a useful means of assessing a bat's condition.

At rest, bats' heart rates are comparable to those of other mammals of similar size (In flight, they are comparable to those of flying birds. Heart rates of bats in flight may reach 1000 beats per minute; those of bats that are alert and responsive can reach 500 to 600 beats per minute. Heart rates of bats in daily torpor may be only 40 to 80 beats per minute, while rates as low as 10 beats per minute have been recorded for some bats in hibernation. In flight, respiratory rates are dependent on air speed and flight angle. Both the respiratory rate and wing beat frequency decline as air speed increases.

Chapter Three

Temporary Housing

Quarantine, Orphans and Rehabilitation

General Information

According to a study at the University of Calgary, rabies rates in North American bats has been over-estimated. Regardless, Bat World Sanctuary recommends the vaccination of all insectivorous bats in captivity. We have been routinely vaccinating all insectivorous bats against rabies since 1990. To date, we have had no known rabies transmission from bat to bat at the sanctuary. We currently administer 0.1ml of rabies vaccine subcutaneously for insectivorous bats weighing between 4 and 35 grams, and .05ml of vaccine for bats 3.9 grams and under. Non-releasable bats are vaccinated annually. Releasable bats are vaccinated prior to release. We have submitted serum samples from some of our vaccinated bats for rabies titer checks and these vaccinated bats developed protective levels of rabies antibody titers. Studies suggest that recombinant rabies vaccine is an adequate and safe immunogen for bats by all routes tested, and the vaccine appears to protect most vampire bats against experimental rabies irrespective of the immunization route employed (Aguilar-Setie´, et al. 2002). Additionally, 20 pallid bats (*A. pallidus*) housed at Texas A&M University developed a titer after being vaccinated; however, five had to receive a booster in order to develop a titer, and one bat failed to develop a titer despite being vaccinated twice. It should be noted that use of rabies vaccine on bats is extra label use and that exposure to potentially infected bats should be treated as recommended by the CDC.

The length of time a bat remains in quarantine should be determined according to the length of time it takes injuries to heal. Otherwise, bats that have been vaccinated, are parasite free and appear healthy should not remain in quarantine for over one month.

Crevice Bats

Crevice bats should always be provided with roostmates in quarantine, including bats with stabilized injuries. Because male big browns (*E. fuscus*) occasionally tussle during the fall and winter months, these bats can be housed alone when necessary. However, even these bats should be housed within sight or sound of conspecifics to mimic natural conditions more closely. Crevice bats collected or received together at the same time, from the same colony, should be housed together. An exception to the rule is any bat that isolates itself from others by roosting in exposed positions low on enclosure walls or on the enclosure floor. This is a sign of illness, and the bat should be isolated and housed separately in a bat hut or similar caging until its condition can be determined and appropriate treatment started. Permanent captive crevice bats may also become sick or sustain injury. Captive bats that exhibit signs of illness, isolating themselves from others or roosting in exposed positions, should be removed from the community enclosure, and housed separately until a diagnosis is made. Injured crevice bats placed in Bat Huts should be housed within sight or sound of conspecifics to ease stress. However, it is very important to note that males of some species isolate themselves from others at the onset of mating activity to establish territory. This is normal behavior, and these males should not be isolated.

Figure 3-1. Mother and infant red bats. *L. borealis. Photo by L. Sturges.*

Tree Bats

Foliage species are relatively solitary animals and should be housed separately. An exception involves mothers with pups, who should **always** be housed together (Figure 3-1).

Quarantine Housing

Glass aquariums or plastic "critter keepers" and similar hard-sided containers or enclosures should **never** be used to transport or house bats as they will cause severe injury to toes, thumbs, wrists, forearms and fingers. Additionally, Styrofoam coolers should never be used to transport or house bats. Styrofoam particles frequently adhere to a bat's claws and fur and may subsequently be ingested during grooming, resulting in illness or death. Bat enclosures must not be kept in areas that are not accessible to children or rooms where other animals are being enclosed.

Bat Hut

This carrier is constructed of fine but sturdy mesh and measures 8.5" (21.7cm) high, 7" (17.78cm) wide and 8.5" (21.7cm) long. (Figure 3-2A). The bat hut was designed specifically for transporting and holding microbats for short periods of time. With simple modifications the bat hut is suitable for transport of both tree and crevice bats It can be secured during automobile transport by running the seatbelt through the handle. This enclosure is suitable for transporting up to 10 crevice bats or one foliage bat. This enclosure works well for bats that need to be isolated due to injury or illness, however, a larger enclosure, such as the cube enclosures described below, should be used if bats are to be isolated more than 12 hours.

Figure 3-2. A. A bat hut.

Pop-Up Mesh Enclosures

These collapsible and inexpensive enclosures are constructed of fine mesh on all sides and made for butterflies, however, they are also perfect for bats in rehabilitation such as foliage bats with young and bats healing from injuries that require restricted movement. The small cube enclosure measures 12" x 12" x 12". (Figure 3-2B). The larger enclosure measures 13.5"x13.5"x 24" (Figure 3-2C). The enclosures also fit into standard large and small incubators making them ideal to house orphaned microbats (Figures 3-2D and 3-2E). These enclosures should be modified to include enrichment for foliage roosting and crevice dwelling bats following the examples in Enrichment (Figure 3-2F).

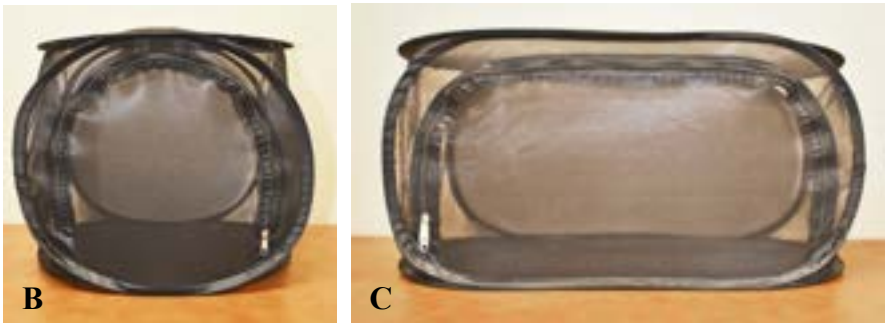


Figure 3-2. C & D: Pop-up cube enclosures made for butterflies work well for bats in rehabilitation and fit into most standard incubators. A cloth should be used to cover the uppermost part of the enclosure to give security to bats roosting inside.(**Figure 3-2D & E**). Enrichment should be added for both foliage roosting and crevice dwelling bats (**Figure 3-2F**).

Modifications to Accommodate Microbats using Mesh Dog Crates

Figure 3-3. A: Use a sharp blade to carefully remove any false bottom or corner tags in the enclosure. **B:** Turn the enclosure upside down and use the bottom of the enclosure to measure and cut layers of foam sheeting (available where fabric is sold) to match the size of the enclosure floor. **C:** Turn enclosure upright again and place foam layers inside. Trim off any excess foam that does not allow padding to fit flush against the floor.

Figure 3-3. D: Cover the foam layers with a plastic garbage bag. Cut off the excess length and seal the edges tightly with duct tape. **E:** Cover the plastic bag with a standard-sized dark pillowcase. Pillow cases can be switched out and washed for ease in cleaning. **F:** The pillowcase opening should face the front and be tucked toward the floor so bats do not easily find the opening and crawl inside.

Adding Enrichment and Roosting Apparatus

Figure 3-3. G: Rubbermaid™ weave drawer liner can be used to create slings to hold roosting pouches and a bridge for diversity and an additional roosting space (see Enrichment). Unroll a 60" section of the netting, fold and cut in half lengthwise. Slide the netting over the support poles of the enclosure and secure with zip ties. **H:** Ensure the netting is even on both sides. Fold the netting in half to form a sling and secure in place with zip ties. (Note: Zip ties should always be closed from the outside of the enclosure.) Pouches placed into the slings stay securely in place. **I:** Surgical towels or similar cloths that do not snag claws can be folded over the support rods inside the enclosure to provide additional hiding spots. **J:** Artificial foliage secured to the ceiling of the enclosure provides the necessary enrichment for foliage bats (see Enrichment).

Adding Heat and a Sense of Security

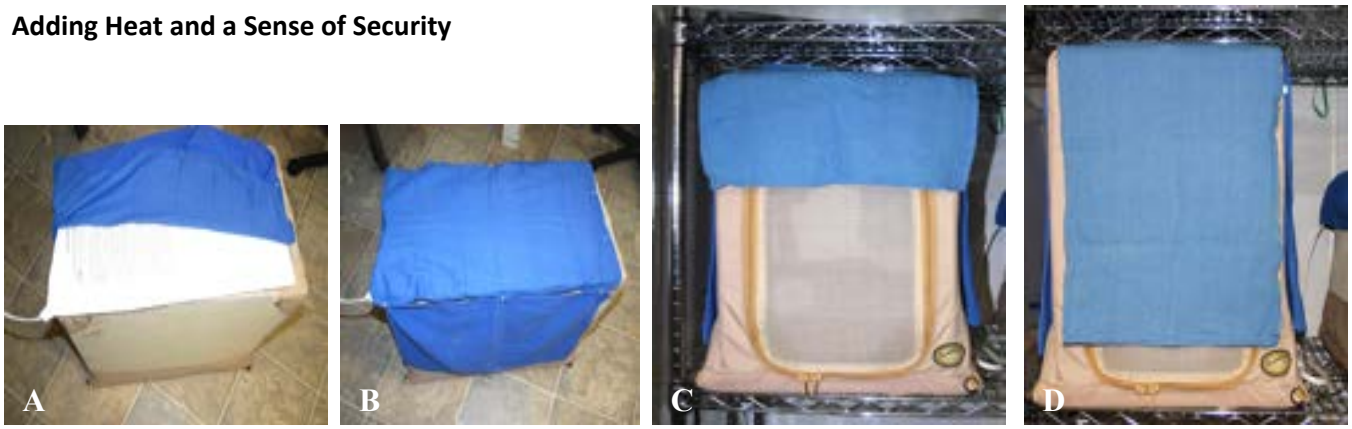


Figure 3-4. A: A heating pad, set to low, should be placed on the top or the side of the of the enclosure, but **NEVER** on the bottom. **B:** Simple covers can be made with surgical toweling and zip ties. **C:** Covers should be adjusted to allow light to enter the enclosure by day. **D:** Enclosures should always be covered at night to provide a darker and more secure environ-

Water Dishes

Water dishes can easily be created by using one-ounce plastic Boston round or travel bottles as described in Water Dishes (Figure 3-4E). Use a zip tie to create a snug-fitting loop that will allow the handle of the dish to slide in and out. The zip tie should be secured from the outside of the enclosure. Two to four water dishes should be placed throughout the enclosure; against the walls and toward the ceiling as shown.

Figure 3-4. E. A water dish created from a small plastic bottle and secured in place with a zip tie. *Photo by A. Lollar*.

Enclosure Cleaning

Bats should be removed and placed into a Bat Hut or similar enclosure before cleaning the enclosure. Roosting pouches and toweling should be changed daily to aid in the removal of remaining ectoparasites. It is important that replacement roosting items match in both shape and placement within the enclosure. Switching placement of roosting items within the enclosure will limit the bats' ability to feel familiar and secure in a enclosed environment.

Enclosure surfaces should be cleaned on an as needed basis using hot water only, as some species of bats use scent marking to mark their territory. Unless the enclosure is being prepared to accept new bats, bleach or other chemicals should be avoided. Water and food dishes should be removed and cleaned daily with soapy water, then rinsed well. Water dishes should be immediately returned to the enclosure and refilled with fresh water. Forceps, utensils and feeding apparatus should always be sanitized after each use. Soiled foliage and leaves attached to the ceiling of the enclosure should be left in place to clean. These items can be cleaned using a paper towel dampened with hot water. The leaves should be thoroughly dry before placing the bat back inside. Paper towels placed on the enclosure floor, on top of the padding, will aid in absorbing urine and feces, particularly with lasiurine bats. Using newspaper should be avoided as bats have been observed reacting adversely to the sound of shuffling newspaper. Puppy training pads should equally be avoided as these items are scented with an attractant that could produce an adverse odor when used in bat enclosures.

Temperature, Humidity and Lighting

Temperate species of bats can be successfully maintained at temperatures between 68° to 77° Fahrenheit (20° to 30° Celsius), and between 60% to 90% humidity. Bat World Sanctuary has maintained several species of insectivorous and frugivorous bats in large indoor flight enclosures at humidity levels between 50% to 60% (although infants and weak bats require higher humidity levels).

Insufficient humidity can cause dehydration, resulting in loss of appetite and skin conditions such as dry wing membranes. This type of dehydration primarily occurs during winter months when heaters are used, and can prove deadly if not caught and treated in time. Cave-dependant bats such as little brown bats (*M. lucifugus*) typically develop skin conditions when kept in too-dry environments. Orphaned, sick or weak bats also need additional heat and humidity. This is particularly important for unfurred infants that require warm, humid temperatures to maintain health and proper growth rates. Appropriate temperatures for bat pups of many species are 90° to 100° Fahrenheit and humidity levels of 70% to 90%. It is important to note that a constant level of high humidity can encourage mold growth on enclosure surfaces which may pose a health risk to both the bats and their handlers. Therefore, it is important that humidifiers are properly cleaned and disinfected on a weekly basis to prevent the build-up of mold on enclosure surfaces as well as bacteria in the water.

The use of Econo-heat panel heaters (see Products) during the winter months will help to maintain a higher humidity level, particularly in larger buildings where the use of multiple humidifiers is not feasible. These heaters are constructed from asbestos-free cement fiber board and operate at relatively low surface temperatures of 75° to 194° Fahrenheit, depending on the ambient temperature.

Humidity Chambers

If incubators that provide humidity are not used, a humidity chamber can be created. Enclosures can be placed in these chambers to increase the humidity and temperature for orphaned and convalescing bats. The humidity chamber below consists of 54" adjustable open wire shelving on which enclosures are placed. Two panel heaters are placed on the lower shelves. Stainless steel pans measuring 20.5" x 13.5" x 4.5" are placed on top of the heaters for additional moisture. A 12-gallon whole-house humidifier is positioned on the floor between and below the panel heaters (Figure 3-5A). One side of the shelving unit is against a wall and the opposite side is sealed with a clear Plexiglas® panel. Walk-in cooler door strips made of PVC are installed in front of the shelves creating easy access to the enclosures (Figure 3-5B and C). A temperature and humidity gauge should be placed inside the chamber to always monitor the internal temperature and humidity levels. Heating pads can be added to the tops of the enclosures, if necessary.

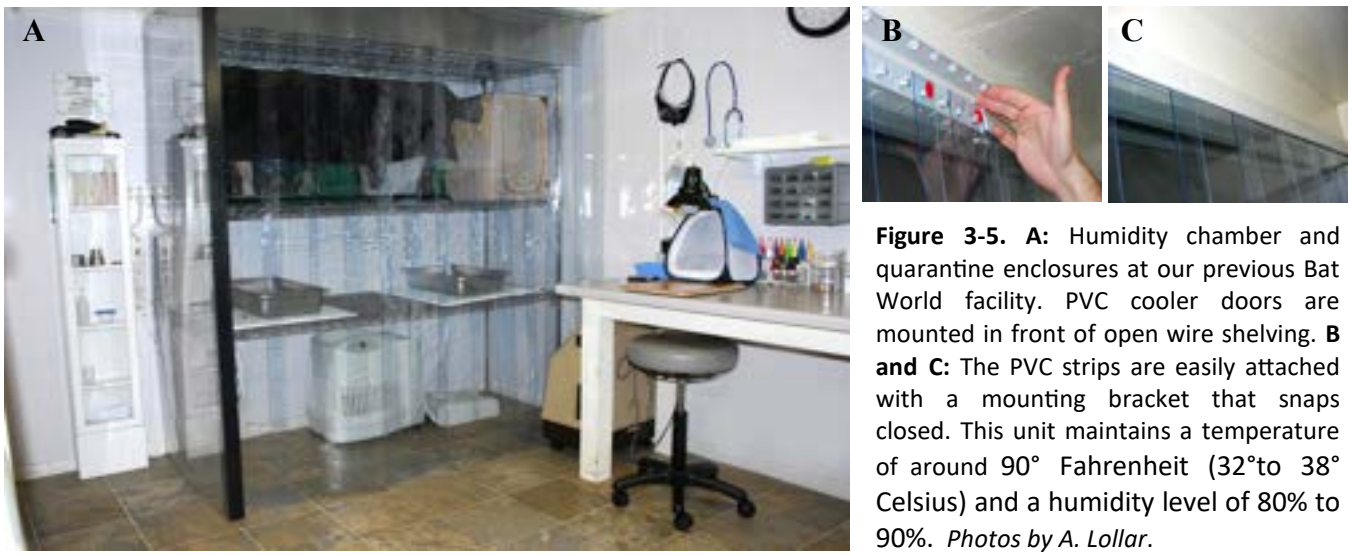


Figure 3-5. A: Humidity chamber and quarantine enclosures at our previous Bat World facility. PVC cooler doors are mounted in front of open wire shelving. **B and C:** The PVC strips are easily attached with a mounting bracket that snaps closed. This unit maintains a temperature of around 90° Fahrenheit (32°to 38° Celsius) and a humidity level of 80% to 90%. *Photos by A. Lollar*.

PVC-Framed Humidity Chamber

PVC framing can be used to create temporary chambers to increase humidity and heat in a portion of the quarantine or temporary housing area. PVC pipe, measuring ½" in diameter can be used to create a 38" x 5' frame (Figure 3-6A). The top of the frame is covered with 4ml clear plastic drop-cloth (Figure 3-6B). The drop-cloth is secured to the frame using 1" binder clips. An anti-microbial shower curtain is installed along the top rail of the frame to serve as an entrance (Figure 3-6C). An electric oil-filled radiator is used to heat the chamber. A warm-mist humidifier is used to maintain humidity. Live potted plants are placed on the floor inside the chamber to help maintain a better quality of air.

Figure 3-6. A: Humidity chamber and quarantine enclosures Bat Conservation & Rescue of Virginia. PVC framework is covered with plastic drop-cloth. **B and C:** An anti-microbial shower curtain serves as the entrance. This unit maintains a temperature approximately 20° Fahrenheit above ambient temperature and relative humidity level of approximately 30% above ambient. *Photos by L. Sturges*.

Lighting

Although bats are nocturnal, it is critical to simulate the natural rhythm of daylight and nightfall for captive bats to regulate internal metabolic processes and maintain good health. Whether bats roost in direct light or in the dark recesses of a cave, light plays an important role in many aspects of their life cycle. Three New World bat species died within 10 days of being held in constant darkness in captivity (Uwe Schmidt, as cited by Greenhall, 1976). A colony of 12 healthy, self-feeding free-tailed bats (*T. brasiliensis*) died within 22 days of being housed in a dark closet, where they only received light once daily during enclosure cleaning and feeding (Dallas Museum of Natural History, pers. comm.).

Natural lighting is preferred over artificial lighting whenever possible; however, when large windows and other means of natural lighting do not exist, artificial lighting, with the use of incandescent light bulbs as well as fluorescent tube lighting, can be used. An artificial photo period of 12 hours of light followed by 12 hours of darkness is recommended. Further, periods of light and darkness should change gradually within the enclosure to simulate sunrise and sunset. This can be accomplished through the use of windows, by using a dimmer switch, or turning on a few lights at a time over a 10-to-15 minute period. The lights should gradually go off in the evening in the same manner. This method was used to successfully maintain nine species of insectivorous bats and seven species of fruit bats for over two decades at Bat World Sanctuary.

Note: Compact fluorescent light bulbs should be avoided as these bulbs appear to emit ultrasonic sounds that cause an adverse reaction in insectivorous bats (L. Sturges, pers. comm.).

Marking Captive Bats for Identification

Identifying individual bats is an important aspect for the management of captive bats, however, the marking method should be carefully evaluated to avoid any potential for harming bats. It is the Bat World Sanctuary position that marking methods that have a likelihood of adversely impacting individual bats should never be used. Marking methods known to cause discomfort, irritation (Figure 3-7), infection, injury (Figure 3-8) and death are leg bands, wing bands, neck bands, body piercing/jewelry, toe clipping, ear notching and freeze branding.

UNACCEPTABLE MARKING METHODS

Leg Banding

Leg banding was a marking technique used on bats by researchers as early as 1921. The metal bands used were the same type as those used on birds but did not take into consideration the morphological differences between bats and birds – most importantly the presence of the flight membranes connected to a bat's legs (Allen, 1921).

Wing Banding

Concerns regarding injury due to banding the wings of bats were noted early on (Beer, 1955). Perry and Beckett (1966) examined the effects of forearm banding on neonatal Brazilian free-tailed bats (*T. brasiliensis*) and found serious damage to the skeletons of growing and developing bats. Approximately 10,000 neonatal bats had been banded in this manner (Perry and Beckett, 1966). In the 1950s and 1960s, it was estimated that over 430,000 Brazilian Free-tailed bats were banded in Mexico, Arizona, Texas, Oklahoma, and New Mexico alone. Very few of these bats were ever recovered (Gary McCracken, pers. comm.).

A severe injury from a flanged band. *Photo by Dr. Renate Keil, Friends of the Earth Germany Hannover*

Figure 3-7. A little brown bat showing clear evidence of long-term chewing on the metal band. *M. lucifugus. Photo by J. Chenger.*

Despite serious concerns regarding bat banding, use of metal bands on bats has continued to the present day. Following long-term use of two types of bands – the metal split ring bird band and the metal lipped/flanged bat band – researchers analyzed recapture information on bats in Australia, scoring frequency and seriousness of banding injuries (Baker et al., 2001). They ultimately concluded that "Despite evidence to the contrary, the issue of band-related injury in bats has largely been ignored by bat researchers, who have tended to believe that the problem is either restricted to a few species, related to poor banding technique or mainly caused by using bird bands. Our results clearly show that both bird bands and bat bands can cause serious injuries to bats, and the problem occurs in most species examined." They also used their data to estimate annual survival rates of banded bats, and their estimates ranged from a survival rate of 0.19 to 0.75, depending on species and type of band. In light of the wide scale of their study (over 6,000 banded bat recaptures from 17 different species), their conclusions must not be taken lightly.

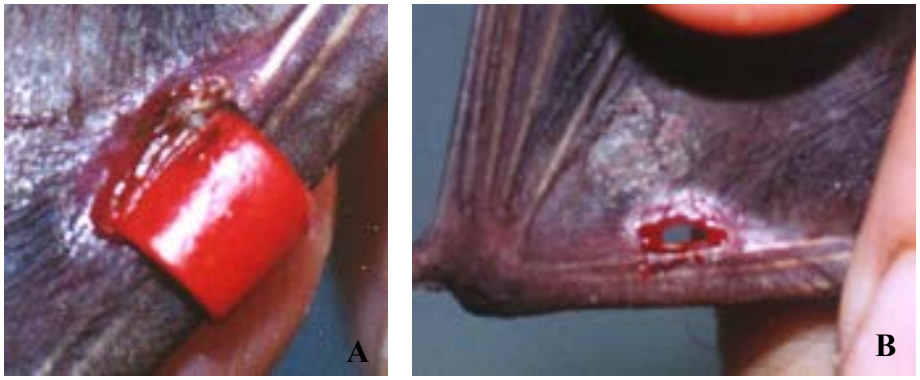


Figure 3-8. **A.** A plastic bird band causing injury to a wild caught free-tailed bat. The numbers were not legible on this band. **B**. Damage to the wing after the band is removed. *T. brasiliensis. Photo by A. Lollar.*

In early 1997, eight Brazilian free-tailed bats, banded with unmodified plastic split ring bands, were recovered and seven of these bats had injuries resulting from those bands (Brian Keeley, pers. comm.). Twenty Brazilian free-tailed bats in a zoo were also fitted with unmodified plastic bands, and 15 of them ultimately suffered injuries. In a captive banding study involving *T. brasiliensis, N. macrotis and N. femorasaccus,* the author observed swelling of the wrist, soft tissue damage and infection within one week of being banded, and in a captive colony of *E. fuscus*, swelling and infections developed in some of the bats after their metacarpals became caught in the bands (Mindy Milam, pers. comm). In 2007, a bat rehabilitator in Africa was permitted to release bats on the condition they be banded prior to release. The bats were housed for 5 weeks post banding. Of 46 banded bats, 18 presented significant band-caused injuries (39%) and four subsequently died. Had the remaining 14 not received medical intervention, they too would have died. (Dickson, pers. comm.).

Neck Bands

Colored neck bands, ball chain necklaces and cable ties should never be used to mark captive insectivorous bats. Some species react adversely to these collars, and they can result in death in captive situations if a bat becomes caught on a roosting surface and unable to free itself. Food can also accumulate under neck bands and cause irritation and infection. Phyllostomid bats have been observed trying to manipulate the ball chain necklaces until they cause skin abrasions, which often became infected. Even with the necklaces fitting tightly enough to prevent them from slipping over the head, these bats had the ability to pull the chain over their heads and choke themselves. Cable ties have been known to cause severe injury when used on bats, as the bats can easily tighten the cables by chewing on them.

Body Piercing

Body piercing as a means of marking captive bats has been attempted in the past. This method utilized human body jewelry, which was placed subdermally between the shoulder blades of captive *A. pallidus, T. brasiliensis, A. jamaicensis, E. fuscus* and *D. youngi* (Barnard, 2004). This is an unacceptable marking method for any species of bat due to the invasiveness of the procedure, initial pain and subsequent discomfort, high risk of infection, and uncertain long-term effects on the health of the bats.

Toe Clipping and Ear Notching

Toe clipping and ear notching are not recommended as a means of marking bats. Further, bats use their toes for grooming and roosting, and the pinnae of the ear are critical for acoustic orientation and prey location. This is an unacceptable marking method due to the invasiveness of the procedure, pain and subsequent discomfort, high risk of infection, and uncertain long-term effects on the health of the bats.

Freeze Branding

Freeze branding attempts have been unsuccessful due to the small size of microbats and their highly irregular surface relative to the size of typical marking. The brands take two months to appear and can result in loss of melanocytes only at random points, inadequate contact and consequently no effects at other points, and freezing at both dermal and subdermal tissue at other points. This is an unacceptable marking method due to the invasiveness of the procedure, pain and subsequent discomfort, and high risk of infection.

PIT Tags

Passive integrated transponder (PIT) tags are microchips that are implanted subdermally and can be scanned to identify individual bats. They have been used with relative success but are considered less preferable than the methods previously listed due to their propensity to cause scarring and loss of fur (L. Sturges, pers. comm). The size of needle used to implant the microchip may necessitate local anesthesia during the application process. Further, veterinary review of procedures should be undertaken as the large size of the implantation needle presents a significant route of infection. Due to the relative size, both the chips and implant devices can cause pain and long-term damage, and chips may migrate within the body over time (Figure 3-9).

Figure 3-9. A PIT tagged big brown bat, pregnant with twins. The tag may have migrated or the growth of the fetuses may have caused shifting of the implant. *E. fuscus. Photo from Fort Collins Bat Project, USGS*.

Acceptable Marking Methods

Tattoos

Tattooing as a method of marking bats was used as early as 1932 (Griffin, 1934). Bat World Sanctuary has been tattooing the ears of hand-raised Brazilian free-tailed bats (*T. brasiliensis*) since 1995, using a modified small animal tattoo gun. The orphaned pups are recovered from a wild colony at Bat World's wild sanctuary and are subsequently released into this location after being hand-reared.

Figure 3-10. A green tattoo on the ear of a free-tailed bat. (*T. brasiliensis*). *Photo by A. Lollar.*

Each year since 1995, tattooed juvenile pups have been recovered one to three weeks post release. In 2004, a tattooed male was found eight miles from the release site five days after being released (Figure 3-10); in 2006, a tattooed female was found approximately 400 miles away five years after release; and in 2009, microscopic examination revealed insect parts in the guano of a tattooed juvenile released five days earlier. In 2013, a lactating tattooed female was recovered at Bat World's wild sanctuary. This female had been tattooed 4 years earlier and released back into her original colony, where she apparently migrated back and forth to Mexico and subsequently went on to reproduce. In August of 2015, a tattooed female was recovered in Mineral Wells, Texas after being found grounded in a park. On examination a faded tattoo was discovered on her ear that indicated she had been hand-raised and released back to the wild 13 years prior.

Fur Clipping

Fur clipping is an appropriate method for marking bats in captivity. Depending on the size of the bat, several small areas of fur may be clipped close to the body using small scissors. Fur clipping can last as long as six months, depending on the season and molting periods (see Figure 4-7 C). It is important to note that clipped areas of fur are not easily detected on bats with lighter colored fur, such as *A. pallidus*. The author uses the non-toxic paint method described on the following page, when marking bats with light colored fur.

Figure 3-11. Virginia Big-eared Bat (*Corynorhinus townsendii virginianus*) with non-toxic acrylic paint applied to the inside of the ear for captive identification. *Photo by R. Sturges.*

Non-Toxic Paints

Bats can safely be marked with a non-toxic marker such as an All Weather Paint Stick® (a waxy non-toxic marker typically used for livestock). The paint stick should be mashed until softened and applied with a cotton swab. Alternately, non-toxic acrylic artist paints can be applied to the inside of the ear, the forearm and other locations for short term identification. Bats may groom the paint off in a matter of days, so reapplication is often necessary. Applying marks to the inside of the ear is recommended as this area is more difficult for the bat to groom and the mark will last longer (Figure 3-11). This method has been used successfully for many years in Bat World Sanctuary's rehabilitation facility, where as many as 100 adults and orphaned pups are housed together at one time. Because of the wide variety of colors available, we use a color chart to distinguish individual bats according to their needs, often combining colors when necessary (e.g., marking one ear a certain color and marking the opposite ear a different color). The rump of the bat can also be marked when three or more colors need to be applied. Our color chart includes the following:

Pink = Antibiotics
Yellow = New arrival
Orange = Bat is being hand-fed a complete soft food diet
White & Orange = Bat is being transitioned from milk formula to a soft food diet
Gold = Bat is being trained to eat mealworms
Green = Scheduled for release
Blue = Handled by a particular caretaker only

Using the color chart above, the caretaker can easily identify that a bat with one yellow ear and one orange ear is a new bat that is being hand-fed blended mealworms. Because this paint is easy to remove with warm water, the colors can be altered when needed (i.e., when this bat is being trained to eat mealworms, the yellow mark can be removed and the orange mark can be replaced with gold).

Ketchum Animal Tattoo Ink - Green

This nontoxic animal tattoo ink paste contains a concentrated pigment to ensure a permanent mark when used in tattoos. It is also long lasting when simply applied with a cotton swab to various parts of a bat's body for identification. A thin coating of the paste can last up to one week when applied to the inside of an ear. It is important to purchase the green paste as the other varieties and colors typically wear off within a day.

Natural Markings

Bats can often be identified using natural markings, and this method should be used whenever possible. Natural marks include healed injuries and scarring, white patches of fur, a lopsided or irregular ear, disfigured or scarred lips, and missing toes and thumbs. Distinguishing marks should be noted upon initial exam and thereafter used to identify a particular bat.

Additionally, most bats have distinct facial characteristics, allowing for individual identification (Figure 3-13). Looking closely, it is easy to see that the ears of the bat on the left are spaced farther apart at the base than the bat on the right. The bat on the left has larger eyes, a larger nose, and the ears are held slightly higher, completely exposing the eyes. The bat on the right has a wider muzzle with ears that naturally lay lower and partially shield the very top of the eye. Familiarizing yourself with each bat's facial characteristics will give you the ability to spot the differences of individual bats at a glance.

Figure 3-13. Free-tailed bats with different facial characteristics. *T. brasiliensis. Photo by A. Lollar.*

Daily Examinations

Insectivorous bats can contract a variety of ailments, and if treatment is not initiated immediately, some of these conditions can result in death within 24 hours. Therefore, it is imperative that bats be given daily physical examinations the entire time they are in captivity. Daily examinations allow the detection of potentially serious conditions in early stages, thereby increasing the likelihood of successful treatment. Daily exams should be given at approximately the same time each day. Examine the eyes, respiration, and condition of the fur. Palpate the abdomen for signs of anorexia, and take note of the bat's behavior, including the way it does or doesn't grip the roosting surface (or your hand) with its toes and thumbs. Look at the bat's mouth and toes for early signs of dental issues which include salivation, a dirty muzzle or dirty toes (see Illness and Injury). Any change in its usual condition, grooming habits, or demeanor may indicate early stages of disease. Once the handler is familiar with an individual bat's traits and mannerisms, visual examinations will suffice, particularly for foliage bats, self-feeding bats, and bats in hibernation.

Weighing bats can be advantageous under certain circumstances, such as artificially hibernating bats and calculating correct doses of medications. However, it is never necessary to weigh bats on a daily basis. In fact, doing so causes undue stress for the bat and can give the handler a false sense of security. Daily examinations allow a keeper to observe conditions that cannot be detected by weighing alone. For example, a bat with an abscessed tooth may be able to chew despite the infection and may not lose weight until the infection becomes systemic, at which point it may be too late to treat the infection, and the bat consequently dies.

The Figure on the following page provides an example of a captive colony daily checklist. A description column for individual identification is listed beside each bat's name. In cases where the bat has no distinguishing or natural marks, the fur is clipped in specific areas (see Marking Captive Bats for Identification).

An abbreviation of the species is also given beside each bat's name. Although a column can be added to list the sex of each bat, in this particular example the name alone is sufficient to identify the sex. When large numbers of bats are cared for it is advisable to also list the total number of each species in a separate column. If more than one caretaker is involved, a column should be included to write the initials of the person caring for the bats on that particular day. This chart contains only a small number of bats, so a column is not shown for the overall number of bats. Bats that are unable to eat on their own must be hand-fed twice daily - in the morning and again in the evening - therefore, an AM and a PM column is listed for each day.

The key in Figure 3-14 provides insight into the care of each bat at a glance. The yellow rows indicate the bats that self-feed from dishes on their own. The "X" in the AM and PM columns indicate these bats have had a twice daily check and appeared in good health at that time. However, notice the "squiggle" mark in the yellow row after the bat named Alexis. On Monday morning this self-feeding bat was found with an empty stomach. Closer examination revealed she had developed a gum infection which apparently made it too painful for her to self-feed the previous night. Rather than create a new chart, the yellow row after Alexis' name has been squiggled through to signify that she can no longer self-feed. A note is also written in the "special notes" section regarding the additional care this bat will from then on require. The date her medication is started, as well as the type of medication she is to receive, is listed in the appropriate columns. This bat will be given a pink mark on her ear indicating she is on antibiotics. Additionally, she will be hand-fed and treated with antibiotics twice daily, so an "X" will be placed in the AM and PM columns indicating she has been hand-fed and received medication on that day. Also notice the chart contains backward slashes in the AM and PM columns after the bat named Nigel, who is being trained to eat mealworms from a dish. Using the key, it is quickly apparent that Nigel is learning to self-feed. On both Sunday morning and Sunday evening, Nigel only ate half his usual amount during his training session. He refused to eat on Monday morning and was found with a full abdomen on Tuesday morning. If this pattern continues throughout the remainder of the week, Nigel's column will be filled in with yellow.

Figure 3-14. Example of a daily checklist for a captive colony.

CAPTIVE COLONY CHECKLIST

NAME	DESCRIPTION	Date	Med	Sun AM	Sun PM	Mon AM	Mon PM	Tues AM	Tues PM	Wed AM	Wed PM	Thu AM	Thu PM	Fri AM	Fri PM	Sat AM	Sat PM
Lorenzo (Li)				M	M	M	M	M									
Bruno (Tb)	White spot, left shoulder																
Charlie (Tb)	Missing left thumb claw			X	X	X	X	X									
Nigel (Tb)	Healed R radial fracture @elbow			\	\	R	\	F									
Erica (Tb)	Missing 1/2 toe, right foot			M	M	M	M	M									
Alexis (Tb)	Fur clipped between ears	5/18	Clav	X	X	X	X	X									
Ruth (Tb)	Fur clipped, lower back-center			X	X	X	X	X									
George (Ef)	Fur clipped, right hip			X	X	X	X	X									
Harry (Ef)	Fur clipped, right shoulder			X	X	X	X	X									
Victoria (Nh)	Smallest, juvenile																
Anastasia (Nh)	Left ear slightly larger than right			X	X	X	X	X									
Marie (Nh)	Fur clipped between ears			X	X	X	X	X									
Scarlett (Nh)	Largest, adult			X	X	X	X	X									
				X	X	X	X	X									

Species
Nycticeius Humeralis (Nh) – Evening Bat
Lasiurus Borealis (Lb) – Red Bat
Lasiurus Ega (Le) – S. Yellow Bat
Tadarida Brasiliensis (Tb) – Mexican Freetail
Lasiurus Intermedius (Li) – N. Yellow Bat
Lasiurus Cinereus (Lc) - Hoary Bat
Pipistrellus Subflavus (Ps) – Eastern Pip
Eptesicus fuscus (Ef) – Big Brown Bat
Myotis lucifugus (Ml) – Little Brown Bat
Yellow = Self feeding
X = Daily check, bat okay
\ = Half fed by hand (refused to eat more)
F = Found full (probably self fed)
M = Hand fed mealworms
R = Refused
Squiggle = previous self feeding bat now being hand fed

SPECIAL NOTES

Mealworm training: Nigel and Erica

Alexis found empty 5/18. Obvious gum infection. Started Clavamox BID. Hand-feeding blended food until infection clears and she can self-feed.

Introducing New Bats

Most adult species of insectivorous bats accept new adult roostmates with little to no consequence. Regardless of the species, newly arriving crevice bats often adjust more quickly to captivity when housed with an existing colony of captive bats. See Roosting and Hibernating Patterns and Behavior for additional information on species that roost together.

Figure 3-14. A free-tailed bat investigating a new roostmate located inside the Bat Hut. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

Hand-raised juvenile bats that are not weaned should **never** be placed with an existing colony of adult bats. *E. fuscus* females have been reported to gang up, attack and kill a newly introduced, hand-reared juvenile *E. fuscus* (L. Burt, pers. comm.). When uncertain about bat's behavior toward a new roostmate, particularly with smaller species or hand-reared pups that are being returned to their colony, a Bat Hut can serve as an "introductory" enclosure. The Bat Hut, with the new bat(s) inside, should be placed into the roosting area of the existing colony at night when bats are awake and most active (Figure 3-14). Leaving the Bat Hut in place overnight is usually a sufficient time period to allow bats to acclimate.

Chapter Four
Enrichment and Security

The primary problems captive animals face are fear and boredom. Both stimulation and emotional security can be provided for captive bats by creating an environment that is similar to their natural habitat. To understand the requirements of a particular species, it is crucial to know the conditions the bats choose as natural roosts in the wild and mimic those conditions accordingly. Continual regrouping should not be performed as a colony will no be able to stabilize. Additionally, colony group size must be appropriate for the species; enclosure space should be sufficient for maintaining any distance individual bats may prefer from other roostmates; and feeding and roosting areas must remain consistent.

The psychological needs of bats in captivity, both temporary and permanent, must be met to ensure overall health and normal behavior. The American Veterinary Medical Association (AVMA) defines animal welfare as "all aspects of animal well-being, including proper housing, management, nutrition, disease prevention and treatment, responsible care, humane handling, and when necessary, humane euthanasia. It is important to recognize that psychological well-being is a significant factor in disease prevention, as behavioral changes and deterioration in physical condition can occur when psychological needs are neglected."

Flighted and Non-flighted Bats

Flying is an important aspect of the psychological and physical health of fully flighted captive bats, and of critical importance if those bats are intended for release. It is therefore inappropriate to house flighted bats in enclosures that do not allow them to fly. Flighted pregnant females that are allowed unrestricted flight will experience fewer complications during the birthing process. Bats incapable of flight, such as bats that are permanently disabled due to injury, can also lead enriched lives in captivity and will often reproduce, providing they receive stimulation in the form of roostmates and a diverse environment.

CREVICE BATS

The social needs of bats in captivity are just as important as environmental factors such as heating, lighting and the enclosure they are house in. Many crevice-dwelling bats are gregarious and colonial. The most valuable thing that can be done to enrich the life of a colonial bat in captivity is to provide it with roostmates. Crevice bats should not be housed alone unless essential. In circumstances where crevice bats must be housed alone, providing enrichment and simulated natural habitat will greatly enhance the emotional stability of the bat.

Deprivation of companionship in colonial bats has been known to result in symptoms that include anorexia, obesity, vomiting, hair loss, enclosure chewing, and death. Examples include an adult big brown (*E. fuscus*) that was utilized as an educational animal in a zoo for eight years. Other than a female big brown housed in an adjacent enclosure, this male big brown lived in isolation his entire life. Shortly after the female died, the male bat's physical condition began to deteriorate. He stopped self-feeding, became anorexic, and began to lose fur. The bat was ultimately transferred to a facility that housed non-releasable *E. fuscus*, where he immediately clustered with three big brown females upon introduction. He accepted blended food later the same evening and was again self-feeding the following day. Another example is that of a Brazilian free-tailed bat (*T. brasiliensis*) which was housed alone at a wildlife center where he was being used for outreach educational programs. The bat was able to fly but was housed in a small enclosure that would not allow flight. After six months in captivity, he developed what appeared to be gastrointestinal problems and would vomit profusely after every meal. The bat was fed a diet of mealworms supplemented with Vionate®, a vitamin and mineral powder sprinkled on the worms. After suffering from extreme weight loss, but not finding any physical cause, he was transferred to our facility where he was introduced to a small colony of free-tailed bats that housed in a spacious, simulated

natural habitat flight enclosure. Within minutes the bat was tightly wedged into a cluster of his own species. No further vomiting was observed after arrival, even though he received mealworms which also were sprinkled with Vionate® powder. Johnson (1997) states that individual pallid bats housed with a colony will change their behavior when housed separately. A pallid bat housed in the "Bat Lab" at New York University appeared more irritable and likely to bite after being separated for a few days; another appeared more lethargic and inactive after he was housed alone.

Figure 4-1. A big brown (*E. fuscus*), a free-tailed bat (*T. brasiliensis*), and a cave bat (*M. velifer*) sharing a roost. *Bat World facility*. *Photo by A Lollar.*

Roostmates

Colonial, crevice-dwelling bats should always be provided with roost mates, even though they may not always roost together. Ideally, roostmates should be of the same species, although other species will suffice when individuals of the same species are not available (Figure 4-1). It is not humane to force a colonial bat to lead a solitary captive life. Housing a lone colonial bat in an enclosure that is placed against another enclosure housing a colonial bat is not sufficient. Colonial bats should be housed together in the same enclosure.

The author has enclosed the following species together, without incident, when flight areas were available: *A. pallidus, E. fuscus, M. lucifugus, M. velifer, T. brasiliensis, N. humeralis, E. perotis, N. macrotis, N. femorasaccus and L. noctivagans.* Although pallid bats (*A. pallidus*) have been reported to eat smaller bats in captivity (Engler, 1943), Lollar housed a male with a colony of Brazilian free-tailed bats (*T. brasiliensis*) without evidence of carnivory. Brazilian free-tailed pups were born into this colony and were found on more than one occasion nestled under the wing of the pallid bat. This colony was provided with an unlimited supply of mealworms each evening. Lack of an abundant food supply might be responsible for early reports of carnivory, behavior the author has not observed in any insectivorous species cared for over the past three decades.

Pipistrelles (P. *subflavus, P. hesperus*) have been housed without incident with Brazilian free-tails (*T. brasiliensis*) and evening bats (*N. humeralis*). Evening bats are much "fussier" bats than the Brazilian free-tailed bats (*T. brasiliensis*), however, and will sometimes make loud, complaining screeches when annoyed. It is not recommended that pipistrelles be enclosured with any of the larger crevice-dwelling species such as big browns

(*E. fuscus*), pallid bats (*A. pallidus*), mastiff bats (*Eumops*), big free-tailed bats (*Nyctinomops macrotis*), or the California leaf-nosed bat (*Macrotis californicus*). Although big brown bats (*E. fuscus*), pallid bats (*A. pallidus*), mastiff bats (genus: *Eumops*), and big free-tailed bats (*N. macrotis*) are typically gentle in captivity, it is not usually a good idea to house the smallest bats with the larger ones.

There are detailed accounts of several mammalian species (e.g., *Mammalian Species Accounts*) written by different authors and published by the American Society of Mammalogists. These accounts include information about distribution, ecology, and behavior. Information about roosting patterns will be of value. For example, some crevice-dwellers cluster together in tight groups while roosting. Others roost somewhat separated from one another.

Mating may occur when males and females are housed together, particularly over long periods of time. Mating activity can include aggression and territorial defense. Males frequently sustain bites or other injuries during aggressive interactions. Sexually active males housed with females may also react aggressively toward (i.e., bite) the caretaker. Therefore, it may be preferable to segregate males and females. Neutering of males is another option for permanent captives (see Orchiectomy).

Table 4
Crevice Bat Roosting Patterns

Number	Species	Have been found in roosts with species listed in number:
Family Mormoopidae		
1	*Mormoops megalophylla* (Peters' ghost-faced bat)	26, 38
Family Phyllostomidae		
2	*Artibeus jamaicensis* (Jamaican fruit-eating bat)	
3	*Choeronycteris Mexicana* (Mexican long-tongued bat)	9
4	*Leptonycteris yerbabuenae* (Lesser long-nosed bat)	9
5	*Leptonycteris nivalis* (Long-nosed bat)	9
6	*Macrotus californicus* (California leaf-nosed bat)	38
Family Vespertilionidae		
7	*Antrozous pallidus* (Pallid bat)	9, 11, 16, 25, 28, 30, 38
8	*Corynorhinus rafinesquii* (Rafinesque's big-eared bat)	9, 31
9	*Corynorhinus townsendii* (Townsend's big-eared bat)	3, 5, 7, 8, 12, 25, 26, 38
10	*Euderma maculatum* (Spotted bat)	
11	*Eptesicus fuscus* (Big Brown bat)	1, 7, 22, 23, 26, 28, 38
12	*Idionycteris phyllotis* (Lappet-browed bat)	9, 25
13	*Lasionycteris noctivagans* (Silver-haired bat)	23, 31

14	*Myotis auriculus* (Southwestern myotis)	
15	*Myotis austroriparius* (Southeastern myotis)	22, 38
16	*Myotis californicus* (California myotis)	7
17	*Myotis ciliolabrum* (Western small-footed Myotis)	
18	*Myotis evotis* (Long-eared myotis)	
19	*Myotis grisescens* (Gray myotis)	24
20	*Myotis keenii* (Keen's myotis)	
21	*Myotis leibii* (Small-footed myotis)	
22	*Myotis lucifugus* (Little brown bat)	11, 15, 23, 26, 28
23	*Myotis septentrionalis* (Eastern or Northern Long-eared myotis)	11, 13, 22, 31
24	*Myotis sodalis* (Indiana myotis)	19
25	*Myotis thysanodes* (Fringed myotis)	7, 9, 12, 26
26	*Myotis velifer* (Cave myotis)	1, 9, 11, 29, 26, 28, 38
27	*Myotis volans* (Long-legged myotis)	
28	*Myotis yumanensis* (Yuma myotis)	7, 11, 22, 33, 45
29	*Nycticeius humeralis* (Evening bat)	45
30	*Parastrellus hesperus* (Canyon bat)	7
31	*Perimyotis subflavus* (Tri-colored bat)	8, 13, 23
Family Molossidae		
32	*Eumops floridanus* (Florida bonnetted bat)	
33	*Eumops perotis* (Western mastiff bat)	
34	*Eumops underwoodi* (Underwood's mastiff bat)	
35	*Molossus molossus* (Pallas' mastiff bat)	
36	*Nyctinomops femorosaccus* (Pocketed free-tailed bat)	
37	*Nyctinomops macrotis* (Big free-tailed bat)	
38	*Tadarida brasiliensis* (Brazilian free-tailed bat)	1, 6, 7, 11, 15, 22, 26, 28, 29

Furniture

Items intended for roosting and enrichment (i.e., furniture) should be made of easily cleaned materials appropriate for the species. Roosting pouches, reptile rocks and towels made of non-snagging materials all provide enrichment as well as hiding spots. Enrichment items should be clean and free from sharp edges or small holes where fingers, wrists and toes may become trapped. They should contain an opening large enough to allow the handler to easily reach inside and extract a bat if needed. It is important to take note of the spot that the bats have chosen to use as a day roost, as that roost needs to remain the same both in object and location. When this roosting spot becomes soiled, a duplicate should be available in order to mimic the preferred roosting item as closely as possible. Design the interior of an enclosure to accommodate the individual needs of a captive bat. For example, if a colony of non-flighted bats contains one or more amputees, then fill the enclosure with a variety of roosting pouches allow these bats to nimbly move around the entire enclosure with little difficulty.

Roosting Items for Crevice Bats

Although some species, such as Corynorhinus, prefer to roost openly in both roosting and flight enclosures, most crevice-dwellers will require a choice of several areas within the roosting enclosure where they can hide in the dark folds of a soft cloth. Fabric roosting pouches (Figure 4-2A) provide crevices for bats to hide and roost without risking injury. The dark crevices simulate a natural environment. Pouches can be attached to the inside of roosting enclosures as described in Temporary Housing. They can also be placed flat inside bat huts and on roosting shelves.

Figure 4-2. A: A roosting pouch made of denim. **B:** Three free-tailed bats hanging inside a roosting pouch (*T. brasiliensis).* **C:** A big brown bat in a roosting pouch (*E. fuscus)*. **D:** A free-tailed bat enjoying hand-fed worms while sitting in a roosting pouch (T. brasiliensis). *Bat World facility. Photos by A. Lollar.*

Pet Tech Magnaturals large hideaway (Figure 4-3A) is made of lightweight foam polymer and measures 13" x 7.5" x 5.75". This piece has high-powered magnets embedded in the resin (Figure 4-4B). Roosting pouches do not fit inside this item so it is best used for enrichment purposes only (Figure 4-3c).

Reptile rocks made out of plastic polymer make excellent roosts for molossid bats (Figure 4-3D & E). The rocks in these photos are mounted inside a galvanized metal enclosure as described in Permanent Housing. A fabric roosting pouch should be placed inside larger reptile rocks for cushioning and warmth, as well as ease of gathering bats from within.

Figure 4-3. A & B: A Pet Tech Magnaturals large hideaway. **C:** A big brown bat sitting in a hideaway mounted on the ceiling of a simulated cave (*E. fuscus*). D: A big free-tailed bat roosting in a roosting pouch placed inside a reptile rock made of plastic polymer. (*N. Macrotis*) **E:** A mastiff bat peers out of her roosting rock which is mounted with the opening facing the bottom. *(E. perotis). Bat World facility. Photos by A. Lollar.*

Cleaning

Foam and plastic polymer rocks should be cleaned as needed by scrubbing the entire rock using a small brush dipped into a 10% bleach solution along with a small amount of dish soap, then rinsed well. The rocks should be dried thoroughly before use. Alternately, these rocks can also be placed into a facility dishwasher and cleaned using the regular cycle intended for dishes. Pouches must be turned inside out and washed in the washing machine using unscented detergent. Dry pouches in the dryer inside out, turning right side out mid way through the dryer cycle to ensure the material is dried throughout.

Additional Roosting Items for Crevice Bats

Products made for small birds, ferrets and other animals sometimes make excellent roosting and enrichment items for bats (Figure 4-9). The items below are examples of items that require minimal modifications for use with insectivorous bats. Some come with ties attached to the top that enable them to be hung from the enclosure ceiling or enclosure frame.

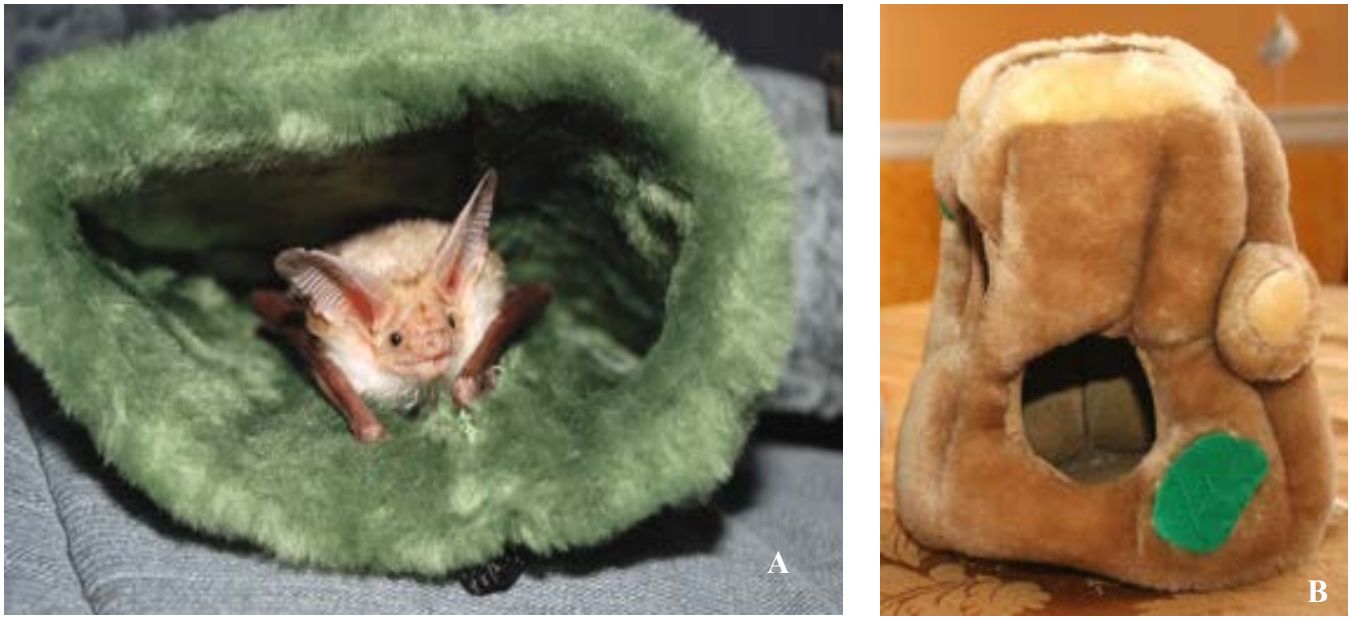
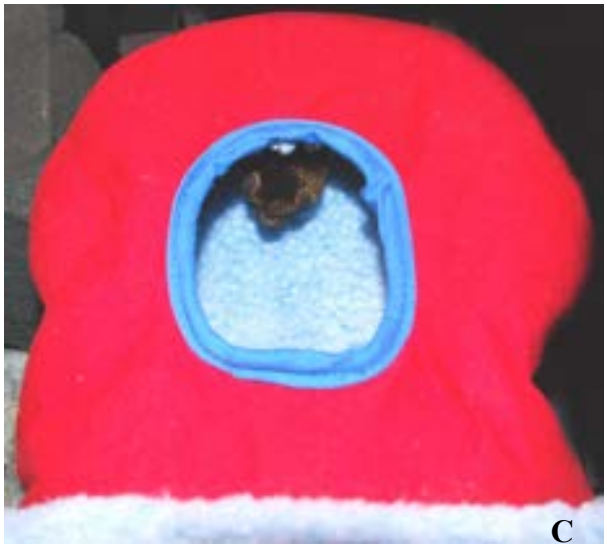


Figure 4-6. A: A "Happy Hut™" made for small birds. Measures 1.5" x 7" x 4.5". Pallid bat (*A. pallidus*). *Photo by A. Lollar.* **B:** "Hide a Squirrel™" dog toy. (Comes with three squirrel toys inside.) The empty plush tree trunk makes an excellent roost for tree bats or enrichment for crevice bats. Measures 6.5" x 7.5": x 6.5". *Photo by L. Sturges.*



C: A "Snuggle Sack™" made for small birds. Measures 8" x 6" x 9". Big brown bat (*E. fuscus*). Bat *World facility. Photos by A. Lollar.*

TREE BATS

Roostmates

Adult tree bat species received from the wild should always be housed separately. An exception to this rule are females received with nursing pups. Many of the tree-roosting species have two to five pups in each litter. They stay closely clustered during infancy, clinging to one another as they hang from the branches of a tree or other foliage where the mother places them when she leaves to feed at night. Orphans will cluster together in a similar manner in captivity and fare better when housed together (Figure 4-7A and B).

Figure 4-7. A: Orphaned red bat pups. (*L. borealis*). *Bat World MidCities facility. Photo by K. Rugroden*

A mother and her pup(s) should also be housed together until the pups have been weaned and are being hand-fed. At that time, the mother should be separated from the pups, the males in particular, as they begin interacting aggressively as they mature. It is best if pups are allowed to remain together until they are about three months of age, and then the sexes should be separated. This is particularly important for males. While female siblings sometimes continue to roost side by side, even grooming one another for as long as a year, males tend to roost somewhat separated from one another in the same enclosure and commonly make warning sounds (i.e., clicking) if another bat moves within 3" to 6" of them. (Females occasionally demonstrate the same behavior.) It may be best if bats demonstrating this behavior are enclosed separately from others.

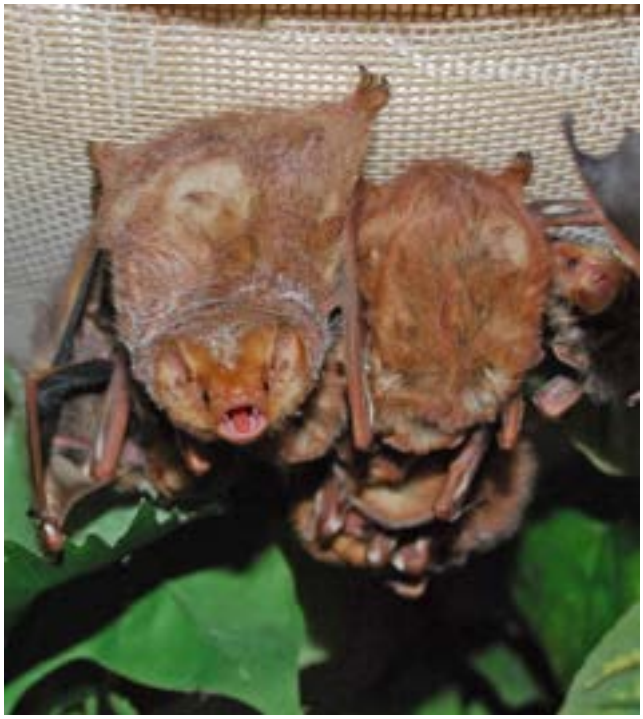


Figure 4-7. B: Juvenile red bat pups (*L. borealis*) on the ceiling of an enclosure. *L. borealis. Bat World facility.*

Yellow bats (*L. ega, L. intermedius,* and *L. xanthinus*) and hoary bats (*L. cinereus*) can be maintained in the same manner as red bats (*L. borealis*).

Although the author has found hoary bats (*L. cinereus*) to be gentle and tolerant of other species in captivity, they have been known to pursue and kill pipistrelles in the wild. Because of this, and the fact that lasiurine bats can be somewhat temperamental (*L. borealis* and *L. seminolus* in particular), it is not generally recommended that other species be housed with any of the tree-roosting species.

Several hand-raised tree bats have remained together in a full-sized flight enclosure for years without incident at Bat World Sanctuary, although artificial branches and artificial foliage secured to the enclosure ceiling separate the preferred roosting spots of these bats by several feet.

Furniture

Environmental enrichment can be provided for solitary bats by providing items in their enclosure that provide visual and tactile stimulation such as artificial foliage as well as natural leaves and small branches from trees (Figure 4-11A). Items should be secured to the enclosure ceiling with zip ties which are tied from the outside. Trim and smooth sharp branches or wires which may protrude from artificial plants before attaching these items to the enclosure. Rough tree bark and branches or thick grape vines, including some as large as 1" in diameter, are good choices (Use only branches with roughened, not smooth, surfaces.)

Withered leaves should be removed as they crumble easily and litter enclosures, however, dry branches can be left in enclosures and may contribute to foot health and aid in naturally trimming the toe claws. Some tree bats prefer to roost in small wicker baskets that have been hung upside down from the enclosure ceiling.

Tree bats are prone to abrasions on thumbs, forearms, and toes in captivity. Enclosures such as Reptariums are convenient for the handler but seem particularly hard on the feet and thumbs of tree bats and should therefore be lined with Rubbermaid®, Duck or Con-Tact® weave drawer liner (Figure 4-8B). Breeze enclosures and similar type soft mesh crates constructed with plastic weave are not as abrasive to the feet and thumbs of tree bats and do not require being lined. Camouflage flannel fabric can also be used to provide roosting spots for tree bats (Figure 4-8C) and is helpful for bats that are healing from injuries or those who have foot and toe problems and thus require a soft surface on which to hang.

Figure 4-8. A: Red bat (*L. borealis*) roosting in fall-colored leaves. *Bat Conservation & Rescue of Virginia*. Photo by L. Sturges. **B:** A hoary bat (*L. cinerus*) roosting against a wall of the enclosure lined with Rubbermaid™ weave shelf liner. **C:** Silk foliage and camouflage flannel fabric inside a tree bats enclosure. *Photos by D. Hyatt.*

Butterfly enclosures are good choices for temporarily housing tree species. A section of flannel or fleece cloth, or a surgical towel can be attached to the ceiling of the enclosure to provide enrichment and more options from which to hang (Figure 4-9A).

Alternately, cube enclosures made for butterflies (Figure 4-9B) provide excellent temporary housing for tree bats when limited movement is preferred such as bats healing from injuries, mother bats with pups, and panicked bats prone to thrashing and injuring themselves on surfaces. In these cases, it is advisable to add enrichment items to the enclosure which will both help to calm the bat as well as restrict movement, such as foam logs or "hide-a-squirrel" dog toys.

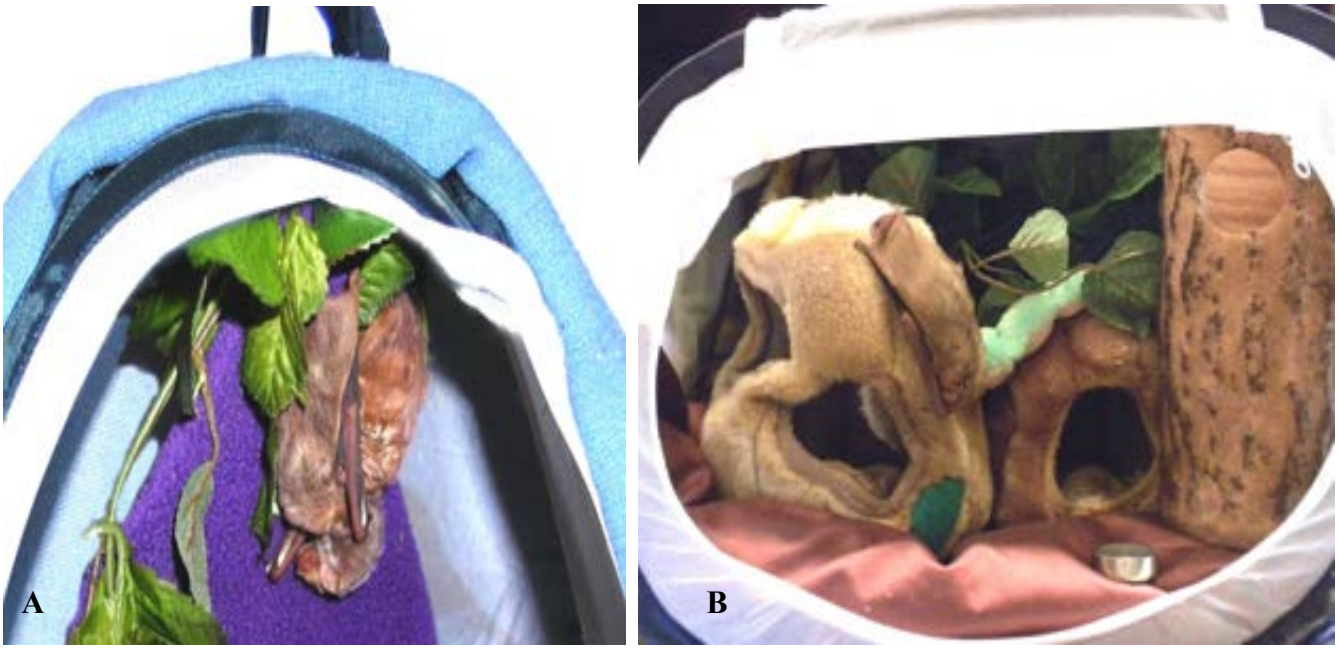


Figure 4-9. A: A red bat mother with her juvenile pups (*L. borealis*) hanging in a butterfly enclosure. *Bat World MidCities facility. Photo by K. Rugroden.* **B:** A butterfly cube enclosure filled with enrichment items to restrict the movement of an injured yellow bat. *L. intermedius*. *Photo by D. Hyatt.*

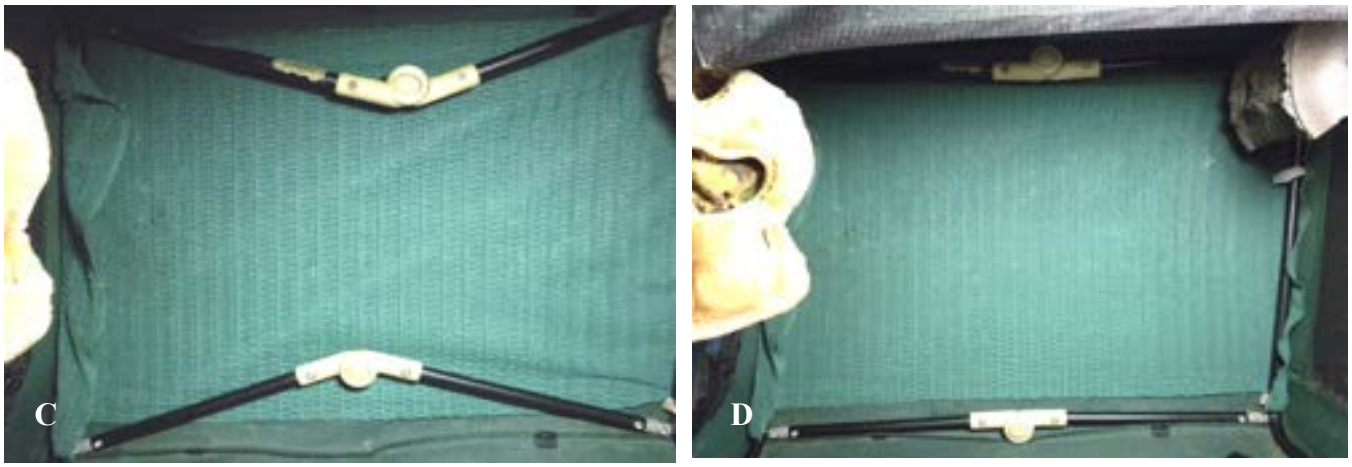


Figure 4-9. C and D: Rubbermaid weave shelve liner being inserted into the framework of a crate. The bars used to stabilize the crate help to hold the green mesh in place. *Photo by D. Hyatt.*

CHAPTER FIVE

DISHES

Mealworm Dishes

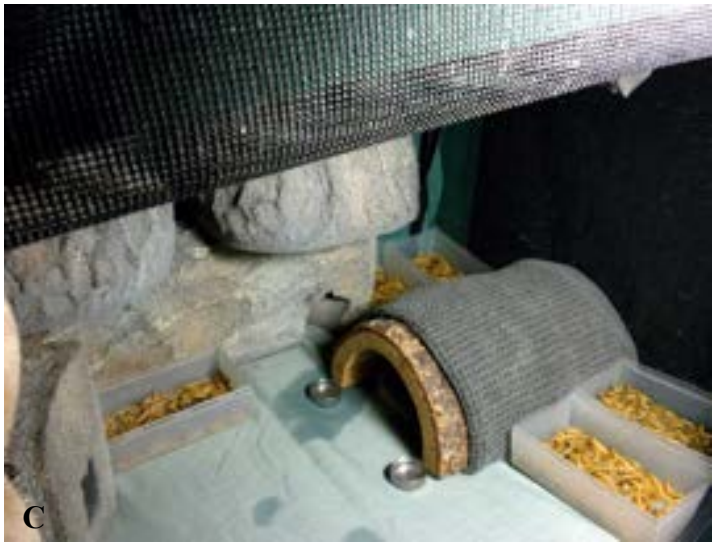
A wide assortment of dishes can be used for bats that self-feed from dishes. Dishes should be deep enough to allow the bottom to be completely covered with an ample supply of mealworms but shallow enough to allow bats to easily climb in and out of the dish. Dishes 1" to 2" deep work best for most species of insectivorous bats. A minimum of four 5" x 2"x 2" deep mealworm dishes should be provided per every ten bats. It is important to remember that mealworms can easily climb on roughened surfaces, so use dishes with a smooth surface to prevent mealworms from escaping.

CREVICE BATS

One side of the food dish should be placed against a surface on which the bat can cling. Placing trays against the walls of the enclosure allows a bat to crawl down the side of the enclosure and feed from a tray while still hanging upside down. Some bats choose to sit directly inside the dish of mealworms as they feed. Dishes placed against a climbable surface enable these bats to easily climb out when they are ready to leave the dish. For an added sense of security, the dish can be placed directly beneath a roosting cloth or pouch so shy bats can grab a worm and then crawl back into a hiding area to eat (Figure 5-1D). Do not place worms directly under roosting areas as worms may be contaminated with urine and feces. All dishes and water containers should be emptied and washed in an antibacterial detergent daily. Rinse thoroughly with hot water.

Figure 5-1. A: A Magnaturals Mushroom Ledge holds two small dishes of mealworms. The dish is magnetized and held to the enclosure wall with magnets which are attached to the outside of the enclosure. The ledge sits on top of a foam log to prevent it from tipping forward and spilling the mealworms. *Photos by A. Lollar*.

Figure 5-1. C: An enclosure shared by 15 self-feeding, non-flighted free-tailed bats (*T brasiliensis*). Plastic containers measuring 5" x 2.5" x 2" deep provide ample opportunity for all the bats to self-feed nightly. **D:** The dishes are placed with one side against a surface that allows the bat to easily climb in and out of the dish. *Bat World facility. Photos by D. Hyatt.*



A Multipet Tree House or similar alternative is excellent for both training bats to self-feed as well as providing a secure place for shy bats to self-feed (Figure 5-2A). The Tree House measures 6.5" high and 5" in diameter. A glass crock measuring 3.5" x 1.75" can be placed into the bottom to hold mealworms. This item can be washed in the washing machine but should be air dried.

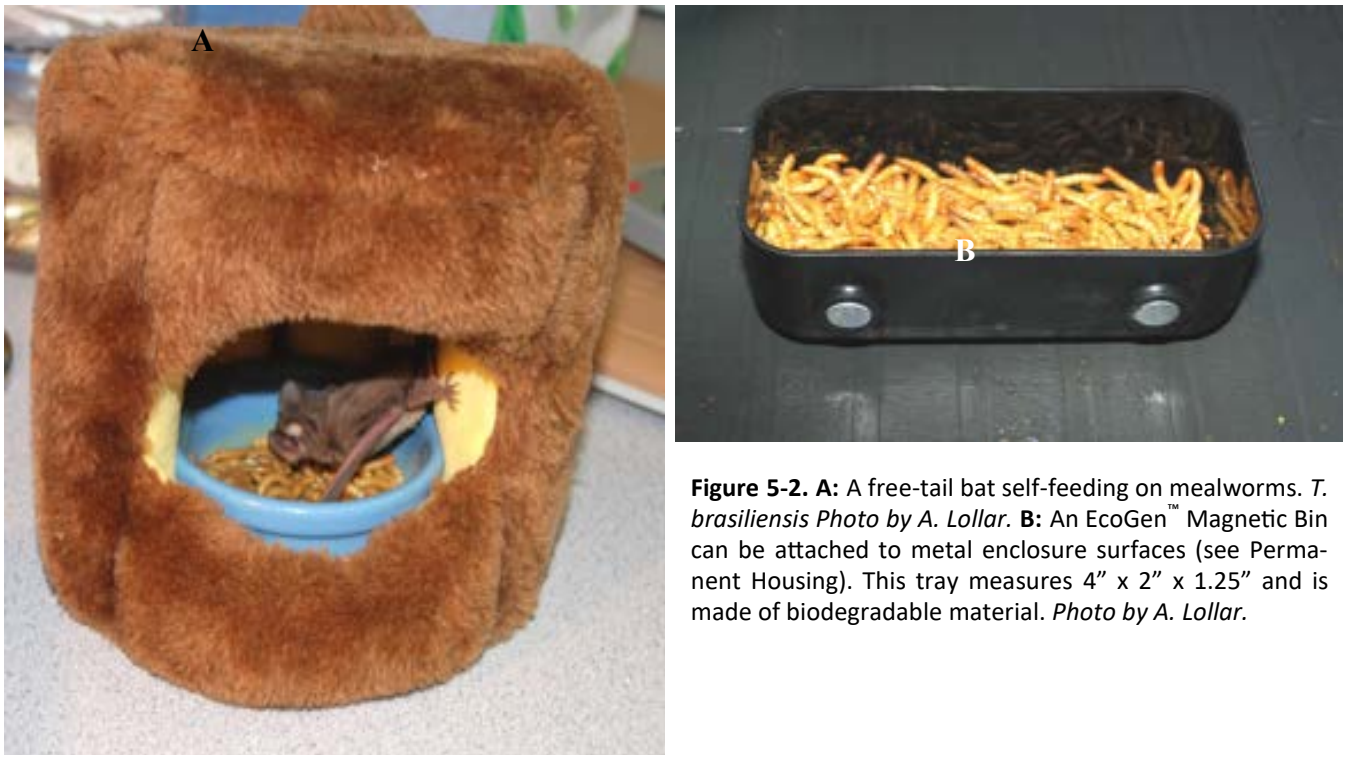


Figure 5-2. A: A free-tail bat self-feeding on mealworms. *T. brasiliensis Photo by A. Lollar.* **B:** An EcoGen™ Magnetic Bin can be attached to metal enclosure surfaces (see Permanent Housing). This tray measures 4" x 2" x 1.25" and is made of biodegradable material. *Photo by A. Lollar.*

Rubbermaid® drawer organizers can be used when feeding large colonies of bats (Figure 5-3A). However, wide rectangular trays as pictured below are not recommended due to the volume of waste that will occur when groups of bats sit inside the pan to eat, as the subsequently urinate and defecate onto the mealworms (Figure 5-3B).

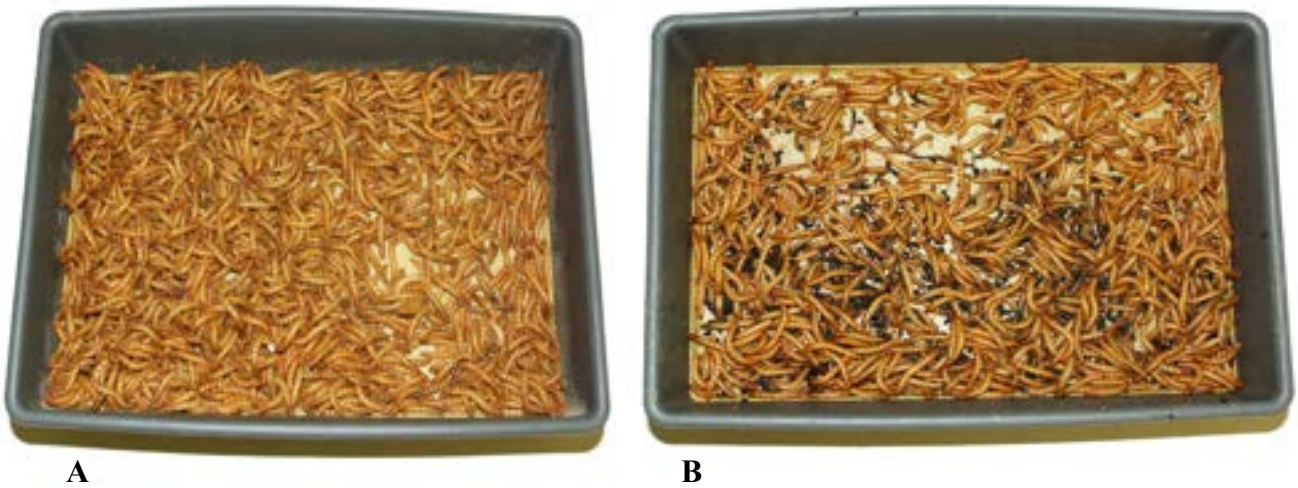


Figure 5-3. A: A Rubbermaid® drawer organizer measuring 9.5 x 7" x 2" deep. The tray on the left is filled with fresh worms. **B:** Waste which occurred from the previous night's feeding. Almost all the leftover worms are dead. *Photos by A. Lollar.*

TREE BATS

Tree bats prefer to hang over the dish and on a comfortable surface while they eat, so the food dish should be placed against a enclosure wall or another surface to enable the bat to cling from above (Figure 5-4A). Tree bats will often urinate into the dish of worms as they feed. Allowing these bats to roost on an absorbent surface while feeding helps to prevent this from occurring.

Tree bat pups can be fed from the same dish (Figure 5-4C); however, after six months of age these bats prefer to be somewhat separated as they feed.

Small coop cups (Figure 5-4B) can also be hung from the netting of enclosures while the bats cling to the enclosure from above the dish.

Figure 5-4. A: A hoary bat self-feeds from a dish. *L. cinerus. Bat World facility. Photo by D. Hyatt.* **B:** Small bird coop cups can be attached to mesh caging.

Figure 5-4. C: A small plastic storage container measuring 9" x 7.5" x 5.5" has been converted into a "tree bat feeder." The container is turned on its side, plastic mesh has been cut to fit the back wall and secured into place with zip ties through holes drilled into the bottom. A mesh lid has also been secured to the front of the enclosure with zip ties. The lid can be lowered and secured into place with hook and loop tabs when necessary to close the feeder. A black office drawer organizer serves as a dish measuring 6.5" x 3.25" x 2" deep. Red bats. (*L. borealis*). *Bat World facility*. *Photo by A. Lollar.*

Water Dishes

Water dishes can be created from numerous small objects including plastic bottles and small pill containers. Plastic tends to absorb bacteria, although hard plastic, which coop cups are made of, is less absorbent than soft plastics. Glass and stainless-steel items are the preferred choices for water dishes because they do not absorb bacteria and resist biofilm adherence. Galvanized items are not recommended as they are hard to clean, can oxidize, and may pose toxic risks to bats.

Bat World Sanctuary recommends a depth of 1/4" to 3/4" for water dishes, however deeper dishes can be used providing they are filled with marbles (Figure 5-6E) to prevent a bat from falling completely into the water and becoming immersed. A minimum of four 1/4" deep water dishes or two 3/4" water dishes should be provided per every ten bats.

Water dishes should be placed in an area of the enclosure that remains dark during the day so bats may drink without the stress of exposing themselves to light. Avoid placing water dishes under areas where bats may congregate and contaminate the water by dropping feces and urine into the dish. Alternately, a cover can be fashioned over the water to keep it clean. Once locations are chosen, water dishes must remain in the same spots within the enclosure to avoid confusion and undue thirst. Additionally, never fill a water dish with mealworms or vice-versa. Captive bats have been observed attempting to drink by licking the sides of a dish that previously contained water but instead had been filled with mealworms (M. Singleton, pers. comm.).

Crevice bats should have numerous water dishes placed throughout their enclosure. Tree bats should have a water dish within reach of their daytime roosting spot (Figure 5-5). These bats easily become dehydrated in captivity and therefore must have water that is always readily accessible to encourage them to drink.

Figure 5-5. A: A modified round 1.5" x .5" "stacking organizer" used as a water dish and hanging within reach of a hoary bat (*L. cinerus*). Also see Figure 5-5D. *Bat World facility. Photo by D. Hyatt.*

Simple water dishes appropriate for temporary housing can be created by using small plastic bottles such as one-ounce Boston Rounds (Figure 5-5B) or small travel bottles. Use scissors to cut the container according to the shape in the photo (Figure 5-5C). Be sure to round the sharp edges of the top of the container. Use a zip tie to create a snug-fitting loop that will allow the handle of the dish to slide in and out. The zip tie should be secured from the outside of the enclosure (see example in Figure 3-4E).

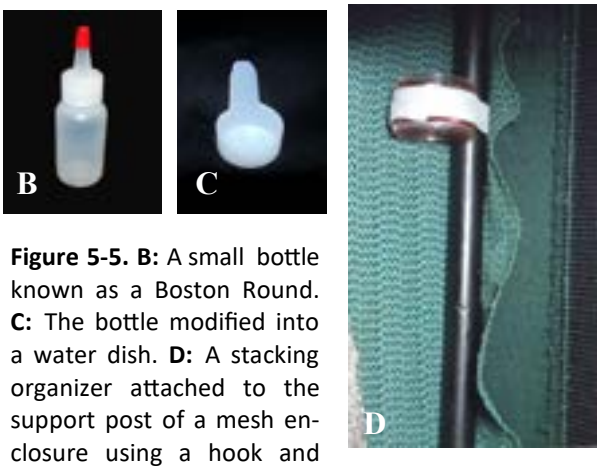


Figure 5-5. B: A small bottle known as a Boston Round. **C:** The bottle modified into a water dish. **D:** A stacking organizer attached to the support post of a mesh enclosure using a hook and loop strap.

Plastic water dishes should be washed with detergent and bleach, then rinsed thoroughly and refilled with fresh water twice daily to help prevent bacteria build-up. The glass and stainless-steel water dishes described on the following page should be washed and refilled with fresh water once daily.

The importance of sanitizing water dishes daily cannot be overly stressed. Dirty water dishes can lead to the accumulation of bacterial biofilm, a slimy substance that can stick to the inside walls of water dishes. Biofilm can cause middle ear and sinus infections, the formation of dental plaque, gingivitis, endocarditis, systemic inflammation, cardiovascular disease, urinary tract infections and chronic kidney disease.

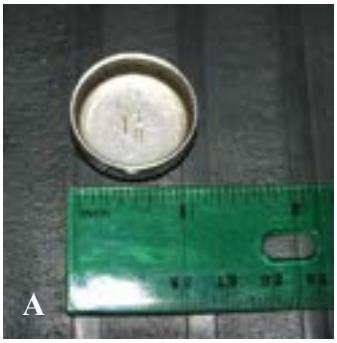


Figure 5-6. A: A stainless-steel expansion plug. **B:** A tri-colored bat (*P. subflavus*) drinking water from the small plug. Note the pouch above the water, which keeps the water clean by preventing debris from falling into the dish from above. *Photo by D. Hyatt*.

Stainless-steel automotive expansion plugs (size 1 1/8" x 1/4") make excellent water dishes for insectivorous bats (Figure 5-6 A). Additionally, these plugs fit inside a modified Boston Round as pictured on the previous page.

Glass Petri dishes have been used in the past for both food and water dishes for insectivorous bats, however, these dishes are expensive, fragile and easily broken. Glass furniture casters (Figure 5-6C), available at thrift and antique stores, provide the same basic antibacterial properties as Petri dishes with the benefits of being heavier, less prone to tip over, and virtually unbreakable. Magnaturals (magnet powered terrarium environments made for reptiles) offer a water dish that can be attached to the side of crevice bat caging with magnets (Figure 5-6E). However, because this dish is over 1" deep it must be filed with marbles to prevent drowning.

Figure 5-6.C A glass furniture caster. **Figure 5-6. E:** A Magnaturals Rock Ledge Water Dish filled with marbles. An additional magnetic ledge has been placed above the water dish to prevent water from becoming soiled from the bats roosting above. *Bat World facility. Photo by A. Lollar.*

CHAPTER SIX

PERMANENT HOUSING AND FLIGHT ENCLOSURES

Housing for Non-Flighted Crevice Bats

The minimum permanent enclosure size for non-flighted crevice bats should be no smaller than two times the wingspan of the largest bat enclosed, and eight times the body length of the bat in height. An enclosure of this size is appropriate for as many as ten medium-sized (10g to 15g body weight) non-flighted colonial bats. Enclosure dimensions should increase in proportion when containing additional bats. If a heat source is provided by use of a heating pad, it should be placed only on one side of the enclosure to create a thermal gradient. It is important to note that heat is not required for healthy adult bats. Supplemental heat can cause dehydration, and even thermal burns, especially if placed on high settings. Therefore, if a heating pad is used it should only be used on a low setting and should always be attached to the outside of the enclosure. In addition, several layers of cloth should be placed between the heating pad and the outside of the enclosure.

It is important that enclosures are not constructed from materials such as glass, Plexiglas, or other slick materials. Bats slip on these types of materials, causing them to panic and frequently sustain injury. Wood is not a good choice as it absorbs odor and can be difficult to clean (although that should never be used as an excuse to inadequately clean an enclosure—Figure 6-1C). Instead, soft mesh dog crates should be used as many of these products are netted almost entirely throughout and are easily modified into permanent housing for insectivorous bats (Figure 6-1A). In addition these enclosures can be thoroughly cleaned by removing enclosure covers to launder and scrub frames.

Crates that feature a side opening are preferable as this allows the handler more convenient access to the bats (Figure 6-1B). For added convenience, enclosures should ideally be positioned so that the interior of the enclosure is at eye level. Bat enclosures must be kept in rooms that are not accessible to children, pets, or wildlife. A roosting enclosure can be placed inside a netted flight enclosure on a table or shelf to accommodate both flighted and non-flighted bats. The roosting enclosure door can remain open to allow flighted bats access to a flight area.

Figure 6-1. A & B: A soft mesh dog crate with a zippered door. The crate measures 18” x 24” x 28”. Several different roosting and enrichment items are available throughout the enclosure providing housing for 15 non-flighted crevice bats. *Photo by D. Hyatt.*

Figure 6-1. C: Inappropriate and dirty wooden housing for insectivorous bats, measuring 12” x 12” x 18”. *Photo by A. Lollar.*

Note: Non-flighted bats may attempt to fly inside flight enclosures when enclosure doors are left open. Others will simply take advantage of the increased space and explore or choose to roost in areas of the flight enclosure rather than the roosting enclosure itself. A mesh ladder or other means of gaining access back into the roosting enclosure should be made available to non-flighted bats (see Flighted Bats in this section).

Although some species, such as Corynorhinus, prefer to roost openly on the ceiling of roosting enclosures, most crevice bats will require a choice of several areas within the roosting enclosure where they can hide in the dark folds of a soft cloth or a roosting pouch (Figure 6-2). These dark crevices simulate their natural environment. Rubbermaid weave or Phifertex® Vinyl Mesh should be attached to any walls and ceilings that are not netted to allow the bat to climb throughout the enclosure interior. Cork bark should never be placed in bat enclosures because particles of bark may adhere to the bat's toe claws and subsequently be ingested when bats clean their toes with their mouths.

The interior of permanent housing for crevice bats should contain a variety of roosting areas and take into consideration the individual needs of the bats being housed. A single enclosure can provide housing for several different species as long as the roosting apparatus meets the needs of each species. In other words, *N. humeralis, M. lucifugus, T. brasiliensis and P. subflavus* can be successfully housed together providing there are enough diverse roosts available inside the enclosure to accommodate each species of bat. An enclosure housing these four species should contain roosting pouches, reptile rocks, silk foliage and other items that will provide mental stimulation (see Enrichment). Alternately, bridges, ramps and a variety of other items can be made of wood, fabrics, and plastic craft mesh. Avoid items made of loose knit fabrics such as terry cloth that may snag claws and result in injury.

Openings into enrichment items and roosts placed inside roosting enclosures should be wide enough to allow the caretaker to insert an entire hand to retrieve a bat and should be carefully designed so that they do not provide traps where wings or legs can be caught. Bats often intentionally wedge themselves into the back corners of a roosting pouch or other objects and can easily be coaxed forward by gently pushing the outside corner where they are roosting.

As previously mentioned, it is important to take note of the spot that the bats have chosen to use as a day roost, as that roost needs to remain the same, both in object and location, at all times. When this roosting spot becomes soiled, a duplicate should be available to mimic the preferred roosting item.

Figure 6-2: An enclosure measuring 48" x 24" x 24" (122cm by 60cm by 60cm) suitable for both non-releasable bats as well as bats healing from injuries. A cloth bridge holds a roosting pouch against the heated ceiling. Roosting pouches, non-snagging towels and a plush house made for birds create security as well as enrichment for permanent non-flighted captive bats. Multiple glass furniture casters provide water while reptile rocks and a plush tree stump hold stainless mealworm dishes. A small aroma mister filled with water provides humidity. *Bat World Facility. Photo by A. Lollar.*

Housing for Non-flighted Tree Bats

The minimum permanent enclosure size for non-flighted tree bats should be no smaller than two times the wingspan of the bat, and eight times the body length of the bat in height. A enclosure of this size is appropriate for one tree bat. Soft mesh dog crates should be used as many of these products are netted almost entirely throughout and easily modified into permanent housing for tree bats (Figure 6-4). Rubbermaid™ weave should be attached to any walls and ceilings that are not netted to allow the bat to climb throughout the enclosure interior. This foam weave is especially important for tree bats who are prone to thumb and toe injuries (see Enrichment, Tree Bats). A heat source should be available and can be provided by a heating pad placed on the side of the enclosure.

The interior of permanent housing for tree bats should contain a variety of roosting choices for the bat to hide in and sleep. Enrichment in the form of silk foliage, tree bark, or small branches and wicker baskets turned upside down, should also be added to the interior of the enclosure. Tree bats have been known to use Snuggle Sacks, Happy Huts, and Hide-a-Squirrels as roosts (see Enrichment). Avoid items made of loose knit fabrics such as terry cloth that can snag claws and result in injury. Instead, flannel, surgical cloths, and Rubbermaid shelf liner are recommended.

As previously stated, it is important to take note of the spot that the bats have chosen to use as a day roost in which to sleep, as that roost needs to remain the same, both in object and location, at all times. When this roosting spot becomes soiled, a duplicate should be available to mimic the preferred roosting item as closely as possible. Never change an established location of water dishes as foliage bats become easily dehydrated in captivity (see Water Dishes).

Tree bats often flap around on the enclosure floor throughout the night, which should not be cause for alarm. This is normal behavior for non-flighted tree bats. Due to this behavior, the floor of a tree bat's enclosure should be thickly padded, and any branches or bark used inside the enclosure should never extend to the floor where they may come into contact with the bat and cause injury. Additionally, water dishes placed on the floor should be positioned against the wall or against an enrichment item such as a plus Hide-a-Squirrel. Do not place a water dish in the middle of the floor as the bat may become wet as it flaps on the floor at night.

Figure 6-4. A soft mesh crate measuring 18" x 24" x 28". This enclosure provides permanent housing for one non-flighted tree bat.

Several roosting and enrichment items are available throughout the enclosure. The padded floor is free from clutter to enable the bat to safely flap on the floor throughout the night. *L. intermedius. Photo by D. Hyatt.*

Temporary Indoor Flight Enclosures

Temporary flight enclosures are preferable when limited space is available or when small numbers of flighted bats need to be housed separately for short periods of time. The minimum size for a temporary flight enclosure is 10' wide x 10 long x 6' high.

Pop-up tents, or screen rooms, are typically economical and often include a floor secured in place with a zipper, which is an added feature in preventing escapes. If a tent does not include a floor, then one can be created using tarp. The tarp should be sewn securely at the bottom of four sides of the tent. Bats learning to fly will often end up on the floor and then scurry to the sides of the tent. If a floor is not thoroughly secured, bats will ultimately find their way out of the tent and may not survive. Tents can either be secured with a frame that is included, or bungee cords can be used to secure the tent to the ceiling of a room or garage (Figure 6-5A).

While some tents may be made entirely of mesh, many are not. Those tents should be modified using mesh that is secured to all slick sides of the tent (Figure 6-5B).

The floors of temporary flight areas should be padded with soft blankets or foam to prevent injuries when bats land on the floor.

Some tents can be rolled up when not in use (Figure 6-5C).

Cleaning

Floors should be swept with a broom and mopped with a 10% bleach solution. Walls and screen can be wiped down with soapy water and rinsed in place.

Figure 6-5A: An "E-Z UP Cube Mesh Canopy Screen Room" that is designed to be used with an EZ-Up canopy. **B**: Clips are used to attach screen panels to the slick corners of the tent. **C**: The tent is rolled up when not in use. *Photos by C. Myers*

Permanent Flight Enclosures

Flight Enclosure Sizes

The minimum acceptable flight enclosure size for flighted microbats is approximately 12 times the wingspan of the largest bat in the enclosure, squared. A flight enclosure measuring 12' x 12' (144 sq ft) will provide enough flight area for up to 20 flighted microbats with 12" to 14" wingspans. Flight enclosure dimensions should increase by two feet in each direction per every 10 flighted microbats contained over the number of 20. The height of the flight enclosure should be 7' to 7'5". This height provides suitable flight for the bats while allowing the ceiling to remain within easy reach of caretakers needing to retrieve bats. The shape of the enclosure can be square, rectangular, or hexagonal.

Entryway

Flight enclosures should have a double door entry (i.e., vestibule) to prevent accidental escapes (Figure 6-6). Microbats can squeeze through a crack as small as one-quarter by one inch. Therefore, both doors must fit tightly to the framework to prevent downed microbats from crawling under the door to the outside. The door leading into the flight enclosure should open into the vestibule rather than the flight enclosure to prevent accidents with flying bats. Before opening or closing doors, always check around the framework to ensure no bats are roosting close to the door where they may become crushed as the door is opened or closed.

Construction Materials

Enclosures can be constructed of softwoods as used in home construction, structural plastic lumber made from PVC, or aluminum tubing. Other materials needed are 1/6" polypropylene mesh (for the inside walls), 1/6" heavy duty polypropylene mesh (for the ceiling) and Zoomesh or PVC coated wire mesh if a second layer of mesh is called for on the exterior of the enclosure.

The walls and ceiling of the enclosure should be covered in 1/6" mesh. Never use larger than 1/6" mesh as anything larger will allow the forearm of a bat's wing to slip through the hole as he climbs across the screen, causing severe injury or self-mutilation if the wing becomes trapped (Lollar, 1994). Never use wire mesh on the inside of bat enclosures as it causes injuries to toes and thumbs.

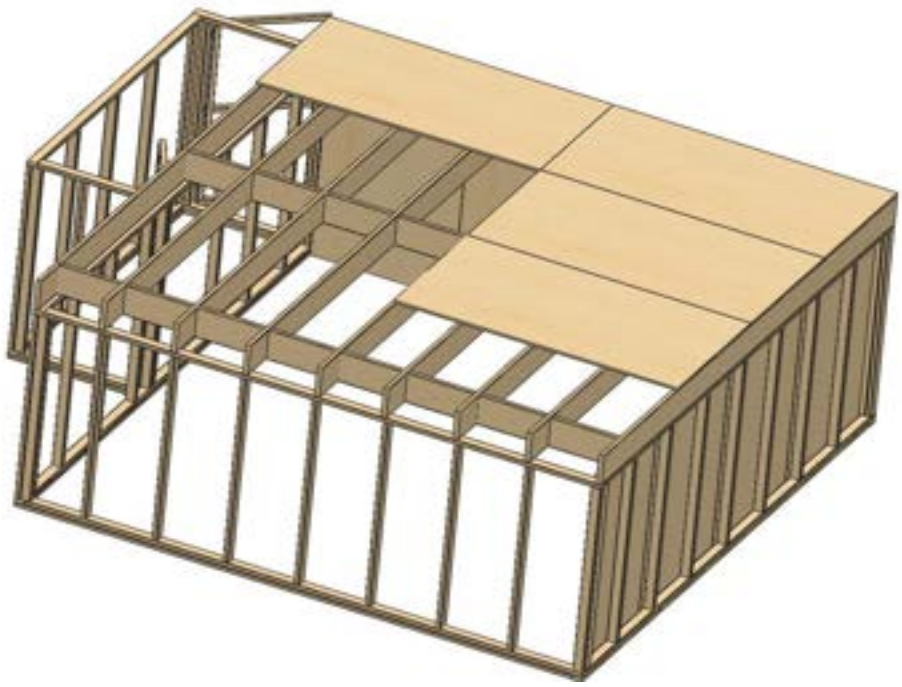


Figure 6-6. An example of a flight enclosure measuring 16' x 16' x 7'. A enclosure this size is appropriate for 40 medium-sized flighted insectivorous bats. The door to the vestibule opens to the outside; the door to the flight enclosure opens inside the vestibule. Two solid walls allow the attachment of feeding shelves and roosting items. Plywood or PVC planking on the ceiling of the enclosure provide darkened areas inside of the enclosure for necessary seclusion. *Graphic by L. Crittenden.*

Walls

The flight enclosure should consist of two solid walls and two open mesh walls (Figure 6-6). Solid walls provide darkness and a sense of security while open walls allow a natural change of the light cycle. Plywood or PVC board can be used to create the solid walls, and should be nailed or screwed to the exterior framework from the *inside* of the enclosure (Figure 6-6). This creates a completely flat wall from floor to ceiling, with no hidden areas for bats to hide or where guano can accumulate. Alternately, cinderblock walls can be utilized, although these walls should be painted using a color such as dark green.

Solid walls allow the attachment of roosting/feeding shelves in unlimited locations. Wooden walls should be covered (in wallpaper fashion) with heavy-duty tarp or plastic for ease in cleaning. Alternately, camouflage tarp or a wallpaper forest mural can be used to create a natural looking environment (Figure 6-7A). Removable panels of polypropylene mesh must be attached to provide a climbing surface over the mural or tarp covered wall (Figure 6-7C). Removable mesh panels are free-hanging (i.e. attached only at the top) to allow quick access to bats as well as ease in cleaning. Additionally, some crevice bats enjoy roosting behind these panels, allowing the keeper to visually inspect the bats ventrally.

To create removable mesh panels, first attach a strip of stainless-steel binding to the very top of the wall (Figure 6-7B). The binding must be affixed at the very top of the wall, directly beneath the ceiling. Be sure to turn sharp ends under and crimp flat using pliers or a hammer, as described in Figure 6 -12C.

Use scissors to cut 1/6” polypropylene mesh into panels measuring 18” wide and the height of the flight enclosure. At the top of the panel, use a zip tie to attach one donut-shaped neodymium magnet (measuring 3/4" x 1/4" x 1/4) to each end. (Note: Regular magnets are not recommended as they lack the strength to hold the screen panels securely in place.) Cut the excess off the zip tie, and file the cut end until smooth. Attach the mesh panels to the steel binding, overlapping if necessary. The mesh panels will hang in curtain-like fashion and provide cushioning for flighted bats as they land. Note: Some crevice bats prefer to roost behind the mesh, with their backs against the wall, and should be allowed to do so (Figure 6-7D).

All mesh secured to the remaining framework of the enclosure must lay flush against the wood and be attached with staples one to two inches apart. There should be no gaps that may allow escapes. Tears or accidental holes should be immediately repaired using zip ties or by hand-sewing with a needle and thread. Staples, screws and nails must be flush, smooth and tight to prevent accidental injuries when bats land or climb inside the enclosure. Make certain sharp edges of staples do not project into the enclosure.

Cleaning

Mesh panels can be removed, washed in the sink with warm soapy water, rinsed and returned to the wall with minimal disturbance to bats. The tarp or plastic covered walls beneath the mesh can be washed at the same time the mesh is removed for cleaning. Mesh that is stapled into place can be cleaned with a scrub brush, then rinsed and dried with a lint free towel.

Figure 6-7. A: Solid and open flight enclosure walls meet in the corner. Mesh attached to open framework is secured tightly against the frame with staples, leaving no gaps in which bats can escape. **B:** A mesh panel attached to steel binding with magnets. **C:** Mesh panels provide a cushioned landing and are easily removed for cleaning. **D:** Free-tailed bats that have chosen to roost behind mesh, allowing easy inspection of body condition. *T. brasiliensis. Bat World facility. Photos by A. Lollar.*

Flooring

Wood shavings or other loose materials are not recommended as bats will hide beneath these materials and may be stepped on as caretakers enter the enclosure. Additionally, such substrates will cling to the bat's fur. Bare concrete or hard tile floors are not recommended as they can severely injure bats that fall. High-density foam or carpet padding, covered in fire resistant laminated polyester is recommended for permanent flight enclosure flooring.

A layer of two-inch foam (purchased at fabric stores) or carpet padding (purchased at hardware stores) is sufficient for lightweight insectivorous bats (Figure 6-8A). The laminated polyester should be tightly secured to the framework around the bottom of the flight enclosure using stainless steel binding attached with screws (Note: It will be necessary to drill pilot holes in the binding before inserting screws.) This type of flooring prevents bats from crawling beneath the padding, and also prevents debris from filtering beneath the padding (Figure 6-8B). Additionally, mealworms are unable to crawl beneath this type of padding when it is secured correctly.

Ceiling

Flight enclosure ceilings should contain open areas to allow light to enter, as well as darkened areas for roosting and sleeping (Figure 6-8C). Sections of plywood or structural plastic lumber should be attached to the ceiling, on the top outside of the enclosure, to create the necessary seclusion and add stability to the enclosure. The solid areas of ceiling also provide access to the top of the enclosure from above if repairs are ever needed.

The entire inside of the ceiling should be lined with 1/6" polypropylene mesh stapled securely to the entire ceiling (Figure 6-8C). Heavy duty polypropylene mesh can be used on the ceiling for added security. The mesh must lay flush against the ceiling enclosure, with no gaps that may allow escapes.

Foliage should be attached to the ceiling to provide a simulated natural habitat (Figure 6-8D). Synthetic branches and artificial foliage can be attached to the flight enclosure ceiling using zip ties and staples (Figure 6-8E). It is not necessary to cut the end of the zip tie when securing branches; however, if the ends are cut, they must be filed smooth to prevent the sharp edges from injuring the bats.

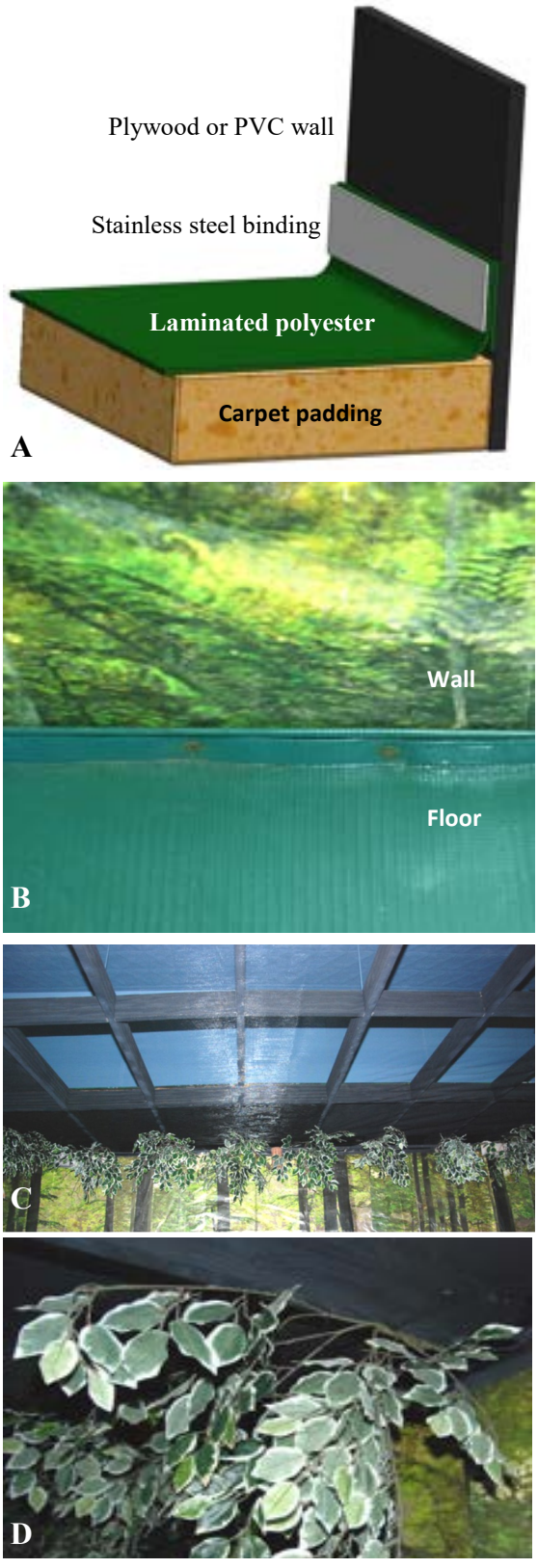


Figure 6-8. A: Layers of a padded floor. **B:** A padded floor inside a flight enclosure. Note: The walls of this enclosure are covered in a wallpaper forest mural rather than plastic. **C:** A flight enclosure ceiling showing both closed and open ceiling areas allowing secluded areas as well as light to enter. **D:** Artificial foliage attached to the flight enclosure ceiling provides roosting areas and enrichment for tree bats. *Bat World facility. Graphic by L. Crittenden. Photos by A. Lollar.*

Housing for Flighted Crevice Bats

Cave Roost

Although it is important that enclosures are not constructed from materials such as glass (e.g., aquariums), Plexiglas® or other hard, slick materials, galvanized metal can be used when properly covered with mesh and appropriate roosting items. The simulated cave roost below was designed to house up to 60 flighted and non-flighted crevice bats of various species, including bats that choose to roost openly on enclosure ceilings. This design allows bats to freely fly in and out of the cave roost at will, is a convenient way to access bats.

The cave roost is constructed of a plywood frame (Figure 6-9A). Heavy-duty wheels can be mounted on the bottom for ease in moving when necessary. The open cave area measures 56" W x 24" D x 32" H and is lined with galvanized sheet metal on the walls and ceiling. Black magnetic sheeting material (30ml) is then attached to the galvanized metal, covering all the walls and ceiling (Figure 6-9B). A layer of Phifertex® vinyl mesh fabric is then attached to the magnetic sheeting using neodymium magnets to hold the mesh in place (Figure 6-9C). Note: Polypropylene mesh should **not** be attached to flight enclosure walls behind the cave; rather, these walls should be covered from floor to ceiling with plastic sheeting or tarp (see Walls, Permanent Flight Enclosures). This will prevent bats from roosting behind the cave roost where they cannot be easily reached.

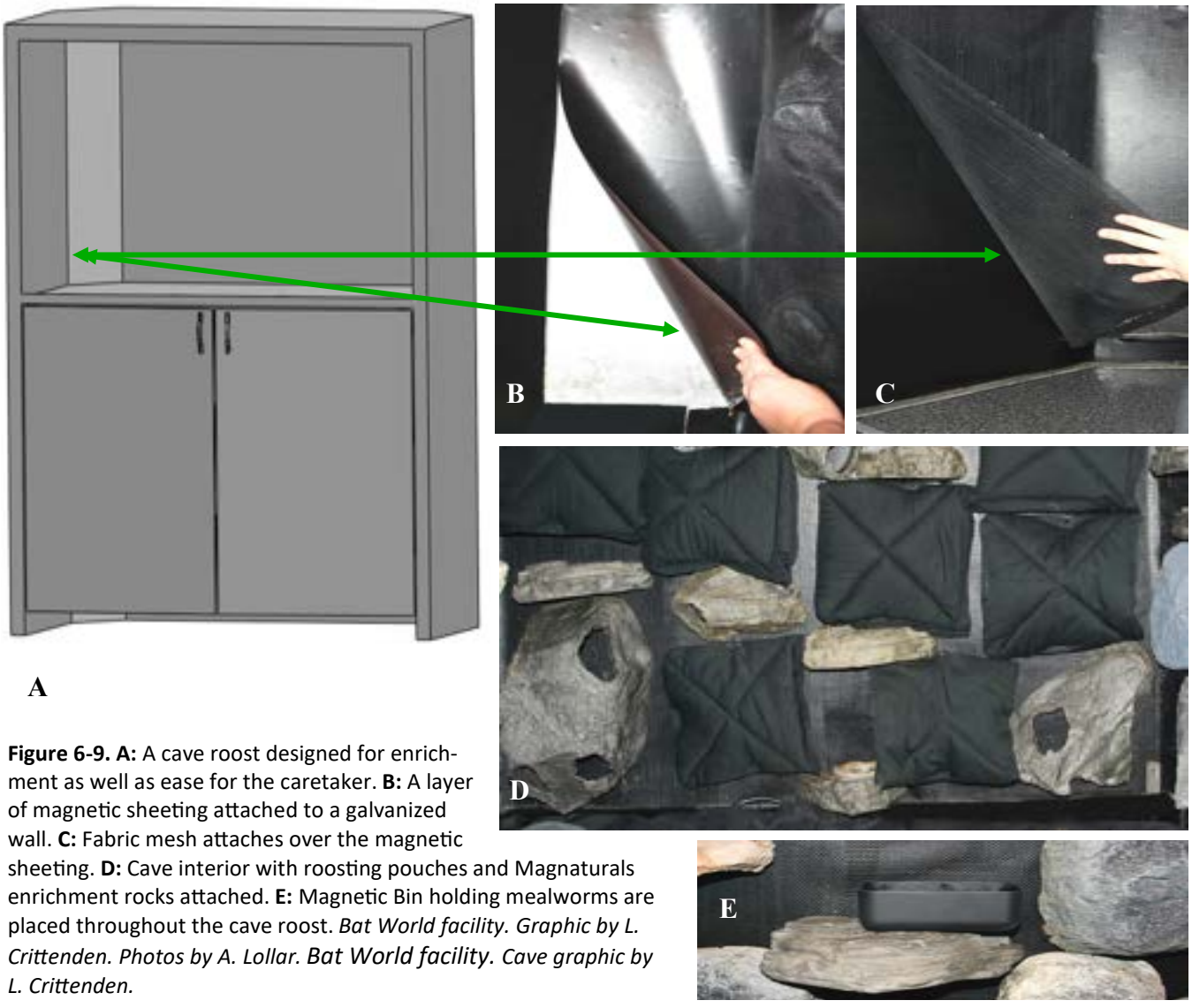


Figure 6-9. A: A cave roost designed for enrichment as well as ease for the caretaker. **B:** A layer of magnetic sheeting attached to a galvanized wall. **C:** Fabric mesh attaches over the magnetic sheeting. **D:** Cave interior with roosting pouches and Magnaturals enrichment rocks attached. **E:** Magnetic Bin holding mealworms are placed throughout the cave roost. *Bat World facility. Graphic by L. Crittenden. Photos by A. Lollar. Bat World facility. Cave graphic by L. Crittenden.*

The cave floor is covered in countertop laminate. The edges of the laminate along the walls and back are sealed with a metal strip and secured in place with screws (Figure 6-10A). The edge of the laminate along the front opening of the cabinet is sealed with aluminum edging (1/2" high) to help prevent mealworms from escaping (Figure 6-10B).

Bats sometimes attempt to roost in dangerous spots such as the crack between cabinet doors, where they can become crushed as the doors are opened or closed. It is therefore extremely important to cover all hinged door areas with a layer of vinyl fabric (Figure 6-10C and D). Vinyl is slick and prevents bats from gaining a foothold if they attempt to roost in these dangerous spots. The vinyl should wrap the entire area where the cabinet door meets the frame, both inside and outside the door, covering the hinges in the process. The vinyl can be stapled directly onto the wooden doors and framework using a staple gun.

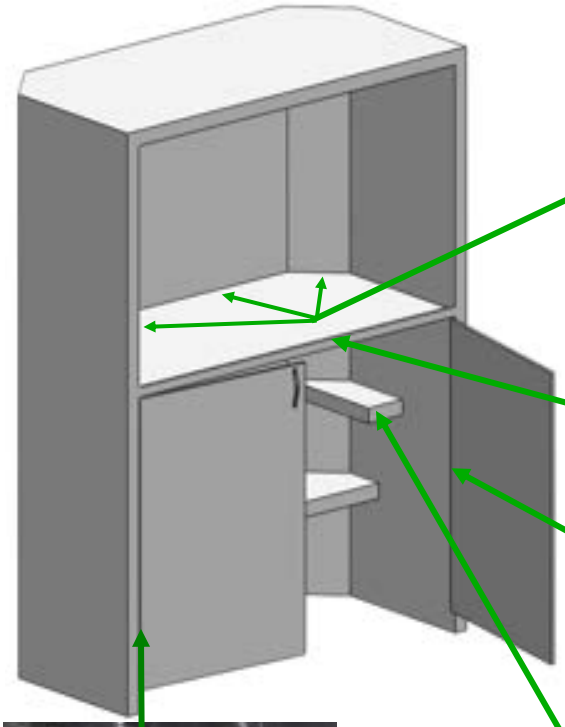
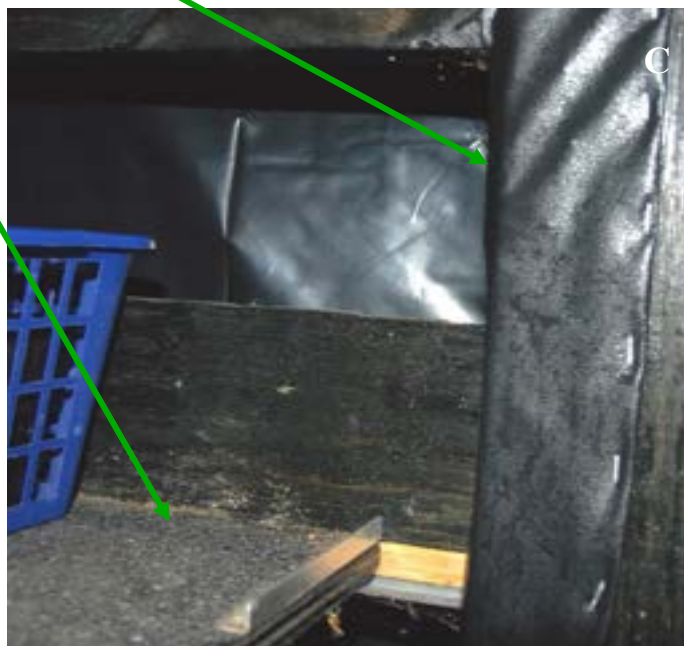


Figure 6-10. A: A laminated floor can be cleaned with a whisk broom. Flat metal binding is used to seal the edges of laminate.

Figure 6-10. B: A 1/2" high aluminum edge along the opening of the cave roost helps to prevent the escape of mealworms.

Figure 6-10. C: Storage area behind cabinet door. Shelves hold mealworm dishes, extra roosting pouches, etc.. The edge of the door frame is covered in vinyl to prevent bats from roosting in the door frame. **Figure 6-10. D:** The outer door frame edge covered in vinyl to prevent bats from gaining a foothold and roosting in the hinged area of the door where they may become crushed. *Bat World facility*. *Graphic by L. Crittenden.*



Some non-flighted bats may attempt to fly inside flight enclosures, while others will simply take advantage of the increased space. They may explore or choose to roost in areas of the flight enclosure rather than the cave itself, as described on the following page. A mesh ladder or other means of gaining access back into the roosting cave should be made available to non-flighted bats. Additionally, a soft cushion should be placed on the floor directly below the cave opening to protect non-flighted bats that may fall to the floor as they attempt to fly. **Never ever step directly onto the cushion without first checking for bats that may be hiding beneath the pad.**

Several roosts in the form of pouches and roosting cloths should be made available to bats that choose to roost along the flight enclosure wall or ceiling.

Cleaning

Cave Roost: Pouches used inside roosting rocks must be turned inside out and washed in the washing machine. Rock roosts can be scrubbed using a mild bleach solution, or simply placed into a facility dishwasher. Roosting rocks must be dry before reattaching to the inside of the cave. Screen should be lifted in sections to clean the magnetized sheeting and the fabric mesh. A scrub brush can be used to remove urine and guano from the mesh inside the cave roost. Use a small whisk broom to sweep up guano and mealworm debris from the cave floor. Plain tap water and paper towels are typically sufficient for wiping down walls and the floor of the cave roost; however, a mild bleach solution may also be used.

Flight Enclosure Floor: Padded floors covered with laminated polyester are easily maintained by daily sweeping and mopping with a 10% bleach solution.

Ill-Fated Designs

While this flight enclosure (Figure 6-14) may look decent at first glance, it serves as a bad example. The mesh size used for this particular enclosure was 1/4" inch rather than 1/6", allowing bats' forearms and feet to slip through, thereby causing severe injury or death. This mesh size also allows insects intended as food, such as crickets, to escape. Dog kennels were used as vestibules, requiring mesh to be hand-sewn inside the entire interior of the kennel. The floor is concrete, rather than padded and covered with laminated polyester, and is consequently more dangerous for bats and more difficult to clean. Note that the mesh is glued to the concrete floor with silicone around the bottom edges. While this does serve to prevent bats from escaping, the glued areas of mesh against the floor allow bacterial build-up as food and guano become trapped in the mesh. Because the enclosure is 8 feet tall, it requires a ladder to reach bats roosting on the ceiling.

There are no solid walls or framework on which to attach feeding shelves, roosting pouches, or enrichment items. While there is a corner roost that offers some seclusion, the enclosure is void of enrichment. This enclosure is free-standing, suspended in the air using cables and hog rings. This free-standing design is prone to degradation over time, as the weight of the hanging material causes snagging, tearing, and sagging, resulting in a need for constant repairs.

The water trough is both dangerous and inconvenient. Bats that fall in may not be able to reach the edge to crawl out, and bats flying overhead will drop guano and urine into the water, resulting in unhealthy conditions and requiring gallons of water be emptied and refilled daily.

Enclosures such as this are highly inappropriate for all species of bats and are difficult to maintain for the caretaker. Enclosures should be designed to offer a simulated natural environment, optimal comfort, and a sense of security for bats while also providing convenience for the caretaker. Poorly designed enclosures typically result in needless injuries and fatalities, as well as frustration for personnel.

Figure 6-14. Example of a poorly designed flight enclosure at the Smithsonian National Zoo. *Photo by M. Singleton.*

Chapter Seven
Feeding Adult Bats

General Information

Insects are generally a high-protein food item, although the nutritional content of insects varies from one species to another. Specific caloric requirements for many bat species are unknown. However, one proposed energy budget for a fringed myotis (*M. thysanodes*) in early pregnancy (weighing 9g) is 3,341 calories (0.37kcal/g/day) during nocturnal activity (flight and night roost maintenance), and 1,410 calories (0.16kcal/g/day) for day maintenance at 68° Fahrenheit for a regulating female, or 690 calories (0.08 kcal/g/day) for a non-regulating female. The total energy budget would thus be 4,751 calories (0.53kcal/g/day) for a regulating female or 4,031 calories (0.45 kcal/g/day) for a non-regulating female (Hill and Smith, 1984). By entering torpor and allowing their body temperature to drop to levels below the lower thermal critical, that is, below the ambient temperature at which an animal must expend metabolic energy to maintain a constant warm internal temperature or homeostasis, many microchiropteran bats are able to decrease energy demands.

The author does not presume to know the specific nutritional requirements of bats in the wild. What is known, however, are specific nutritional regimens that promote long-term maintenance of many species of bats in captivity. For example, the Bat World Sanctuary complete soft food diet described on page 76 has been somewhat modified over the years. However, the author has maintained a reproductive colony of Brazilian free-tailed bats (*T. brasiliensis*) on the same basic diets described in this chapter, and a number of individuals have survived from birth to age ten through 18 years. Some of the young conceived in these colonies are now over ten years old and continue to participate in mating activity. Third generation young are also participating in mating activity (see Table 8-1). In addition, species considered particularly difficult to maintain in captivity, such as the red bat (*L. borealis*), have been successfully raised from birth on these diets.

A detailed discussion of the success and nutritional composition of various captive diets for insectivorous bats can be found in Rasweiler, 1977. This work includes valuable information about mammalian protein, carbohydrate, fat, vitamin, and mineral requirements and discusses conditions that can result from excesses as well as deficiencies. Further information about nutritional requirements of captive bats can be found in Wilson, 1988.

Insectivorous bats probably obtain some of their vitamin and mineral requirements from green plant material present in the digestive tracts of some insects. The following chart describes plants that may provide nutrients to bats via the insects consumed.

Table 7-1
Plants that may Provide Nutrients to Bats through Insects

PLANTS	INSECTS	BATS
FOODS/PRODUCTS: Alfalfa, clover, cotton, flax, soybean, tobacco, cabbage, cantaloupe, lettuce, pea, pepper, pigeon pea, squash, and tomato FLOWERS: Ageratum, bird of paradise, chrysanthemum, gardenia, geranium, mallow, marigold, petunia, snapdragon, strawflower, verbena, and zinnia	Tobacco budworm	Brazilian free-tailed bat (*T. brasiliensis*)
FOODS/PRODUCTS: Corn, tomato, alfalfa, artichoke, asparagus, avocado, cabbage, cantaloupe, collard, cotton, cowpea, cucumber, eggplant, flax, grapes, lettuce, lima bean, melon, millet, oats, okra, pea, peaches, pears, pepper, plum, potato, pumpkin, raspberries, rice, snap bean, spinach, sorghum, soybean, sugarcane, sunflower, squash, strawberry, sweet potato, tobacco, watermelon, and wheat	Cotton bollworm moth Corn earworm Tomato fruit worm	Brazilian free-tailed bat (*T. brasiliensis*)

PLANTS	INSECTS	BATS
FOODS/PRODUCTS: Alfalfa, asparagus, bean, beet, broccoli, cabbage, cauliflower, celery, chickpea, corn, cotton, cowpea, eggplant, lettuce, onion, pea, peanuts, pepper, potato, radish, safflower, sorghum, soybean, spinach, sugar beet, sweet potatoes, tobacco, tomato, and turnip	Beet armyworm	Brazilian free-tailed bat (*T. brasiliensis*)
FOODS/PRODUCTS: Alfalfa, apple, barley, Bermuda grass, buckwheat, cotton, clover, corn, grape, oat, orange, millet, papaya, peach, peanut, rice, ryegrass, sorghum, strawberry, sugar beet, Sudan grass, soybean, sugarcane, timothy, tobacco, and wheat	Fall armyworm	Brazilian free-tailed bat (*T. brasiliensis*)
FOODS/PRODUCTS: Pecan trees.	Hickory shuck worm	Brazilian free-tailed bat (*T. brasiliensis*)
FOODS/PRODUCTS: Tomatoes and grape leaves	Sphinx moths	California leaf-nosed bat (*M. californicus*)
FOODS/PRODUCTS: Corn, spinach, soybeans and various vine plants. Note: The greatest impact is by the larvae (corn rootworms) which damage corn crops. In one summer season, 150 bats of an average maternity colony can eat 38,000 cucumber beetles which means approximately 18 million rootworms are not produced	Cucumber beetles Corn rootworms (larvae)	Big brown bat (*E. fuscus*)
FOODS/PRODUCTS: Broad-leafed woody and herbaceous plants of many families, sedges and conifers	Leaf hoppers	Underwood's bonneted bat (*E. underwoodi*)
FOODS/PRODUCTS: Timber	Bark beetles	Northern yellow bat (*L. intermedius*), Seminole bat (*L. seminolus*)
FOODS/PRODUCTS: Orchards and soybeans	Green Stinkbugs, Brown stinkbugs	Big brown bat (*E. fuscus*), big free-tailed bat (*N. macrotis*), pocketed free-tailed bat (*N. femorasaccus*)
FOODS/PRODUCTS: Alfalfa, broad-leafed woody and herbaceous plants, conifers, soybeans, sedges, sugar beets, tomatoes, and vineyards	Beet leafhopper Potato leafhopper	Big brown bat (*E. fuscus*), pallid bat (*A. pallidus*), eastern red bat (*L. borealis*), Yuma myotis (*Myotis yumanensis*), tricolored bat (*P. subflavus*), canyon bat (*P. hesperus*), Underwood's bonneted bat (*E. underwoodi*), big free-tailed bat (*N. macrotis*), pocketed free-tailed bat (*N. femorasaccus*), Brazilian free-tailed bat (*T. brasiliensis*)
FOODS/PRODUCTS: Timber	Spittlebugs	Pallid bats (*A. pallidus*), Yuma myotis (*Myotis yumanensis*), evening bat (*N. humeralis*), big free-tailed bat (*N. macrotis*), pocketed free-tailed bat (*N. femorasaccus*)
FOODS/PRODUCTS: Tobacco and tomato	Stilt bugs	Canyon bat (*P. hesperus*)
FOODS/PRODUCTS: Sedges, broad-leafed woody and herbaceous plants of many families, and conifers	Leaf hoppers	Underwood's bonneted bat (*E. underwoodi*)

PLANTS	INSECTS	BATS
FOODS/PRODUCTS: Pine and spruce tree	Sawflies	Townsend's big-eared bat (*P. townsendii*)
FOODS/PRODUCTS: Damage many plants by causing the formation of plant galls in which the larvae live	Midges	Little brown bat (*Myotis lucifugus*)
	Mosquitoes	Little brown bat (*M. lucifugus*), Brazilian free-tailed bat (*T. brasiliensis*), northern yellow bat (*L. intermedius*), southeastern myotis (*M. austroriparius*)
	Roaches	Allen's big-eared bat (*I. Phyllotis*)
	Termites	Hawaiian hoary bat (*L.c. semotus*), big brown bats (*E. fuscus*)
	Mayflies	Little brown bat (*M. lucifugus*), gray bat (*M. grisescens)*
	Crickets	Pallid bat (*A. pallidus*), Seminole bat (*L. seminolus*), western mastiff bat (*E. perotis*), big free-tailed bat (*N. macrotis*), pocketed free-tailed bat (*N. femorasaccus*)

Mealworms

The standard diet for most insectivorous bats in captivity consists of live mealworms. Other vitamin, mineral, and fatty acid supplements are also necessary and are added to mealworms and the complete soft food diet described on page 76. It is not advisable to exceed the authors' recommendations for vitamin or mineral supplements as this can result in serious disorders.

Mealworms are the larvae of the darkling beetle (*Tenebrio molitor*). (For nutritional content see Finke, 2002.) This diet may be supplemented with crickets (*Acheta domestica*) for some bat species such as pallid bats (*A. pallidus*) and big brown bats (*E. fuscus*). Unless the bat's teeth are cleaned on a weekly basis, it is not a good idea to feed wax moth larvae (*Galleria mellonella*) except in soft food mixtures because the outer tissue layer of the larvae can become embedded in the gums of a bat's teeth, resulting in gum infections and subsequent tooth loss over time (Lollar, 1994). Do not feed captive bats net sweepings (live insects caught outdoors) in areas where mosquito fogging takes place because the insects may contain pesticide residues that could adversely affect bats.

Although mealworms and crickets are often available at pet stores, they may be purchased in greater quantities at reduced prices from several commercial distributors. Mealworms may be purchased in small, medium, large, and giant sizes. The smaller worms are best for bats weighing 3g to 6g. Medium and large-sized worms may be best for species weighing more than 6g. Large or giant-sized mealworms are simpler to use when feeding a bat that is only able to eat the viscera (i.e., insides) of the mealworm. This might be the case for a bat with very worn teeth or a gum infection that makes it impossible for the animal to chew the harder, chitinous outer portion of the worm. Bats need fiber in their diet, which can be found in the chitin of mealworms. Fiber is provided in the soft food diet by blending the mealworms with other foods, as described further.

MEALWORM MEDIUM

Mealworms commonly arrive packaged in a cloth bag filled with crumpled or shredded newspaper. Upon arrival, they should be placed immediately into the nutritional mealworm medium listed on the following page.

The current medium used at Bat World Sanctuary consists of 60% organic wheat bran and 40% Missing Link® made for felines. When large quantiles of mealworms are used, it is more cost-effective to use the equine variety of Missing Link. Both varieties provide additional nutrients that produce healthy mealworms.

Allow mealworms to remain at room temperature in the above medium for two days before placing the container in the refrigerator. This initial period allows the worms to "plump up" considerably and reach optimum calcium levels. During this time, provide moisture for mealworms by placing thinly sliced "moisture food" on top of the medium. Use nutritious fruits and vegetables such as apple, corn on the cob, sweet potatoes, squash, carrot, organic greens, and fresh green beans. Avoid foods taht are overly juicy or sticky such as cucumber or banana, as well as bitter foods such as banana peel.

On the second day, refrigerate the worms and medium in a ventilated container. Mealworms develop into pupae, which subsequently develop into beetles. Remove any beetles that develop in the medium containing adult worms. The beetles lay eggs in the apple or potato skins, and larvae (mealworms) hatch from the eggs. Refrigeration slows the process and helps prevent contamination by parasites such as grain mites.

Mealworm medium should be discarded and replaced with fresh preparations every one to two weeks. It is particularly important that you do not keep mealworms in a warm, moist environment such as a laundry room. An exceptionally humid environment will speed up the life cycle (i.e., development into the beetle) and will frequently result in the development of mold which could be fatal if fed to bats.

Preparing Mealworms for Self-feeding Bats

Early in the day, remove mealworms that will be used for the evening feeding from the refrigerator. The use of a sifter, as pictured on the right, greatly reduces the time-consuming process of removing mealworms from the medium at feeding time. It is important that no grains adhere to worms fed to the bats.

Mealworms can be easily sifted out of the mixture with a large-holed strainer (Figure 7-1), then placed under light so they will "self-clean." Sift the worms until they are free of wheat bran and other debris, then place the sifted worms into a shallow pan.

Figure 7-1. Sifting mealworms from medium. *Photo by L. Crittenden.*

Tilt the pan so that all the worms slide to one end of the pan (Figure 7-2A). Then, place the pan under a light source. Within a few minutes the majority of clean worms will gravitate toward the opposite end of the pan, leaving debris behind (Figure 7-2B). This method of sorting worms saves hours a day on meal preparation for insectivorous bats.

After the worms have been sorted in a pan and are completely clean, place the clean worms into another pan, then place nutritious moisture food such as corn on the cob, carrot, organic greens, fresh green beans, or thinly sliced apple, sweet potato or squash on top of the worms (Figure 7-2C). Mazui Better Bug® Gut Loading Diet may also be added to the worms for additional nutrition (Kate Rugroden, pers. comm.). Place the pan in an area away from bright lights and allow mealworms to feed on the moisture food throughout the day. Mealworms frequently take on the coloration of the fruits, grains, and vegetables on which they have fed and subsequently taste different, adding variety and more nutrition to a captive bat's diet.

In the evening, remove any leftover vegetables and fruit from the pan of clean mealworms. (Uneaten vegetables or fruit can be stored in the refrigerator and reused or added to the mealworm medium.) After removing the fruit or vegetables, sift mealworms in a strainer to remove worm feces. Place the sifted mealworms into a pan and sprinkle with the following supplements per every two cups of clean mealworms:

- 1/2 tsp organic spirulina
- 1/2 tsp organic cranberry juice powder (for tartar control, see page 130)
- 2 teaspoons of Missing Link® or 2 teaspoons of Vionate® powder (Alternate these two supplements on a nightly basis.)

Toss the worms with your fingers to thoroughly coat the worms with the supplements. If necessary, sift the mealworms to remove excess powdered supplements. The excess powder can be saved and reused the following night.

Hand-feeding Adult Bats

The number of mealworms a bat will consume in captivity depends on a variety of factors including the species, the general health and condition of the individual animal, its nightly activity (i.e., is it flying), the season, and the ambient temperature. Bats that are not self-feeding should be fed twice a day, once in the morning and again in the evening. Feeding times should be roughly 12 hours apart. Species weighing between 10g to 20g typically eat anywhere from 10 to 20 one-inch mealworms at each feeding, while smaller species weighing between 3g to 10g may only eat 5 to 10 mealworms at each feeding. Large species weighing 30g to 70g can eat 5 to 10 giant mealworms a feeding.

Feed a bat as many worms as it will accept at each feeding twice a day for the first couple of days. It is important to check the distention of the abdominal area periodically as the bat feeds. The area on the underside of the bat just between the legs should not be sunken in as this is a sign that the bat has gone without food for too long. A flat abdomen means the bat has not yet had enough to eat. An overly distended abdomen means the bat has been allowed to consume too much food.

Figure 7-2. A: Sifted worms are bunched up at one end of the pan and placed under a light source. **B:** Within minutes, clean worms move to the opposite end of the

C: A pan of clean mealworms feeding on carrots. These worms are intended for the evening feeding. *Photo by A. Lollar.*

D: Adding vitamin supplements just before feeding time. *Photo by L. Crittenden..*

Teaching Adult Bats to Self-feed

Some wild bats can be tempted to eat when first received by offering them a live mealworm. Allow the bat to hang head down on the side of its cage (tree bats) or to rest horizontally inside a roosting pouch (crevice bats), and, using forceps, gently run a mealworm along the bat's jaw line. This usually causes the bat to open its mouth, allowing the mealworm to be placed inside. A bat will often clamp down on the worm, recognize it as food, and continue to eat. If the bat will not eat a mealworm whole, try offering it a decapitated worm. Pinch off the head of the mealworm, and, using forceps, squeeze out a small amount of the viscera (i.e., insides) into the bat's mouth.

Some bats will immediately open their mouths and bare their teeth, tasting the viscera in the process and providing an opportunity to again place a worm in their mouth. However, some bats will shy away from food offered in this manner and must be held gently but firmly in the hand with the head somewhat lower than the rest of the body. Mealworm viscera can then be offered as described above. If a bat still appears too fearful to eat mealworms, soft food should be offered.

The length of time it takes for a bat to learn to feed from trays or dishes varies from species to species and from individual to individual. Bat species that glean insects from surfaces or forage for insects on the ground may learn to eat from a tray placed on the bottom of a cage more quickly than species that feed mainly in flight. Molossid bats can be difficult to teach to self-feed. The facial structure of these bats appears to make it difficult for them to grasp a moving insect from a flat surface, although many can be taught to self-feed over time (Lollar, 1994). Some species, such as *M. lucifugus,* will feed from trays of mealworms on their own without ever being taught. Some bats never learn to self-feed and must be hand-fed twice daily (Figure 7-3A and B).

Bats should be accustomed to eating hand-fed mealworms before training is initiated. When first training a bat to self-feed, hold the animal over a small tray of mealworms (crevice bats) or allow it to hang freely on the side of a cage and directly over the dish (tree bats). The tray should be shallow but large enough for the bat to climb in and out without allowing the mealworms to escape and heavy enough so the bat can't tip it over. Mealworms can easily climb on roughened surfaces, so use a tray with a smooth surface. Remove mealworms from the tray with blunt forceps, and offer them to the bat one by one. Hold the bat close to the tray or dish so it can watch as you pick up each mealworm (Figure 7-4A). Hand-feed it several mealworms until it begins reaching into the tray on its own. Once the bat has taken a few worms from the dish completely on its own, do not continue to use the forceps to help the bat.

Figure 7-3. A: A 4g *P. subflavus* appears to enjoy a hand-fed, small-sized mealworm. *Photo by D. Hyatt.* **B:** A 60g *E. perotis* being hand-fed a giant-sized mealworm while hanging in her roost. *Photo by A. Lollar.* Both species typically require being hand-fed in captivity.

To do so will hinder the training process and may result in the bat becoming dependent on the caretaker's help during each meal.

The training process will build trust between the caretaker and the bat, and should be a pleasant experience for the bat. Teaching bats to self-feed can be frustrating; it is very important to stay calm even when things aren't going well. Always end a training session in a positive manner. If the bat appears stressed during the training process, give it a "treat" of viscera, then put it away and allow it to calm before trying again. It is important to remember that some bats may never learn to self-feed. These bats should be fed the complete soft-food diet discussed later in this section.

Figure 7-4. A: Training a free-tailed bat to self-feed on mealworms. *T. brasiliensis. Bat World facility. Photo by J. Waltz.*

Crevice Bats

After a crevice bat has taken mealworms from a dish on its own while being held in the hand, dishes can be added to the cage to encourage self-feeding. After training, most bats begin eating from the dish the first night. Cover the bottom of the tray or dish with mealworms (see Mealworm Dishes for photos of dishes filled with the proper amount of mealworms). Alternately, a plush tree house mage for birdsis an excellent device for training bats to self-feed as well as providing a hiding place for shy crevice bats to self-feed (see Mealworm Dishes). Place trays against the walls to allow bats to crawl down the side of the cage and feed from a tray while still hanging head down. Ensure that mealworms placed in trays for self-feeding are free of medium, shed skin, pieces of worms, and dead worms.

In the morning, remove guano, dead worms, and mealworm feces, then place the remaining live worms back into the mealworm medium in the refrigerator. Bats should never be fed dead mealworms. Wash the dish with detergent after each use, and rinse well.

Tree Bats

As a general rule, tree bats that have been taught to self-feed from mealworm trays do not find the mealworms left in their cages for self-feeding. More importantly, due to the tendency of tree bats to overfeed, leaving trays of mealworms in their enclosures can be dangerous. Instead, hang the bat over the dish so it can self-feed (Figure 7-4B), then remove the bat five to ten minutes later, when the bat appears full. Check the distension of the abdomen, and if the bat appears full, remove the tray of mealworms.

After the tree bat has been feed, offer water by hand, allowing them to drink their fill. Wipe any debris and moisture from the bat's face and neck using a cotton swab or soft piece of gauze, then return the bat to its normal roosting place.

B: A hoary bat learning to self-feed on mealworms*. L. cinerus. Bat World facility. Photo by A. Lollar.*

Remove the dish after the bat has been fed. Remove guano, dead worms, and mealworm feces, then place the remaining live worms back into the mealworm medium in the refrigerator. Wash the dish in detergent after each use.

Additional Notes

- Nitrile finger cots worn on the thumb and index finger will prevent staining of the fingers from mealworms.

- Mealworms should never be left in enclosures with severely debilitated bats or with bats that have sustained back or other injuries that seriously impede terrestrial movement because they can be overcome and eaten by the mealworms. On the contrary, trays or dishes of fresh mealworms should be left in enclosures both day and night when large colonies of healthy crevice bats are being maintained.

- Upon first learning to self-feed, some bats will overeat. This is true of big brown bats (*E. fuscus*) in particular. However, the author has found that bats of several different species including big brown bats (*E. fuscus)*, Brazilian free-tailed bats (*T. brasiliensis*), cave bats *(M. velifer*), evening bats (*N. humeralis*), and pallid bats (*A. pallidus*) will in fact regulate their consumption within a period of approximately two to three months and remain within appropriate ranges for the species, despite initial (and sometimes dramatic) weight gains. It should be noted, however, that because some bats initially become obese when given unlimited access to food, bats intended for future release may need to be hand-fed the complete soft food diet followed by mealworm viscera.

- If a bat allowed to self-feed has exceeded the upper end of the weight range for the species, its diet can be carefully adjusted by reducing each feeding by only two or three mealworms until the desired weight is attained. Many captive bats will also increase their consumption and body weight naturally in the fall in preparation for migration or hibernation (see Hibernation).

- Bats that do not learn to self-feed will need to be hand-fed for the duration of their captive lives. Caretakers who are not prepared to care for a bat in this manner should place the bat in an accredited sanctuary.

Feeding Crickets

Crickets (*Acheta domesticus*) constitute a part of the normal diet in the wild for species such as pallid bats (*A. pallidus*), and big brown bats (*E. fuscus)*. House crickets are available from several insect supply houses. These insects are less nutritious than the mealworm diets because crickets are more selective in their feeding habits and cannot be provided with supplemental nutrients as easily as mealworms can, which is why they are only used as a supplement to traditional diets. Information regarding the care and feeding of crickets is provided by Patricia Winters as follows:

It is best to refrigerate crickets immediately on arrival for about 30 minutes in order to reduce their activity level, making the transfer from the delivery carton to a storage container much simpler. Do not refrigerate them for any longer as they may die within just a few hours of initial refrigeration. Crickets should be maintained in a large aquarium or plastic storage container covered with a screened top. Place rabbit-food pellets, greens, and carrots on the bottom of the storage container and add a small dish of water filled with small pebbles to prevent the crickets from drowning. Then place the crickets in the container and cover with the screened lid. Keep the storage container with crickets in a dry environment at about 70° Fahrenheit. Dampness and odor is a constant problem when housing crickets.

Check the container carefully each day for any mold growth either in the container or on the food, and dispose of all contents, including the crickets, if contaminated materials are detected. Thoroughly clean the container

with a disinfectant and rinse well before adding fresh medium. All water and any remaining food must be removed daily and replaced with a fresh supply.

The Bat World Sanctuary Complete Soft Food Diet

A variety of soft food mixtures have been used to maintain bats in captivity. These mixtures, often referred to as bat glop, are generally prepared in bulk, frozen, and then defrosted in small quantities and fed to bats. The use of soft food mixtures was generally intended to minimize the time and/or expense of caring for multiple bats used in research studies because bats will frequently refuse to eat mealworms when first taken into captivity. However, newly captive bats can usually be encouraged to eat the complete soft food diet. Soft food is also recommended for emaciated bats, bats with dental infections, and juvenile bats being transitioned to whole mealworms.

It is important to note that bats fed soft mixtures only (without live insect supplements) often did not fare well. In contrast, several species of insectivorous bats, including a reproductive colony of *T. brasiliensis*, have remained healthy for over 28 years on the soft food diet described in this section. However, these bats are supplemented daily with the viscera of live giant mealworms. It is therefore critical that viscera from live meal worms or giant mealworms are fed daily along with soft food.

Soft Food Recipe (Feeds 15 to 20 medium-sized insectivorous bats.)

1 cup frozen mealworms (about 1,200 large mealworms) or a combination of frozen mealworms & wax worms
1/3 cup of very cold water (80ml)
2 tablespoons of organic baby food
2 tablespoons of organic or non-gmo corn oil
1 teaspoon Missing Link® (Well Blend)
1 teaspoon of Vionate®
1/4 teaspoon organic spirulina

Use a high-speed glass blender to prevent overheating. Pour the water into the blender. Gradually add frozen mealworms while blending on the highest setting. Blend until it is the consistency of honey. Add baby food (use bland flavors, such as sweet potato or other flavors like corn, squash, carrots, peas, green beans, apple, and pears). Add the organic corn oil, Missing Link®, Vionate® and organic spirulina. **The mixture must remain cool while blending**; if it overheats, it will spoil. If mixture is in danger of becoming heated during the blending process, add a little cold water or an ice cube. Blend the final mixture until it is very, very smooth (the consistency of applesauce), while continually checking the temperature while blending.

Freeze soft food in small containers or an ice cube tray (store frozen cubes in freezer bags). Note: mixtures that have not been thoroughly blended will clog feeding syringes, so be certain frozen mealworms are well-blended. Soft food can be stored in a refrigerator for 3 days or in a freezer for up to 90 days. Soft food that has already been thawed should never be refrozen. Discard soft food that has been frozen for more than 90 days.

About 25 healthy bats can be hand-fed soft food per hour; however, it takes longer to feed debilitated bats. O-ring syringes are perhaps the best choice of syringe as others tend to clog easily.

Permanent captives that have lost teeth or have extremely worn teeth can remain on a soft food diet for the rest of their lives. **These permanent captives must also be fed viscera from live mealworms daily (large or giant sized) in addition to soft food**.

Additional Notes

Adding an ice cube to the frozen mealworms during the blending process will help the food to remain cold while blending, which will prevent spoiling.

If not blended for a sufficient period of time, soft food may have a grainy consistency and may contain chunks of worms or softened worm skins that bats will not accept. The mixture should flow freely through the tip of a 3ml syringe. Check to make certain it is thoroughly blended by drawing the mixture into a 3ml syringe while it is still in the blender. If the entire 3ml does not flow freely back out of the syringe when the plunger is pushed in (i.e., if it clogs the syringe), continue blending until it will.

Check the temperature of the sides of the blender throughout the blending process. They should remain cool. If overheated, the mixture will spoil, and bats will refuse to eat it. This is why frozen mealworms must be used.

Soft food that is turning rancid will develop tiny air bubbles that are easily noticed when the food is drawn into a syringe. Rancid food (or food that is even questionable) should be discarded.

Once the syringe is filled with soft food, it should be placed in a bowl of warm water. Before feeding, the temperature of the mixture should be tested by placing a small amount on the inside of the wrist; the food should be moderately warm (never hot). It is very important that the mixture not be overheated when warming it prior to feeding. If overheated, moisture will be drawn out of the mixture, and it will take on a lumpy consistency that most bats will not accept.

If a bat is arousing from daily torpor, it will shiver as it warms up. It needs to be sufficiently warmed before feeding so that it can digest its food. A bat is also more likely to aspirate or choke on food if forced to feed while it is shivering. You can speed up the arousal process by holding the bat in your hand. When it has stopped shivering, hold it so that the head is parallel to its body, and place a small drop of the soft food in the bat's mouth. Never hold the bat in a head-up position when feeding any kind of food.

When feeding species of the family Vespertilionidae, point the syringe towards the chin or to one side of the mouth to avoid getting soft food in the bat's nostrils. Molossid bats may require more prompting to get them to begin eating. Gently force the lower jaw downward with the tip of the syringe against the top of the lower teeth, and then place a small amount of food directly in the bat's mouth, as shown on the following page. Although many weak bats cannot be forced to eat live mealworms or even mealworm viscera, most can be coaxed into eating soft food.

It may take a few minutes for the bat to begin eating. Bats that are very weak will swallow the food placed in their mouths very slowly, and patience is needed to insure adequate food intake and a positive experience for the bat. Allow them to take their time with each mouthful. Even for bats that readily accept soft food, it is critically important to wait a few seconds between mouthfuls to make certain they have swallowed all the food before offering more. Some bats may to eat to fast and will aspirate if not forced to wait a few seconds between mouthfuls.

Feed soft food mixtures twice a day to bats unable to eat live mealworms, once in the early morning and again in the evening, approximately 12 hours apart. Bats weighing 10g to 20g will typically eat 1.0ml to 2.0ml of a soft food at each feeding. Bats weighing 20g to 35g may eat as much as 3.0ml per feeding. Smaller species may only eat 0.5ml to 0.75ml per feeding. Even the smallest of bat species in the United States (i.e., a 3g bat) should be fed a total of at least 1.0ml per day (0.5ml per feeding). With the exception of newly volant juvenile bats, it is not advisable to exceed these quantities when feeding bats soft food mixtures.

Table 7-2
Bat World Sanctuary Complete Soft Food Diet
Nutritional Analysis

Ascorbic Acid (Vitamin C) (mg/100 g)	< 1.00/100g
Ash	1.11%
Calcium	0.41%
Copper (ppm)	4.06
Crude Fiber	1.46%
Crude Protein (%)	9.41%
Fat (acid hydrolysis)	10.33%
Iron (ppm)	35.8
Magnesium	0.038%
Manganese (ppm)	6.36
Moisture	77.03%
Phosphorus (ppm)	1,714
Potassium	0.23%
Sodium	0.26%
Vitamin A (as Retinol only) (IU/100g)	5,395.58
Zinc (ppm)	10.61

Amino Acid Analysis

Alanine	0.72%
Arginine	0.44%
Aspartic Acid	0.61%
Cystine	0.12%
Glutamic Acid	1.57%
Glycine	0.46%
Histidine	0.24%
Isoleucine	0.22%
Leucine	0.87%
Lysine	0.30%
Methionine	0.08%
Phenylalanine	0.51%
Proline	0.75%
Serine	0.33%
Threonine	0.50%
Tryptophan	0.09%
Tyrosine	0.26%
Valine	0.59 %

Proper Feeding Technique, Crevice Bats

Food must never be allowed to collect under the chin and neck of the bat. Allowing the bat to become soiled with soft food or mealworm viscera will result in loss of fur and subsequent skin infections (Figure 7-7C). These infections can become systemic if not properly treated, resulting in death. Bats with dense fur are particularly prone to infections when improper feeding techniques are used.

Pay close attention to both the face, as well as ventral surfaces as you are feeding soft food to a bat. Placing gauze under the bat's chin, in bib-like fashion, or holding the bat so that excess food drips off the chin and away from the bat, rather than on the caretaker's hand, will keep the bat clean during the hand-feeding process. **Never** put a bat away with food adhering to its coat as infection will result. Use an interdental brush dipped in warm water to brush food gently and thoroughly off the fur, paying close attention to the area under the chin and neck (see Bathing and Grooming).

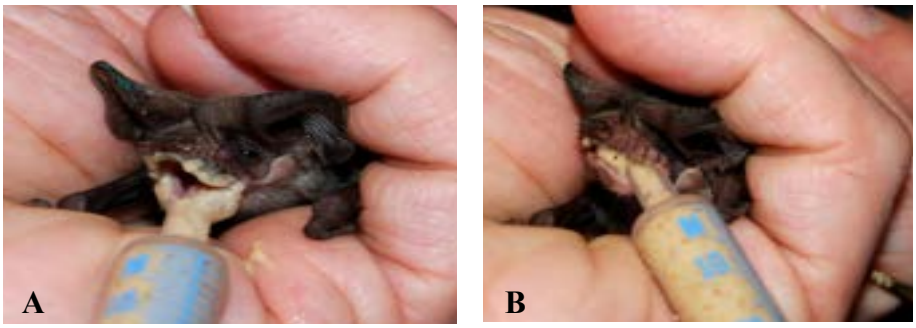


Figure 7-5. A: Gently force the lower jaw downward with the tip of the syringe, and then place a small amount of food directly in the bat's mouth. **B**: As the bat chews, slowly dispense more food into the mouth, being sure to wait several seconds between mouthfuls to ensure the bat has swallowed all of the food before offering more. *T. brasiliensis. Photos by M. Kreb.*

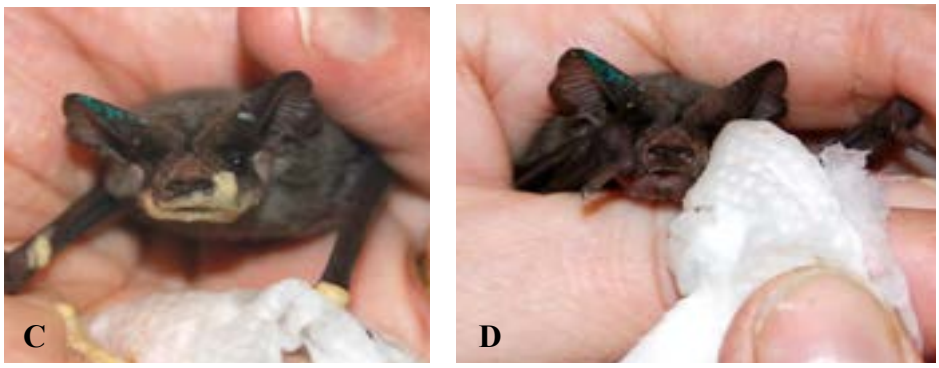


Figure 7-5. C: After the bat is full, use a damp paper towel or gauze to wipe any food that has collected on your hand beneath the bat. Be sure to clean your hand first (not the bat) as anything remaining on your hand will likely end up on the bat as you put the bat away. **D**: After your hand is clean, gently wipe the bat's face and chin with a dampened paper towel or gauze. Be sure to check the throat and clean that area if needed. If necessary, use an interdental brush to clean the fur as described in Bathing and Grooming Procedures. Be sure to dry any fur that becomes wet. **E:** After feeding, this bat is clean and ready to be returned to her roost. The total time spent feeding and cleaning this bat was approximately four minutes. *T. brasiliensis. Photos by M. Kreb.*

Proper Feeding Technique, Tree Bats

The soft food diet should be fed to tree bats using a method that prevents food from accumulating on the fur. One technique involves holding the bat with its head tilted in a downward position, so it lays prone against your fingers, with its head extending past your fingertips. Rest your thumb on the shoulder blades to secure the bat in your hand. Dispense the food a mouthful at a time. As the bat chews, slowly dispense more food into the mouth, being sure to wait several seconds between mouthfuls to ensure the bat has swallowed all the food before offering more.

Another technique is to allow the bat to hang from the side of a cage or Bat Hut while being fed soft food (Figure 7-6A). This method is particularly beneficial when minimal handling and disturbance of the bat is necessary, such as for a lactating tree bat with pups attached to her body, or bats healing from injuries.

Figure 7-6. A: An injured hoary bat being fed as she roosts within her cage. *L. cinerus. Bat World facility. Photo by D. Hyatt.*

Improper Feeding Techniques

While gloves may be necessary for safely handling bats during initial examinations, the use of gloves and face masks will greatly impair a caretaker's ability to properly feed insectivorous bats. Masks reduce the caretaker's visibility when looking down and may also decrease the bat's ability to reach a level of comfort and visual familiarity with its handler, causing the bat to struggle (Figure 7-7A). Gloves increase the likelihood that mealworm viscera and soft food will adhere to the bats fur because the handler is unable to feel that the bat is getting wet until the bat's neck and throat become saturated (Figure 7-7B).

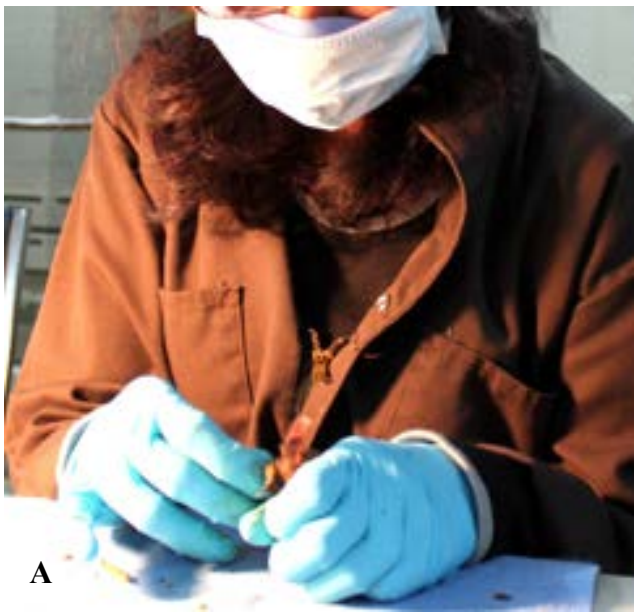


Figure 7-7. A: Use of masks and gloves as well as not holding the bat at eye level will impede proper feeding techniques, causing a struggling bat and the gloves to become soiled with food. Smithsonian National Zoo. *C. townsendii virginianus. Photos by M. Singleton.*

Figure 7-7. C: Ulcerative dermatitis resulting from the improper feeding techniques described in A and B, occurring at the Smithsonian National Zoo. This endangered bat did not survive due to improper care and infection. *C. townsendii virginianus. Photos by M. Singleton.*

Table 7-3
Average Weights of Insectivorous Bats
(in grams)

Family Mormoopidae	
Mormoops megalophylla (1)	13-19
Family Phyllostomidae	
Choeronycteris mexicana (1)	10-25
Leptonycteris yerbabuenae (3,2,3)	18-30
Leptonycteris nivalis (1)	24
Macrotis californicus (3,2,3)	12-20
Family Vespertilionidae	
Antrozous Pallidus (1)	12-17
Corynorhinus rafinesquii (1)	7-13
Corynorhinus townsendii (1)	7-12
Euderma maculatum (1)	16-20
Eptesicus fuscus (1)	13-20
Idionycteris phyllotis (3,2,2,)	8-16
Lasionycteris noctivagans (1)	8-12
Lasiurus blossevillii (1)	10-15
Lasiurus borealis (1)	10-15
Lasiurus cinereus (1)	20-35
Lasiurus ega (1)	10-15
Lasiurus intermedius (1)	18-24
Lasiurus seminolus (1)	10-15
Lasiurus xanthinus (2,2)	10-15
Myotis auriculus (2,2)	Unknown
Myotis austroriparius (1)	5-7
Myotis californicus (1)	3-5
Myotis ciliolabrum (1)	4-5
Myotis evotis (4,2,2)	4.2-8.5
Myotis grisescens (7,2,2)	7.9-13.5
Myotis keenii (4,2,2)	4.0-5.9
Myotis leibii (7,2,2)	4.1-5.5
Myotis lucifugus (1)	7-9
Myotis septentrionalis (1)	5-9
Myotis sodalis (7,2,2)	7.1-7.5
Myotis thysanodes (1)	6-11
Myotis velifer (1)	15
Myotis volans (1)	5-9
Myotis yumanensis (1)	4-6
Nycticeius humeralis (1)	5-7
Parastrellus hesperus (1)	3-6
Perimyotis subflavus (1)	4-6
Family Molossidae	
Eumops floridanus (7,2,2)	30.2-46.6
Eumops perotis (1)	65
Eumops underwoodi (1)	53-61
Molossus molossus (5,5)	12-15
Nyctinomops femorosaccus (1)	10-14
Nyctinomops macrotis (1)	24-30
Tadarida brasiliensis (1)	11-14

Information was derived from a diversity of sources including regional data. For bats found in in the state of Texas, information was taken from [1] Schmidly, 1991. For bats not found in the state of Texas, information was taken from: [2] Barbour and Davis, 1969; [3] Norwalk, 1994; [4] Nagorsen and Brigham, 1993; [5] Emmons, 1990; [6] Eisenberg, 1989; [7] Mammalian Species Account.

Chapter Eight

Mating Behavior and Reproduction

Mating Behavior

Reproductive captive colonies of insectivorous bat species can be maintained using the housing, feeding and routine examination procedures described in this manual. The author has maintained a captive reproductive colony of between 40 and 70 Brazilian free-tailed bats (*T. brasiliensis*) for the past 24 years. This colony has produced third generation offspring (see table 8-1). The author has also maintained small colonies of big brown bats (*E. fuscus*), evening bats (*N. humeralis*), cave bats (*M. velifer*), little brown bats (*M. lucifugus*), big free-tailed bats (*N. macrotis*), pocketed free-tailed bats (*N. femorosaccus*) and pallid bats (*A. pallidus*).

Caretakers must be sensitive to the possibility of reproductive behavior and associated aggression, which may necessitate procedural modifications. For example, the Brazilian free-tail colony maintained by the author is reproductively active. Males in these colonies develop a distinctive odor and mark mating territories by rubbing secretions from their gular glands (a gland on their throat) and anuses, as well as penises, on roosting pouches and caging surfaces (Figure 8-1B, C and D).

Figure 8-1. A: Enlarged gular gland. **B:** The male rubs his nose on the enclosure surface. **C:** After rubbing his muzzle on the enclosure surface, the male rubs his gular gland in the same spot. **D:** The male then rubs his penis onto the surface, sometimes dribbling a small amount of urine. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

The testes, anal areas and gular glands of some males become more pronounced during times of the year when males are sexually active. Mating males also demonstrate an obvious affinity for particular locations within the enclosure and defend these areas, both vocally and physically, against intrusion by other males (Figure 8-1E, F and G). Two types of audible vocalizations have been noted by the author in relation to mating activity by these males (Lollar, 1994; French and Lollar, 1998). The first is a buzz that may be used to announce the establishment of mating territories or to call females to these areas. The second is a faint, audible chirping vocalization that may function as a mating song or perhaps an indication of more immediate sexual intent. Mating males also respond with increased vocalization and wing flapping when particular females in these colonies are handled, and may bite caretakers that are extracting females from the male's territory.

Copulation has been observed both inside and outside of roosting pouches guarded by territorial males in these captive colonies. During copulation, males grip females by the scruff of the neck with their teeth, and curve the lower part of their bodies around the back end of the females (Figure 8-2A). Otherwise passive males will often become aggressive during mating activity and may inflict injury on one another sufficient to require medical attention (see Bite Wounds). If untreated, such injuries could be fatal.

Figure 8-1. E: Two non releasable male *T. brasiliensis* squaring off over territory. The males, each in the vicinity of their own territory, meet in the middle after vocalizing intent. **F:** The more aggressive of the two rushes into the territory of the less aggressive male**. G:** The males begin to fight by opening their mouths wide and biting the face of their opponent.

Figure 8-2. A: Free-tailed bats copulating. Male holds the female's fur at the scruff of her neck by his teeth. **B**: A permanently injured, elderly free-tailed bat two days after giving birth to her second pup in captivity. T*. brasiliensis. Bat World facility. Photos by A. Lollar.*

When handling bats in reproductive colonies, the caretaker must be careful to place a bat back to the same exact location from where it was found within its enclosure to avoid aggressive interactions or interfering with reproductive activity. Placing a bat in a different location will often initiate aggression by a territorial male that is guarding the area. Plenty of space and an abundance of roosting pouches must be provided for reproductive colonies. There should be at least three times as many roosting pouches as there are mating males. Be particularly observant during mating activity. Examine these bats daily for any injury and treat accordingly. Remove any bats that do not appear to be faring well in a reproductive colony, and place them into a smaller, non-mating colony. Weight fluctuations often occur in both males and females during periods of mating activity. Unless complications develop, females that become pregnant should be left in the roost to give birth and raise their young (Figure 8-2B).

An unlimited food supply and ambient temperature regulation provided in captive situations can result in reproductive behavior at any time throughout the year. For example, some females in the author's captive colony of *T. brasiliensis* have given birth to fully developed young twice in one year even though this species gives birth only once a year in the wild. A female *Myotis velifer* maintained in captivity for several years gave birth to and successfully raised two pups in one year, including a female born on May 3, 2001, and a male born on November 1, 2001 (B. French, pers. comm.).

Of additional interest regarding *T. brasiliensis* is the observation of a maternity colony in Mineral Wells, Texas (Figure 8-3). The author observed a colony occupying a crawl space and crevices created by shifting sandstone in a two-story building from January of 1993 to 2013. In mid-January of each year, bats (mainly males) begin arriving in the building and roosting within crevices created by shifting sandstone blocks in the walls of the crawl space on the west and southeastern sides of the building.

Figure 8-3. A section of the nursery colony at Bat World's wild sanctuary. *T. brasiliensis. Photo by A. Lollar.*

By the end of February, approximately ten thousand bats are roosting in these crevices. Many females begin appearing in the building in April. In early June of each year, approximately 5,000 females form a maternity colony within the crevices of the south wall of the building. Young are born between mid-June and mid-July (Figure 8-3B), with two or three pups always born late, in the first week of August. The author has noted that both in captivity and in the wild, pups are typically born during mid-morning hours. This timing may help to ensure that mothers are rested and physically able to forage for insects at nightfall.

The number of bats in the building began increasing each year in early August when flightless young were still present, with a sudden and dramatic increase in numbers occurring between August 18th and August 24th of each year, when an estimated 100,000 bats occupied the building. Bats are subsequently seen circling both inside and outside of this and similar buildings in the town. This apparent "swarming" activity took place from dusk until about midnight and again briefly in decreased numbers at dawn. This pattern continued for four to six days, after which there was a decrease in the number of bats occupying the building and the site previously occupied by the maternity colony was completely abandoned. There was continual fluctuation in the population throughout September and October, with numbers varying from an estimated twenty to thirty thousand bats. The numbers gradually diminished from November through mid-December, at which time all bats had left the building. These observations lead the author to speculate that bats of this species gather at maternity sites prior to their migration to Mexico. Such "gathering" behavior may serve as pre-migratory orientation for the young.

Copulation and associated vocalizations were recorded by the author in an upper window encasement on the west side of the wild sanctuary building in Mineral Wells on March 17, 1996, and by French in Bracken Cave in central Texas on March 28, 1996. In the cave, three bats were observed crawling over the back of the others where an estimated 40,000 to 50,000 bats roosted on the ceiling of the inner chamber. These bats were 15cm to 30cm apart, and all three were observed in apparent copulatory positions with bats beneath them. One of the three appeared to copulate with two bats in less than a minute, then flew off. Mating behavior had not previously been recorded in the wild for this species. These observations lead the author to believe that mating commonly occurs in spring at sites used as summer nursery roosts by *T. brasiliensis* in the U.S.

Table 8-1
Select Data on a Captive Reproductive Colony of *Tadarida brasiliensis*

Year	Mother	Father	Offspring	Year	Mother	Father	Offspring
1994	Thumbelina	Ricochet ‡	Bingo (m)*	2002	Varooka	Unknown	Vindaloo (m)*
1996	Baby ST	Bingo*‡	Beatrice (f)**	2003	Elvira*	Unknown	Eureka (f)**
1997	Beatrice**	Unknown	Bitty (f)***	2004	Beano	Unknown	Bocephus (m)*
1998	Morticia	Unknown	Maddie (f)*	2005	Eureka**	Vindaloo*‡	Violet (f)***
1998	Maddie*	Unknown	Markus (m)**	2006	Bitty***	Unknown	Stillborn
1999	Maddie*	Unknown	Mable (f)**	2007	Prudence	Unknown	Philomena*
2000	Putter	Gimlet‡	Pitterpatter (f)*	2008	Philomena*	Unknown	Prissy**
2000	Exit	Gimlet‡	Elvira (f)*	2009	Pandora	Unknown	Phineus (m)*
2001	Andrea	Unknown	Andy (m)*	2010	±		

Select free-tailed bats (*T. brasiliensis*) in Bat World Sanctuary's non-releasable captive colony that have reproduced over the last 16 years. Neutering has been preformed on most males since 2002 to slow reproduction. *First generation. **Second Generation. ***Third generation. ‡Suspected father. ± Neutering was preformed on all remaining males.

Orchiectomy

General Information

In bats, the male's sperm is transported to the female reproductive tract via the male duct system. As described by Hill and Smith (1984), the vas efferens and epididymis open into the vas deferens (i.e., ductus deferens) which empty into the seminal vesicle, the ejaculatory duct, and then the urethra. There are a number of erectile bodies in the penis including the corpora cavernosa responsible for erection in the penile shaft and the corpus spongiosum which surrounds the urethra. These vascular tissue bodies become erect when engorged with blood during sexual arousal. There are varying degrees of fusion of the paired corpora cavernosa in bats depending on the species. In some species they are completely fused into a single body for most of their length; in other species the distal portions are unfused. There is an ossification of the fibrous tip(s) of the corpora cavernosa in many bats which helps to create stiffness. The point of ossification is referred to as a baculum. The corpus spongiosum extends into the head of the penis in megachiropterans. Microchiropterans have accessory cavernous tissue responsible for erection of the head of the penis.

If mating for species propagation is not intended and aggressive behavior in unneutered males is problematic, it may be desirable to neuter captive male bats.

Veterinary assistance for an orchiectomy or other surgical procedures is recommended. Insectivorous bats can be neutered by first anesthetizing the bat with isoflurane using a modified cone induction system (see Anesthesia). During the procedure, visual monitoring of depth of respiration, auscultation of heart rate and response to pain should be used to determine level of anesthesia.

Procedure

Place the bat horizontally on its back (Figure 8-4). Extend the legs to allow access to the scrotum. Scrotal prep is done with chlorhexidine gluconate 4% or povidone iodine. Use curved-tip forceps to gently press in to the pelvic area and isolate the testicle. Close the forceps around the testicle, pushing it to the surface. Hold the testicle securely in place, then use surgical scissors or a #15 scalpel blade to make an incision through the skin and fascia of the scrotum. Be careful not to cut any vessels that may be visible through the surface of the skin. Using a second pair of fine-tipped forceps, grasp the testes to exteriorize it and expose the spermatic cord. In some species, such as the Brazilian free-tailed bat (*T. brasiliensis*), the spermatic cord can be gently torn, rather than tied and cut away, to remove the testicle. The incision can be closed with tissue adhesive. The bat should be removed from the cone, hand-held with its head lower than the rest of its body, until completely awake, at which time it can be released back into its enclosure. Post operative care includes one dose of of Metacam® for pain and one of Veraflox® once a day for 10 days (see Medications).

Figure 8-4. A: Gently pressing into the pelvic area and isolate the testicle. **B:** Exteriorize the testes and expose the spermatic cord, then gently remove by tearing. **C:** Close the incision with tissue adhesive. *T. brasiliensis. Bat World facility. Photo by M. Singleton.*

Caring for Pregnant and Lactating Females

General Information

Like many other mammals, female bats have a reproductive system with paired ovaries and a duct system that receives the ovum and conveys it to the site of implantation, the uterus, where it is sustained for the gestation period (Figure 8-5A). The vaginal portions of the paired ducts are fused into a common vagina that opens externally and independently of the urinary and intestinal tracts. The paired ducts may remain unfused, opening separately into the vagina. In some bats the uterine horns are partially fused so that there is a common uterine canal. In other bats, the uterine horns are completely fused so that there is a single uterine canal.

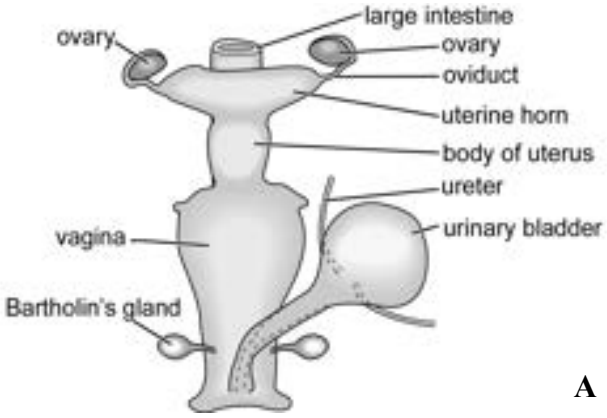


Figure 8-5. A: Female reproductive tract. *Eptesicus fuscus. David Chapman. Modified from Hill and Smith.*

Fertilization takes place in the oviduct and the blastocyst is moved into the uterus where it implants and remains for the gestation period. Hormones secreted by the ovarian follicle cause changes in the inner lining of the uterus, and blood vessels and glands in deeper layers branch into the uterine lining. These changes are important for nourishment of the incoming zygote (i.e., fertilized egg), implantation, and development of the maternal portion of the placenta once the blastocyst is implanted in the endometrial lining of the uterus.

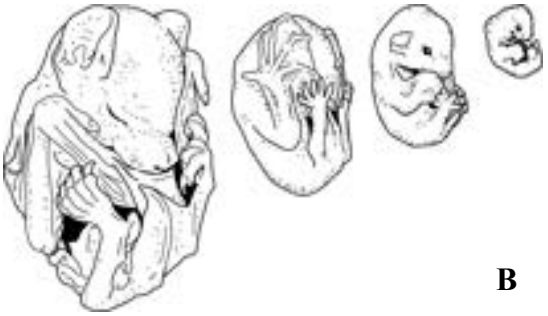


Figure 8-5. B: Developmental stages of a bat fetus. *David Chapman.* **C:** An aborted fetus from a free-tailed bat. *T. brasiliensis. Photo by A. Lollar.*

Many North American bats hibernate and have reproductive patterns characterized by delayed fertilization and over-winter storage of sperm in the female reproductive tract. Mating typically takes place in the fall prior to hibernation. Sperm is stored in the female uterus throughout the winter. When ova are ovulated after females emerge from hibernation in the spring, fertilization takes place. This is the case for *Perimyotis*, *Parastrellus, Eptesicus, Nycticeius, Lasiurus, Corynorhinus, Antrozous* and many of the *Myotis* species. In some species, such as the Brazilian free-tailed bat (*T. brasiliensis*) mating takes place in the spring (Lollar, 1994, French and Lollar, 2000) and is followed by immediate fertilization, implantation, and fetal development (Figure 8-5B and C). In other species, mating is followed by immediate fertilization and implantation, but fetal development is delayed until the following spring. This reproductive strategy is known as delayed development and is the case for *Macrotus californicus* and one of the annual cycles in *Artibeus jamaicensis*. In some species, males produce sperm in the fall which is stored in the male reproductive tract until spring when copulation occurs (Racey, 1970). In North American species, gestation generally ranges from 45 to 90 days, and pups are born in the late spring or early summer when there is an abundant insect supply.

Most bats give birth to only one or two young, which nurse from two teats. However, Lasiurine bats may give birth to as many as five pups, which nurse from four teats (see Number of Young Per Year in this chapter).

Some, such as the big brown bat (*E. fuscus*), give birth to only one pup in some parts of their range (Rocky Mountains and westwards), while those in eastern North America give birth to twins. The northern (or eastern) long-eared bat (*M. septentrionalis*), the silver-haired bat (*L. noctivagans*) and the California leaf-nosed bat (*Macrotis californicus*) may give birth to either one or two pups. In bats that give birth to one young, ovulation may alternate from one ovary to the other with implantation occurring in the uterine horn on the ovulating side. In some bat species, such as the little brown bat (*M. lucifugus*), the right ovary tends to dominate. Although most species of bats that give birth to more than one young ovulate from both ovaries, in the California leaf-nosed bat (*M. californicus*) only the right ovary is functional and all implantations take place in the right horn of the uterus. Insectivorous bat species in the United States and Canada give birth to only one pup, twins, or litter per year, typically in June or July, although pups have been born in some parts of the country as early as April and as late as August. While females of some species form maternity colonies where young are reared, others, such as red bats (*L. borealis* and *L. blossevillii*) remain solitary during parturition.

Care During Pregnancy

Pregnancy in captive bats is usually signified by a sudden increase in appetite early on, and the abdomen will feel hard rather than soft or palpable. In later stages, the abdominal region is grossly distended, and milk can be seen in the mammary glands beneath the skin when the fur is parted. Bats occasionally loose fur on the abdomen (see photo Figure 2-3). Crevice bats give birth to one, and sometimes two, pups, as described above. Tree bats typically give birth to between two and five pups.

Wild pregnant bats are sometimes found grounded a week or two prior to giving birth. These bats may be first time mothers who are unable to forage sufficiently to sustain energy for themselves and their growing fetus. In cases like these the mother should be cared for until she gives birth. They should be carefully checked for signs of dehydration and rehydrated with an injection of electrolyte solution (see Dehydration and Fluid Replacement Therapy) and receive treatment for injuries. Pregnant females should be offered food in the manner described in Feeding Adult Bats.

Allow pregnant and lactating females to consume as much food as they desire. Pregnant and lactating bats of medium size may consume as much as 3mls of soft food or 20 to 30 mealworms, twice daily (see Feeding Adult Bats). If a pup is clinging to the mother and she needs to be hand-held for feeding, do not attempt to detach the pup. Instead, hold the mother and pup together in a position within the hand that allows her to remain comfortable during the hand-feeding process. Tree bat mothers should be hand-fed while hanging inside a enclosure, as described in Feeding Adult Bats.

Pregnant females will require an exceptionally warm environment. Incubators used for orphaned pups and convalescing bats are ideal for temporarily housing pregnant females (see Temporary Housing) so long as they provide ample room and several roosting areas and pouches. Temperatures should be maintained between 90^{o} to 100^{o} Fahrenheit.

Once crevice bat mothers have settled into captivity, do not change their surroundings in preparation for them to give birth. Any disturbance prior to, or immediately after giving birth, should be avoided as any additional stress can cause mothers to reject infants. If a pregnant female is housed with other crevice bats and there is concern regarding the interaction of roostmates with the newborn, the roostmates should be transferred to new housing rather than moving the pregnant female. Never house *E. fuscus* orphans with adult females that are not pregnant or that have not recently given birth because they have been reported to attack orphans.

Normal Birth

When a pregnant bat is close to giving birth, she may move to or roost in an area of the incubator or enclosure she normally doesn't use. She may also exhibit loss of appetite, or if she does eat, may vomit soon after. A pregnant female exhibiting such cues should be observed periodically throughout the day. The bat should be disturbed as little as possible during observations, and not handled unless absolutely necessary.

When a female prepares to give birth, she may assume a head-up position on the enclosure wall or a hammock-like position on the enclosure ceiling and begin licking at her abdomen or genitalia. The passing of a large stool and/or amniotic fluid, and rapid, heavy respiration may be observed. Some females will vocalize during the birthing process. Although most megabats are born in a head-first position typical of other mammals, many microbats are born feet first.

Figure 8-6. A newborn pup, still attached to the mother through the umbilical cord. *T. brasiliensis. Photo by A. Lollar.*

Pups are typically naked at birth and will be pink in color (although some, such as red bats, are born with patches of a fine, pale gray, peach-like fuzz). Pups may be born with eyes open (Figure 8-6), as is the case with the Brazilian free-tailed bat (*T. brasiliensis* - Lollar, 1994) or with eyes closed, as is the case with most other species. A normal birth can take anywhere from a few minutes to a couple of hours. The placenta is expelled after birth and remains connected to the pup via the umbilicus. Do not attempt to detach it from the pup. Circulation through umbilical vessels continues in some species for several minutes, after which the cord rapidly blanches as circulation ceases. When the cord dries up the placenta detaches, normally within 24 to 48 hours of birth. If the cord is cut or broken before circulation ceases, the neonate will bleed to death. If the umbilicus tears or breaks, the cord should be ligated. In some species, such as the evening bat (*N. humeralis*), mothers eat the placenta and umbilical cord to within 2.0mm to 3.0mm of the navel the first hour to hour and a half following delivery.

Following a normal birth, mothers generally rest for a few moments and then clean and bond with their infants. Mothers and pups exchange vocalizations and mothers often rub their muzzles on the infant's face and body. However, sometimes a mother will coax an infant onto the ceiling or enclosure wall and then ignore the pup until she has groomed herself, after which she will begin cleaning and then nursing the infant. Some species, such as cave bats (*M. velifer*) tend to keep their pups neatly tucked under one wing most of the time for the first several days of life. Others, such as the Brazilian free-tailed bat (*T. brasiliensis*) roost separately from their pups most of the time, only moving to the pup to nurse it; it is particularly important that incubation be provided for these pups.

Difficult Birth

If a birth has not occurred within one or two hours of the onset of behavioral cues described above, the mother may be experiencing difficulty and should be examined. The pup may be improperly positioned so that the head or a wing is lowest in the vaginal canal rather than the feet. Because it is extremely difficult to reposition a fetus in a small bat, surgical intervention may be required. In an emergency situation when veterinary help is not available, a caregiver will need to intervene.

Figure 8-7. A pup stuck in the vaginal opening of a free-tailed bat. *T. brasiliensis. Bat World facility. Photo by J. Waltz.*

If the fetus is positioned at the vaginal opening, but the opening does not seem to be dilating enough to allow the infant through, an episiotomy may be necessary. Using a cotton swab, apply Cetacaine® to the vagina to anesthetize the area (Figure 8-8A). Then, using small sterile surgical scissors, make a small snip through the skin and underlying tissue on one or both of the lateral sides of the vaginal opening. Do not make an incision down towards the rectum or up towards the anterior labial commissure. The incisions should be made at the three o'clock and nine o'clock positions (Figure 8-8B). Try not to make an incision any longer than 1.0mm, as a larger incision may cause the uterus to prolapse. Be careful not to cut or bruise the fetus.

Figure 8-8. A: Apply Cetacaine® (a numbing agent) to anesthetize the vaginal opening. **B:** Very small incisions should be made at the three o'clock and nine o'clock positions. *T. brasiliensis. Bat World facility. Photo by J. Waltz.*

After making the incision, firmly but gently grasp the emerging pup with the fingertips, and ***slowly and very gently*** pull it out of the birth canal ***during a contraction*** (Figure 8-9A). Pulling on the pup with too much force may cause the uterus to prolapse, in other words, the uterus protrudes through the vaginal opening and outside of the bat's body. If this happens, hold the female upside down in the hand, carefully extract the placenta without tearing it or detaching it from the pup, then use the rounded tip of a small sterile rubber catheter lubricated with water-soluble jelly to gently "tuck" the uterus back inside the vagina. If the uterus cannot be tucked back inside, or if it repeatedly prolapses, it will need to be ligated and removed.

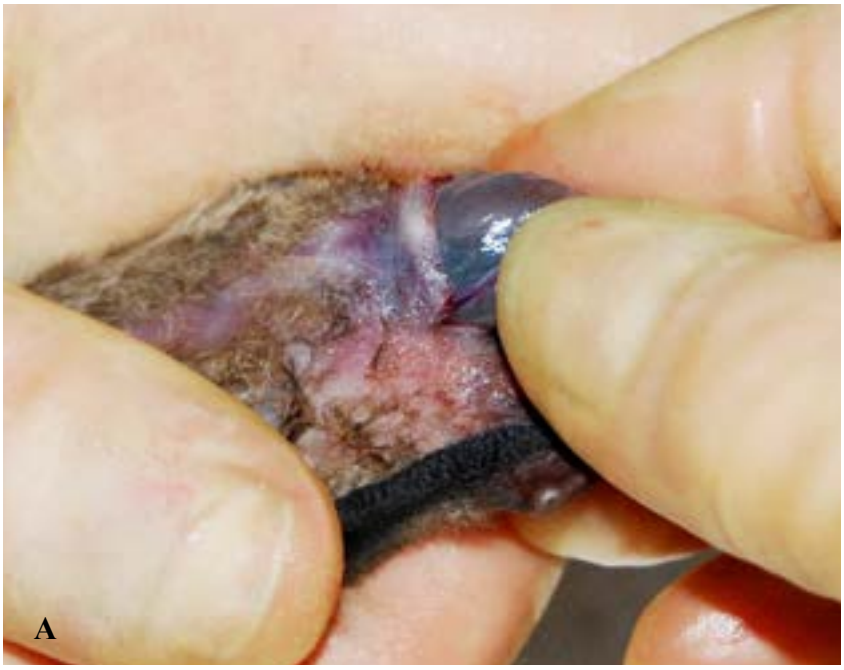
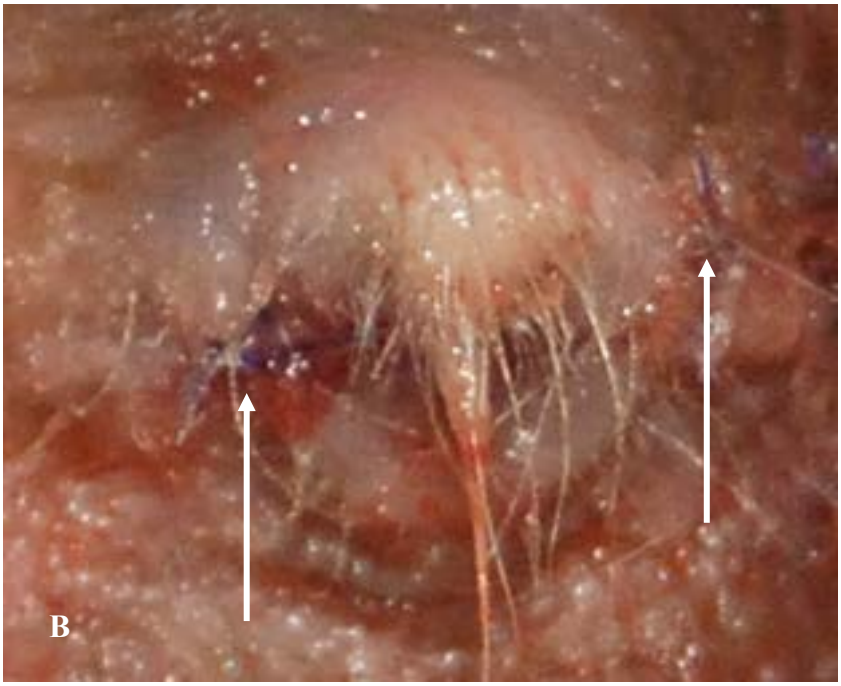


Figure 8-9. A: Gently grasp the emerging pup with the fingertips, and slowly and **very gently** pull it out of the birth canal **during a contraction**. **B:** Be extremely careful to avoid gluing anything other than then the incised areas, indicated by the arrows. *T. brasiliensis. Bat World facility. Photo by J. Waltz.*

After the pup has emerged, gently but quickly clean its face of any fluid or vernix. Then, massage the pup's chest to encourage respiration. If necessary, wrap the pup in a soft cloth and administer oxygen (see Medications) while completing the episiotomy on the mother.



Gently clean the mother's abdomen with gauze pads dampened with warm water, and dry the area. Close the incisions with Gluture®. Magnification is **strongly recommended** when applying this product to close episiotomies. Do not apply the glue directly from the container, rather, use a small pipette to apply. ***Be extremely careful to avoid gluing anything other than the incised areas*** (Figure 8-9B). Bats that have had an episiotomy or a prolapsed uterus should be injected with an electrolyte solution to combat dehydration, followed by oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 10 days (see Medications).

If the uterus does not prolapse following an episiotomy, the afterbirth should be expelled with, or immediately after, the pup has emerged. If it is not expelled, do not attempt to pull it out. The afterbirth, which is still connecting mother and infant, will eventually be expelled by the mother.

Both mother and pup will be exhausted after a difficult birth. Do not handle them any more than absolutely necessary. Excessive handling of the mother may cause her to reject the pup; over-handling of the pup and/or allowing it to become cold can result in death. Allow them both to rest quietly for at least a few hours.

After a difficult birth infants may appear weak and hang very still for several hours. Check the pup every 15 minutes, but do not interfere unless the pup becomes cold to the touch or the mother actually moves to a separate section of the enclosure and leaves the pup by itself. Resist the urge to coax the infant to the mother's teat. The mother will nurse the infant when she is ready. If a mother moves away from the pup and does not attempt to care for it in any way, even after she has finished grooming herself, it will need to be hand-fed (see Feeding and Care of Infants). Note: the author has raised approximately two-dozen *T. brasiliensis* pups orphaned immediately after birth. These pups did not receive colostrum and remained healthy into adulthood.

Continue to house the mother with the infant because even reluctant mothers will sometimes begin caring for and nursing their pups if the pups are initially fed. Healthy females that have given birth but that are not lactating or refuse to care for their pups, should remain in captivity for two weeks to make certain no problems develop following delivery.

CAESAREAN SECTION AND OVARIOHYSTERECTOMY

This procedure as described should be performed under general anesthesia, and by a veterinarian when possible. Subcutaneous fluids and antibiotics should be given preoperatively and before anesthesia. Place the bat on a pre-warmed circulating fluid warmer or on a towel placed over a heating pad (set on the lowest setting). Under anesthesia (see Anesthesia), prepare the abdominal area for aseptic surgery with chlorhexidine gluconate 4% or povidone iodine, without clipping the fur.

Make an incision along the midline through the skin and linea alba (a white line of connective tissue) exposing the uterus immediately underneath. The incision should extend just above the pubic area to just below the sternum. Incise the uterine horn and extract the fetus. Little, if any, amniotic fluid is encountered. Do not separate the placenta from the infant. Clean the infant's face with a warm, moistened sponge. Wrap it in a soft cloth, leaving the face exposed, and place it on the heated surface. Pups sometimes require oxygen (see Oxygen Therapy). The author recommends that an ovariohysterectomy be performed on the mother at this time. Control any hemorrhage with hemostats and ligation; sterile 6-0 (1.0 metric) absorbable sutures. Identify the ovaries as small whitish nodules at the craniolateral aspect of the uterus, caudal to the kidneys. Ligate the uterine body with a single ligature just cranial to the urinary bladder and remove the uterus and ovaries. Flush the abdomen with warmed sterile saline before closure. Meticulously reoppose the surgical wounds, again using absorbable sutures.

Bats that have caesarean sections should be injected with an electrolyte solution to combat dehydration, followed by oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days (see Medications). If available, deep tissue pain can be managed with Buprenex for up to 48 hours (see Medications) before then continuing with Metacam. During recovery, the bat should be housed to stay in a hanging position as much as possible. Limit movement so the bat rests and does not crawl or attempt to fly. Bats with caesarean sections will sometimes accept their pups after four to five days. The pups need to be cared for until the mother accepts them (see Care and Feeding of Infants).

Captive Mothers with Pups

Crevice bats

Wild crevice bat mothers who give birth in captivity typically care for their pups initially, but sometimes abandon the pup in as little as 24 hours. The author has rescued and cared for numerous *T. brasiliensis* mothers who gave birth in captivity. One mother cared for her pup for two weeks before abandoning the infant. In captivity, a crevice bat mother may appear to be caring for her pup but may not continue to lactate. It is critical to check

the stomachs of pups daily to make certain the infants are being fed. Milk should be visible through the skin of the abdomen. If the pup is found empty on several occasions throughout a 24-hour period, it will need to be hand-raised by a caretaker. Occasionally, a mother crevice bat may display aggressive behavior toward her infant. In cases such as this, the infant and mother should be separated and the infant hand-raised. Do not attempt to attach the infant to the mother; doing so will result in injury and possible death of the infant.

Tree Bats

Captive tree bat mothers frequently nurse their pups during the day, but will coax them onto the foliage or netting at the top of the enclosure in the evening (when she would normally be foraging in the wild). The siblings hang together in a group. The mother then roosts elsewhere within the enclosure and does not usually return to the pups until early morning, when she forms a sort of hammock beneath them and coaxes them onto her chest so that they can begin nursing again (Figure 8-10).

If the mother does not return to the pups in the early morning, the pups should be placed on the enclosure ceiling (netting) so that they are hanging by their feet and close enough to the mother that they will be able to touch her. When in such close proximity, the pups will reach out for the mother with their wings, and she typically responds by moving closer to the pups so that they can nurse. Although pups cling to a mother with their milk teeth, thumbs, and the claws of their toes, they will assist in supporting their own weight by clinging to vegetation or netting with one or both feet as they nurse.

Figure 8-10. A rescued mother eating a mealworm while her pups cling to her underside. *L. borealis. Photo by L. Sturges*.

In captivity, tree bat mothers may appear to be caring for pups, but may not continue to lactate. It is critical to check the stomachs of pups daily to make certain the infants are being fed. Milk should be visible through the skin of the abdomen. Unless mothers are exhibiting aggressive behavior toward the young, non-lactating mothers and pups should remain together even if pups are being hand-fed by a caretaker. Non-lactating mothers may be released after two weeks of captive care if they are still in good health (see Releasing Bats to the Wild).

Tree bats that give birth to stillborn fetuses or pups that die soon after birth will sometimes nurse orphans. The author has frequently observed this behavior in red bats (*L. borealis*). Do not, however, allow more than one pup to nurse from mothers of a species that normally give birth to a single infant. Bats that normally give birth to multiple pups (e.g. red bats) often do not successfully raise the entire litter. It is not recommended that orphans be fostered with these species unless the mother is only caring for a single infant, in which case an additional orphan may be given to the mother. Although these mothers will sometimes accept more than one orphan, they may not produce sufficient milk to successfully raise any of the pups.

Be very careful when offering orphans to mothers. Some mothers will not accept orphans and may bite and injure them. Remove pups from these mothers immediately if any signs of aggression toward the infant is observed. Orphaned pups should be checked once every four hours to make certain they have milk in their stomachs. If not, they should be hand-fed. Note: Do not house more than one tree bat with pups in an enclosure as injuries will likely result to pups. As previously stated, do not house orphans with adult females that are not pregnant or that have not recently given birth because unrelated females have been known to attack orphans.

Notes on Rescuing Tree Bats with Pups

Tree bats are most commonly found between mid-May and late July. Pregnant or nursing bats are frequently driven from trees by aggressive birds, where they land on small bushes, the eaves of houses and on the ground. Tree bats may also be found on the ground following strong storms. Females with only two fully furred pups are often found later in the season. Because many females give birth to four and five pups, this may indicate that one or more pups have died before being weaned. However, when rescuing these mothers, it is important to look on the ground and in nearby trees to make certain no pups are left behind.

Because tree bats often panic when handled (see Behavior), it's best to touch a small tree branch (about the length of your arm and the diameter of a pencil) to the bat's feet. Tree bats will typically grasp the branch with the feet and then can be carefully lifted, allowing visual inspection for injuries. If the infants remain attached to their mother, and no apparent injuries are observed, the branch, with the bats attached, can be placed into a nearby tree. Make sure to secure the branch at a height of about 6 feet in a cluster of leaves to provide shelter. Position the branch so there is a clear drop zone below so the mother can drop into flight and move her pups easily. Check the site the following morning to look for the pups. If the pups are found alone, they should be retrieved and hand-raised.

If an injury is apparent, place the mother and pups inside a soft mesh transport carrier such as a bat hut. Encourage her to transfer her grip from the branch to the screening with soft nudges of a gloved hand. This move must be made very slow and carefully. If the mother's injuries do not preclude flight, she is likely to dislodge the pups and fly off without her young. If this should happen, do not place the pups into a tree for possible retrieval by the mother. An injured mother is not likely to successfully care for her pups. Instead, these pups should be hand-raised.

Mothers who are injured and unable to fly may panic when inside the Bat Hut or transport carrier. Once panicked, these bats will flap relentlessly inside the carrier. This frequently results in further injury to the mother or pups, particularly if the enclosure is not soft-sided. It is important that the mother, with pups attached, be moved very slowly and with extreme caution. A mother who becomes disturbed, dislodging her pups in the process, should be transferred to a second transport carrier, separate from her pups. Providing the mother is not aggressive to her pups, the young may be physically reattached to the mother once she has been examined and treated for injury, and placed into temporary housing.

Complications

FETUS DEATH IN UTERO

If a pregnant female presents with malodorous urine and concurrent loss of appetite, a fetus has likely died in utero. A Caesarean section will need to be performed as described in this chapter. The female should be injected with an electrolyte solution followed by oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days (see Medications).

HYPOCALCEMIA

Hypocalcemia is a low blood calcium level that sometimes develops in lactating bats. The symptoms include muscle tremors and twitches in early stages; convulsions occur in later stages. Species that normally carry their young may be found roosting away from the pups. This condition progresses rapidly and is fatal if not treated in early stages. Administer Calsorb orally once a day until symptoms subside (see Medications). Remove nursing pups and hand-feed them until the mother recovers.

HERNIA

A difficult delivery can result in a hernia. The author has observed this condition in both wild and captive bats following natural deliveries. These hernias can sometimes be surgically repaired. If corrective surgery is preformed, the bat should followed by oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days (see Medications). If available, manage deep tissue pain with Buprenex for up to 48 hours before then continuing with Metacam (see Medications).

MASTITIS

Mastitis is an infection of the tissue of the breast that can occur after pups stop nursing. Symptoms of mastitis include excessive grooming of one breast, swelling, redness or warmth of one breast, discharge, vomiting and lethargy (Figure 8-8). In severe infections, an abscess may develop, resulting in a discharge that may contain blood.

Abscesses should be drained using a sterile 27-gauge needle. Apply a topical anesthetic, such as Chlor-a-Flush before lancing the area. Carefully insert the needle bevel side up into the abscess, then gently apply pressure to remove as much purulent material as possible, preferably until only clear blood appears. Using gauze, apply moist heat to the infected breast for 5 to 10 minutes, two to four times daily, which will help to alleviate pain. Antibiotics are usually very effective in treating mastitis in bats. Give oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days (see Medications). Remove any nursing pups and hand-feed them until the mother is stable.

Figure 8-8. A big brown bat with a severe case of mastitis. *E. fuscus. Photo by D. Kinamon.*

Table 8-2
Number of Young Per Year

Species	No. of Young
Family Mormoopidae	
Mormoops megalophylla	1
Family Phyllostomidae	
Artibeus jamaicensis	1 to 2
Choeronycteris Mexicana	1
Leptonycteris yerbabuenae	1
Leptonycteris nivalis	1
Macrotus californicus	1 to 2
Family Vespertilionidae	
Antrozous pallidus	1 to 4
Corynorhinus rafinesquii	1
Corynorhinus townsendii	1
Eptesicus fuscus	1 to 2
Euderma maculatum	1
Idionycteris phyllotis	1
Lasionycteris noctivagans	1 to 2
Lasiurus blossevillii	1 to 3
Lasiurus borealis	1 to 4
Lasiurus cinereus	1 to 4
Lasiurus ega	1 to 4
Lasiurus intermedius	1 to 3
Lasiurus seminolus	1 to 4
Lasiurus xanthinus	1 to 4
Myotis austroriparius	2
Myotis auriculus	1
Myotis californicus	1
Myotis ciliolabrum	1
Myotis evotis	1
Myotis grisescens	1
Myotis keenii	1
Myotis leibii	1
Myotis lucifugus	1
Myotis septentrionalis	1 to 2
Myotis sodalis	1
Myotis thysanodes	1
Myotis velifer	1
Myotis volans	1
Myotis yumanensis	1
Nycticeius humeralis	2
Perimyotis hesperus	2
Parastrellus subflavus	2
Family Molossidae	
Eumops floridanus	1
Eumops perotis	1
Eumops underwoodi	1
Molossus molossus	1
Nyctinomops femorosaccus	1
Nyctinomops macrotis	1
Tadarida brasiliensis	1

Chapter Nine

Feeding and Care of Infant bats

General Intake for Bat Pups

Orphaned bats are typically dehydrated when received. They should receive a subcutaneous injection with an electrolyte solution (see Dehydration and Fluid Replacement Therapy). Pups can then be fed as soon a fluids are absorbed, usually within 10 to 20 minutes. Pups that are furless, or that have tiny, sharp-hooked milk teeth should be fed milk formulas.

Do not dilute formula when feeding infant bats! Additionally, do not attempt to hydrate the pup orally by diluting milk with LRS or Pedialyte, etc.). Emaciated infants require maximum nutrition to fill caloric deficits; diluting milk formulas for starving infants only increases the risk of nutritional deficiencies such as Metabolic Bone Disease (MBD).

Pups that are fully furred or have adult teeth (i.e., canines rather than milk teeth) are juveniles. As with orphaned pups, they should be completely hydrated with SQ injections before food is offered. Failure to restore bodily fluids before introducing solid foods can be fatal (see Dehydration and Fluid Replacement Therapy). Juveniles that are underweight should be fed the intermediate mealworm diet in this section. Juveniles that are not underweight should be fed the mealworm diets for adult bats, including both live mealworms and the complete soft food diet (see Weaning and Feeding Juvenile Bats on page 109).

Orphaned bat pups need nurturing. Gentle handling and soothing tones must be used when caring for these animals. Insectivorous bat pups do not imprint. Pups spend a great deal of time in physical contact with their mothers and with conspecifics; therefore, direct handling is recommended for pups' well-being and sense of security. For this same reason, bat pups should not be housed alone.

Figure 9-2 A & B. The sunken area between the shoulder blades is a sign of emaciation. A free-tailed pup is shown on the left and a fully furred juvenile free-tailed bat on the right. Both bats are also dehydrated. *T. brasiliensis. Bat World Facility. Photos by A. Lollar.*

Feeding Implements

Once a milk formula has been prepared, an electric coffee or candle warmer can be used to keep the milk warm during feeding sessions. Note that milk formula will scald if the container is placed directly on the warmer. Instead, place the container of formula inside a bowl of warm water, and place the bowl of water on the coffee warmer (Figure 9-3). Constantly monitor the temperature to ensure it stays warm but not too hot. Bat pups typically prefer milk at a temperature that feels somewhat warmer (115° to 120° Fahrenheit) on the wrist than that appropriate for human infants.

Figure 9-3. A coffee warmer works well to keep milk formulas warm during feeding. Glass droppers are preferred as they are easily sterilized and help to keep the milk warm. *Bat World facility. Photo by A. Lollar*

While some rehabilitators prefer to use plastic syringes to feed milk formulas, the author prefers using glass medicine droppers for two reasons. 1) Plastic is not sterile and must be cleaned with a bleach solution between feedings and 2), as the milk is dispensed, plastic syringes allow the milk to cool much faster than glass. Bat pups require a consistently warm temperature of formula for proper digestion. Therefore, if plastic syringes are used it is critical to ensure the milk stays consistently warm during the feeding process.

During feedings, bat pups need to be kept warm. Never expose a pup to drafts from fans or air-conditioners. Crevice pups can be placed on a warm, clean cloth on top of a heating pad for feeding (page 100). Tree bat pups should be held in the hand (page 102).

Notes on Milk Replacement Formulas

The composition of milk varies from species to species. Composition also varies throughout the course of lactation (Table 9-1). Most U.S. commercial milk replacers developed for other mammals **do not** provide the necessary nutrition for insectivorous bat pups and some may even be toxic.

In 2007, bat care specialists across the U.S. reported a sudden increase of health issues with hand-reared orphans. The symptoms resembled poisoning and included chronic dehydration, kidney failure, vomiting, extreme hardening of the skin on the back (making SQ injections excruciating for the pup), pneumonia, diarrhea, anemia, MBD, and bones -including the shoulders, elbows and knees- fracturing under weight of the pup's own body. The only common denominator was commercial milk replacement formulas. For this reason, the author had two separate sources of the formula tested at two different laboratories. The report on these formulas came back as high in cadmium, mercury, arsenic, and lead. In addition, both samples contained little to no calcium, and one formula contained traces of an anti-malarial drug.

Seeking a solution, the author contacted Mark Finke, PhD Nutritional Scientist, in order to develop a safe alternative to commercial formulas using simple ingredients that bat care specialists could easily obtain. The milk formula recipes were developed over a one-year period, using the substantial research available on the milk compositions of crevice dwelling species (both Molossidae and Vespertilionadae). However, due to the very limited research available on the milk composition of tree bats, the formula is not recommended for foliage-roosting Vespertilionadae species. To date, thousands insectivorous bat pups of various crevice-dwelling species have been raised successfully to adulthood on the Bat World Sanctuary milk replacement formulas (Table 9-2).

Feeding Schedules

It takes only a small amount of milk to fill the stomachs of most pups. Because some infants are naked or sparsely furred for the first few weeks of life, milk can clearly be seen through the skin of the abdomen. Depending on the size, age, and condition of an infant, it will take anywhere from a few drops to 1.0ml of milk per feeding. Pups of most species should not be allowed to drink more than 1.0ml per feeding; serious gastric disturbance can result from overfeeding. Pups taking 1.0ml of formula per feeding should not be fed more than four times per day (once every six hours). Because foam feeding tips (see page 98) preclude exact measurement of formula consumed, visual or tactile examination should be used to determine when a pup is full. The stomach should be slightly rounded, but not bulging with milk (Figure 9-4 A). A distended abdomen indicates the pup has been allowed to drink too much, a condition that can be fatal (Figure 9-4 B). (Also, see Overfeeding on page 107)

Figure 9-4 A: A big brown pup with a proper rounded abdomen after being fed milk formula. *E. fuscus. Photo by C. Shaw, Shaw Wildlife.*

Figure 9-4 B: A free-tailed pup with an abdomen that is almost distended. *T. brasiliensis. Photo by A.Lollar*.

Regardless of the species or the age of an infant, feeding schedules should be determined by the amount of time it takes for an individual pup's stomach to almost empty. To determine an infant's feeding schedule, first become familiar with the look and the feel of the pup's abdomen both before and after its first feeding. Take note of the visual appearance and how the abdomen feels when gently palpated with the fingertips. Note the time and check the pup each hour thereafter. Do not let the stomach empty completely and appear concave. Keep enough formula in the pup at all times to keep the abdomen flat to slightly rounded. Feed the pup again when the milk is nearly gone (i.e., when the stomach is almost flat, or only a small amount of milk is visible in the stomach). If the pup is already furred, milk will not be visible through the abdomen and the handler will need to rely solely on tactile examination. Note the time it took for the stomach to partially empty in order to estimate when the next feeding will be due.

It is important to note that the milk formula recipes created for Molossidae and Vespertilionadae are very rich, much like a bat mother's own milk. Therefore, milk may remain in the stomach longer with the pup requiring less feedings. It is not unusual for an orphaned *T. brasiliensis pups*' stomach to take 8 to 12 hours to empty.

The author receives calls every summer from rescuers who simply fed a pup "every two hours" or "every four hours". It is **critically important** to realize that each pup is an individual and you will need to determine the feeding schedule according to the time it takes that pups stomach to empty. Feeding infants too often will result in bloat, i.e., distention of the stomach, severe pain, white feces and death (see Complications in this section). Younger pups and pups that are emaciated will likely need to be fed more often than older pups that are healthy. In other words, as pups grow older and become healthier, the number of daily feedings will decrease.

Determining Orphan Status with Crevice-Dwelling Pups

After observing thousands of infant *T. brasiliensis* in a nursery colony for over two decades, the author developed the following guidelines to determine orphan status in colonial crevice-dwelling bat species:

1) Healthy pups will appear chubby and area between their shoulder blades be flat or very slightly sunken in. (Figure 9-1 A).

2) Orphaned pups will gradually move away from their colony, moving first to the outside edge of other pups, and then finally away from the group entirely (Figure 9-1 B)

3) Severely sunken shoulder blades is a sign of emaciation and means a pup is orphaned and in need of rescue. Even if milk can be seen in the abdomen of an emaciated pup, that pup has likely been stealing milk from other mothers and still needs to be rescued as he will not survive. (Figure 9-2 A & B).

4) If a pup has fallen from a roost, and the precise location of where the pup fell is unknown, the pup should be rescued regardless of being healthy. This is especially important in roosts containing large numbers of bats, such as under a bridge (pers. Comm. Justin Stevenson). Placing the pup back in an unknown location may prohibit a mother from finding her pup and the pup may starve to death.

Figure 9-1 A: Healthy, plump free-tailed pups in a wild colony.

Figure 9-1 B: An orphaned free-tailed pup who has moved away from his colony. The sunken area between the shoulder blades is a sign of emaciation despite that this pup has recently fed. An arrow points to the milk that can be seen is his stomach. *T. brasiliensis. Bat World*

Only bat pups that are healthy, plump and fat should be placed back into the exact location from where they fell. These pups should be marked with a nontoxic paint before placing them back into the roost, and, if found away from the roost again, they should be recued. Pups should **never** be placed on a tree, ladder (or anything similar) in hopes the mother will come back to take her pup. The **only** exception to this is watching nonstop to make certain the mother bat rescues her pup. Too often, pups are placed up on something high at night and are then gone the following morning, leaving the rescuer to assume the mother came to get her pup. In reality, the pup likely crawled away and starved or was snagged by a predator.

Feeding Crevice Bat Pups

Vespertilionadae
Cervice-dwelling vesper bat pups will typically lap fluids and accept a drop-by-drop method of feeding. Begin by holding the pup upside down. This is extremely important because infants are likely to aspirate fluid into the lungs when learning to lap formula if the head is not kept lower than the rest of the body. Placing a small amount of warm formula onto the pup's mouth typically induces a lapping response. Continue to dispense the formula drop-by-drop as the pup drinks (Figure 9-5). Vespertilionadae pups that do not readily lap milk should be allowed to nurse from foam tips (Figure 9-9A) as described below.

Figure 9-5: An orphaned big brown pup lapping milk formula from a cannula. *E. fuscus. Photo by D. Wilkins.*

Molossidae
Unlike other bat species, Molossidae are physically unable to lap liquids. Therefore, milk should be offered to these pups through soft foam sponges. Natural or white foam eye-shadow applicator tips (Figure 9-6A) are used for this purpose (Lollar, 1994). Feeding free-tail pups with latex nipples, catheters, or any thing other than foam tips is not nurturing as well as uncomfortable for the pup. Additionally, it can easily result in aspiration as pups will not be able to control the amount of milk being placed into their mouths.

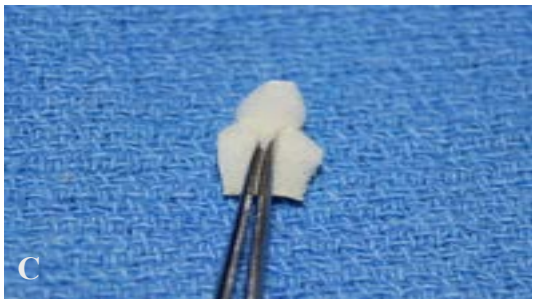
Figure 9-6. A: Foam eye shadow applicators available at cosmetic stores.

Remove the foam tip from the plastic wand by immersing the wand in hot water to loosen the foam from the plastic wand, then slide the foam tip off the wand.

The foam tip has a seam that runs along the entire edge of the tip (Figure 9-6B1). While the tip is still wet, tear the tip in half along the seam to form two matching halves (Figure 9-6B2). Use small scissors to cut the tip of the foam into a wedge shape (Figure 9-363). This size and shape are readily accepted by bat pups. Note: while (due to hunger) some pups will accept tips that are not reduced in size or removed from the wand, it will not be a comfortable or nurturing experience for the pup. As rehabilitators, it is our duty to make nursing a happy experience for orphaned pups, which means not taking shortcuts.

B: Foam tip removed from the wand and slightly separated at the seam. **2:** the foam tip torn in half at the seam**. 3:** The tip has been trimmed to resemble a wedge shape.

To save time, a package of tips can be soaked all at once, then divided and trimmed down for use. Allow them to dry on a flat surface before storing in a baggie for later use.



C: Prongs must be buried in the foam to protect the pup's mouth as the tip is introduced. *Photos by A. Lollar.*

When nursing from foam tips, pups should be placed abdomen down inside a folded washcloth, and on a heated surface to keep them warm. Heating pads set low to medium can be utilized for this purpose. There should be two layers of wash cloth between the pup and the heating pad to prevent accidental burns. Allow the washcloth to warm before placing the pup into the folds for feeding. Cover the pup's body with the cloth, leaving only the head exposed, as shown in Figure 9-8A. Use a clean, dry cloth for each feeding.

Begin by positioning the forceps on the foam (Figure 9-6C) so that the prongs are somewhat buried in the foam. This protects the pup's mouth. Dip the foam tip into warmed formula. The tip should remain in the formula for several seconds to absorb heat. Remove excess formula by dabbing the tip on a paper towel. Excess formula on foam tips can cause choking or be uncomfortable to the pup. Test the temperature of the tip against the inside of the wrist before placing it into the pup's mouth.

Next, position the index finger on one side of the pup's face and the thumb on the opposite side. Then, gently lift the pup's head which will cause the pup to open his/her mouth. When this occurs, gently guide the foam tip into the pup's mouth, positioning the end of the tip about midway onto the tongue. Some pups will begin nursing immediately while other may take several attempts. You can also encourage the pup to take the tip by gently stroking the pup's mouth with the warmed tip while making clicking sounds. Soft clicking mimics the directive calls some mother bats use to locate their pups.

Once a pup is nursing, release the forceps from the sponge tip, as the pup will keep it clamped between its teeth (Figure 9-7A & B). As the pup continues to nurse, dispense warmed formula, one drop at a time, onto the foam sponge with a glass dropper. Wait a few seconds between drops so the tip does not become oversaturated. As the pup nurses, the tragus will move up and down slightly each time the pup swallows.

Be careful to drop the formula onto the portion of the foam tip that is furthest from the pup's face so that any excess milk drips away from the infant. Also take care as to not oversaturate the foam tip with formula.

Some pups are difficult to feed and will spit the foam tip out of their mouth. Some will swallow a few drops of formula but will not begin sucking. These pups will eventually start nursing once they overcome initial fear of the handler.

Some pups will discard the foam tip as soon as they are full; others will hang onto the tip even after they have stopped drinking milk. **Do not try to remove the tip from a pup's mouth**. Any remaining formula in the tip may be accidentally forced down the pup's throat, causing it to aspirate. These pups will eventually discard the tip after being returned to the incubator. Foam nursing tips should be disposed of after use and replaced with new ones for each feeding.

It is important to note that when some pups are first handled, they may immediately grasp the cloth or fabric that encloses them with their milk teeth, refusing to let go. Do not attempt to remove the pup's teeth from the fabric. Instead, carefully dispense warmed formula onto the cloth just below the pup's mouth and allow the pup to suck the formula from the fabric.

Figure 9-7. A: Newborn free-tailed pup nursing from a foam tip*. T. brasiliensis. Photo by A. Lollar.*

B: Big brown pup nursing from a foam tip. *E. fuscus. Shaw Wildlife facility. Photo by C. Branigan*

Caring for large numbers of orphaned crevice-dwelling pups requires some modifications in care procedures. Over the course of several days, some pups can be conditioned to being fed in groups (Figures 9-8). Pups that lap formula can be taught to drink from shallow dishes. Start by holding pup over a shallow dish of warmed formula while feeding it from a catheter or dropper. While the pup is lapping, move the catheter away and carefully lower the pup until it drinks from the shallow dish. Be careful not to immerse the bat's nose in the formula. Once pups have been individually taught to lap formula from a shallow dish, they can be fed in groups on top of a heating pad. When feeding pups from foam tips, each pup should be nursing from its tip and covered before the next pup is placed into position. While Molossidae pups will not lap and should always be fed from a foam tip, other crevice species can be fed in groups to either lap milk from a dish or nurse from foam tips. It is important to follow the pup's lead and feed him/her in a way the pup finds the most comfortable and will easily accept.

Figures 9-8. Orphaned free-tailed pups nursing from foam tips*. T. brasiliensis. Photo by R. Myers.* Orphaned big brown pups lapping from a dish sitting on a heating pad to keep both the milk and the pups warm. *E. fuscus. Bat World Facility. Photo by A. Lollar*

Figures 9-9. An incubator set up for crevice-dwelling pups. *Bat World Facility. Photo by A. Lollar*

Housing Crevice Bat Pups

Unfurred infants require warm temperatures and high humidity and should be housed in incubators (Figure 9-9) or humidity chambers as described in Temperature, Humidity & Lighting. Caging described for adult crevice bats in Temporary Housing is also appropriate for crevice pups. A heating pad should be attached to the top and sides of the enclosure for additional warmth. Infant crevice bats should be placed in a pouch positioned close to a heat source. Be sure to leave at least two of the walls of the enclosure clear of the heating pad so that infants can move away from the heat source if needed. A thermometer should be placed inside the enclosure and close to the heat source to monitor the internal temperature. The appropriate temperature is between 90° to 100° F and with humidity levels between 70% to 90%. Bats should be moved into flight areas with padded floors by eight to ten weeks of age to ensure development of proper flight ability.

Determining Orphan Status in Tree Bat Pups

Unlike other bat species, tree bats will give birth from two to five infants. These bats are solitary and are only found roosting together when mothers are raising their pups. An orphaned tree bat found grounded should always be considered an orphan and should be rescued. Placing the pup into a tree in hopes the mother will come back is almost always a death sentence for these pups as they are frequently eaten by blue jays.

Tree-bats in particular are prone to dehydration and should receive a subcutaneous injection with an electrolyte solution on intake (see Dehydration and Fluid Replacement Therapy). Pups can then be fed as soon a fluids are absorbed. Pups that are furless, or that have tiny, sharp-hooked milk teeth should be fed milk formulas. Pups that have canines can be fed the intermediate formula (See page 109).

Feeding Tree Bat Pups

Unlike crevice pups, tree bat pups must be fed formula while being handheld. It is **critical** to keep these pups clean during the feeding process. Tree bats are furred at a very young age. If formula drips into the fur and dries on the skin, it can result in serious skin infections that often lead to death. Additionally, matted and dirty fur can interfere with a bat's ability to thermoregulate. A pup can die within just a few hours if it cannot thermoregulate. Pups that become soiled must be bathed and dried as described on the following page. As a general rule it takes about 30 seconds to feed a tree bat pup when fed correctly; it takes about 30 minutes to clean the pup when fed incorrectly. It is to your benefit to not allow a tree bat to become soiled.

Position the pup so it lies prone on the thumb, secured by the forefinger and middle finger resting on the pup's shoulder blades. Using a glass dropper, dispense formula drop by drop as the pup laps. Although some tree pups squirm when first being held in this position, most catch on quickly and sit quietly on the thumb thereafter. Some enthusiastic pups attempt to crawl forward, appearing intent on swallowing the entire dropper. These pups can be controlled with gentle pressure of the fingertips on the pup's shoulder blades.

Figure 9-10. An orphaned red bat drinking formula from a medicine dropper. *L. borealis. Photo by L. Crittenden*.

Both the pup and the glass dropper should be tilted in a "V" position, so that the pup's mouth and the dropper meet at the bottom of the **V** (Figure 9-10). This position helps to keep air bubbles from forming in the dropper and prevents soiling by allowing excess milk to drop away from the pup's face. **Note: the pup's head must extend past your thumb, as pictured, so that milk drops away from both the thumb and the pup**. Otherwise, milk will wick between your thumb and the pup's neck and saturate the pup's chin, neck and chest.

Housing Tree Bat Pups

Figure 9-11. Orphaned infant tree bats hanging from the ceiling of their soft mesh enclosure. *L. borealis. Bat World MidCities facility. Photo by K. Rugroden*

Infant tree-bats require warm temperatures and high humidity and should be housed in incubators or humidity chambers as described in Temperature, Humidity & Lighting. Caging described for adult tree bats in Temporary Housing is appropriate for tree bat pups. A heating pad should be attached to the top and sides of the enclosure for additional warmth. Be sure to leave at least two of the walls of the enclosure clear of the heating pad so that the infant can move away from the heat source if needed. A thermometer should be placed inside the enclosure and close to the heat source in order to monitor the internal temperature at all times. Heating pads can be adjusted and added or removed according to the temperature reading inside. Appropriate temperatures for bat pups of many species are 90° to 100° Fahrenheit with humidity levels of 70% to 90%.

Infant tree bats should be positioned so they can hang by their feet from the ceiling of the enclosure (Figure 9-11), **not the sides**. Hanging from the ceiling allows pups to urinate and defecate without becoming soiled. Position the pups so that several can hang together in a cluster. Hand-raised tree bat pups should be moved into full-sized flight cages with padded floors by eight weeks of age to ensure development of proper flight ability.

Additional Care for Tree Bat Pups

Tree bat pups should be stimulated after each feeding with a soft piece of gauze to encourage urination/defecation. If not stimulated, pups tend to urinate and defecate on themselves, which, if not cleaned and dried immediately, is likely to cause hypothermia and death. Gently dab at the pup's anus and genitals with a soft square of gauze that has been dipped in warm water (cotton swabs are too rough for this purpose). Gently rub the area until the pup urinates or defecates. While newborn tree bats require stimulation, most of the crevice species do not. (Also see Bathing and Grooming Tree Bat Pups in this chapter). At about two weeks of age, it is no longer necessary to stimulate these infants.

Be careful not to contaminate the oral or nasal cavities with fecal material by touching the face with the same gauze pad used to stimulate the pup. This can result in serious bacterial infection from *Providencia rettgeri*, resulting in a build-up of fluid in the thoracic cavity and death (D. Cottrell, DVM., pers. comm.). Also be sure to keep wing membrane and tips free of feces. Clean the wings with warm water and dry with a soft gauze pad. (Fungal infections will cause wings to become discolored and oily. This condition is painful and should be treated Nolvasan suspension (see Skin Conditions.)

Bathing and Grooming Tree Bat Pups

Figure 9-12. A juvenile tree bat being groomed with an interdental brush

Begin by holding the bat so that its head higher than the rest of the body to ensure that no water gets in the nose or mouth. If only a small section of the bat is soiled, dip a gauze pad into warm water, then saturate the soiled area on the bat and slide off any foreign particles. For bats that are extremely soiled, use a syringe to saturate the soiled area. When thoroughly saturated, feces and other foreign particles will slide easily from the fur as the area is gently wiped with a damp gauze pad. Also, be sure to clean the wings of badly soiled bats.

As soon as the fur is clean, quickly place the bat in a pre-warmed, absorbent drying cloth on top of the heating pad. Wrap the cloth around the bat and gently dab the wet areas of its body with the cloth to absorb excess moisture. Replace the cloth with another warmed one when it becomes damp. After gently towel drying the fur, wrap the bat inside another dry cloth and turn it upside down, keeping the head lower than the rest of the body, and carefully wipe the mouth and face with a damp piece of gauze. Make sure the gauze is only slightly dampened so that no excess water can be inhaled during cleaning. After gently rubbing the bat's fur, and wing and tail membranes with a soft, dry cloth to absorb excess moisture, use a small blow dryer to finish drying the fur. The dryer should be placed at least one foot from the bat. If a pup squirms to get away while being held, the dryer is too close, and the air stream is too forceful or too hot. Keep the dryer at an appropriate distance so the bat remains passive, enjoying the warmth.

Fluff the fur with the brush while drying the pup. Brush the dense fur backwards to dry the fur closest to the body, then brush the fur forwards in the natural direction it lays, to dry the top of the fur (Figure 9-12). While some prefer using mascara brushes, the author prefers to use dental brushes with softer bristles. Only minimal pressure should be used when brushing a bat. (To fully realize the small amount of pressure needed, place the bristles on a sensitive area of your body such as the inside of a wrist or elbow, then brush in one direction.) Make certain the pup is completely dry—both the fur and wing membranes—before returning it to its enclosure. Tree bat pups will usually begin grooming their bodies vigorously once they have been bathed and dried.

Again, feeding a tree-pup in the correct V position will help you avoid the tedious process of bathing and drying these pups.

General Cautionary Notes in Caring for Bat Pups

Pups can aspirate fluids or choke on food while being hand fed. A bat may be choking if it suddenly gags and/or appears to gasp for breath during feeding. If aspiration is suspected, keep the bat's head down with the abdomen against the palm of the hand. Gently but firmly tap the bat's back with your index finger, just below the shoulder blades to force the substance from the airway. Force of tapping should be no more than that that of fingertips lightly drumming a tabletop. Fluid in the nasal passages should be cleared by applying gentle pressure with a cotton swab on the nasal passages just below the eye and down the bridge of the nose. Repeat the process until the nose is clear. Normal respiration will sometimes be restored immediately. However, if liquids or food enters the lungs, the bat is likely to develop aspiration pneumonia. Signs of respiratory distress include soft squeaky sounds with each breath. Treat as described in Respiratory Disorders. After feeding, the face and chin should be gently wiped clean with a foam sponge dipped in warm water.

Never put a pup away with milk on its face or body. Doing so will result in eye infections and/or skin infections, that may result in death.

Bat World Sanctuary Milk Replacement Recipe

VESPERTILIONIDAE, EXCLUDING TREE BAT SPECIES

- 3.5 ounces (100ml) canned Meyenberg evaporated goat milk, reconstituted
- 1.5ml corn oil (non-GMO preferred)
- 1.5 scoops Similac Neosure Baby Formula
- 1 tsp dried egg white

MOLOSSIDAE

- 3.5 ounces (100ml) canned Meyenberg evaporated goat milk, reconstituted
- 2 scoops Similac Expert Care Neosure Baby Formula
- 2.5ml corn oil (non-GMO preferred)

Start by reconstituting the entire can of Meyenberg goat's milk with an equal amount of water. Store in a separate container in the refrigerator. To make either of the above recipes, use a small container with a tight-fitting lid and add 3.5 ounces of the reconstituted goat milk, then add the Similac Neosure and corn oil. Also add dried egg white if required for the species. Shake well to mix. This makes about 1/2 cup. Store in the refrigerator. Do not freeze. Discard after 24 hours or sooner if it begins to thicken or smell spoiled. Wash the container thoroughly with soap and water before making new formula. Use bleach to disinfect if necessary. Rinse thoroughly. If the container has any residual smell then it has not been washed thoroughly enough and the next batch of formula will be contaminated. Discard any unused reconstituted goat's milk after seven days or sooner if it begins to smell spoiled. Store Neosure at room temperature and discard any unused powder after 30 days.

Calculated Nutrient Values for Vespertilionidae (As Is)
Energy 1.42 kcal/ml; Moisture 73.5%; Protein 7.3%; Fat 8.2%; Carbohydrate 9.8%; Calcium 0.20%; Phosphorus 0.15%; Vitamin A 3,340 IU/kg; Vitamin D 430 IU/kg.
Calculated Nutrient Values (Dry Wt)
Energy 5.36 kcal/ml; Protein 27.4%; Fat 30.9%; Carbohydrate 36.8%; Calcium 0.75%; Phosphorus 0.58%; Vitamin A 12,500 IU/kg; Vitamin D 1,650 IU/kg.

Calculated Nutrient Values for Molossidae (As Is)
Energy 1.60 kcal/ml; Moisture 72.2%; Protein 4.7%; Fat 10.7%; Carbohydrate 11.2%; Calcium 0.22%; Phosphorus 0.16%; Vitamin A 3,830 IU/kg; Vitamin D 540 IU/kg.
Calculated Nutrient Values (Dry Wt)
Energy 5.76 kcal/ml; Protein 17.0%; Fat 38.5%; Carbohydrate 40.3%; Calcium 0.79%; Phosphorus 0.59%; Vitamin A 13,700 IU/kg; Vitamin D 1,900 IU/kg.

Recommended Milk formula for Tree Bat Species

For reasons we do not yet understand, tree bats do not fare well on either of the above milk formula recipes. Instead, a successful formula for tree bats consists of the following ingredients (Kate Rugroden, pers. comm.).

- Fox Valley 34/40, 13.7g (7 teaspoons)
- Fox Valley Ultraboost, 5.74g (2.5 teaspoons)
- Body Boost Colostrum Plus (or similar brand), 1.24g (3/4 teaspoon)
- 1 Lactaid tablet [9,000 FCC Lactase units] (.27g), crushed to a fine powder
- 3.5 ounces (100ml) water

Tree bat orphans with developed canines should receive a milk formula mixed 50/50 with soft food (see Feeding Adult Bats). If the bat will accept live mealworms, feed milk formula and live mealworms on a 50/50 ratio.

Table 9-1
Comparison of Bat Milk Compositions

	Fat %	**Protein** %	Carbohydrate %	Energy kj/g
Family: Vespertilionidae				
Eptesicus fuscus				
Early lactation	12.8	9.5	3.6	6.7
Late lactation	21.2	9.5	3.6	10.5
Myotis lucifugus				
Early lactation	12.4	9.4	3.9	7.4
Late lactation	15.8	8.5	3.9	8.6
Milk replacement recipe: Vespertilionidae	8.2	7.3	9.8	5.6
Family: Molossidae				
Tadarida brasiliensis				
Early lactation	17.3	8.3	3.6	9.0
Peak lactation	25.8	7.7	3.4	12.1
Milk replacement recipe: Molossidae	10.7	4.7	11.2	5.8

IMPORTANT NOTE: Do not substitute or omit any of the ingredients in the Bat World milk replacement recipes. Each ingredient is critical and specific for the following reasons.

- Egg white powder is critical for the additional protein needed by crevice-dwelling Vespertilionadae pups.
- The amino acid profile in the Molossidae milk replacement recipe is very good, thereby minimizing the need for excess protein.
- Corn oil contains a very specific chain of fatty acids necessary for proper growth.

Table 9-2
Ten Year Study on Pup Survival Rates Using Select Milk Replacement Formulas◊

Year	# of Pups	Species	Emaciated at intake	Injured at intake	Secondary complications	Died from secondary complications	Died from injury	Survived	Formula used
1999	47	*T. brasiliensis*	22	5	MBD (4) Bloat (2)	3	4	40	MH*
	5	*E. fuscus*	—	—	—	—	—	5	MH*
	35	*L. borealis*	2	7	Bloat (3)	—	5	30	
	3	*N. humeralis*	1	1	—	—	1	2	MH*
2000	55	*T. brasiliensis*	31	7	MBD (12)	5	2	48	MH*
	52	*L. borealis*	—	7	Bloat (4)	—	7	45	MH*
2001	62	*T. brasiliensis*	27	10	MBD (11)	—	7	55	MH*
	28	*L. borealis*	—	7	Bloat (4)	4	4	20	MH*
2002	115	*T. brasiliensis*	67	22	MBD (24)	6	19	90	MH*
	49	*L. borealis*	5	11	Bloat (1) MBD (3)	2	11	36	MH* MH*
	1	*L. cinerus*	—	—	—	—	—	1	MH*
	1	*P. subflavus*	—	—	—	—	—	1	MH*
	9	*M. lucifugus*	9	—	SIDS (2)	2	—	7	MH*
2003	76	*T. brasiliensis*	52	13	MBD (22)	4	1	71	33/40**
	56	*L. borealis*	1	8	MBD (5)	2	4	50	33/40**
	2	*N. humeralis*	2	—	—	—	—	2	33/40**
2004	99	*T. brasiliensis*	42	22	MBD (30)	10	19	70	33/40**
	25	*E. fuscus*	25	—	MBD (11) Bloat (5)	8	—	17	33/40**
	72	*L. borealis*	3	10	MBD (1)	3	8	61	33/40**
2005	70	*T. brasiliensis*	38	18	MBD (21)	9	10	51	FV***
	64	*L. borealis*	—	14	Bloat (3)	—	12	52	FV***
	7	*E. fuscus*	7	—	MBD (4)	—	—	7	FV***
	1	*L. intermedius*	1	1	—	—	1	0	FV***
2006	102	*T. brasiliensis*	44	2	MBD (25) Bloat (14) Other (16)†	25		77	33/40**
	63	*L. borealis*	7	3	Bloat (22)	35	2	26	33/40**
2007	87	*T. brasiliensis*	36	7	MBD (21) Bloat (17) Other (58)†	58	0	29	33/40**
	26	*L. borealis*	2	1	Other (12)†	11	1	14	33/40**
	3	*N. humeralis*	—	—	MBD (3)	—	—	3	33/40**
2008	261	*T. brasiliensis*	99	83	MBD (0)□ Bloat (7)	3	61	223	BWS‡
	72	*L. borealis*	6	2	Bloat (27)	25	2	45	BWS‡
	2	*N. humeralis*	—	—	Bloat (1)	—	—	2	BWS‡
2009	230	*T. brasiliensis*	112	19	MBD (0)□	—	6	224	BWS‡
	48	*L. borealis*	—	9	Bloat (4)□	1	1	46	BWS‡
	1	*L. cinerus*	1	—	Bloat (1)	—	—	1	BWS‡
	5	*N. humeralis*	5	—	—	—	—	5	BWS‡

◊ Reflects wild orphaned bat pups raised by the author over one decade. *Mother's Helper Milk Replacer Puppy Formula™, Lambert Kay®; **Zoologic 33/40® milk replacement formula, Pet Ag; ***Fox Valley 32/40 milk replacement formula. †Symptoms observed outside of bloat and MBD: chronic dehydration, kidney failure, vomiting, hardening of the skin on the back, pneumonia, diarrhea, anemia, and bones (shoulders, elbows and knees) fracturing under the weight of the pup's own body; ‡Bat World sanctuary milk replacement recipe; □ No cases of MBD developed in Molossidae using the milk replacement recipe; □ Bloat in Vespertilionidae bats was alleviated when increased protein was added to the recipe.

Complications in Hand Raised Pups

BLOAT

Bloat is one of the most common causes of death in bat pups. It can be recognized by severe abdominal distention and, sometimes, the presence of bubbles in the digestive tract visible through the translucent skin of the abdomen (Figure 9-13 A). There are several reasons why this condition occurs in bat pups.

Feeding too Often

Abdominal distention accompanied by white or grayish feces indicated bloat caused by feeding a pup too often. This type of bloat should be treated by feeding a diluted mixture of one part milk formula to nine parts very warm water (115° to 120° Fahrenheit). Do not allow the pup to drink the normal amount it consumes at every feeding as this will cause additional distention. Rather, feed the pup about one-fourth of the normal amount taken. As the stomach empties of previously undigested milk, continue to feed the water and milk dilution until feces appear normal.

Overfeeding

Bloat caused from over-feeding will be obvious immediately after the pup has been fed as the stomach will appear dangerously distended. The stomach is distended with milk to the point that it covers the bottom two ribs and extends across the abdomen and down to the pelvis. This can normally be treated by skipping the next one to two feedings until the pup's stomach has returned to normal. The condition is life threatening if the stomach is marble-sized and hard, and/or the pup is in respiratory distress. When milk inside the stomach is clearly visible through the skin of pups that aren't yet furred, excess formula can be aspirated directly from the stomach using a 1ml syringe with a 28-gauge needle attached. In order to prevent damage to the pup or its stomach, it is critical to break the seal created between the barrel of the syringe and the plunger of the new syringe prior to the procedure. This can be accomplished by moving the plunger up and down inside the barrel of the syringe. This procedure must be done as aseptically as possible to prevent the development of peritonitis, which can be fatal.

This technique requires two caretakers for the procedure. Aseptically swab the abdomen with povidone iodine and 70% isopropyl alcohol. Position the pup on its back on a padded surface, such as a soft cloth. The pup must be held firmly and gently in position by one caretaker to prevent the pup from moving. The other caretaker then carefully inserts the needle 3 to 4mm directly into the stomach. Using a steady hand, very slowly pull back on the plunger. Withdraw enough excess milk so the abdomen returns to a more normal size (Figure 9-13B). Maintain slight pressure on the plunger as you withdraw the needle from the abdomen. Pups undergoing this procedure should receive oral administration of Veraflox for 10 days (See Medication Section for dosage).

Figure 9-13 A: Excess milk in a dangerously distended stomach of a free-tailed pup. *T brasiliensis. Bat World facility. Photo by A. Lollar*

Figure 9-13 B: The excess milk being slowly extracted with a 28 gauge needle and syringe. *T. brasiliensis. Photo by A. Lollar*

Lack of Beneficial Bacteria

The absence of beneficial organisms that normally reside in a healthy pup's intestinal tract can also cause bloat. Absence of beneficial flora allows other organisms to grow out of control, resulting in a build-up of intestinal gas. To treat this condition, administer 0.01ml of simethicone for every gram of body weight every two hours (to relieve gas) and add 0.02ml of Bene-Bac™ gel, Fox Valley LA probiotic powder or another high-quality beneficial flora product such as to each feeding until abdominal distention is relieved.

METABOLIC BONE DISEASE (MBD)

MBD that results from Vitamin D deficiency is called rickets in young individuals and osteomalacia in adults. MBD can also be caused by an inadequate intake or absorption of calcium. Vitamin D and fat are important dietary components because they facilitate calcium uptake.

Orphaned pups that have survived for a number of days without sustenance or that have been fed inappropriate diets are likely to develop growth abnormalities; however, these can be avoided if proper nutrition is provided. Rapidly growing bones like the long bones of the arm are often affected by nutritional imbalances such as MBD. Common clinical signs associated with MBD include swelling or curvature of the long bones of the wing (Figure 9-14), inflammation of the joints, muscle weakness, and neuromuscular hyperirritability often progressing to tetanic spasms and sometimes convulsions.

Figure 9-14. A juvenile big brown bat with MBD. *E. fuscus. Photo by D. Kinamon.*

The condition is painful. In severe cases, a bat will rest with its wings slightly extended at all times and may experience intermittent spasms of the wings in particular. Pups with MBD will sometimes cry out when touched.

The author has raised approximately 3,500 insectivorous bat pups of various species over the past three decades, and has observed many signs of nutritional deficiency in bat pups. MBD has frequently developed in severely emaciated pups raised on commercial milk replacement formulas, despite the addition of extra calcium as well as additional vitamin and mineral supplements. The Bat World Sanctuary milk replacement recipe, developed in 2008, eliminated all occurrences of MBD in *T. brasiliensis, L. borealis* and *N. humeralis* orphans. A total of 492 orphaned *T. brasiliensis* pups were raised on this recipe in 2008 and 2009, of these, almost half were severely emaciated upon arrival, and many would most certainly have developed MBD had they been raised on commercial milk replacement formulas.

Treatment

While mild cases may be reversible in early stages, MBD cannot be reversed in later stages when curvature of the bone is visible. For pups exhibiting symptoms as described above, administer Calsorb® orally once a day until symptoms subside. (This medication should be mixed with a small amount of honey as it is extremely bitter.) Add also 1 gram (1/4 tsp) Calcium Carbonate to every 3.5 ounces of milk replacement recipe. For juveniles, add 1 gram (1/4 tsp) to every 3mls of soft food diet. Metacam® should also be administered for pain (see Medication section). Margaret A. Wissman, D.V.M., D.A.B.V.P. (ExoticPetVet.net), states that calcitonin-salmon is an effective treatment for MBD in many species of exotic animals.

Weaning and Feeding Juvenile Bats

Juvenile bats typically accept soft food or mealworms when they have reached the appropriate developmental stage, which can be gauged by the growth of canines. Depending on the species, this is usually at four to six weeks of age. Canine teeth should be fully developed before mealworms or soft food is offered. Soft food should be fed to the bat through the tip of a 3ml syringe. Crevice bats should be held in the hand, as described in Feeding Adult Bats. Tree bats should be positioned so the head is slightly lower than the rest of the body (the same V position) as described for infants.

Juvenile bats should be fed every 8 to 12 hours (two to three times per day). Juvenile bats can typically be allowed to eat as many mealworms or as much of the soft food diet as they will accept at each feeding, although small species (adult weight less than 10g) should not be allowed to eat more than 1.0ml per feeding, and medium-sized species (adult weight 10g to 20g) should not be allowed to eat more than 1.5ml per feeding. Milk should be offered after each feeding of mealworms or soft food until the bat refuses. Although the author cautions against allowing significant abdominal distention in newborn pups, juveniles will normally have somewhat distended abdomens following each feeding.

It is important to note that even when canine teeth are fully grown, both wild and captive juvenile bats will continue to supplement their diets with their mother's milk (Figure 9-15). It is therefore normal for adult-sized orphaned juvenile bats to continue drinking milk, particularly if they have been nutritionally deprived as orphans. **Juvenile bats who refuse mealworms or soft food are not ready to be weaned and should never be forced to do so, regardless of their age or the fact that they may be adult sized**.

It is also critical to note that juvenile bats sometimes accept mealworms or soft food initially, but then later revert and attempt to nurse on the syringe or the mealworm or refuse adult food entirely. These bats should be allowed to return to nursing from a tip or lapping from a syringe or medicine dropper (whichever they prefer) for another week or two, at which time mealworms or soft food can again be offered. Some pups may go back and forth from milk formula to soft food/mealworms for a few weeks. It is important to be patient and always follow their lead until they are ready to be weaned. Juvenile bats who are completely ready to be weaned will no longer accept milk.

Figure 9-15. An almost adult-sized juvenile big brown bat nursing from his mother. *E. fuscus. Photo by Melanie M. Wells.*

Caring for Geriatric Bats

Some species of bats have been successfully maintained in captivity for long periods of time. Old bats often have worn teeth, and their hair may turn gray or white. The joints of the fingers, ankles and knees may enlarge, possibly from swelling due to arthritis. These bats lose the ability to fly and often move very slowly.

In captivity, older bats are sometimes chased or crowded from roosting pouches and feeding trays by younger, more rambunctious roostmates. To protect these bats, it is best if they are housed with other geriatric bats, or other passive individuals. Roosting pouches, food and water trays should be placed within easy reach of older bats and should be placed in the same position each day (Figure 9-16). These bats do not require diversity, and in fact are likely to become stressed or even injured if anything in their living space is not where they have come to expect it to be. Enrichment can be provided by hand-feeding special treats such as mealworm and waxworm viscera, and gentle grooming.

Feeding requirements may also change for some geriatric bats. That is, they may require more frequent feedings of smaller quantities. Most older bats will be on the complete soft food diet because their teeth will eventually become so worn that they will not be able to chew solid foods. These bats may need to be fed small quantities three times a day. Some geriatric bats will also have difficulty grooming. It is therefore important that they are kept clean and brushed on a daily basis.

Figure 9-16. An elderly pallid bat expecting her daily treat of mealworm viscera. This bat stays in a modified roost made of foam which sits on the enclosure floor, with her food and water dish in close proximity. A blue surgical towel covers the bottom of the roost and is changed daily. *A. pallidus. Bat World facility. Photo by A. Lollar.*

Chapter Ten
Routine Therapies

Injection Techniques

Common locations for administering medications by injection include intramuscular (IM), intravenous (IV), and subcutaneous (SQ). The small size of most insectivorous bats makes intravenous and even intramuscular administration of medications difficult and even dangerous. Most parenterally administered medications are therefore given to bats subcutaneously. Despite the fact that some medications are intended to be administered only intramuscularly or intravenously in other animals, subcutaneous administration of the medications recommended in this manual has proven to be of value in bats as described in the treatment sections.

Pre-packaged, sterile, disposable 1.0ml or 0.5ml syringes with 25 to 27 gauge, 1/2'' needles are recommended. The use of syringes with removable needles allows medications to be mixed or diluted in a single syringe. Withdraw solutions slowly until the syringe has filled to the desired level. Withdraw the needle and hold the syringe with the needle pointing upward, and then tap the side of the plastic syringe with the forefinger so that any air bubbles move to the top. Push the plunger in slightly until all air inside the syringe has been expelled.

Figure 10-1. Two injection techniques preferred by the author. *E. fuscus. Bat World facility. Photo by A. Lollar.*

The author recommends using one of two techniques. 1) Place the bat on a flat surface. Keep the animal's head and upper body gently secured within a soft cloth, leaving the body exposed from the lower shoulder area on down. To administer the injection, choose a site near the lower shoulder or back and to one side of the midline. Insert the needle with the bevel up, horizontally just beneath the skin, keeping the needle parallel to the bat's body at all times. **Before injecting any solution, always check the location of the needle beneath the skin by lifting it slightly once it has been inserted as indivcated with the red arrow.** If the needle has been inserted beneath the skin correctly, the skin will rise with the needle when it is lifted (Figure 10-1A). Do not insert the needle down into the body. If the needle punctures any part of the bat's body wall it will cause severe damage which may likely result in seizures and death. 2) Hold the bat in the palm of one hand with its head facing the heel of the hand. Using the ring and little finger, apply gently pressure to hold the bat's head and shoulders in place. Insert the needle with the bevel up, horizontally just beneath the skin, again, always keeping the needle parallel to the bat's body. Check the location of the needle beneath the skin by lifting it to be positive you are not inside the body cavity. If the needle has been inserted beneath the skin correctly, the skin will rise with the needle when it has been lifted (Figure 10-1B). Do not lift the bat's skin with your fingers for injections. The small size of bats and their propensity to wiggle increases the possibility of accidentally injecting the fingers.

Properly administered, the skin surrounding the injection site will form a small bubble where the medication is injected. This bubble quickly disappears as the fluid is absorbed into the bat's body. Do not recap or reuse needles. Recapping increases the likelihood of needle sticks, and needles are intended for one time use only. Used needles and syringes should be discarded in biohazard waste containers (Sharps containers).

Oxygen Therapy

Oxygen should be administered to bats suffering from shock, heat stroke, or respiratory distress. Oxygen can be administered by simply attaching one end of the rubber tubing to the tank and the other end to the tip of a 3ml syringe with the needle removed (Figure 10-2A). Hold the barrel of the syringe over the bat's nose (Figure 10-2B).

The regulator should be set to a flow rate of 1.0 liter per minute. A makeshift oxygen chamber can also be created by attaching the oxygen tank to a modified pet container with the rubber tubing. Drill a small hole on one side towards the bottom of the pet container where the rubber tubing can be inserted. Place a soft cloth on the floor of the container. The regulator should be set to 1.0 liter per minute and oxygen (100% concentration) allowed to fill the chamber before the bat is placed inside. The bat should be placed on top of the soft cloth on the bottom of the container, or within the folds of the cloth with the face exposed and left inside until respiration and behavior returns to normal.

Figure 10-2. A: A portable oxygen concentrator. *Bat World facility. Photo by A. Lollar.* **B:** A hoary bat receives oxygen after surgery. *L. cinereus. Bat World facility. Photo by M. Singleton.*

Anesthesia

Isoflurane is an inhalant anesthetic used on animals that produces rapid induction of anesthesia with a short recovery period. The author has not observed any adverse reactions to Isoflurane in insectivorous bats.

In veterinary practice Isoflurane is used with a precision, temperature-compensated vaporizer. A modified cone induction system is necessary for use on insectivorous bats. This system is constructed by cutting off the closed end of the plastic casing used to package a 12ml syringe and taping the modified end of the casing to the y-piece connecting the inhalation/exhalation hoses. The flared end of the casing is placed over the bat's head while the bat is handheld until relaxation of the wings and legs indicate anesthesia. Bats generally remain at a surgical plane of anesthesia at a level of 1% to 2% Isoflurane.

When veterinary assistance is not available, emergency surgical procedures can be performed by experienced bat care specialists using Isoflurane anesthesia administered in the plastic case used to package a 6ml syringe. Place a cotton ball into the closed end of the plastic case. For a 10g to 15g bat, use anywhere from 0.3ml to 3.0ml of Isoflurane onto the cotton ball. This is typically sufficient to induce anesthesia within 10 to 30 seconds. (When using lower doses, it may be necessary to add Isoflurane to the cotton ball periodically.) Hold the bat with the head lower than the rest of the body and place the case at the back of the bat's head, allowing the fumes to drift over the bat's face (Figure 10-3A). Depending on the physical condition of the bat, it can take anywhere from a few seconds to a minute to anesthetize the bat. To make sure the bat is properly anesthetized, release one of the feet from its grip. If the bat does not attempt to re-establish its grip, it is anesthetized. Once anesthetized, allow the case to remain about 1.0cm to 2.0cm above the bat's head as the surgical procedure is performed (Figure 10-3B).

Closely observe the bat's respiration during anesthesia and place the casing back over the bat's head at the first sign of movement other than respiration. The bat's respiration will be slower than it was prior to anesthesia, but clearly visible. The case should remain in position during the procedure. It is critical to monitor respiration throughout anesthesia. If respiration increases anytime during the procedure, the case should be lowered farther over the bat's head (it may be necessary to add additional Isoflurane to the cotton ball in the plastic casing at this time. If respiration becomes shallow or visible in the chest region **at any time** during the procedure, immediately remove the case away from the bat and position the bat's head so it is lower than the rest of the body. Open the mouth and gently stimulate the tongue with a cotton swab. Rub the sensitive areas under the wings, massage the chest, and administer oxygen (see Oxygen Therapy).

After surgery is completed, if respiration becomes shallow (not clearly visible), administer oxygen until improvement is seen (see Oxygen Therapy). Note: Do not feed bats three hours before or immediately after administering anesthesia.

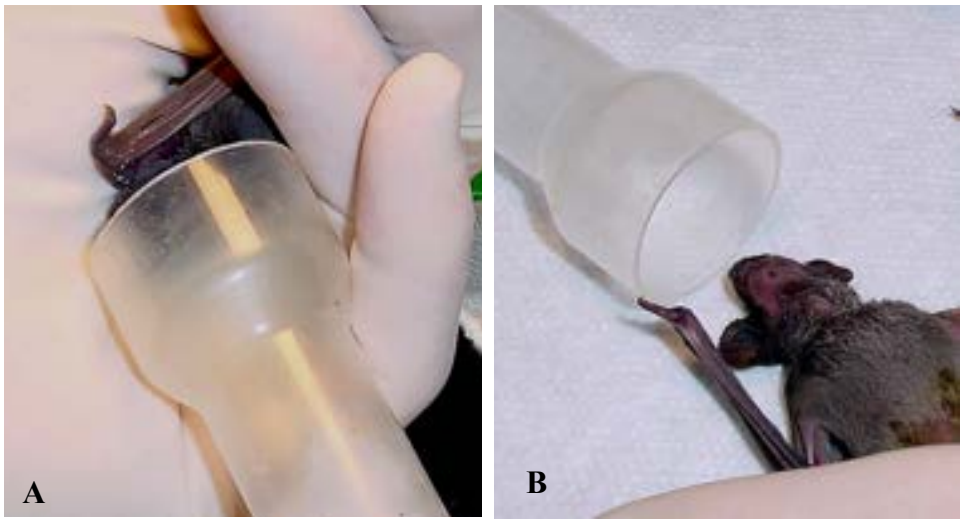


Figure 10-3. A: Anesthesia is administered to a free-tailed bat by placing the flared end of the case over the bat's head.
B: After the bat is anesthetized, the case is placed about 1.0cm to 2.0cm above the bat's head as the procedure is performed. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

Blood Sampling

Bats have about 6.5ml of plasma per 100g of body weight (Kallen, 1960 [cited by Bassett and Studier, 1988]). Thus, a 10g bat has only 0.65ml of plasma. Be sure the bat is warm (i.e., not in torpor) so that blood flows freely through the vessels of the wing membranes. Research done in the UK suggests the only acceptable vessel for blood sampling is the vein that runs close to the femur or nearby in the interfemoral membrane, and the practice of taking blood from the cardiac vein (located at the crook of the elbow) is unacceptable, as the area is congested with blood vessels, nerves and tendons, and the resulting hematoma is likely to impair flight (P. Racey, pers. comm.).

Puncture a vein in the interfemoral membrane with a 25-gauge needle (Figure 10-4) and collect the blood that flows from the puncture with a heparinized, glass microcapillary tube. Using the thumb and the index finger, apply slight pressure for one to several minutes to stop the blood flow.

Although blood can be collected from small insectivorous bats in this manner for certain types of analysis, a sufficient quantity cannot be obtained for some kinds of blood tests. Small bats, particularly those suffering from illness or injury, may die from loss of even a small quantity of blood. Although 1/10th of the total blood volume of a healthy animal may be drawn for testing, this is not the case for bats that are traumatized, dehydrated, or that have suffered any blood loss. It may not be safe in these cases to draw more than 1.0% of the total blood volume at any one time, and it is not recommended that blood be drawn from these bats more often than once every six weeks.

Figure 10-4. Blood should be drawn from a vessel in the interfemoral membrane. Modified from Kunz and Nagy, 1988. David Chapman.

Species ***Red Blood Cell Count**	**(RBC x 10-6)**	**(WBC\ml^3)**	**(ml/100g)**
M*yotis sodalis*	10.61-14.38		
Tadarida brasiliensis	8.12-14.56		
Myotis velifer	8.40-13.92		
Perimyotis subflavus	14.57 (mean)		
Lasiurus borealis	19.61 (mean)		
E*ptesicus fuscus*	11.69 (mean)		
Myotis lucifugus		5780 (mean)	9.0-13.0

*(Riedesel, 1977), **(Kallen, 1977)
See the above references for further information on the cardiovascular system and blood physiology of bats.

Bathing and Grooming

Bats are meticulous groomers. In captivity, bats often groom after feeding by combing the claws of one foot through their fur, and licking both the furred and unfurred areas of their body. They use their teeth to clean off the hair and dirt that accumulates on the claws during grooming. Mother bats may also groom their infants, although many pups begin grooming immediately after birth. Red bat pups will begin licking their wing membranes long before their eyes open. However, orphaned pups and adult bats that have sustained mouth or facial injuries, or back, wing, leg, or toe injuries, or bats that are simply weak from other injuries or illness may be unable to groom adequately and will quickly become soiled. These animals need to be cleaned and brushed by the caretaker after each feeding. If bats are not kept clean and well groomed, hair loss will result, further interfering with the bat's ability to thermoregulate and frequently leading to the death of the animal (Lollar, 1994). Hair loss may also result from unsanitary caging, lack of hygienic procedures during feeding and medical treatment, nutritional deficiencies, stress, and fungal infections. (See Skin Conditions).

Figure 10-5 A: Interdental brushes.

B: A small bowl of detergent and an interdental brush. *Photos by A. Lollar*

Items required for cleaning and grooming a bat include a heating pad, a small bowl of liquid detergent (Figure 10-5A), an interdental brush (a small, tapered brush used for cleaning between human teeth—Figure 10-5B), gauze pads, soft, absorbent cloths for drying, and a travel-size hair dryer (see Products page). Pre-warm a few absorbent drying cloths by placing them on a heating pad. Keep the heating pad on a medium setting.

If only a small section of the bat is soiled, dip a gauze pad into warm water, then saturate the soiled area on the bat and slide off any foreign particles. When thoroughly saturated, feces and other foreign particles will slide easily from the fur as the area is gently wiped with a damp gauze pad. If the hair is not damp enough, it will be pulled out when attempting to remove feces from the fur. Also be sure to clean the wings of badly soiled bats. Hold the bat in a horizontal position, extend one wing, use the curve-tipped syringe to squirt water liberally over the surface, and again gently slide off any particles of food or feces that adhered to the membrane. Use the same procedure for the other wing and the tail membrane. Do not squirt water on or near the bat's head.

Bats that are extremely soiled or infested with external parasites can be held under a gentle stream of warm water from a faucet (Figure 10-6). Begin by holding the bat securely in the palm of the hand, keeping its head higher than the rest of the body so that no water gets near the nose or mouth. After the bat's fur and wing membranes are saturated, apply soap by dipping your fingertips into the detergent. Thoroughly massage the coat and wing membrane using your fingertips. Rinse the bat of soap by again holding it under the warm stream of water, again being careful to keep the bat's head away from the stream of water.

Figure 10-6. A free-tailed bat is bathed to remove dead external parasites. Note the head is held away from the stream of warm water to prevent water from getting down the bat's nose and throat. *Bat World facility. T. brasiliensis. Photo by J. Waltz.*

As soon as the fur is clean, quickly place the bat in a pre-warmed, absorbent drying cloth on top of the heating pad. Wrap the cloth around the bat and gently dab the wet areas of its body with the cloth to absorb excess moisture (Figure 10-7A and B). Replace the cloth with another warmed one when it becomes damp. After gently towel drying the fur, wrap the bat inside another dry cloth and turn it upside down, keeping the head lower than the rest of the body, and carefully wipe the mouth and face with a damp piece of gauze. Enure the gauze is only slightly dampened so that no excess water that can be inhaled during cleaning.

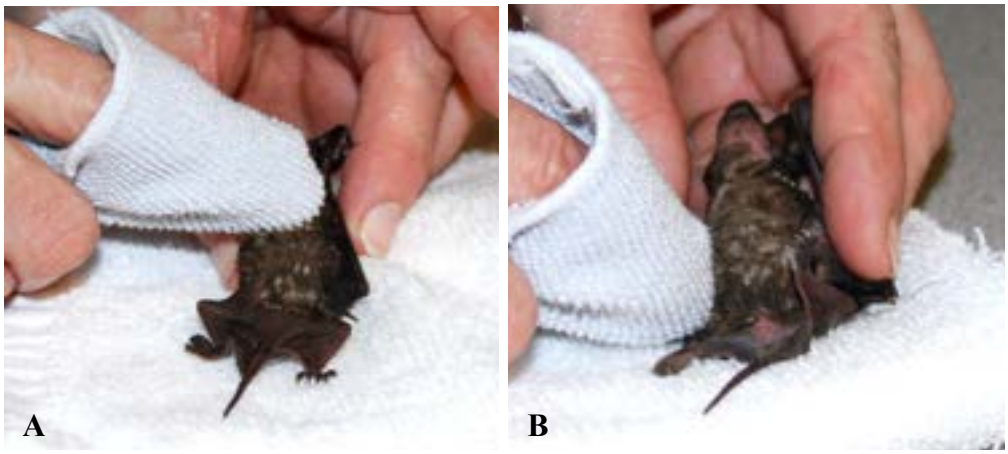


Figure 10-7. A and B: After the bat is bathed, place it onto a warm cloth then gently blot excess water from the coat before drying the bat with a blow dryer. *Bat World facility. T. brasiliensis. Photo by J. Waltz.*

Fur should be brushed as the bat dries. Use an interdental brush to gently brush through the fur. Allow the bat to see and smell the brush before beginning. Only minimal pressure should be used when brushing a bat. To fully appreciate the minimal amount of pressure that should be exerted, place the bristles on a sensitive area of your own body like the inside of your wrist or elbow and then brush in one direction. Brush the fur against the natural direction of growth (Figure 10-7C) in order to dry the undergrowth and comb through any mats that are close to the skin. Then, brush the fur in the natural direction of growth. Start by brushing through the fur behind the ears, on top of the head, and then on the back and tail membrane. Next brush through the fur under the chin and underside of the bat. Most bats are sensitive about being brushed on the part of the torso under the wings, so be careful to avoid being bitten when brushing that area.

C: Brush the bat's fur opposite of the direction in which it grows in order to reach the thick undercoat and any mats located against the skin. *P. subflavus. Bat World facility. Photo by M. Singleton.*

If a bat becomes distressed, place it in a small mesh container such as a BatHut, to continue drying the fur. Keep the dryer at least one foot away from the bat while drying (Figure 10-7D). Monitor the bat very closely to ensure it does not overheat.

D: A tri-colored bat drying inside a BatHut. A stand fashioned from wire holds the travel dryer in place. *P. subflavus. Bat World facility. Photo by A. Lollar.*

Captive adult red bats (*L. borealis*) occasionally stop grooming themselves for no apparent reason. Healthy adults will begin grooming themselves once a caretaker has groomed them. Injured or ill bats generally begin grooming again when they begin to recover, although some injuries may permanently prevent a bat from grooming a particular part of its body. A bat with such an injury should have the affected area groomed daily.

Medications

Medications are typically selected based on blood work and culture results from urine or tissue samples that have confirmed the presence of specific microorganisms. Blood samples are compared with baseline data obtained from healthy animals to determine additional information. Due to the small size of insectivorous bats, however, it is not possible to obtain sufficient quantities of tissue samples for culturing or comparison with baseline data.

The author cautions against the indiscriminate use of broad-spectrum antibiotics when time allows culture and sensitivity results that would permit the use of a more specific antibiotic. However, when time of the essence, and/or access to culture and sensitivity results are not available, the use of broad-spectrum antibiotics has allowed bat care specialists to save animals with clinical signs formerly associated with high mortality.

Except when indicated, medications should always be administered with food. The use of medications for bats is extra-label drug use and no claims can be made for the efficacy or safety of the dosages.

Note: The recommended dosages for many of the medications used to treat conditions in bats as described in this book are significantly higher than those used to treat other mammals. Nonetheless, careful observation and trial and error by the author for a period of almost 30 years have led to treatments that have proven successful for ameliorating a variety of clinical signs of disease in insectivorous bats.

ANALGESICS	***Dose/g bw**	**DOSAGE**	**DURATION**	**WARNINGS**
Cetacaine® Topical gel		Apply small amount onto mucus membranes where pain control is required.	Topical anesthesia occurs within 30 seconds and lasts 30 to 60 minutes.	**Do not use in the eyes.** Localized allergic reactions may occur after prolonged or repeated use.
Metacam® Oral Suspension Meloxicam, 1.5mg/ml (NSAID)	0.002ml/g	0.02ml PO, BID	Unknown in insectivorous bats. Has been used for 30 continuous days without incident. Can be given with Tramadol for increased efficacy.	Do not use in conjunction with corticosteroids, ketoprofen, aspirin or any other NSAID drug as intestinal bleeding and gastrointestinal ulceration may result.
Buprenex Injectable Buprenorphine 0.3mg/ml	0.0001ml/g	0.02ml PO, BID May be applied to the gums to be absorbed through mucous membrane.	Up to 5 days	Vomiting, diarrhea, loss of appetite, sedation, tremor, hypoventilation, dyspnea and cyanosis can occur.
ANESTHETICS	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNINGS**
Isoflurane Inhalant Anesthetic	NA	See Anesthesia or Euthanasia.	See Anesthesia or Euthanasia.	Isoflurane is not significantly metabolized; therefore, toxic metabolites are not produced.
Telazol®**, Diazepam and Ketamine**		**Do not use**		Serious adverse reactions leading to death.

ANTIBIOTICS	Dose/g bw	DOSAGE	DURATION	CAUTIONS
Amoxicillin Oral Suspension, 50mg	0.005ml/g	0.05ml PO, BID	14 to 30 days	Side effects can include loss of appetite and vomiting.
Baytril® Injectable Solution Enrofloxacin 2.27%		**Do not use**		Has been associated with birth defects and stillborn pups in *T. brasiliensis*
Cephalexin 250mg/5ml	0.005ml/g	Mix 5ml (one tsp) water with 8gm (one tsp) Cephalexin. Administer 0.05ml PO, BID	14 to 30 days	Keep refrigerated.
Clavamox® Drops (Amoxicillin trihydrate/ Clavulanate potassium).	0.005ml/g	Reconstitute with 14ml water. Administer 0.05ml PO, BID.	14 to 30 days (Continue for 48 hours after bat is asymptomatic.)	Keep refrigerated**.** Discard after ten days. Do not use if mixture becomes discolored.
Clindamycin Injectable Solution 300mg/2ml	0.15 ml/g	Mix 0.10ml with 0.90 ml sterile water to lessen sting. Dose 0.10ml, SQ, SID. Store unused mixture for subsequent use.	7 to 21 days	Localized pain associated with injection. Side effects are uncommon and may include vomiting.
Convenia® 80mg/ml	SQ: 0.068 mg/g	Use a sterile collection tube to dissolve 0.2g in 1ml sterile water. Mix to dissolve powder. Administer 0.10ml SQ.	One dose only. Can be repeated in two weeks if needed.	Localized pain associated with injection. Powder must be kept refrigerated. Store mixed solution in refrigerator for up to two weeks..
Doxycycline 25mg/5ml	0.005 ml/g	Reconstitute according to directions. Administer 0.05ml PO, BID	21 days	Administer with food. May cause light sensitivity.
Penicillin G Procaine 300,000 units per ml (Procaine hydrochloride 130.8 mg - local anesthetic)	0.001ml/g	Mix 0.10ml with 0.90 ml sterile. Dose 0.10ml of this mixture SQ, SID. Refrigerate unused solution for subsequent use.	10 to 14 days	Side effects may include vomiting, diarrhea, muscle spasms, muscle pain, and headache.
Veraflox® Pradofloxacin oral suspension, 25 mg/ml.	0.125ml/g	0.05ml PO, SID	Up to 21 days	Side effects are not common but can include vomiting and loss of appetite.
ANTICONVULSANT	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Zonisamide Capsules 25mg	0.5 mg/ml	Dissolve the contents of one-half a capsule into 25ml of simple syrup. 0.1ml to 0.15ml PO, BID	Ongoing as needed. Do not stop medication abruptly. Rather, decrease dose by smaller amounts each week for two weeks.	Keep refrigerated. Shake before using. Discard after one month. Can cause drowsiness, decreased appetite, coordination issues, skin rash, itching, facial swelling, confusion, nausea, vomiting and change in temperament.
ANTIFUNGALS	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Biogamma *Pythium oligandrum* cream	NA	Gently massage on affected areas once daily	Until condition is cleared.	No adverse effects

ANTI-GAS	Dose/g bw	DOSAGE	DURATION	WARNING
Simethicone	0.003 to 0.005mg/g	0.03ml to 0.05ml PO every 2 hours as needed.	24 to 48 hours	No adverse effects
Bene-Bac™ Gel	NA	Add 0.05ml orally or to every 5ml of milk formula. PO, SID	As needed for bloat or until antibiotic treatment is complete.	No adverse effects. Do not use if spoiled (smells rancid).
ANTHELMINTICS	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Valbazen® Albendazole 113.6mg/ml	0.0004ml/g	0.007ml PO, SID.	3 days	Do not administer to pregnant bats.
Albon Oral suspension 5% Sulfadimethoxine 50mg/ml	0.002ml/g	0.02ml PO, SID	5 to 10 days (continue for 48 hours after bat is asymptomatic.)	Use with caution on sick, weak, or underweight bats.
Panacur Suspension Fenbendazole 100 mg/ml	0.005ml/g	0.05ml PO, SID.	One dose weekly for three weeks	Do not administer with flukicides. May be given with Valbazen. If bats appear weak, administer every other day for 10 days.
Revolution® Selamectin	NA	0.005ml applied directly onto the skin of the tail membrane.	One dose only	Use with caution on sick, weak, or underweight bats.
ANTIMICROBIALS	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Manuka honey Active UMF16+	NA	Apply topically to the wound and surrounding tissue.	Until injury is healed. Do not clean hardened layers of Manuka honey from the wound as it acts as a protective layer. Instead, apply as needed to keep the wound covered.	Thoroughly drain abscesses before applying. Drain abscesses daily or as needed, then reapply Manuka.
Nolvasan® Solution chlorhexidine diacetate	NA	Dilute with water to 10% Flush affected areas twice a day.	One to two applications.	Can cause eye irritation. Avoid getting into eyes.
Chlor-a-Flush Lidocaine 0.5%, chlorhexidine 0.2% solution	NA	Apply liberally to affected area.	Two to three times daily or as necessary, until healing is complete.	Can cause eye irritation. Avoid getting into eyes.
OraVet	NA	Use a cotton swap to apply a thin layer of gel to the teeth.	Apply once weekly to control plaque and tartar.	No adverse effects
CORTICOSTEROID	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Dexamethasone Injectable Solution 2mg/ml	0.003ml/g	Mix 0.03ml dexamethasone with 0.25ml LRS and administer entire dose SQ, BID. Warm fluids before injecting.	2 to 7 days. When given for more than 3 days, taper dose by administering SID for 2 days, then DID every other day for 4 days.	May cause excessive thirst and urination. Do not use in conjunction with NSAIDS as gastric bleeding may result.
DIURETIC	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Lasix® Furosemide	0.0001 mg/g	0.01ml administered orally	One to two doses only for bloat caused by hypoproteinemia.	May cause appetite loss, diarrhea, thirst, nausea and vomiting.

SYMPATHOMIMETIC	Dose/g bw	DOSAGE	DURATION	WARNING
Epinephrine 1:1000 Sterile Solution	0.01mg/5g	Mix 0.1ml epinephrine with 9.0ml sterile water. Inject 0.01ml SQ per every 5 grams of body weight.	Dramatic improvement should be seen within five to 10 minutes. Inject an additional dose if symptoms are not alleviated within 20 minutes.	An additional dose will be needed if symptoms return.
ELECTROLYTES	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Electrolyte Solution Parenteral fluids - Lactated Ringers, Normosol, Plasmalyte	NA	See Dehydration and Fluid Replacement Therapy	Until bat is fully hydrated.	Except when heat exhaustion/ stroke is suspected, always warm fluids before a SQ injection. Excess fluids can accumulate in the head, neck, and wrists. In severe cases fluid can accumulate in the lungs.
NUTRICETICALS	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Progenix Recovery ` Hydrolyzed protein	NA	Mix 1-part Progenix Recovery to 1 part water. Administer up to 1.0ml.	24 hours, then switch to soft food diet.	Can result in diarrhea if used in excess. As soon as improvement is noted, switch to soft food.
C**alsorb® Gel,** 170mg/ml Calcium supplement	NA	For pups and adults: 0.02ml to 0.04ml PO, SID.	1 to 2 doses only	Is extremely bitter. Should be given with honey to help mask the taste.
Denosyl Tablets S-Adenosylmethionine 90mg) or SAM e	0.005ml/g	Dissolve one 90mg Denosyl® tablet in 5.0ml water. Slip the brown coating off the tablet as soon as it has softened. Continue dissolving the tablet in the water. Administer 0.05ml PO, BID.	10 to 14 days	Should be given on an empty stomach. Can be mixed with soft food.
Milk Thistle Alcohol free liquid	NA	Administer 0.05ml to 1.0ml twice daily	10 to 14 days.	Side effects are rare but can include itching and diarrhea.
Pet-Tinic® Iron supplement	0.005ml/g	0.05ml PO BID	Until improvement is observed.	No adverse affects
RABIES VACCINE	**Dose/g bw**	**DOSAGE**	**DURATION**	**WARNING**
Three year vaccine.	Adults: 0.01ml/g	0.05ml SQ for pups weighing up to 3.9 g. 0.1ml SQ for pups and adult bats weighing 4g and over.	One dose	Bats that are already incubating rabies infection may present with clinical signs of infection within two weeks of being vaccinated, and should be humanely euthanized.

Chapter Eleven

Diagnosis and Treatment of Illness

Dehydration and Fluid Replacement Therapy

Figure 11-1. Glossy wings on a well-hydrated bat. *E. fuscus. Bat World facility. Photo by A. Lollar.*

The average daily water budget for a bat is determined by what they take in (food and water), and what is lost in feces and urine, as well as evaporative loss that occurs during flight and normal activities. The average daily water budget is 24.5% and 15.8% of the body weight for a big brown bat (*E. fuscus*), and Brazilian free-tailed bat (*T. brasiliensis*) respectively. Without sufficient intake, a 10 to 20g bat can have a daily water loss of as much as 1 to 3mls.

Bats that have been confined in areas without food or water or are too weak to fly due to injury or illness will become dehydrated. Bats in captivity can become dehydrated if the humidity is too low or they don't have always have access to fresh water. Orphaned bats are always dehydrated to some degree.

Well hydrated bats will have smooth and slippery mucous membranes and the wing membrane will appear glossy (Figure 11-1). A bat that is slightly dehydrated (around 5%) will have slightly dry mucous membranes and may have stringy saliva. Other signs include loss of appetite, vomiting, and feces stuck to the tail membrane. The skin of a bat that is over 5% dehydrated will take longer than one second to return to normal after being tented, and the mucus membranes will appear dry and tacky. A bat that is around 8% dehydrated will have a flattened or sunken abdomen with wrinkled skin, and the wing membrane may appear somewhat dull. The eyes of a severely dehydrated bat (over 10%) will sink back in the sockets (and the bat may be unable to open its eyes). The skin will remain in place when pinched. Inability to coordinate muscular movements may be observed, or the bat may be comatose. Bats over 10% dehydrated may not survive.

Dehydrated bats cannot be rehydrated with oral fluids alone and therefore must be given subcutaneous (SQ) injections of electrolytes (e.g., lactated Ringer's solution, Normasol or Plasmalyte), regardless of whether or not they accept fluids orally. Depending on the severity of dehydration, electrolytes administered SQ are usually absorbed within 5-30 minutes (see Injection Technique on the following page). Severely dehydrated bats that do not absorb fluids may be suffering from irreparable organ failure.

Most adult bats will also be sufficiently hydrated after only 1 or 2 injections. Once hydrated, infant bats can be fed (see Feeding and Care of Infant Bats) and adult bats can be offered small amounts of soft food (see Feeding Adult Bats). The Bat World Sanctuary soft food diet is easier to swallow, has complete nutrition, and contains additional fluids which will assist in the rehydration process. Note: Signs of over-hydration include shivering and edema around the face, head, neck, and wrists. Over-hydrated bats should be kept warm until excess fluids have been absorbed.

Table 11-1: Fluid Replacement Schedule

Weight (g)	Dose (ml)	Frequency (hours)
Pups:		
Less than 1.0	0.50	1 injection every 24 hours
1.0 to 5.0	0.75	1 to 2 injections within 24 hours
Juveniles or Adults:		
3.0 to 5.0	1.0	1 to 2 injections within 24 hours
5.1 to 15.0	1.0 to 3.0	1 to 2 injections within 24 hours
15.1 to 20.0	2.0 to 3.0	1 to 2 injections within 24 hours
20.0 to 65.0	5.0 to 15.0	1 to 2 injections within 24 hours

Shock

Shock is an acute, life-threatening drop in blood flow and/or pressure, leading to widespread tissue ischemia (diminished blood flow). Most mammals will experience some degree of shock with all but the most minor injury. Physical trauma, excessive fear, and reactions to drugs administered to bats may all result in shock. Clinical signs include prostration and shallow, rapid respiration. The eyes lack their normal luster, and a "staring or dazed expression" may be noticed, as if the bat is not aware of its surroundings.

The peripheral circulation of bats is basically similar to that of other mammals, although there are some modifications to the circulatory system. The heart is elongated and somewhat larger relative to other mammals of comparable size. It is positioned near the center of the chest and slightly tilted to the left in Megachiropterans with longer bodies. In short-bodied Microchiropterans, the heart is rotated so that it is in a nearly transverse position. Bats have variable heart rates that can range from as low as 10 beats per minute during hibernation to as high as 1000 beats per minute during flight (Reite and Davis, 1966 [cited by Altringham, 1996]; Hill and Smith, 1984). They also have high stroke volumes relative to other mammals of comparable size. Bats are also able to regulate the volume of blood circulating in the capillary network of the wings by using special shunts. Because heat can be dissipated across the wing membranes, this system helps to maintain internal body temperature.

Bats experiencing shock due to trauma or fear are often those that have been rescued from another animal, such as a cat or dog. These bats should be quietly placed into a warmed oxygen chamber if available (see Oxygen Therapy) until respiration returns to normal (one to two hours). A flow of oxygen regulated at 0.5 to 1 is sufficient for most insectivorous bats. Oxygen can also be administered by attaching the tubing from an oxygen tank to the tip of a 3ml syringe. Then, hold the barrel of the syringe over the bat's nose, as shown on page 110. It is imperative that any unnecessary noise or movement be avoided, although long-term captives may benefit from the soothing tones of the handler's voice.

Bats exhibiting signs of shock within 24 hours of the administration of medications may be experiencing a reaction to the medication. Although subcutaneous injections may have little value in cases of shock for other mammals, the author has found that subcutaneous injections of epinephrine have proven of value in treatment of shock in response to a drug reaction in bats (see Medications). Oxygen should also be administered until respiration returns to normal. A flow of oxygen regulated at 0.5 to 1 is sufficient for most insectivorous bats. An additional injection of epinephrine will be necessary if clinical signs have not subsided within 20 minutes.

Several useful commercial products, such as Progenix Recovery (see Medications), have proved successful in treating hypoglycemic shock in starving bats. Oxygen should also be administered until respiration returns to normal.

Respiratory Disorders

As previously mentioned, heart rates vary from one bat species to another, but in a bat at rest they are generally comparable to that of other mammals of similar size. Rates of some bats at rest may be 250 to 450 beats per minute, while those of bats in daily torpor can drop as low as 40 to 80 beats per minute, and as low as 10 beats during hibernation (Reite and Davis, 1966 [cited by Altringham, 1996]; Studier and O'Farrell, 1976 [cited by Altringham, 1996]; Hill and Smith, 1984). Heart rates vary significantly within an individual depending on its activity level and the ambient temperature. Respiratory rates will also vary depending on a number of factors, including activity level. In flight, respiratory rates are dependent on air speed and flight angle and are about 10 Hz for an average-sized microbat (four to six times higher than that of a bat not in flight) (Altringham, 1996).

Because heart and respiratory rates are so variable in bats, it can be difficult to recognize signs of respiratory distress. Therefore, it is important that caretakers become familiar with normal respiration by observing healthy bats at rest. A simple but effective method for assessing the respiratory condition of bats is to observe the location on the body where respiration is visible. Unlike most mammals, where normal respiration is visible in the chest, respiration in bats should be visible in the abdominal area on both sides of the pelvis, and on the back on both sides of the hips. A rapid rising and falling in these areas indicate normal respiration in a non-torpid bat at rest. Somewhat slower respiration visible in these areas is normal for healthy bats in a state of torpor. However, labored respiration visible **in the chest area** is most likely a sign of respiratory distress, such as pneumonia. Respiratory distress has also been associated with rabies infection.

ASPIRATION

Bats occasionally choke on food or aspirate fluid into the lungs while being hand-fed, or vomiting. If a bat suddenly gags and then appears to gasp for breath during hand feeding, it is choking. Hold the bat head down with its abdomen against the palm of the hand and incline the hand so that its head is lower than the rest of its body. Then, gently but firmly tap a finger on its back just below the shoulder blades in an attempt to force the substance from the airway (similar to drumming the fingertips on a tabletop). Normal respiration will be restored if the bat survives the initial event and the substance is dislodged.

If food particles or liquids enter the lungs, a bat is likely to develop aspiration pneumonia and will exhibit subsequent respiratory distress by wheezing or making soft squeaky or rattling sounds with each breath. Food or fluid in the nasal passages should be cleared by applying gentle pressure with a cotton swab on the nasal passages just below the eye and down the bridge of the noise. Wipe away any fluid that is expelled from the nose, and repeat the process until the nose is clear.

PNEUMONIA AND PNEUMONIA-LIKE SYMPTOMS

Nasal discharge, wheezing, and soft squeaky or rattling sounds that accompany each breath are signs of pneumonia. Use a neonatal stethoscope to listen for these sounds. In a quiet room, place the stethoscope on the upper back and then chest areas and listen carefully. Rattling sounds associated with pneumonia are sometimes audible without the use of a stethoscope. Affected bats may also have matted, cloudy eyes, and be severely dehydrated and emaciated.

Bats that exhibit signs of pneumonia need to be given: 1) an injection of an electrolyte solution (do not offer these bats liquids orally as they are likely to aspirate the fluid into their lungs), 2) an injection of Penicillin, and 3) an injection of Dexamethasone (see Medications). Dexamethasone helps to reduce inflammation of the bronchi and bronchioles in order to help the bat breathe easier. (Dexamethasone has been shown, in controlled studies, to reduce plasma leakage, resolve Mycoplasma induced inflammation, and reduce the number of Mycoplasma organisms even when used as the only therapy. ([Bowden, et al, 1994; McDonald, 2001]). Note: Exceeding recommended doses of Dexamethasone can cause immunosuppression.

Gently clean visible any secretions from the nose and eyes with gauze or a cotton swab dipped in warm water. Squeeze the excess water from the gauze or cotton swab before cleaning the bat or it is likely to inhale drops of water into its lungs, compounding the problem. Hypothermic bats will need to be warmed. Allow the animal to warm up slowly by placing it in a padded roosting pouch on the inside of an enclosure. Keep a heating pad attached to the outside of one side of the pouch so that the bat can move away from the heat source if it chooses. Bats that are extremely weak and unresponsive should be placed in an oxygen chamber once they have warmed up. Oxygen should be administered at 1.0 liter per minute for 15 minutes out of each hour for a two-day period (see Oxygen Therapy).

Following initial injections, subsequent injections of an electrolyte solution, as well as injections of Penicillin, should be given once every 24 hours for 10 to 14 days. Following the initial injection of Dexamethasone, subsequent injections should be given every 12 hours for a period of two to four days, or until labored breathing diminishes. Dexamethasone should not be stopped abruptly, but rather tapered off (see Medications).

Begin offering the bat small mouthfuls of soft food on the second day, but only if respiration is normal and abnormal lung sounds have ceased. Do not attempt to force these animals to eat. Rather, continue to offer soft food three to four times a day until the bat begins to accept it. Be extremely careful when offering soft food; keep the bat on its abdomen with its head lower than the rest of its body. The bat will need to eat very slowly to avoid aspirating food into the lungs.

A bat that is breathing through the mouth and showing no visible signs of improvement within the first 48 hours is unlikely to recover and should be euthanized. A bat that is agonal (gasping for air) should be euthanized immediately.

Note: Bats placed in educational or biological research facilities have been known to develop cloudy eyes and, subsequently, signs of respiratory distress. These animals typically die within a matter of days. Throat cultures from one bat revealed a Proteus infection. The bat was treated with antibiotics and recovered. It may be relevant to note that these bats were often caged in rooms that housed other vertebrates, including reptiles and other mammals (commonly mice). The author believes that such infections may possibly have been transmitted to the bats from other animals in the facility either through improper handling routines or airborne transmission. For this reason, the author recommends that bats be housed in rooms separate from all other animals, including reptiles, and that very careful hygiene procedures be followed in such facilities to minimize the possibility of disease transmission.

Anemia

Anemia is associated with a variety of diseases or injuries. In this condition, there is a reduction in the number of circulating red blood cells. The condition exists when the hemoglobin content is less than that needed to fulfill the oxygen demands of the body. It may result from excessive blood loss, excessive blood cell destruction, or from decreased blood cell formation.

In other mammals, anemia due to excessive blood loss is treated by stopping the bleeding, restoring blood volume by transfusion if needed, and administering treatment for shock. Anemia due to excessive blood cell destruction requires treatment of the specific (hemolytic) disorder. Anemia due to decreased blood cell formation is treated in deficiency states by replacement therapy directed at the specific deficiency (e.g., administration of iron supplements). Anemia's due to decreased blood cell formation may also result from disorders of the bone marrow. Toxic agents (e.g., chemicals) are one source of bone marrow disorders. Treatment involves removal of the toxic agent and sometimes administration of antidotes.

Bats that develop pale skin and gums but are not exhibiting signs of respiratory distress (see Respiratory Disorders), may be suffering from anemia. These bats are often lethargic and move very slowly even when they are feeding. Vomiting may also occur. The author addresses three types of anemia resulting from intestinal parasites, iron deficiency, and kidney disease.

Intestinal parasites can cause nutritional deficiencies, particularly that of folate, iron, and/or Vitamin B12. Bats suspected of parasitic anemia should be treated with antiparasitic drugs (see Medications), along with an iron supplement (as described below) and nutritional therapy, such as the complete soft food diet (see Feeding Adult Bats).

Iron deficiency can also result from an inadequate iron intake, malabsorption of iron, chronic blood loss, intravascular hemolysis, or pregnancy and lactation. The condition should be treated with an iron product such as oral ferrous sulfate or ferrous gluconate. The author prefers Pet-tinic®, a liquid iron supplement. Give the bat 1 drop (0.05ml) of Pet-tinic® after each feeding for two to four weeks, depending on how quickly normal gum color and activity levels return.

Signs of kidney disease or failure in bats include pale to white gums, excessive thirst, vomiting, lethargy, lack of appetite and weight loss. Unfortunately, due to the small size of insectivorous bats, it is impossible to reverse the condition. If one or both kidneys fail completely, the bat's kidneys can no longer filter wastes well enough to remain healthy. A bat showing signs of end-stage renal disease should be humanely euthanized (see Euthanasia).

Infections of the Gums and Teeth

Young bats have deciduous teeth called milk teeth which are tiny, sharply hooked and pointed, enabling a pup to cling to the teat or fur of the mother. The incisors, canines and premolars are replaced with a second set of teeth once in the lifespan of the bat. The deciduous teeth are at least partially developed at birth and replaced by permanent teeth within a few weeks (Vaughan, 1970). For example, evening bats (*N. humeralis*) have permanent teeth by four weeks of age, and pallid bats (*A. pallidus*) by five weeks. There are fewer deciduous teeth than permanent teeth. Species of Myotis have 22 deciduous teeth, which are replaced by 38 permanent teeth (Vaughan, 1970). Adults have four kinds of permanent teeth including incisors, canines, premolars, and molars (Figure 11-2). The occlusal surfaces of the molars are made up of cusps and connecting ridges used to chop insect exoskeletons into small fragments (Vaughan, 1970).

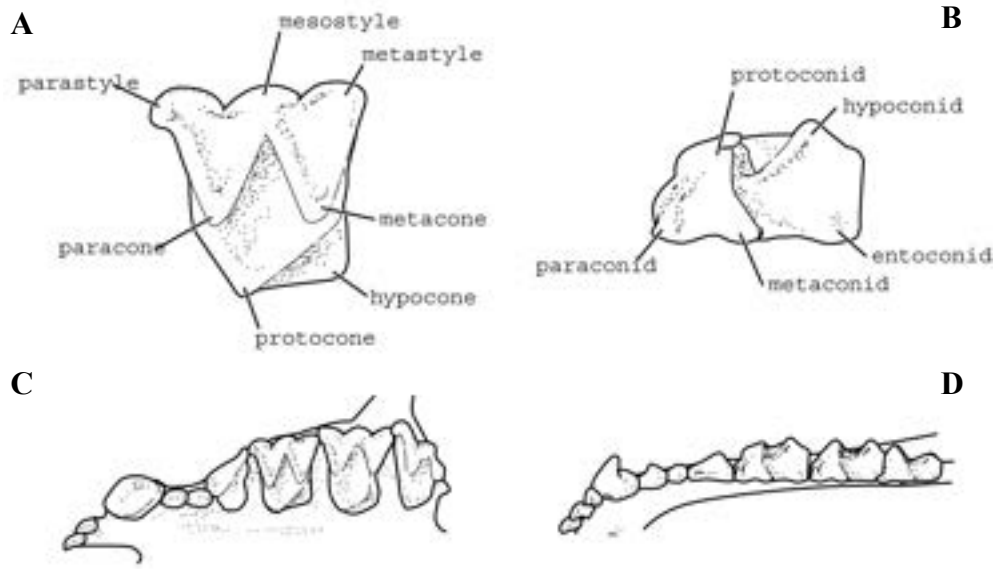


Figure 11-2. Bat teeth: **A:** Cusps on occlusal surfaces of first upper molar of left side of the black mastiff bat. *Molossus ater*. **B:** First lower molar of right side of the black mastiff bat. *Molossus ater.* **C:** Left upper tooth arcade of little brown bat. *Myotis lucifugus.* **D:** Right lower tooth arcade of the little brown bat. *Myotis lucifugus*. David Chapman. Modified from Vaughn, 1970.

The oral cavities of some species of bats such as the nectar and pollen-feeding long-nosed bats (*L. nivalis*), are often infested with mites (genus *Radfordiella*). These mites can cause osteolysis of the hard palate and odontolysis of the teeth (Phillips, et al., 1969 [cited by Schmidly, 1991]). The destruction to bone, teeth and connective tissue often results in tooth loss. The author has received insect-eating bats (*T. brasiliensis*) from the wild with gum infections and/or abscessed teeth. Big brown bats have also been admitted from the wild with abscessed teeth (per. comm. L. Sturges).

Dental issues are a primary problem in maintaining captive insectivorous bats. Captive *T. brasiliensis, E. fuscus* and *A. pallidus* appear to be particularly susceptible to dental disorders (Lollar, 1994). Although soft food diets were initially suspected of contributing to the development of plaque deposits, long term captives fed exclusively on live mealworms (cultured in traditional media) also develop plaque deposits and subsequent gum infections and/or abscesses.

It is impossible to duplicate the natural diets of wild bats for those in captivity. Insect parts, such as wings and legs, may act as a natural dentifrice. Some species, such as big brown bats (*E. fuscus*) are beetle specialists. Mealworms do not have the same hard exoskeleton that beetles do, and so may not maintain teeth as natural diets do. It is therefore important to do daily dental checks of the teeth and gums of bats kept in captivity.

Use a high intensity lamp and magnification when examining bat teeth. Gently lift the lip area with a cotton swab to expose the upper and lower teeth and gum line. This procedure may allow examination of only the outer portion of the teeth and gums, as the bat is likely to keep its teeth clamped shut during the exam. However, teeth and gums that appear clean and healthy on the outside are likely to be so on the inside. Examine each tooth thoroughly.

The teeth are typically white but may develop dark stains after being fed mealworms while in captivity. The tarter that has become stained makes the teeth appear black, however it is the tarter that is stained and not the teeth (Figure 11-7). Layers of plaque can lead to chronic gum infections and tooth loss, or may develop into hardened deposits of tartar (this will also lead to chronic gum infections and tooth loss). Left unchecked, bats with gum infections may eventually develop tooth decay and abscessed teeth.

The gums of healthy bats are pale pink in color and appear smooth. Gum infections are first visible as a thin red line along the gum line. Infected gums appear bright red and occasionally lumpy, particularly at the tooth line. If any of the teeth appear to have soft or hard cream, yellow or black stained deposits (Figure 11-5 and 7)., gum infections and abscessed teeth will develop.

An initial sign of tooth or gum problems includes excess saliva production. Other signs include anorexia and debris on the toes. Bats comb their toe claws through their fur, then remove the debris from their toes with their teeth. A bat with a sore mouth may not keep its toes clean. Signs of a severe (life-threatening) dental abscess include a watering or protruding eye, a dull or "dead" eye (Figure 11-3A and B), drainage from an ear, a swollen area on the head, behind the ear, on the jaw, the neck, or near the eye (Figure 11-6), and/or a cabbage-like or fetid odor. An abscess can rupture through the skin causing the pus to harden. Pus that hardens may resemble grains of rice within the fur (pers. comm. L. Sturges).

In the early stages, gum infections are relatively easy to treat by brushing the bat's teeth with an oral cleansing solution such as CHX® gel or Nolvadent® (0.1% Chlorhexidine acetate). Hardened deposits will need to be removed prior to brushing.

Use an artist paint brush, or a lipstick brush to brush the bat's teeth (Figure 11-4). Trim the bristles of a lipstick brush so that they are approximately 3.0mm to 4.0mm in length. It is a good idea to practice the brushing technique (i.e., the pressure) on a sensitive area of your own body such as the crook of your elbow, before attempting to brush the bat's teeth so that you clearly feel the minimal pressure required.

Figure 11-3. A: A pallid bat with a dental abscess, as indicated by the eye appearing "dead". **B:** Abscessed tooth is extracted. **C:** Facial abscess is drained using a 27-gauge sterile needle. Manuka honey is applied to the extraction site inside the mouth. **D:** 24 hours post-extraction. *T. brasiliensis. Bat World facility. Photos by L. Crittenden, and A. Lollar.*

Dip the brush into a small container filled with either CHX® gel, Nolvadent®, or hydrogen peroxide. Blot off any excess liquid by dabbing the brush onto a clean gauze pad and then insert the bristles between the bat's lips. Most bats will immediately open their mouths and bare their teeth, giving the opportunity to gently run the flat edge of the brush across both the inner and outer portions of upper and lower teeth. Ensure there is not too much liquid on the brush, or it may cause the bat to choke.

Gently brush the teeth in this manner, once per day for five to seven days, or until the gums appear smooth and pale pink. After brushing, apply a thin layer of Manuka honey to the affected area. Manuka honey acts as a natural antibacterial agent as well as a barrier, thus preventing re-infection. There may be minor bleeding from the gums during the first few brushings. Administer Clavamox® 21 to 30 days (see medications). Keep a bat with gum infections on a soft diet (See Feeding Adult Bats) until the infection has cleared up.

Hard tooth deposits (Figure 11-5) should be removed by gently scraping the outer surface with forceps until the teeth appear clean. Cetacaine® Gel (a topical anesthetic) should be applied to the gums prior to cleaning hardened tarter off the teeth. The teeth should be brushed daily, for five to seven days, as described above. Bats that re-develop tartar soon after deposits of tartar are removed may be particularly susceptible to dental disorders, and should have their teeth brushed very gently each day as a preventive measure. The use of Oravet® Plaque Prevention Gel may further help to prevent tarter build-up on the teeth of insectivorous bats.

Abscessed teeth will cause the bat significant pain; therefore, Metacam® should be administered when an abscessed tooth is discovered. Lancing abscessed areas on the face and chin and gently forcing the abscess to drain will significantly diminish pain. It is critical that an abscess be fully drained for the infection to clear. This may include aggressively draining and cleaning the abscessed area for several days post-extraction. Ideally, the bat should be on antibiotics prior to an extraction.

Dental abscesses require once-daily injections of Clindamycin for a period of 14 to 21 days, followed by Clavamox®, alone, for a period of 10 days (see Medications). The author has found that extractions sites heal more quickly with an application of Manuka honey (Figure 11-5C). Bats with dental problems must be hand fed the soft food twice daily until healed.

Figure 11-4. Gently brushing the teeth of a pallid bat with a lipstick brush and CHX® gel. *A. pallidus. Bat World facility. Photo by A. Lollar.*

Figure 11-5. Hardened tartar deposits on the teeth of a big brown bat. *E. fuscus. Bat World facility. Photo by A. Lollar.*

Figure 11-6. Bat with a severely abscessed lower tooth. The abscess has extended into his lower jaw. *E. fuscus. Bat World facility. Photo by A. Lollar.*

Abscessed teeth are easily identified by redness and swelling of the gums at the site of the infected tooth, as seen on the right. Abscessed teeth that are loose in the socket can be easily extracted without the use of anesthesia, although an application of Cetacaine® Gel is recommended beforehand, to numb the area.

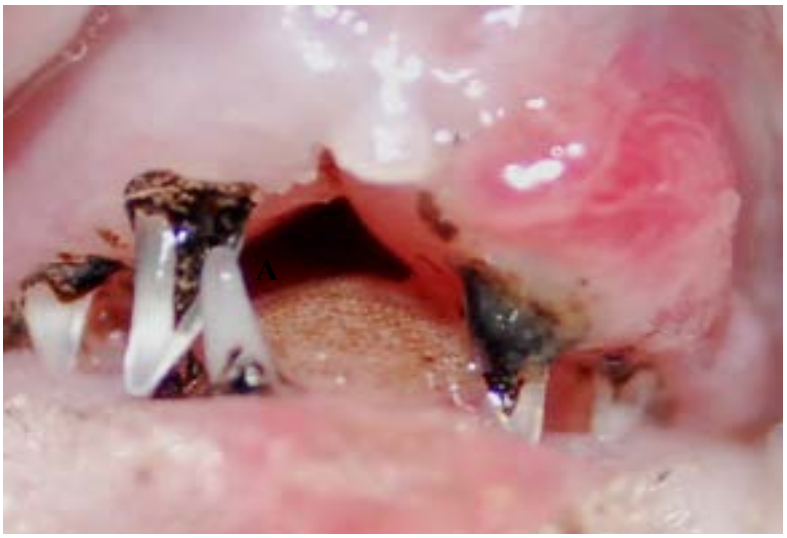


Figure 11-7 A:. A red and swollen area above the upper canine indicates an abscess*. T. brasiliensis. Bat World facility. Photo by A. Lollar*

B: Abscessed canine tooth pulled from the above pictured free-tailed bat. Note the exceptionally long root, making extractions difficult. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

Gently wiggle the tooth back and forth with narrow tipped forceps or tweezers to further loosen the tooth. Forceps 6 inches in length are recommended in order to provide the necessary leverage for an extraction. Using the forceps, grasp the tooth on both sides, and gently rock the tooth back and forth while exerting a slow pulling motion. Do not pull or twist at a tooth because it is likely to break off, leaving the root behind, or even fracture the jaw. This is critically important when extracting the canine teeth because of their exceptionally long roots (Figure 11-7B). The author recommends against extracting canine teeth that are not already loose in the socket due to the risk of leaving the root behind. If a portion of the root is left in the gum, severe pain and subsequent infection can result and the root will need to be surgically extracted. If the tooth is not loose, do not attempt extraction. Continue antibiotic treatment for the prescribed period. There is typically minimal bleeding and rapid healing after an extraction. Manuka Honey applied to inflamed gums and extraction sites can ease pain and promote healing. Wild bats with dental abscesses that have extended into the chest or head should be humanely euthanized.

One case of severe dental issues involved several pallid bats (*A. pallidus*) who arrived at Bat World Sanctuary from a previous caregiver. All the bats had massive dental issues on arrival, including tartar, gingivitis and suspected dental abscesses. The water dish that accompanied the bats was filthy, with the interior sides walls of the dish covered with a slimy black/green film. The bats were immediately started on clindamycin to no avail. Despite all our efforts to save them, most of the bats passed away within a month from sepsis caused by dental disease from *P. aeruginosa,* a bacterium thriving in moist environments such as dirty water bowls. This bacteria caused a severe health decline in the bats resulting in peridontitis, severe suppurative, inflammation and bacterial and purulent (pus) clots in the blood vessels, inflammation of the walls of the blood vessels, bronchopneumonia, bacteremia, and inflammation of the kidneys. This emphasizes the need to ensure both food and water dishes are cleaned on a daily basis, and that dental issues are addressed before they have a chance to become deadly.

Proactive Measures to Prevent Dental Issues

The author has implemented two products that have been proven to successfully reduce tarter build-up, tooth decay and gingivitis in insectivorous bats over. Since using these products, dental infections have and mouth issues decreased by over 90% over a four-year period.

Cranberry Juice Powder
Cranberry is known as a superfood due to their high antioxidant and nutrient content. Cranberry juice polyphenols have gained importance in the dental field over the past decade due to their ability to block cavity-causing bacteria from sticking to teeth, which disarms the pathogens that cause tooth decay. The bioactive component, proanthocyanidins (a chemical compound) is primarily responsible for the protective effect of blocking the adherence of pathogens to the surface of mucus membrane.

To use the powder, simply sprinkle it onto mealworms along with the regular vitamin/mineral supplements (see Feeding Adult Bats). Use sparingly at first and then gradually increase the amount so bats have an easier time accepting it.

Oxyfresh Water Additive
Oxyfresh is a non-toxic, undetectable (odorless and tasteless) product that has been clinically proven to help reduce the disease causing bacteria the mouths of pets. The primary ingredient is Zinc Acetate, which neutralizes volatile sulfuric compounds. Add a few drops to the bat's water dish daily.

Figure 11-8 A: Organic cranberry juice powder. B. Oxyfresh water additive. *Bat World facility. Photo by A. Lollar.*

Eye Infections

The visual capacity of insectivorous bats varies from one species to another. The retinae consist mostly of rod cells, and their eyes are thus adapted for low light conditions (Figure 11-8). Color vision had been demonstrated only in megachiropteran species, but more recently has been described in some microchioptera (Schmidt et al., 1998). The megachiroperta have large eyes and specialized pathways from the retina to the midbrain similar to those found in primates (Pettigrew, 1986). These bats do not use echolocation, but rather depend on vision (along with olfaction and hearing) to orient during flight and to detect predators (Nowak, 1994). Some Phyllostomidae have ultraviolet vision that is advantageous in detection of UV-reflecting flowers on which they feed (Muller, et al, 2009).

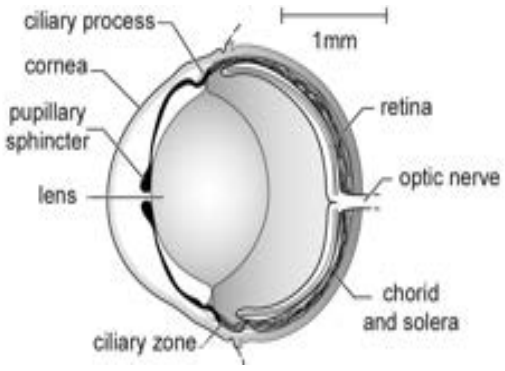


Figure 11-9. Vertical medial section of the eye of *Plecotus auritus*. David Chapman. Modified from Suthers, 1970.

The microchioptera use echolocation to navigate and detect food. They have smaller eyes and are less dependent on vision than the megachiropterans. Nonetheless, vision probably plays a role in daily activity rhythms, reproductive cycles, predator detection, and detection of objects outside the range of echolocation in the microchioptera (Nowak, 1994).

Bright shiny eyes are one of the signs of a healthy bat. The eyes of bats in captivity should be examined daily as part of a routine health check. Dull eyes or droopy eyelids are sometimes the first indication of generalized illness. Cloudy eyes are sometimes associated with rabies infection, although they may also result as a reaction to chemical irritants or bacterial infection. A discharge from the eyes with subsequent matting around the eyelids may also develop. Possible sources of eye irritation include dust or smoke particles in the air, chemical irritants from household cleaners, or bacterial infections potentially resulting from dental problems or inappropriate hygiene procedures. Stress may also play a role in the development of eye problems. Eye infections can be difficult to treat and are often recurrent, depending upon the source of irritation. If left untreated, blindness can result.

Topical applications of a triple antibiotic ophthalmic ointment will usually clear up infections if administered for an entire seven-to-10-day period. The ointment must be applied three to four times daily. Do not apply the ointment directly from the tube into the eye because the contents can become contaminated with bacteria. Squeeze a small strand of ophthalmic ointment onto the corner of a sterile gauze pad so that one end of the strand adheres to the pad while the other drapes off the edge of the pad. Then simply "drape" the free-hanging edge of the strand between the eyelids. Although the bat will close its eye, the ointment will be carried into the eye when the bat opens it again. Bats with infections that do not respond to treatments with antibiotic ophthalmic ointment should receive injections of Clindamycin until the infection clears, which may take as long as 21 days (see Medications). Resistant eye infections may also be successfully treated with Moxifloxacin eye drops, 0.5%, applied three times daily (Sylvia Strasser, pers. comm.).

Use a clean, sterile gauze pad for each eye, and dispose of the pads after use. It is extremely important that the ointment be applied three to four times daily for the entire seven-to-10-day period, even if the eyes clear up beforehand. Incomplete treatment will result in re-infection and possible development of resistance to the antibiotic, complicating subsequent treatment. Note: Do not use ophthalmic ointments with steroids on bats. Steroids retard healing of lacerations or ulcers. Because the eyes of many bat species are very tiny, it is difficult to use standard staining methods to determine if lacerations are present.

To minimize the possibility of eye irritation, keep rooms where bats are housed free of dust and aerosolized cleaning substances. Do not keep other animals in rooms where bats are housed and keep enclosures sanitary. Contamination can easily be spread from one bat to another, or even from one mammal to another, so be careful to wash your hands before and after handling each individual.

A watering or protruding eye can be an indication of an abscessed tooth (see Infections of the Gums and Teeth). Bats are occasionally brought in from the wild with eye injuries. These injuries should be flushed with sterile saline (never with hydrogen peroxide, Nolvasan®, or Betadine® solution). Little else can be done for such injuries other than use of the topical and oral antibiotics listed above for eye infections, with the addition of Metacam® for pain (see Medications).

The author has observed cases in which an injury caused an eye to protrude (proptosis) in Brazilian free-tailed bats (*T. brasiliensis*). In both instances, the damaged eye atrophied and detached on its own. However, such injuries can result in infection that travels to the brain along the optic nerve, leading to encephalitis. Moreover, the bat might experience severe pain. Therefore, the eye should be enucleated by a veterinarian as soon as possible.

Gastrointestinal Disorders

The digestive systems of bats is similar to that of other mammals. The esophagus connects to the cardiac vestibule, a special chamber that opens into the large cardiac chamber of the stomach. The cardiac chamber connects to a tubular pyloric region, which opens into the small intestine via the pyloric sphincter. Modifications of these regions are present in non-insectivorous bats.

Gastrointestinal disorders can develop in response to endoparasitic infections, stress, or the administration of some medications (see Parasites and Medications). Abdominal distention, vomiting, diarrhea, loss of appetite and weight loss are all signs of gastrointestinal disorders.

GASTRITIS

Gastritis, sometimes referred to as bloat, is a condition that results from the accumulation of gastric secretions, food, or gases in the digestive tract. Clinical signs in bats include abdominal distension and respiratory distress. The disorder can develop following intestinal blockage that results from an inappropriate diet. It can also develop in response to endoparasitic infections, stress or the administration of some medications. Gastritis can also result from a lack of the beneficial flora normally present in the intestinal tract of healthy bats. The lack of beneficial organisms can result in the proliferation of pathogenic ones and the subsequent accumulation of intestinal gases.

It is often difficult to determine the cause of gastritis in an adult bat. However, intestinal blockage can sometimes be identified by wetting the fur in the lower abdominal area so that the skin is more readily visible. When distended, a portion of the intestines is visible through the skin of the abdomen when viewed with a high-intensity light source. A large black area in a section of the intestine may indicate that hardened feces are causing intestinal blockage (although hardened stools will not always be visible by external examination). Sustained penile erection is sometimes observed in males with this condition. For intestinal blockage, administer an oral dose of mineral oil (0.02ml/5g of body weight). Administer this dose slowly as mineral oil can be dangerous if aspirated. If there is no bowel movement within three hours, administer a second dose. If feces have not been eliminated within three hours of the second dose, veterinary assistance may be required for surgical intervention.

Accumulations of intestinal gases can sometimes be relieved with simethicone. Administer an oral dose of simethicone (0.0l ml/g of body weight) every two to three hours. Although the use of simethicone may eliminate accumulations of abdominal gas, normal digestion will not be re-established if beneficial organisms are not present in the digestive tract. Following the use of simethicone, administer an oral dose of *Lactobacillus acidophilus* or a probiotic product.

DIARRHEA

Bat feces vary from one species to another but are generally dark (brown or black) and firm (i.e., they should not be runny). Stools of nursing infants or infants being hand fed milk formulas may have a yellowish color. Although soft and somewhat sticky when fresh, feces dry within a short period of time. Feces from most North American insectivorous bats measures about 1mm to 3mm in diameter. The stools of some species such as the Brazilian free-tailed bat (*T. brasiliensis*) are small pellets (4mm to 5mm in length) resembling mouse droppings. Those of other bats such as big brown bats (*E. fuscus*), red bats (*L. borealis*), and evening bats (*N. humeralis*) are longer (up to 15mm in length). Dry bat droppings can be easily distinguished from dry rodent droppings because they crumble easily, unlike rodent droppings which become very hard and do not crumble. Bat droppings also contain shiny insect parts.

Both wild and captive bats can develop diarrhea as a result of endoparasitic, viral, or bacterial infections. Treatment should be directed at the source of the problem (i.e., laboratory analysis of feces or other tissue samples), and and elimination of endoparasites or pathogenic bacteria. Diarrhea in captive bats can also be associated with poor nutrition, poor sanitation, stress or the side-effects of some medications. Following the dietary, hygiene, and care procedures in this manual will help to prevent the development of diarrhea in captive bats.

ANOREXIA

Loss of ability or desire to feed in captive bats can result from a number of causes including but not limited to inappropriate environmental temperature, stress, dental disorders, anemia, and other illnesses including rabies (Constantine, 1967). The condition is a serious disorder that frequently results in the death of captive bats. Clinical signs include dehydration, sunken abdomen, loss of body weight, inadequate grooming, and subsequent loss of fur. Dental disorders should first be eliminated as potential sources of feeding problems (see Infections of the Gums and Teeth).

HEPATIC LIPIDOSIS (Fatty Liver)

Some histopathologic studies of livers obtained from anorexic bats at necropsy have revealed hepatic lipidosis, which is an accumulation of fat in the liver. Fatty deposits in the liver have also been associated with anorexia in cats, cows and raccoons (Wentick, 1992 [cited by Walker, 1996]). Hepatic lipidosis has been associated with poor diet, metabolic reaction to injury and some diseases such as diabetes and pancreatitis.

Fats are carriers of fat-soluble vitamins and play a role in the absorption of vitamin A, carotenes, and calcium (Maynard and Loosli, 1969 [cited by Rasweiler, 1977]). Animals fed a fat -free diet can develop dermatitis, fail to grow, and develop a fatty liver and neurological disturbances. The author has found that insectivorous bats will also develop dry or flaky skin, patchy fur, and depigmentation of the flight membranes if fed a diet deficient in fat. As a preventive measure, the author recommends supplements such as Missing Link® and flax oil to provide fatty acids to the diet, as both contain linoleic and linolenic acids (Omega-3 fatty acids).

Vomiting, anorexia, foul smelling stools, and jaundice (yellowing) where the wing membranes attach to the body (visible first ventrally then dorsally) are signs of fatty liver disease. Jaundice may also be visible at the base of the ears and on the chin (Figure 11-10) but is sometimes hard to see in heavily furred and darkly pigmented bats. With these bats, it will be visible as a yellow cast between the eyes and/or the scent glands on the muzzle. If fatty liver is suspected, administer milk thistle or Denosyl for 10 to 14 days (see Medications) for a period of two weeks. Anorexic bats may need to be initially coaxed to eat by placing the food directly in their mouths with a syringe. Patiently wait for the bat to swallow each bite, then offer more. Continue feeding in this manner several times a day until appetite returns to normal.

Figure 11-10. A: Free-tailed bat with acute hepatic lipidosis. The yellowing of the skin is visible on the lower jaw and wrists. **B:** The same bat after five days of treatment with Denosyl. *Bat World facility. T. brasiliensis. Photo by A. Lollar.*

Urinary Tract Infections

The urinary system in bats functions to maintain a balance between water and salt concentrations in the body. It includes the kidneys, ureters, urinary bladder, and urethra. Urinary tract infections are commonly caused by bacteria, but may also result from viral, fungal, or yeast infections. Inflammation of the bladder (cystitis) often occurs secondary to urinary tract infections. Chronic conditions can be secondary to some other lesions. Necropsy reports by Scott Fitzgerald, DVM, PhD, and graduate student, Julie Lemson, at the Animal Health Diagnostic Lab at Michigan State University describe lesions and extensive fibrosis of the bladder of captive big brown bats (*E. fuscus*) in association with calculi (stones) (Julie Lemson, pers. comm.). The uroliths (urinary calculi) were composed of magnesium ammonium phosphate hexahydrate (struvite calculi). Although struvite crystals can be normal in small mammals, precipitation required for stone formation can result from dehydration. Keeping bats well-hydrated will help to minimize the possibility of stone formation.

Pregnant females may also develop urinary tract infections secondary to intrauterine death. Indications of urinary tract infections include cloudy, blood-tinged, or foul-smelling urine. When possible, a urine sample should be obtained and submitted to a veterinarian for microscopic examination. (This is important because a cloudy discharge from males during the mating season may be sperm.) Crevice-dwelling bats frequently urinate when first disturbed from a restful state. Hold the bat in the hand with the head higher than the rest of the body and allow the urine to dribble onto a slide, which can then be submitted for examination. Bats also often urinate immediately prior to entering their roosting pouches. If a bat does not urinate when disturbed from a restful state, place it back in the enclosure close to its roosting pouch. It will sometimes stop at the edge of the pouch and urinate before going in. Urine can be collected on a slide at this time. For foliage-roosting species, Saran® Wrap can be placed on the enclosure floor temporarily, and urine collected from the wrap. Do not leave Saran® Wrap on the enclosure floor for any longer than needed to collect a urine sample because bats that fall from their roost may become entangled in the wrap.

Captive Brazilian free-tailed bats (*T. brasiliensis*) have tested positive for *Proteus mirabilis* after being housed in cages in close proximity to laboratory mice. This is a Gram negative, facultative anaerobe widely distributed in nature. It has been found in the human intestinal tract, in soil, water, and plants. It is easily detected in feces of most animals but is hardly ever found in high numbers unless the normal intestinal microflora is deranged.

Most urinary tract infections can be successfully treated with a single dose of Convenia®. If *Proteus mirabilis* is identified in cultures, cephalexin should also be given for a period of 10 days. Infections that do not respond to Convenia® or cephalexin may respond to Doxycycline (see Medications). Metacam® can also be given for pain. Suspected blockages can sometimes be cleared by massaging the end of the penis or vagina while applying gentle pressure on the bladder. Bats suspected of having urinary tract infections should be rehydrated with subcutaneous injections of an electrolyte solution for a period of two to three days. When urinary tract infections are associated with intrauterine death, the fetus must be surgically removed by Caesarean section (see Caesarean Section and Ovariohysterectomy).

Note: Both male and female *E. perotis* sometimes make soft peeping noises while urinating which may lead caretakers to believe the bat is experiencing pain; however, this is normal behavior for this particular species.

Skin Conditions

A variety of skin conditions in bats are manifested by depigmentation (i.e., pale spots) and fur loss. Possible causes include dietary deficiencies, parasites, fungal or bacterial infections (including those caused by lack of careful hygiene procedures during treatment), excessive temperatures, low humidity, contact with chemical irritants, unsanitary housing, inappropriate enclosure surfaces, or sometimes stress. Dry, flaky skin, patchy fur, and depigmentation of the flight membranes can all result from diets deficient in fat. These conditions can be prevented or reversed by adding linoleic and linolenic acids to the diet. Molossids exhibiting signs of deficiency can be given 1/2 drop (0.25ml) of flax oil daily until healthy skin and coat are reestablished, generally within three to five days. Other causes of skin conditions can be remedied with the treatment outlined in this manual for parasites, adhesive contaminants, and bacterial infections, as well as the use of appropriate enclosures maintained at proper temperature (70° to 95° Fahrenheit) and humidity levels (60% to 80%).

Infants may develop painful fungal infections on wing tips if they become contaminated with feces. Wing tips will look oily and may be discolored. Gently wash the wing tips with warm water, dry thoroughly using gauze or a soft cloth, and treat with topical applications of Nolvasan® suspension until the infection has cleared.

Tiny pimples or bumps on the arms, wings, or torso may be caused by ectoparasites. The author has also observed a solitary wart-like growth along the bones of the arms or fingers on Brazilian free-tailed bats (*T. brasiliensis*). Its etiology is unknown, but it does not appear to be detrimental to the bat and often disappears without any treatment within a matter of weeks to months.

FACIAL SECRETIONS

Vespertilionid bats occasionally secrete a yellowish substance from their facial glands (Figure 11-11). The secretion is thought to be hormonal in nature and may increase in males during the fall and winter. Interestingly, the author has found that these secretions stop all together in big brown bats (*E. fuscus*) that have had all of their teeth removed due to chronic dental infections (see Infections of the Gums and Teeth). These bats also receive the complete soft food diet twice daily along with viscera from giant mealworms (see Feeding Adult Bats).

Figure 11-11. *L. intermedius* with facial secretions. *Bat World facility. Photo by A. Lollar.*

Facial glands occasionally fill with pus and appear swollen. These glands can become so enlarged that they press against the eyes. In such cases, warm compresses should be gently held against the swollen area to help open the pores so puss can be expressed. In severe cases, these areas may be lanced to express hardened puss. Afterwards, wipe the muzzle clean with a gauze pad and apply a topical application of triple antibiotic ointment. Pseudomonas aeruginosa has been isolated in facial secretions of *P. khulii (*Sandra Bellomo pers. comm). This bacteria is found in nature and can lso be found in the skin of healthy individuals. Minor cases clear up within a few days with proper treatment.

FUNGAL INFECTIONS

Bats are known to contract a number of fungal infections. Dermatophytes found on some bat species include: *Trichophyton persicolor*, *Trichophyton mentagrophytes*, and *Microsporum canis* (Hill and Smith, 1984). Recent research undertaken to combat White Nose Syndrome is greatly enhancing our understanding of fungal infection in bats, and we eagerly await publication and application of as-yet unpublished findings.

M. canis is a common agent of ringworm in humans. *T. persicolor* is a rare cause of human ringworm in Britain and western Europe. Humans are commonly infected with ringworm agents from contact with infected cats or dogs.

Clinical signs of ringworm infections in bats include pale, iridescent areas of skin on the wings, ears, or face (Figure 11-12 A and B), or bald circular patches within the fur. There may also be scaly or yellowish crusted lesions on the skin. A skin scraping should be submitted to a veterinarian for identification. Be certain to quarantine a bat with such an infection because these infections are highly contagious and can be quickly transmitted to other bats in the facility.

Ringworm infections have been successfully treated with oral medications such as Grifulvin V® Liquid as well as Itrafungol (see Medications). Biogamma may prove successful in treating ringworm (see Medications). Manuka honey has also been used by the author with success (Figure 11-12). Cover all affected areas, including those that are furred. Treatment should be continued for a minimum of three weeks. Fur loss will occur during treatment; however, vast improvement should be seen in as little as one week. Note: Some fungal infections can be transmitted to a handler from an infected bat or from an infected human to a bat. The use of Nitrile gloves during care procedures will minimize the likelihood of transmission.

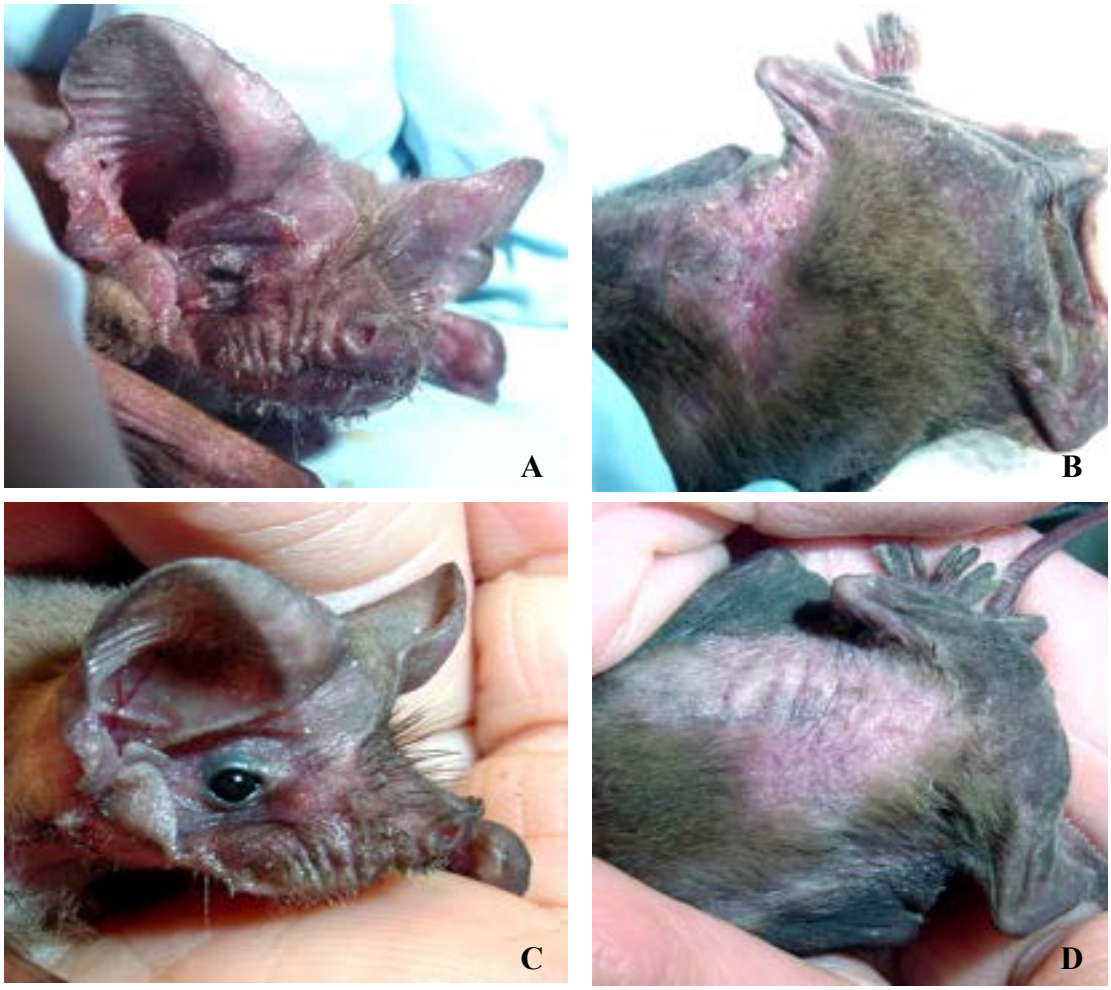


Figure 11-12. A and B A wild-caught Brazilian free-tailed bat with suspected case of Dermatophytes (ringworm). The bat was treated with topical applications of Manuka honey once daily. **C and D:** one week after treatment. This bat was cured of the fungal infection in three weeks using Manuka honey alone. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

CONDITIONS CAUSED BY IMPROPER DIET AND FEEDING TECHNIQUES

Care should be taken so that food is not allowed to get on a bat's fur and that bats are properly cleaned after hand-feeding. Bacterial infections, allergic reactions, trauma, low humidity, and hormonal imbalances may also cause hair loss. Hair loss can be caused by a deficiency in certain nutrients such as zinc, biotin, fatty acids, and protein. Unnatural diets, such as those involving meat baby food and Nutri-cal®, have been known to result in fur loss over the entire body (Figure 11-13). Nutri-cal® has been used by the author as a successful tool in coaxing stubborn bats to begin eating during the hand feeding process, but it should never be used in place of actual food as Vitamin A toxicity may result (Figure 11-14). The author has found that fur loss due to nutritional deficiencies is reversed when bats are fed the Bat World Sanctuary complete soft food diet (Figure 11-12B and C) and healthy coats and fur are maintained thereafter.

Figure 11-13. A: Two year-old toothless free-tailed bat received after being raised on a diet of chicken baby food, mealworm viscera and Nutri-cal®. **B:** The same bat two weeks later, after being hand fed the complete soft food diet twice daily. **C:** Within three months after being fed the soft food diet, this bat grew a full coat of fur. *T. brasiliensis*. *Bat World facility. Photo by A. Lollar.*

Figure 11-14. A and B: An adult big free-tailed bat received after being raised on a diet of Nutri-cal®. The skin on this bat appears burned, likely from Vitamin A toxicity due to the high concentration of Vitamin A in Nutri-cal®. **C:** Pieces of hardened skin removed during a four-hour process. **D and E:** New fur growth is evident after 10 days of being fed the complete soft food diet, along with mealworms. **F:** Two days after hardened skin was removed from the face. **G:** One month later. *N. macrotis*. *Bat World facility. Photo by A. Lollar.*

EROSIVE DERMATITIS

Some bats, such as Myotis, may have sensitivity to Vitamin A. Captive Myotis bats (*M. lucifugus*) maintained by the author developed areas that appear burned on the tip of the ears and mouth after receiving 0.05 mls of Linatone® (a fatty acid supplement high in Vitamin A) once daily for seven days. The condition disappeared when doses of Linatone® were discontinued. Myotis bats (*M. lucifugus*) and Tri-colored bats (*P. subflavus*) occasionally develop erosive dermatitis of unknown etiology. The condition involves a hardened outer-wing membrane along the forearm and wrist that eventually sloughs to reveal underlying skin that appears healthy. The toes and thumbs swell significantly to the point that there are strictures at the joints and occasional loss of one or more digits (Figure 11-15). Clinical signs include excessive thirst, inability to spread the wings, hair loss, and apparent pain. Over time the condition slowly recedes, and lost fur is re-grown.

Culture for bacteria and fungus was negative with no specific microorganisms identified. Additionally, there is no apparent vasculitis (inflammatory destruction of blood vessels) making it less likely that the condition is a disease process due to a systemic condition.

Many therapies have been attempted with limited success, including the use of Dermicel, Collasate and Dexamethasone. The condition has been best alleviated with topical applications of flax oil as well as adding one drop (0.05ml) of flax oil to every 3mls drinking water until the condition improves. Metacam® should be given for pain, along with oral doses of Veraflox for secondary infections.

Figure 11-15. Erosive dermatitis on the thumb, toes and forearm of a little brown bat. *Bat World NoVa facility. Photo by L. Sturges.*

Wing Wasting

Wing wasting was previously of unknown etiology in *T. brasiliensis*, rendering many bats non-releasable. In 2019, the author received confirmation of *pseudomonas aeruginosa* as the primary cause. This bacterium is found widely in nature and especially in damp, poorly ventilated areas such as attics and crawlspaces where crevice-dwelling bats frequently roost. The condition leaves the bat unable to fly and they are often found grounded with no visible injury. The condition appears to be painful at the onset and may include a slight to moderate swelling of the wrists where fluid is accumulating. An additional early sign may include small areas if irritation (Figure 11-16 A) and a decrease of elasticity of the wing membrane (Figure 11-16 F).

As the condition progresses, small wet areas will be noticed in the folds of the wing membrane and the area may become malodorous. Petechial hemorrhaging may also occur, and the outer edge of the membrane will begin to dry and blacken. Within two or three days of the initial signs, the wing membrane will degrade, weep and slough away and painful blisters may also appear (Figure 11-16 B & C). In the final stage of wing wasting, the membrane will become necrotic and break away. After all necrotic tissue is gone, healing will begin (Figure 11-16 D). The skin of the ears may can also be affected by *pseudomonas aeruginosa.*

Early applications of Biogamma cream or Clever Fungus (if available) will cure wing wasting in three to five days (Pers.comm. Marie-Theres Schurrer DVM). These products contain *Pythium oligandrum*, a mycoparasite that feeds on the infectious fungi of the skin/nails, thereby suppressing and killing causative agents. Bats with wing wasting should also receive oral administrations of Veraflox® and Metacam, once daily, until the condition has cleared (see Medications). Bats with wing wasting that are treated in the early stages with Biogamma or Clever Fungus are generally releasable. Note: *Pythium oligandrum* may cause a temporary loss of pigmentation during the healing process (Figure 11-16 G).

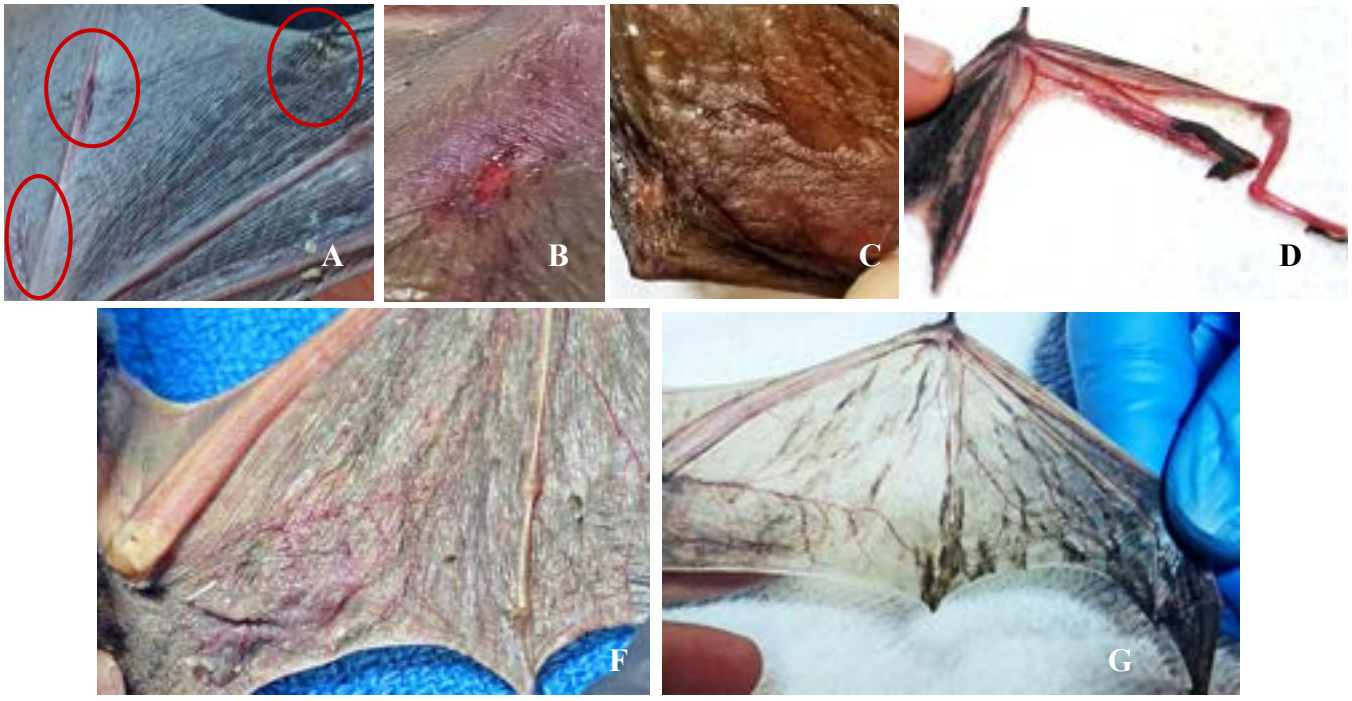


Figure 11-16: A: The beginning stages of wing wasting showing small irritated areas on the membrane (circled). **B.** Sloughing caused by wing wasting. **C:** wet areas appear in places inside the folds of the wing membrane. Petechial hemorrhaging may also occur. **D:** The end result of wing wasting on a bat that was not treated Veraflox and Metacam only. **F:** Irritation and loss of elasticity in the wing membrane of a bat newly admitted bat with wing wasting. **G:** Three days post treatment showing temporary depigmentation on the same bat using Veraflox, Metacam and Biogamma cream. *T. brasiliensis. Bat World Facility. Photo by A. Lollar*

Parasites

ECTOPARASITES

Bats can be infested with a variety of ectoparasites including fleas, ticks, mites, true bugs, and parasitic flies. Some of these parasites will be found only on certain parts of the bat; for example, wing mites will only be found on membranes or along the bones of the wing, while other mites will only be found on a bat's torso. Ticks (hard and soft-bodied species; families *Ixodidae* and *Argasidae*) are usually found on the lower back, tail or wing membranes (Figure 11-17 B), or sometimes on the face or ears. Mites (families *Spinturnicidae*, *Macronyssidae*, and *Laelapidag*) usually occupy specific areas on a bat such as the nasal passages, periodontal tissue, or in clusters in the ears, around the eyes, on the wings, or at the base of the tail. Bats are also parasitized by "true bugs" such as bedbugs (family *Cimicidae*). Wingless parasitic flies (i.e., bat flies) of the family *Nycteribiidae* crawl spider-like in the furred areas of a bat. Many of the parasitic flies of the family *Streblidae* have wings and can fly short distances. They also crawl spider-like on the membranes and fur of bats.

Many of these parasites are very tiny and can be difficult to see without magnification. Ectoparasites are mostly tan, brown, red, yellow, or white in color. Mites have a spider or crab-like appearance and may be red or white (they appear red when engorged with blood (Figure 11-17 C), Bat fleas resemble the fleas on domestic pets and are typically shades of brown or tan. Bugs, such as bedbugs, are larger than most mites or fleas found on bats, although they are also brown in color. Bat flies look like tiny yellow or white flies.

Use tweezers to physically remove any parasites large enough to pick off a bat. Place the parasites into a small beaker or cup filled with 70% isopropyl alcohol to kill the parasites. Although such parasites may be found in small numbers on otherwise apparently healthy bats, it is common for sick or injured bats to have serious infestations. Do not treat bats with flea and tick sprays or powders because they contain chemicals that are toxic to bats. For minor infestations, physically remove visible parasites with a cotton swab moistened with 70% isopropyl alcohol. Revolution should also be applied (see Medications).

For serious infestations, extend each wing and swab the entire wing with a gauze pad wetted with 70% isopropyl alcohol. Use a clean gauze pad moistened with warm water to clean the wing, then dry the wings with a clean cloth. Use an interdental brush dipped in 70% isopropyl alcohol to gently comb through the fur. This will cause many parasites to move to the surface where they can be easily removed with a cotton swab as described above. If necessary, the bat can be bathed to remove dead parasites (see Bathing and Grooming). Reusable pads and cloths used during the procedure should be laundered immediately.

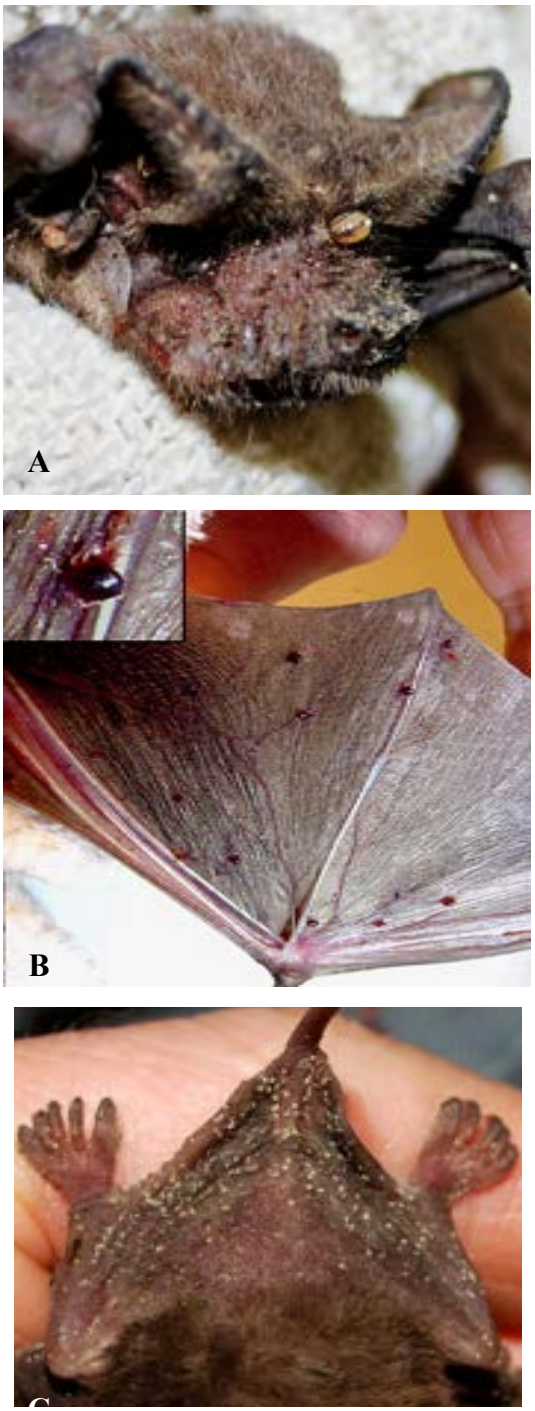


Figure 11-17. A: An unidentified external parasite occasionally found attached to the face at the base of the ears. *T. brasiliensis*. **B:** Ticks on the wing of a free-tailed bat. **C**: Mites attached to the tail membrane of a free-tailed bat. *T. brasiliensis. Photos by A. Lollar*

Wing mites can burrow into the skin of the wings, arms, fingers, legs, and ears of a bat. Other mites will burrow into the skin of the body (Figure 11-18 A). Tiny pimples or bumps on a bat may contain egg sacs or larval stages of ectoparasites (Lollar, 1998). Egg sacs are not easily removed. The eggs of some ectoparasites appear to be almost cemented to the skin. Bats with these infestations can be treated with a single topical dose of Revolution® (selamectin). For use on bats, apply a small dot of the liquid on the tail membrane.

In some cases, parasitized sites will become infected, and it may be necessary to break the outer layer of the skin, exposing the eggs and developing mites. Use a sterile 27 to 29 -gauge, 1/2'' needle. Holding it parallel to the bat's body, slide the tip of the needle beneath the skin at the site. Remove the needle and then gently push on the sides of the site, squeezing the egg sac through the puncture. Use sterile gauze pads and forceps or tweezers to remove any pus or other substance that emerges from the puncture.

These sites will need to be flushed with warm water followed with an application of a triple antibiotic ointment. Bats that have several dozen of these sites on their wings or bodies should be given Veraflox orally for 10 days (see Medications). Although these sites will heal, in some cases small scabs will form and eventually fall off, leaving holes in the wing membranes. New pink skin will develop, filling in the holes within just a few weeks.

ENDOPARASITES

A variety of endoparasites have also been identified in bats. These internal parasites include parasitic flatworms (trematodes, Figure 11-18), roundworms (nematodes), and tapeworms (cestodes). Tapeworms are found in the intestine. Trematodes (flukes) are typically found in the intestine, gallbladder, liver, or lungs. Roundworms may also be found in the intestine, gallbladder, liver, and lungs, in addition to the body cavity, urinary bladder, or bloodstream. The life cycles of some endoparasites are complex. Filaria, threadlike parasitic nematode worm that is transmitted by biting flies and mosquitoes, was found in *H. savii* who suddenly became ill and died (pers. comm. Vyara Krushkova). In some cases, as with flukes, infection requires an intermediate host such as an insect that a bat consumes. In one case, a large number of Nematodirella, a parastate of sheep, was discovered in samples of guano from a roost involving *T. brasiliensis (*pers. comm Deborah Cottrell, DVM*)*. An insect was likely the intermediate host. Others have larval stages that exist in the soil or guano and infection can result from grooming behavior.

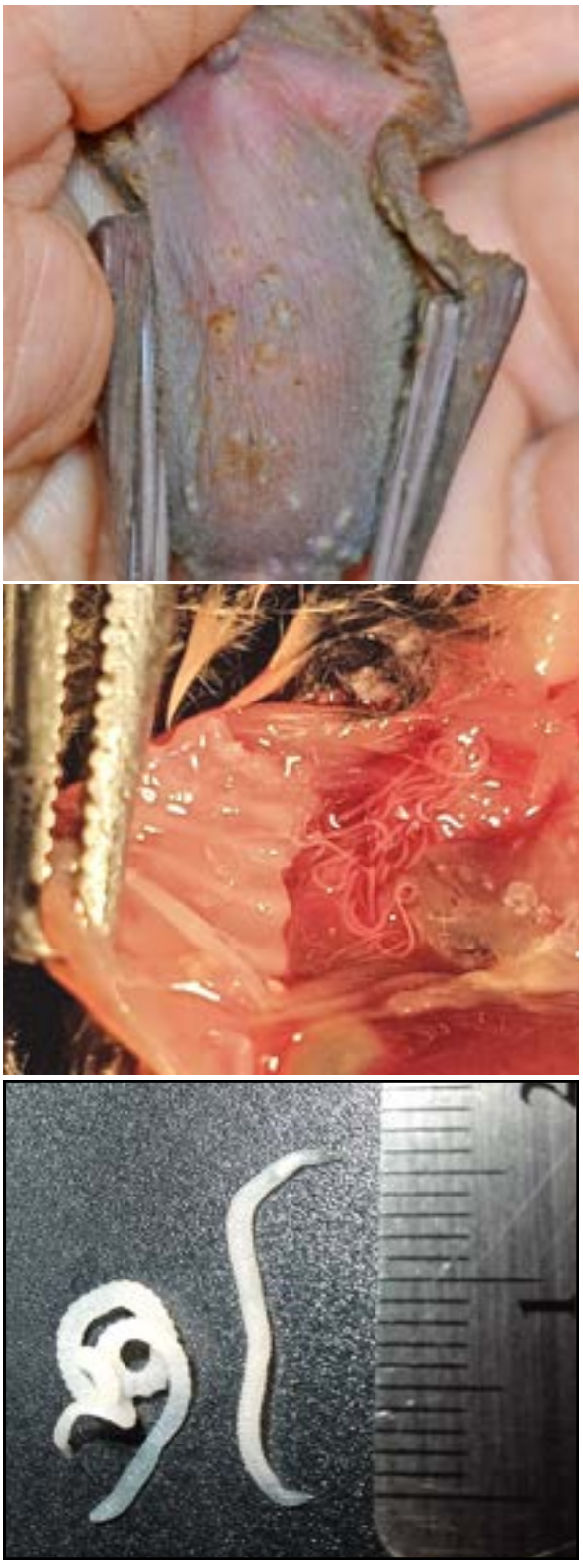


Figure 11-18. A: Egg sacks under the skin of a free-tail pup. **B:** Filaria found in the lungs of *H. savbvvi. Bat World Bulgaria. Photo by V. Krushkova.* **B:** Nematodes expelled from a free-tailed bat after being dosed with Revolution. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

Although some helminths of humans or domestic animals have been found in bats, most species are specific to bats and bats do not appear to be a reservoir for any human parasites.

Symptoms of endoparasites include lethargy, dull or thin coat, loss of appetite or constant hunger, vomiting, diarrhea, slow growth rate in pups, pale gums, torticollis (head torsion), head tilt, circling, tremors, and ataxia (inability to control muscular movements).

Clinical signs of liver flukes include heaving respiration, stiff torso, hunched back, wings crossed in front of the chest and stiff fingers which are held out and away from under the wings (Figure 11-19). Bats with signs of severe trematode infestation (flukes) should be humanely euthanized as the condition is exceptionally painful and they will not respond to treatment.

Figure 11-19. A free-tailed bat with liver flukes. Note the hunched back and stiff wing fingers. *T. brasiliensis. Photo by A. Lollar.*

Bats infected with Nematodes can be treated with a single dose of Revolution® (selamectin) as described on the previous page. Bats infected with tapeworms have been successfully treated with Drontal (Brenda Malinics, pers. comm.). Panacur, Albon and Valbazen are also used to treat endoparasites (see Medications).

Coccidia has bee successfully treated with Bactrim (oral suspension with Sulfamethoxazole 200 mg and Trimethoprim 40 mg). Note that Bactrim must be used with caution as it has been known to cause kidney stones in bats.

Rabies

HUMAN EXPOSURE

Rabies is a viral infection of the central nervous system resulting in fatal inflammation of the brain and sometimes the spinal cord. Tuttle, 2018, states "On a global scale 99 percent of human rabies comes from dogs, killing more than 60,000 humans annually. In contrast, transmission from bats is exceedingly rare. Colonial species, the ones typically found in buildings, rarely become aggressive even when rabid and normally bite only in self-defense if handled… The United States and Canada average just one or two cases per year, and it is unlikely that additional preventative efforts could further reduce such an already rare event."

Exposure to rabies virus typically results from bites of an infected animal. Less common modes of exposure include direct contact of open wounds, cuts or abrasions with saliva or nervous tissue of an infected animal, contact of mucous membranes (e.g., eyes, nose, mouth) with infected saliva or nervous tissue and inhalation of aerosolized virus. Although some of the recent human cases attributed to bat variants of the virus report no evidence of a bat bite, it is not possible to eliminate a bite as the mode of exposure. In some cases, the individuals were known to have actually handled bats or there was a report of a bat having been present in the victim's home some time prior to the onset of clinical signs of the disease. In addition, by the time the disease was diagnosed, some victims had already died or were too ill to provide specifics regarding the kind of contact they had or may have had with a bat or other wild animal. In such cases, medical professionals were forced to rely on whatever information could be provided by family members or friends. Although the author has found that bat bites are most certainly felt, they do not always leave readily detectable marks on the skin. While victims of bites from terrestrial mammals such as raccoons are likely to seek medical treatment, this may not be the case with victims of bat bites. Unfortunately, the lack of a visible bite mark may have led to some victims to dismiss such an encounter as insignificant.

Denny Constantine, formerly with the California Department of Health Services in Berkeley, California studied rabies in bats extensively. According to Constantine, "… increasing numbers of bats were tested after 1953 due to increasing awareness of the problem. The infected bats were among many thousands of bats submitted for testing, usually because the bats, either disabled or dead, had been captured by pets or children, and bites were known or suspected to have occurred. About ten percent of the bats submitted in this manner for testing in the United States proved to be infected... It should be emphasized that these bats represent a highly biased sample, because nearly all of them were ill or dead at the time of collection." This explains why health department statistics can vary significantly from those of wild bat populations and why comparisons of wild to suspect-submission rabies prevalence is of limited value. While previous studies suggest that about 10 per cent of bats taken by the public test positive for the rabies virus, more recent research conducted at the University of Calgary proves the number is closer to one per cent (Klug, et al, 2011).

No survey methods are likely to be entirely unbiased. As sick bats are more easily caught than healthy ones, surveys taken in roosts may overestimate the frequency of infection in the population in general. Daytime surveys of night roosts may contain only incapacitated individuals (i.e., those unable to return to daytime retreats). Constantine indicates that such surveys may lead to mistaken impressions of rabies outbreaks, but that, "…nothing resembling an outbreak or large-scale rabies destruction of a bat colony has been detected, despite careful seeking" (Constantine, 1988). He goes on to state that, "the most reliable and useful survey samples are of bats capable of flight, such as bats issuing from cave entrances. From such sampling, it has been learned that only a small proportion (<0.1 to 0.5 percent) may be infected..." (Constantine, 1988). While surveys of bats issuing from cave entrances would not include bats that are clinically ill and no longer able to fly, they would include infectious bats in pre-clinical stages.

Despite low rates of infection in wild populations, there is likely to be a higher frequency of infection in sick and injured wild bats treated by bat caretakers. They handle a highly suspect population similar to the population many health departments receive for testing. According to the U.S. Centers for Disease Control and Prevention (CDC), post-exposure prophylaxis is indicated following a bite or scratch from a confirmed rabid bat or

from one that is not available, or suitable, for testing. The author has found that some people are reluctant to admit to such encounters. Although this is sometimes due to a concern for the welfare of the animal (i.e., they don't want it killed for rabies testing), more often it is due to a reluctance to admit to inappropriate behavior (i.e., catching or otherwise handling a wild animal without using necessary precautions). This may be particularly true of children. It is, therefore, important that caretakers carefully inform persons turning bats over to them of the potential consequences of untreated exposure to an infected animal. The CDC recommends that a bat be tested for rabies if it is found in a room with a person who cannot be considered an accurate historian (i.e., a person who may not be able or willing to give accurate information about potential contact with the bat such as a child or a mentally disabled, sleeping, or intoxicated person).

Concern has been voiced about the potential threat from aerosolized rabies virus. Only two human cases of aerosol transmission of bat rabies have been suspected, both in the 1950's. Brass (1966) suggests that misquotes, misunderstandings, and information carried out of appropriate context have resulted in misleading reports about this issue. In truth, aerosol transmission is suspected only within the unique conditions that exist in a small number of caves in the Southwest that house large nursery colonies of Brazilian free-tailed bats (*T. brasiliensis*). Rabies virus has been isolated from the air of such caves and sentinel animals placed in them have developed rabies without direct contact with bats. The unique atmospheric conditions resulting in caves housing these large maternity colonies (i.e., the presence of hundreds of thousands of bats combined with poor ventilation) may have played a role in aerosolized transmission of rabies (Constantine, 1967). Viral entry points could have included skin wounds, the alimentary tract, or respiratory mucosa. Brass (1996) points out that aerosolized virus was not detected in subsequent studies of caves housing large bat colonies in Oklahoma, Alabama, and Tennessee, and that rabies researchers do not believe that caves in the northern temperate zone are conducive to airborne transmission. Neither are such conditions found in buildings housing typical bat colonies.

Brass (1994) discusses this issue at length, providing specifics about each of the human cases. In so doing, he states that the evidence that the two deaths in the 1950's resulted from inhalation of aerosolized virus remains questionable. One victim, in particular, an entomologist with the Texas State Health Department who died in 1956, reported no bites but was known to have actually handled thousands of bats as a member of a rabies investigative team. An area of chronic skin irritation might also have had a contributory role in this particular case. The second victim, a consultant mining engineer who died in 1959, reported no bite although one report indicated he had been "nicked" in the face by a bat.

These facts led Brass (1996) to conclude that the risk of inhalation exposure to cavers exploring caves other than the aforementioned nursery colonies in the Southwest is virtually nonexistent: "This mode of transmission should not be of even remote concern to either the general public or the vast majority of the caving community, since it is a phenomenon known only from the research laboratory and possibly the exploration of certain unique underground environments".

Brass (1994) also notes that there has been no report of bat-inflicted rabies in a caver secondary to a bite sustained while underground, despite the hundreds of thousands of man hours spent underground annually by members of the National Speleological Society. Nonetheless, the author does note the possibility of direct contact with bats during cave exploration despite the fact that conscientious cavers try to avoid disturbing bats. He emphasizes prevention and prompt treatment as follows: "…the cavers' best possible protection derives from common-sense caution in handling bats and from prompt wound care and post-exposure rabies prophylaxis in the unlikely eventuality that a bite from a rabid bat (or from one that is unavailable or unsuitable for testing) is sustained."

Currently, rabies infection cannot reliably be excluded by testing of a live animal for rabies. A positive diagnosis of rabies testing in a living animal is conclusive, but a negative test is not. Only laboratory testing of brain tissue can positively identify rabies infection in bats.

BAT BITES

Bites or scratches from the claws of North American bats may or may not leave marks on the skin. All bats are capable of inflicting bites that leave marks even though they may not always do so. Visible bite marks can range from indentations in the epidermis that disappear within moments, to tiny scratches (that can occur when a bat jerks its head while biting), to deeper puncture marks that may or may not result in bleeding. Bites from species found in the United States and Canada are frequently visible as two tiny puncture marks, often spaced about 4mm to 5mm apart, depending on the species. The punctures are caused by the upper and lower canines on one side of the jaw leaving two puncture marks. Occasionally, a bite includes the upper and lower canines of both sides of the jaw leaving as many as four puncture marks.

Bites are commonly received on the fingers or hand by people who handle or otherwise touch a bat inappropriately. Bites can also result on various parts of the body when a person brushes against or has other bodily contact with a bat because the person was unaware of the bat's presence. For example, a bite could occur if an individual sat on a chair that a grounded bat had crawled onto. Marks generally fade quickly and are frequently no longer visible after only one or two days. Some bites may be visible for a longer period of time, although seldom more than a week. Bites that puncture the skin are painful, a sensation similar to that experienced from a needle jab.

Because bats do not always release their bite immediately, they must sometimes be encouraged to do so. Attempting to pry their teeth apart with a pen or similar object is never advised. Blowing in the face of the bat will often cause it to release its hold. When all else fails, make one quick flick of the wrist while the hand is open and held above a soft surface. This action often startles the bat, causing it to release its hold.

CLINICAL SIGNS OF RABIES INFECTION IN INSECTIVOROUS BATS

The incubation period is the interval between exposure to an infection and the appearance of the first clinical sign of disease. An incubation period of at least 209 days was reported in a naturally infected big brown bat (Moore and Raymond, 1970 [cited by Brass, 1994]). There are also reports of incubation periods of over one year (Kaplan, 1969 [cited by Brass, 1994]; Trimarchi, 1978 [cited by Brass, 1994]).

Although the author has observed a number of clinical signs in bats testing positive for rabies, lack of observable clinical signs of disease cannot be used as a basis for determining if a bat is or is not infected with the rabies virus. Even clinically normal bats are of unknown infection status. Although the author has found that bats infected with rabies frequently died within a few days, often within 24 to 48 hours, the maximum period of viral shedding (the period of time during which the virus is present in the saliva and the disease can be transmitted to others) prior to the onset of clinical signs in bats (and most other wild mammals) is unknown. The virus has been detected in bat saliva as much as 12 days prior to the onset of clinical signs of disease (Baer and Bales, 1967; Baer, 1975; Constantine, 1988). Therefore, even bats that appear to be healthy could be shedding the virus and thus be capable of transmitting it to humans or other animals.

Clinical signs of rabies infection in Brazilian free-tailed bats (*T. brasiliensis*) documented by Constantine (1967) are predominantly paralytic rather than furious in nature. Irritability or depression, weakness, anorexia, hypothermia and paralysis may characterize the disease in this species. Clinically ill individuals sometimes flap their wings and squeak loudly when people approach, although they are unlikely to attack observers. They do sometimes bite at objects near them, but generally appear focused on their own debilitated state. Squeaking and buzzing have also been reported by other researchers (Centers for Disease Control, 1954 [cited by Brass, 1994]; Bell et al., 1955 [cited by Brass, 1994]; Moore and Raymond, 1970 [cited by Brass, 1994]; Schowalter, 1980 [cited by Brass 1994]; Haagsman, 1989 [cited by Brass, 1994]). These bats may be dehydrated, emaciated, hypothermic and are often found roosting alone (Sullivan et al., 1954 [cited by Brass, 1994]; Constantine, 1988). They are sometimes observed flying during the daytime and may collide with objects (Bell et al, 1957 [cited by Brass, 1994]; Constantine, 1967; Price and Evard, 1977 [cited by Brass, 1994]).

However, some species of bats normally fly in the late afternoon (Figure 11-18), and healthy bats will also fly out of roosts during daylight if sufficiently disturbed.

The author has had the opportunity to observe hundreds of bats suspected of being infected with the rabies virus over the past 25 years. Most of the bats suspected of being rabid were passive and offered no attempts to bite. Rabid bats that were aggressive frequently and incessantly chewed on items that came into contact with them, including inanimate objects such as caging materials. Infant bats with rabies will sometimes attack, bite and chew aggressively on other infants as the rabies virus can be passed in-utero.

Figure 11-18. A big brown bat chasing an insect over a farm pond during the afternoon. *E. fuscus. Photo by R. Sturges.*

With the exception of panicked tree bats, mating males, and occasionally mating females of some species (such as *T. brasiliensis*) in captive colonies, incessant chewing on inanimate objects in particular is never typical of healthy bats. Healthy males involved in mating behavior sometime exhibit aggression towards intruders (i.e., handlers or other bats that enter their territories (Lollar, 1994). Healthy tree bats can also exhibit rabies-like behavior when panicked, such as biting, snapping and chewing with unfocused eyes, biting at meal worms but not swallowing them, spitting out or not swallowing fluids, and/or twitching of the head and extremities (see Behavior).

Rabid bats often do not show an interest in exploring or moving around within their environment. Rather these animals often seem to prefer to remain exposed in one spot with eyes closed or half closed, only responding when anything approaches them. They do not seem to aggressively seek out objects or other animals but may bite at whatever happens to touch them. Verified reports of unprovoked bat attacks are exceedingly rare. The author frequently receives reports of "attacking bats" from individuals who are surprised by a bat that inadvertently flies into their home through an open door or over their head at a porch light. These people can be quite insistent that the bat in question was attempting to attack them until rescue personnel arrive on the scene and give them the opportunity to see that although the bat will continue to fly around the room, it does not actually attack the rescuer.

Figure 11-19. Brazilian free-tailed bat that died with one leg clamped against the abdomen; a position observed in dead bats testing positive for rabies. *T. brasiliensis. Photo by A. Lollar.*

While not always a reliable indication of rabies infection, uninjured crevice bats with rabies are often found in exposed areas during daylight. Other signs that may indicate the presence of rabies include emaciation, glassy, watery, or matted eyes, a heavy ectoparasite load, a hunched back, and petechial hemorrhage on the ears (although similar signs may also accompany respiratory disease, heat exhaustion, internal injuries and back injuries (Lollar, 1994). The author has also found that the presence of dirt and/or other foreign substances in or around a bat's mouth may be another indication of rabies infection, possibly resulting when an infected animal bites at the ground or other surroundings. Other signs observed by the author include disoriented flight, uncoordinated movements, seizures, spastic paralysis of one or both legs, ataxia, one or both legs clamped tightly against the abdomen (*T. brasiliensis* in particular), lesions around the mouth and chin (Figure 11-20A), abraded gums or a blistered appearance under the upper lip, glassy/watery eyes (Figure 11-20B) abnormal vocalization, hypersensitivity to sound and light, exhibiting anger (by jerking the body) rather than fear, falling asleep while being examined, and agonal respiration. The bat may also accept soft food or milk when offered, but does not swallow, has an inability to swallow, or aspirates upon swallowing. Additionally, the bat may chew on mealworms as if eating but then allow the chewed pieces to fall from its mouth.

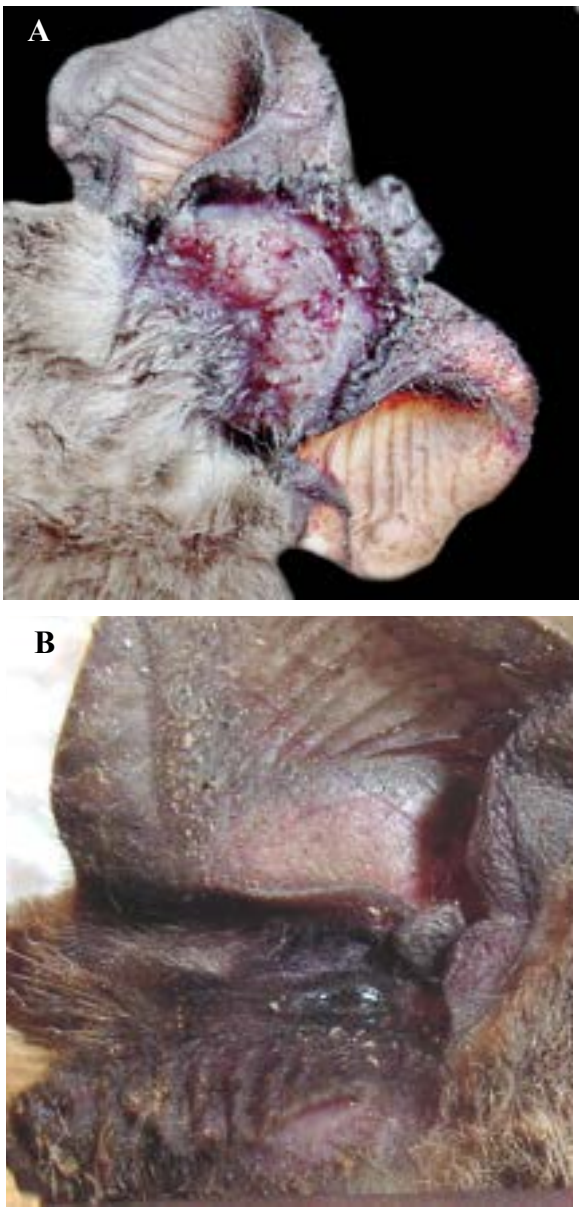


Figure 11-20. A: Lesions on the chin, petechial hemorrhage on the ears. **B:** Watery eyes. *T. brasiliensis. Photo by A. Lollar.*

Caretakers should protect themselves and humanely euthanize bats demonstrating signs of rabies infection (see Rabies [Primary and Secondary Signs) in the Diagnostic chart for help in determining when to euthanize bats suspected of rabies infection). Bats suspected of rabies should be turned over to the proper authorities for rabies testing or appropriately disposed of, depending on state guidelines. In case of an animal bite and/or scratch or contact with saliva or nervous tissue from a suspect animal, consult your family physician or local or state health department immediately.

There has been little research in the area of rabies vaccination for bats, as vaccination of large, wild populations may not be a feasible undertaking. However, Charles Trimarchi, DVM, with the New York State Department of Health (1996), states that, "While most health agencies neither endorse nor prohibit extra-label use of rabies vaccines in wildlife, modern vaccines may protect wild species and because they are killed-virus vaccines, do not pose a risk of vaccine-induced rabies infection".

Bat World Sanctuary has been routinely vaccinating all insectivorous bats against rabies since 1990. To date, we have had no rabies transmission from bat to bat at the sanctuary. We currently administer .05 ml of Imrab 3 rabies vaccine subcutaneously for insectivorous bats weighing between 2 to 35 grams. Releasable bats are vaccinated upon arrival or prior to release. We encourage the vaccination of all insectivorous bats in captivity but remind everyone that this is extra-label use of the vaccine.

Table 11-1
Differential Diagnostic chart

AILMENT	SYMPTOMS	TREATMENT
Abscess	A pus-filled wound or cavity sometimes surrounded by inflamed tissue.	Administer Clindamycin injections and Clavamox® orally. Administer Metacam® for pain. Lance and drain the abscess. Flush with warm tap water. Keep the wound pus free thereafter by re-lancing, draining and flushing when necessary. Abscesses heal from the inside out. The wound must be allowed to drain, use discretion with topical antibiotics. See Bite Wounds. See Dental Disorders
Swollen Abdomen	Adults: Loss of appetite, swollen or hard abdomen, labored breathing, vomiting, constipation, sustained erection in males. Pups: Swollen or hard abdomen, labored breathing, crying out, white or gray stools, may include ravenous appetite.	See Hepatic Lipidosis. See Blunt Force Trauma. See Respiratory Disorders. See Gastrointestinal Disorders. See Caring for Pregnant and Lactating Females.
"Air-filled" Body Cavity	Respiratory distress, crackling sound when palpating the chest area, bleeding from an external wound, bat appears "puffed up" from two to three times its normal size.	See Punctured Lung. See Blunt Force Trauma.
Appetite Change	Increase in appetite, sometimes sudden, may occur in late summer or fall.	See Infections of the Gums and Teeth. See Dehydration and Fluid Replacement Therapy. See Gastrointestinal Disorders. See Parasites. See Caring for Pregnant and Lactating Females. See Hibernation.
Band Injuries	Swelling, inflammation, oozing, bruising, bleeding, scabbing or other damage to soft membrane tissue at the site of the band.	Bands should be carefully removed to prevent further injury. Treat wounds with topical applications of a triple antibiotic ointment. Administer Clavamox® orally. Administer Metacam® for pain.
Bite Wounds	Infected or scabbed wounds and/or abscesses on the wings, tail, legs or head, finger fractures.	Administer Clindamycin injections and Clavamox® orally. Administer Metacam® for pain. Aged bats or bats that appear shocky should receive the oral Clavamox mixture only. Open wounds should be cleaned and treated with a topical application of triple antibiotic ointment or Manuka honey twice daily until healed. See Bite Wounds.
Bleeding, Unusual	Blood coming from the nose, rectum, eyes, penis or vagina.	See Heat Exhaustion and Heat Stroke. See Blunt Force Trauma. See Cesarean Section.

AILMENT	SYMPTOMS	TREATMENT
BLISTERS	Blisters filled with blood, clear or milky fluid.	See Frostbite and Hypothermia. See Heat Exhaustion and Heat Stroke. See Blunt Force Trauma.
BREATH, ODOR	Malodorous breath. Cooked cabbage smell indicates an abscessed tooth.	See Infections of the Gums and Teeth.
BRUISING	A localized collection of blood under the skin, visible when a light is held behind the bat. Seen most often on the sides of the torso, and the wings and legs.	See Blunt Force Trauma. See Heat Exhaustion/Heat Stroke. See Rabies.
DAZED EXPRESSION	A staring or dazed expression, as if the bat is not aware of its surroundings.	See Blunt Force Trauma. See Heat Exhaustion/Heat Stroke. See Rabies. See Shock.
DEHYDRATION	Loss of appetite, dull and/or dry eyes, droopy eyelids, dry wings, feces stuck to tail membrane, vomiting. In severe dehydration ataxia may be present. Fluids may not be absorbed when organ failure is iminent. In these cases, the bat may die within moments of being injected.	Rehydrate (see Dehydration and Fluid Replacement Therapy). Humidifiers will help increase humidity. Humidity levels should be between 60%-80%.
DENTAL DISORDERS	Accumulations of plaque on the teeth that eventually harden. Tarter turns black as it becomes stained by mealworms. Gum infections are first visible as a thin red line along the gum line. Excessive salivation, lethargy, anorexia, a watering or protruding eye, swollen area on the head, behind the ear, on the jaw or near the eye and/or odor.	See Infections of the Gums and Teeth. Note: Many captive dental problems can be avoided by using the tarter control method recommended by Bat World for insectivorous bats. Bats that are hand fed may have less dental problems if they are given a few drops of water immediately after being fed (water may help to rinse the food from teeth).
DIARRHEA	Loose or runny stools. Can be life threatening if the underlying cause is not established and treated.	Rehydrate (See Rehydration and Fluid Replacement Therapy). Short term relief may be given by administering 0.05ml of an over-the-counter anti-diarrhea medication. Further treatment should be directed to the source of the problem. See Gastrointestinal Disorders. See Heat Exhaustion/Heat Stroke.
EMACIATION	Underweight, protruding shoulder blades, concave abdomen, weakness, dehydration, uncoordinated movements.	Rehydrate (See Rehydration and Fluid Replacement Therapy). After the bat is hydrated, offer milk for pups (see Feeding and Care of Infant Bats). Offer adult bats small amounts of soft food or Progenix Recovery at 4-to-6 hour intervals during the first 24 hours. Gradually increase the amount of food offered at each feeding. Offer normal amounts of soft food the following day. Do not give an adult bat solid food until it is fully hydrated.

AILMENT	SYMPTOMS	TREATMENT
Eye Problems	Swollen lids, glassy eyes, dry eyes, wincing, staring or blood filled eyes.	Swollen lids may indicate infection from foreign material. Glassy eyes indicate systemic infection. Wincing eyes indicate pain. Blood filled eyes may indicate head injury. See Eye Infections. See Blunt Force Trauma. See Dehydration and Fluid Replacement Therapy. See Shock.
Facial Gland Secretions	Excessive yellow/orange secretions on the face, impacted facial glands. Infections may cause overproduction of glandular secretions and impacted facial glands.	Clean affected areas with warm water and gauze pads. Impacted glands will need to be lanced with a sterile needle and the area gently pressed to expel pus. Warm compresses applied beforehand will aid in the removal of hardened cellular debris. If infected, apply a triple antibiotic ointment twice daily until healed. Administer Clavamox® orally. See Skin Conditions.
Frost Bite	Redness or hard white patches on the skin, blisters filled with clear or milky fluid or dark blood, mainly on the thumbs, ears and feet.	See Frostbite and Hypothermia.
Fur Loss	Balding patches on the torso, around the neck and the head, flaky skin. Depigmentation of the wing membrane. Note: Fur loss under the neck can occur when soft food or viscera is allowed to drip under the chin of bats being hand fed. To prevent this happening, thoroughly clean any food from fur.	Nutritional supplements listed on the product update page will encourage new fur growth. See Feeding Adult Bats. Maintain proper caging, including appropriate humidity levels. Humidity should be maintained at 60-80%. Use good hygiene practices. Apply triple antibiotic ointment to chapped or irritated skin. Obtain tissue culture to determine any fungal or bacterial infections and treat accordingly. See Skin Conditions, Dehydration, Dental Disorders, Liver Disease, Ringworm and Parasites.
Glue Traps and Other Adhesives	Foreign substance coating the fur and/or wing and tail membranes.	See Adhesive Contaminants.
Head Injury	Often no outward signs of injury. May appear dazed although the eyes are clear, or the eyes may be filled with blood, ataxia, lying to one side or favoring one side of the body.	Administer Dexamethasone. If seizures are present administer Zonisamide. House the bat in a warm, quiet environment. Provide supportive care. See Blunt Force Trauma.
Head Twisting (Torticollis)	Torticollis (extreme twisting of the head as if the bat is attempting to look over its shoulder), ataxia, black tarry stools, labored breathing.	See Parasites.
Hematoma	A localized collection of blood under the skin, visible when a light is held behind the bat. Seen most often on the sides of the torso, and the wings and legs.	See Blunt Force Trauma. See Heat Exhaustion/Heat Stroke. See Frostbite.

AILMENT	SYMPTOMS	TREATMENT
Hypocalcemia	Muscle tremors and twitches in early stages. Convulsions occur in later stages. Species that normally carry their young may be found roosting away from the pups. Note: This condition progresses rapidly and is fatal if not treated early.	Administer Calsorb® orally once a day until symptoms subside. (Mix with honey as the medication is very bitter.) Remove nursing pups and hand feed them until the mother recovers. See Hypocalcaemia.
Insect Stings	Clear eyes, panting, wincing, anorexia, fur may stand on ends, rapid respiration, lethargy and anorexia.	See Insect Stings and Spider Bites.
Joint Swelling/ Bone Abnormalities	Swollen toes or thumbs, swelling at the knee, wrist, or elbow (can be associated with fractures). Sudden onset of swelling at the knee, wrist, or elbow which diminishes only to reoccur in a different knee, wrist, or elbow (migratory joint swelling). Inflamed joints, and painful curvature of the forearm (infant bats).	Administer Clavamox® orally. For migratory joint swelling, administer Doxycycline. See Erosive Dermatitis. See Joint Swelling. See Metabolic Bone Disease.
Kidney Disease	Excessive thirst, vomiting, pale gums, dehydration despite fluid therapy, weight loss despite good appetite.	There is no known treatment for kidney disease in bats. Bats generally die within a week of the onset of clinical signs. When quality of life declines, the bat should be humanely euthanized.
Leg Fractures	Swelling, hematomas, dragging the leg, holding the leg close to the body or refusal to use the leg or foot to hang.	Administer Metacam® for pain. If open wounds are present administer Veraflox® orally. See Leg Injuries.
Leg Paralysis	Dragging one or both legs, or one or both legs clamped or curled against the abdomen.	See Rabies. See Blunt Force Trauma. See Leg Injuries.
Liver Disease (Hepatic Lipidosis)	Vomiting, anorexia, foul smelling stools. Jaundice (yellowing) where the wing membrane attaches to the body (visible first ventrally then dorsally). Jaundice may also be visible on the chin and at base of the ears.	Rehydrate and provide supportive care. Administer Denosyl. If the bat refuses to accept food, be persistent. Encourage eating by gently placing soft food in the mouth. Patiently wait for the bat to swallow each bite, then offer more. Continue feeding in this manner several times a day until appetite returns to normal. See Gastrointestinal Disorders.
Mastitis (Swelling and inflammation of the breast)	Abnormal swelling of the breast, pus-filled and/or bloody discharge, appetite loss, lethargy.	Administer Clindamycin injections and Clavamox® orally. Give Buprenex or Metacam® for pain. Hot compresses may help alleviate pain. Remove nursing pups and hand feed them until the mother is stable. See Mastitis.
Membrane Infection	Small irritated areas on the membrane progressing to wet, sloughing areas and dying skin, especially on the edges.	See Wing Wasting.
Membrane Tears	Holes and tears to the wing membrane, sometimes involving the trailing edge.	See Membrane Tears.
Osteomyelitis (Bone infection)	Pain, tenderness, swelling and warmth in the affected area.	Administer Clindamicyn® injections and oral Clavamox®. Administer Metacam® for pain.

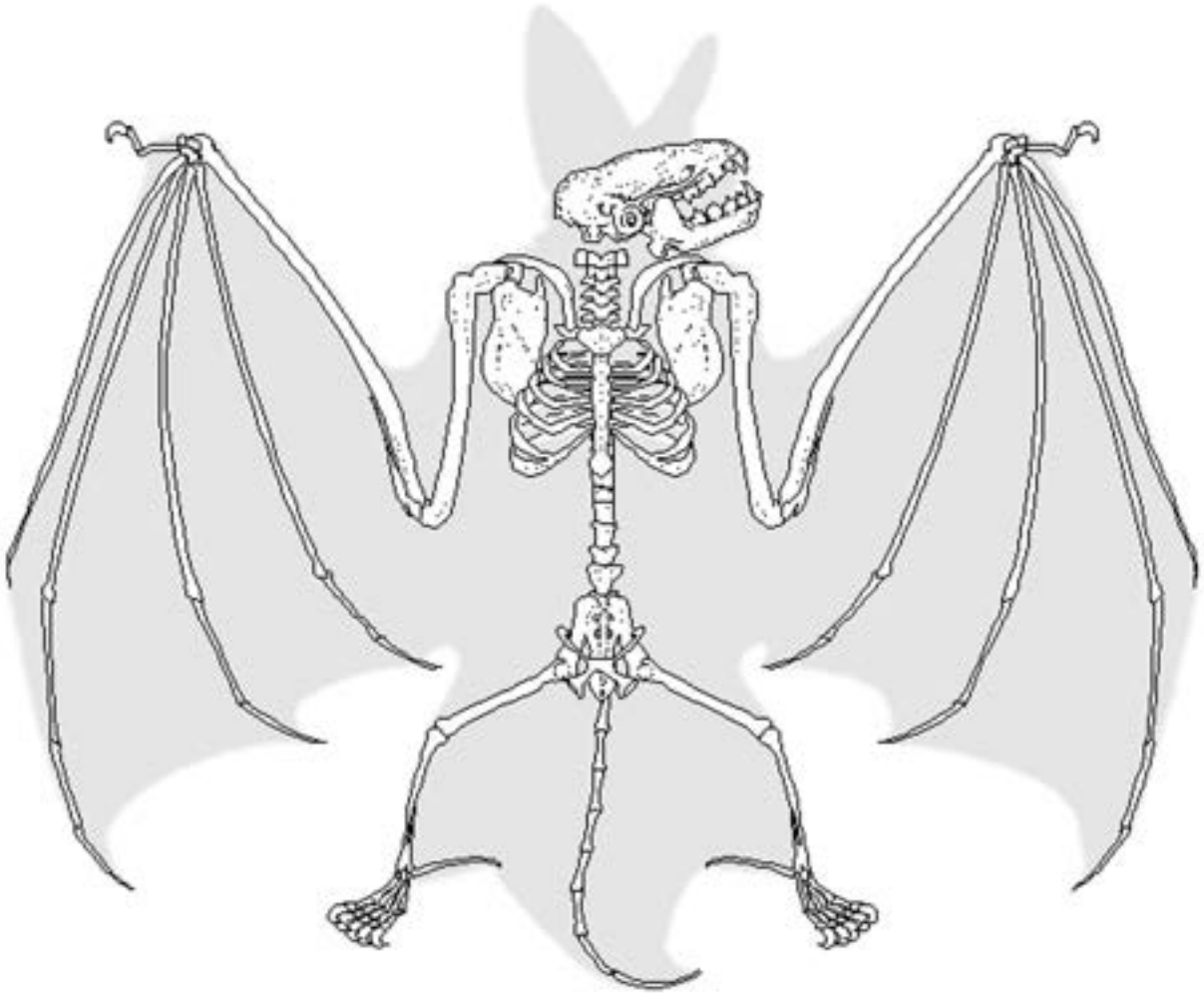
AILMENT	SYMPTOMS	TREATMENT
PALE GUMS	White or gray-white gum color.	See Parasites. See Anemia. See Kidney Disease in this section.
PARASITES (endo and ecto)	Ectoparasites: Mites, ticks, fleas and bat flies present on the body. Endoparasites: Lethargy, dull or thin coat, loss of appetite, excessive appetite, vomiting, pale gums, head tilting or torsion, circling, ataxia, paralysis, diarrhea, tremors, weakness, emaciation, and excessive thirst, heaving respiration, stiff torso, hunched back, wings crossed in front of the chest, stiffening of the fingers so they don't fold.	See Parasites.
PREGNANCY	Sudden increase in appetite in the early stages. Abdomen feels hard rather than soft or palpable. In later stages, the abdominal region is grossly distended, and milk can be seen in the mammary glands beneath the skin when the fur is parted. Bats occasionally lose fur on the abdomen.	See Caring for Pregnant and Lactating Females.
RABIES Seen more frequently in summer through fall. Rabies can be passed in-utero to pups. **Rabies should be assumed if a bat has either two primary or three secondary clinical signs.** NOTE: If anyone has been bitten, scratched, or had direct contact with the bat's saliva, contact your local health department immediately.	**Primary signs:** Disoriented flight, spastic paralysis of one or both legs, ataxia (inability to coordinate muscular movements), one or both legs clamped tightly against the abdomen (*T. brasiliensis* in particular), seizures, attacks/chews on inanimate objects (infants with rabies will sometimes attack and bite/chew aggressively on other infants), chews food/when offered, but does not swallow, inability to swallow water or milk (or aspirates upon swallowing), lesions around the mouth/chin, blisters under the upper lip, dirt in the mouth, abnormal vocalization, hypersensitivity to sound and light, exhibits anger (body jerking) rather than fear, falls asleep while being examined, agonal respiration (high in the chest). **Secondary signs:** Hanging in an exposed area (crevice dwelling-species), emaciated, glassy/watery eyes, heavy parasite load, bites aggressively, petechial hemorrhage around the ears.	Humanely euthanize with Isoflurane (check respiration or heartbeat to ensure the bat is deceased). Submit the bat for rabies testing or dispose of it in accordance with your state regulations. See Rabies. Note: Healthy tree bats sometimes exhibit aggressive behavior that should not be confused with rabies. Mating behavior can also bring out aggressive behavior in *T. brasiliensis*.

AILMENT	SYMPTOMS	TREATMENT
Respiratory Distress	Stuffy or runny nose, matted eyes, wheezing or squeaking sounds during respiration, panting, rapid respiration, shallow respiration, breathing visible in the upper chest region (normal respiration is visible in the pelvic area).	See Respiratory Disorders. See Blunt Force Trauma. See Punctured Lung. See Insect Stings and Spider Bites. See Shock. Bats with agonal respiration (gasping) should be humanely euthanized.
Seizures	Convulsions	See Hypocalcemia. See Heat Exhaustion/Heat Stroke. See Rabies.
Shivering	Vibrating of the entire body, as if cold.	If torpor is suspected, no treatment is necessary. Allow the bat to warm slowly in your hand or a roosting pouch. Do not place the bat on heat to speed the warming process. Note: Fear can also cause the bat to shiver. Use soothing tones and handle the bat gently to gain trust and decrease fear.
Ringworm	Pale iridescent areas on the wings, ears, face or body, or bald circular patches within the fur. There may also be scaly or yellowish crusted lesions on the skin.	See Ringworm.
Skin Conditions	Dry, flaky skin, depigmentation of the wing membrane, shiny patches of skin, yellow tinged skin, crusted lesions, tiny blisters on the skin, petechial hemorrhages. Note: Skin infections (ulcerative dermatitis) can occur when soft food or viscera is allowed to drip under the chin of bats being hand fed, then not cleaned off. To prevent this happening, thoroughly clean food from fur.	See Dehydration and Fluid Replacement Therapy. See Skin Conditions. See Lighting and Humidity. See Gastrointestinal Disorders. See Ringworm. See Parasites. See Feeding Adult Bats.
Systemic Infections	Glassy eyes, anorexia, unkempt fur, lethargy, diarrhea.	Administer Veraflox®. Keep the bat rehydrated and provide supportive care. Progenix Recovery should be given to bats that are anorexic.
Tail Shaft infection	Inflammation in the shaft of the tail of unknown etiology. The infection usually starts at the base of the tail and moves towards the tip until the entire shaft is inflamed. These infections appear very painful.	Administer Veraflox and Clavamox® orally. Lance and clean pus-filled areas. Administer Metacam® for pain.
Tremors	Shaking of the thumbs, feet, appendages or the entire body. May be constant or intermittent.	See Hypocalcemia. See Dehydration and Fluid Replacement Therapy. See Heat Exhaustion/Heat Stroke. See Rabies.

AILMENT	SYMPTOMS	TREATMENT
Urinary Problems	Straining to urinate or a pink tinge to the urine may indicate cystitis, a stone blockage or internal injury from blunt force trauma. In pregnant females, foul smelling urine often indicates fetal death.	Administer Convenia® or oral cephalexin. Administer Metacam® for pain. Rehydrate. Minor blockages can sometimes be cleared by massaging the end of the penis or vagina while applying gentle pressure on the bladder. NOTE: If a serious blockage or fetal death is suspected contact your veterinarian. See Urinary Tract Infections. See Caesarean Section.
Vomiting	Vomiting, often after meals.	See Gastrointestinal Disorders. See Infections of the Gums and Teeth. See Dehydration and Fluid Replacement Therapy.
Weakness	Bat feels soft, with little to no grip of the feet when held in the hand. May also have an unkempt coat and glassy eyes.	Administer fluids. Administer Veraflox® and Clavamox,® Progenix Recovery, then soft food when bat appears to gain strength. See Rehydration and Fluid Replacement Therapy. See Heat Exhaustion/Heat Stroke. See Rabies. See Systemic Infection in this section.
Wing Fractures	Closed fractures do not involve protrusion of bone. Hematomas may be present and swelling may occur, particularly with closed fractures of the wrist. Open fractures involve protrusion of a bone through the skin. Open fractures to the elbow or humerus are difficult to stabilize and may require amputation. Bats will occasionally chew on necrotic or dying tissue.	See Open and Closed Fractures.
Wing Depigmentation	Depigmentation of the wing membrane. sometimes accompanied by flaky skin and balding patches on the torso, around the neck and on the head. Depigmentation in conjunction with inflamed finger joints may be indicative of skin mites.	Humidifiers should be used to increase humidity if needed. Humidity should be maintained at 60-80%. Flax oil can be applied to affected membrane. Do not use over-the counter hand creams on the bat's skin as the bats may lick it off. If skin mites are present the bat should be treated topically with Revolution.®

Chapter Twelve

Diagnosis and Treatment of Injuries



David Chapman, Modified from Hill and Smith, 1984

Anatomy of the Wing

The upper arm bone in a bat is the humerus. The proximal end of the humerus articulates at the shoulder joint with the scapula (Figures 12-1 and 12-2). The muscles that move these bones are the same as those found in humans, although they have been modified for their role in flight (Figures 12-2 and 12-3). The distal end of the humerus (Figure 12-4) articulates with the radius and ulna of the forearm at the elbow. The ulna, however, is very much reduced in size from that seen in other mammals and is fused to the elongated radius (Figure 12-5). This fusion keeps the elbow joint locked in position when the wing is extended during the down stroke (the power generating part of the wing cycle). (See Figures 12-6, 12-7, and 12-8 for elbow joint diagrams.) The radius does not rotate as it does in humans. The carpals are the tiny bones of the wrist, collectively referred to as the carpus (Figure 12-9 and 12-10). The distal end of the radius articulates with two of these, the cuneiforms and the lunar. Movement at the wrist joint is restricted in the forward and backward planes so that the joint is strong and rigid, a necessity for flight.

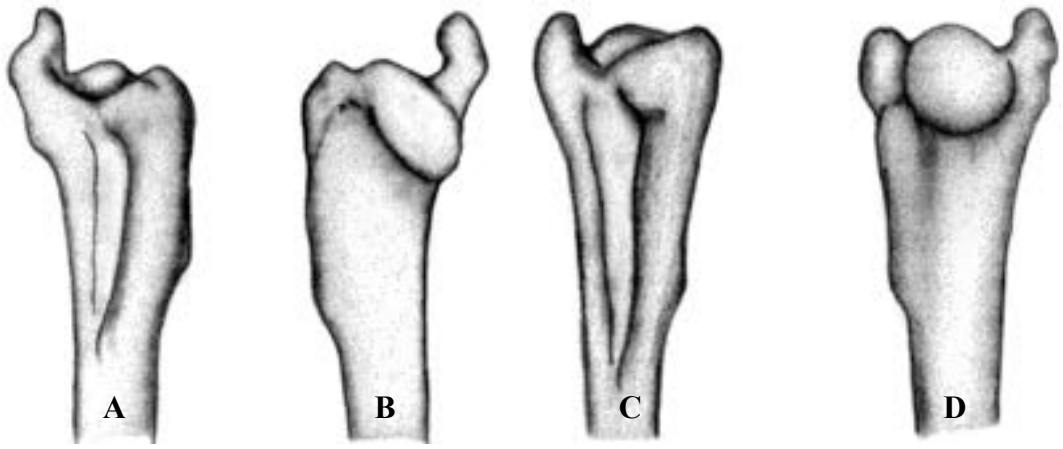


Figure 12-1. Proximal end of the right humerus. **A:** Anterior view. *Myotis lucifugus*. **B:** Posterior view. *Myotis lucifugus.* **C:** Anterior view. *Molossus ater.* **D:** Posterior view. *Molossus ater*. David Chapman. Modified from Vaughn, 1970.

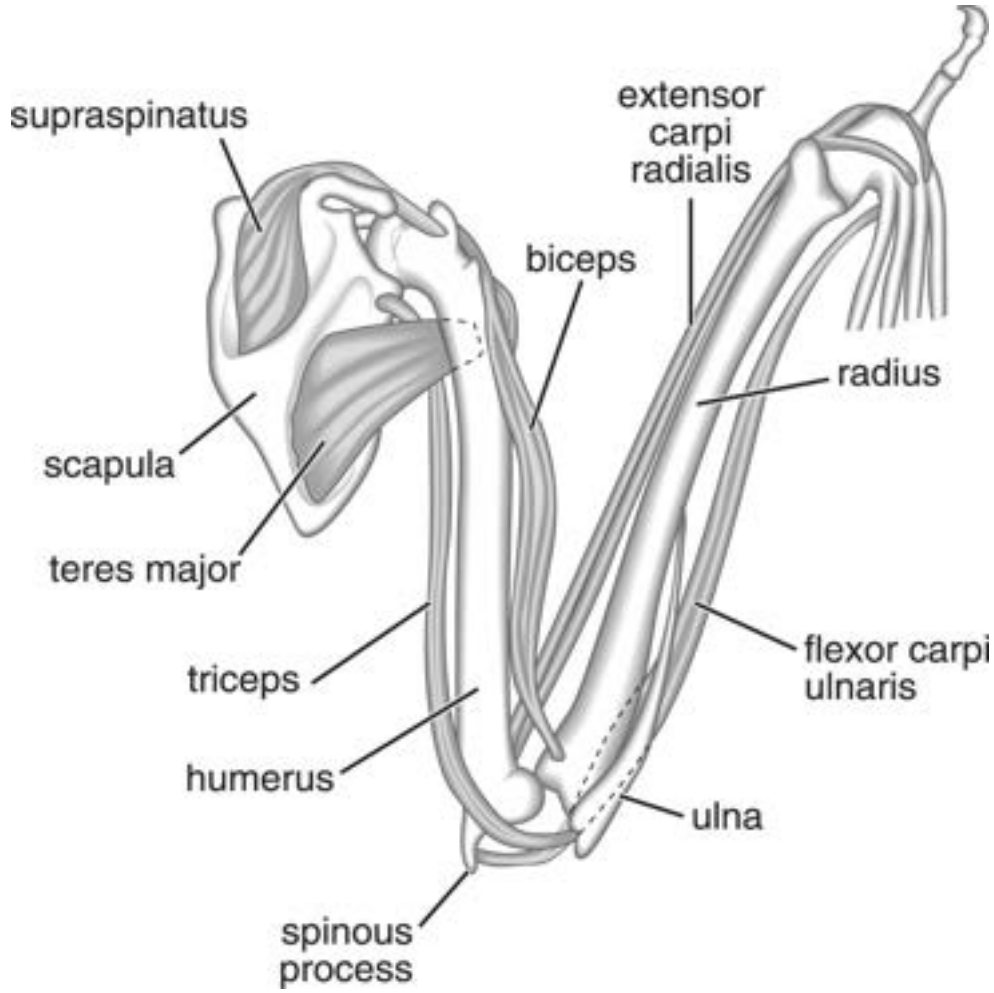


Figure 12-2. The humerus articulates at the shoulder joint with the scapula. Right arm retracted. Dorsal view. David Chapman. Modified from Hill and Smith, 1984.

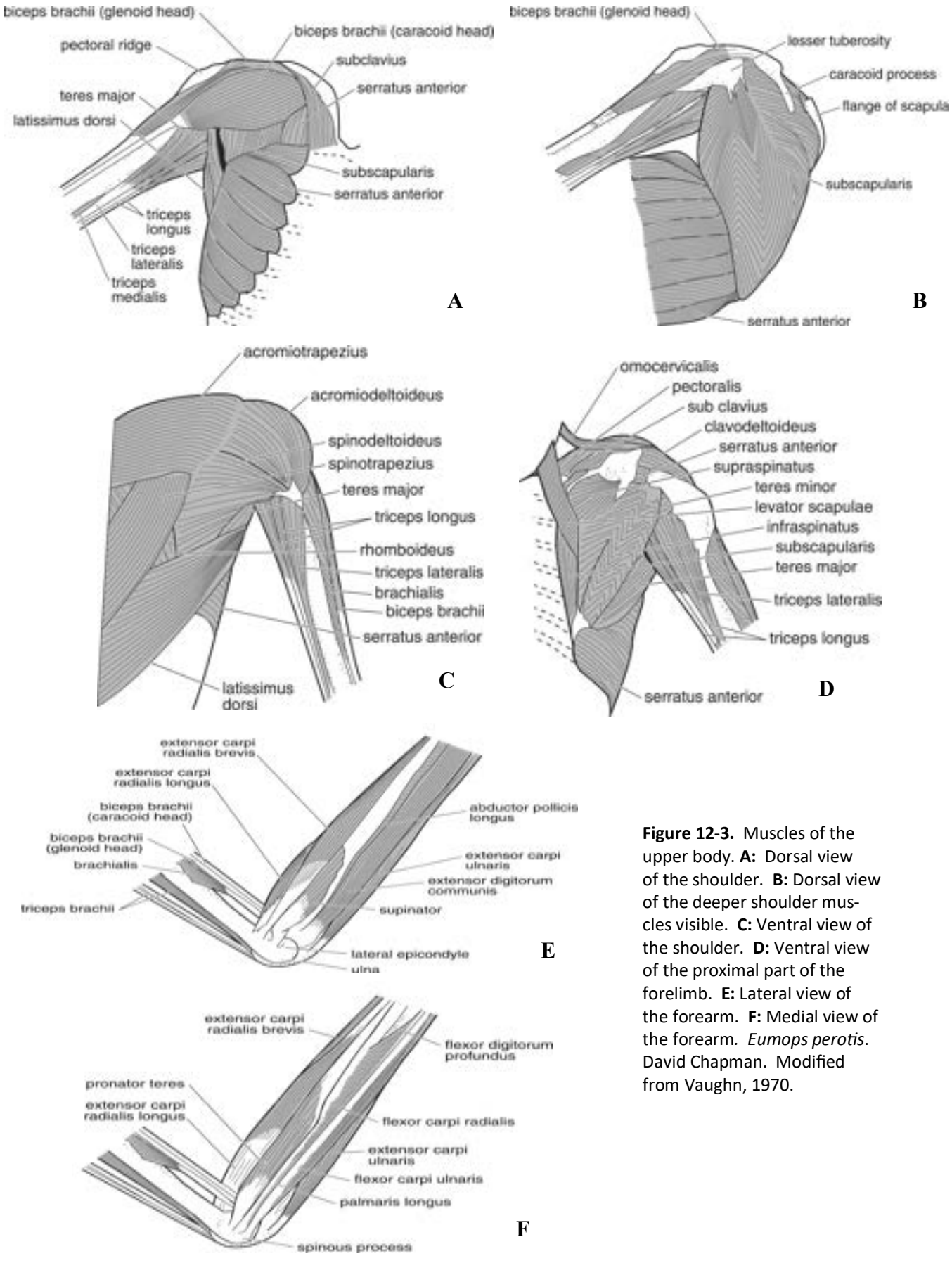


Figure 12-3. Muscles of the upper body. **A:** Dorsal view of the shoulder. **B:** Dorsal view of the deeper shoulder muscles visible. **C:** Ventral view of the shoulder. **D:** Ventral view of the proximal part of the forelimb. **E:** Lateral view of the forearm. **F:** Medial view of the forearm. *Eumops perotis*. David Chapman. Modified from Vaughn, 1970.

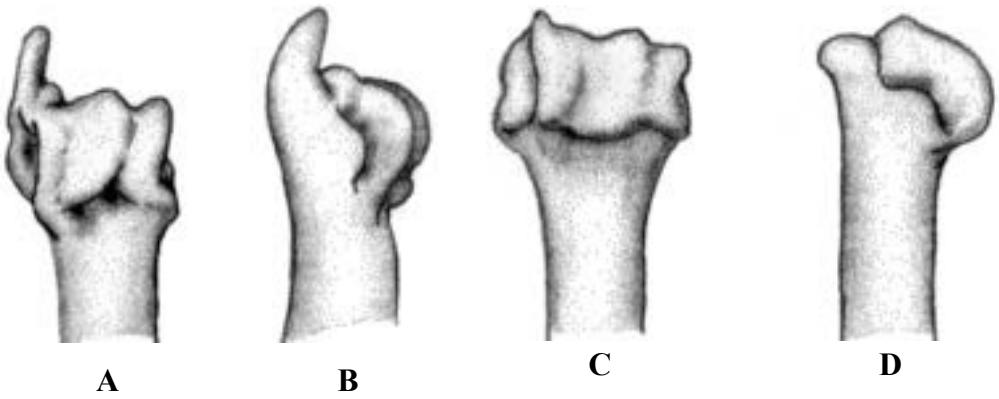


Figure 12-4. Distal end of the right humerus. **A:** Anterior view. *Myotis lucifugus*. **B:** Medial view. *Myotis lucifugus*. **C:** Anterior view. *Molossus ater*. **D:** Medial view. *Molossus ater*. David Chapman. Modified from Vaughn, 1970.

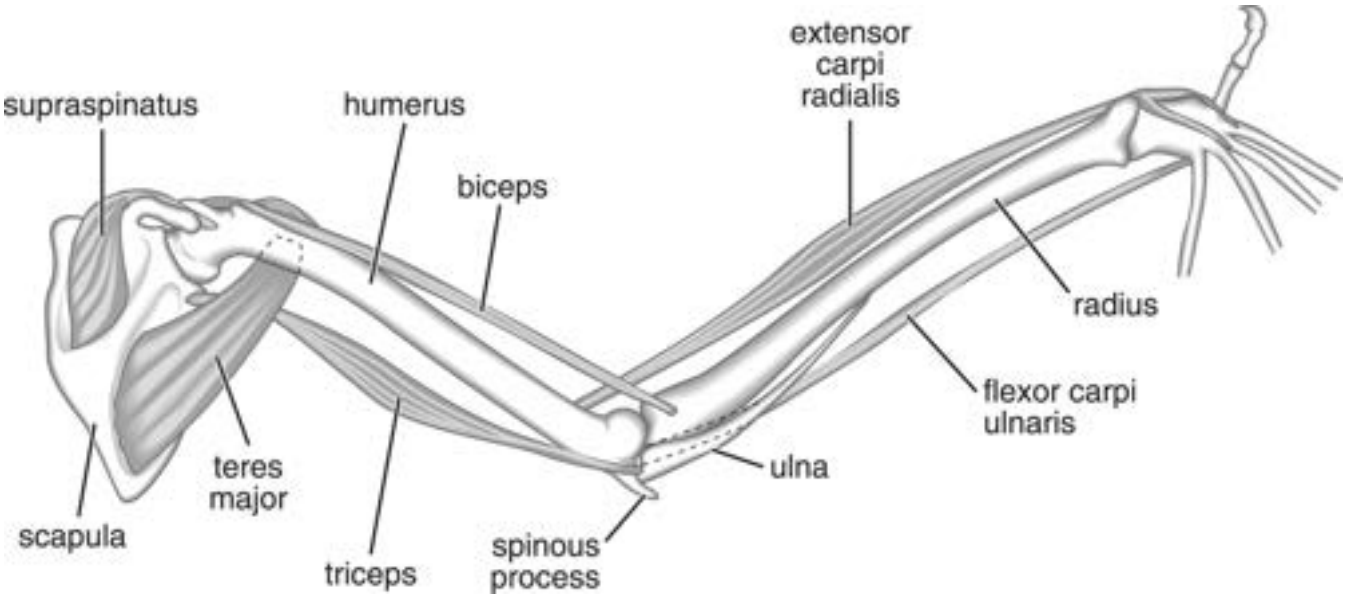


Figure 12-5. The ulna is reduced in size from that seen in other mammals, and is fused to the elongated radius. Right arm extended. Dorsal view. David Chapman. Modified from Hill and Smith, 1984.

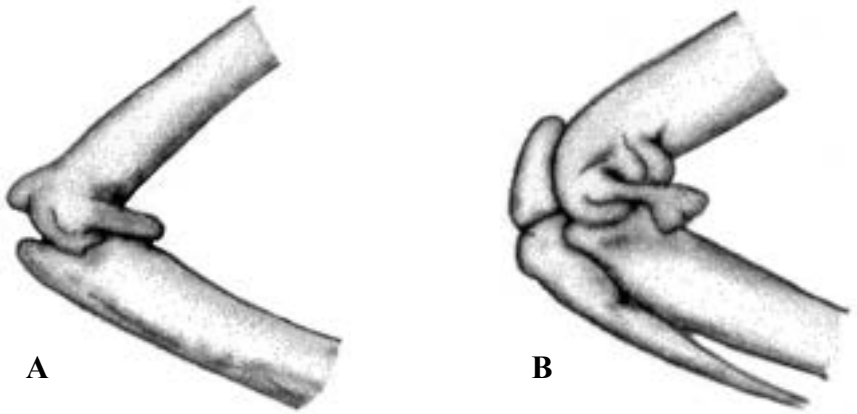


Figure 12-6. Lateral view of the elbow joint. **A:** *Myotis volans*. **B:** *Molossus ater.* David Chapman. Modified from Vaughn, 1970.

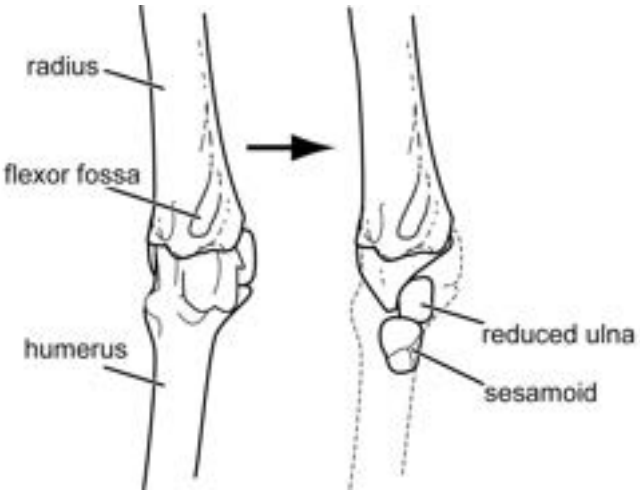


Figure 12-7. Anterior view of the elbow. Flexor fossa is for attachment of the biceps brachii and brachialis muscles. Articular facets of the radius shown on the right. *Molossus molossus*. David Chapman. Modified from Hill and Smith, 1984.

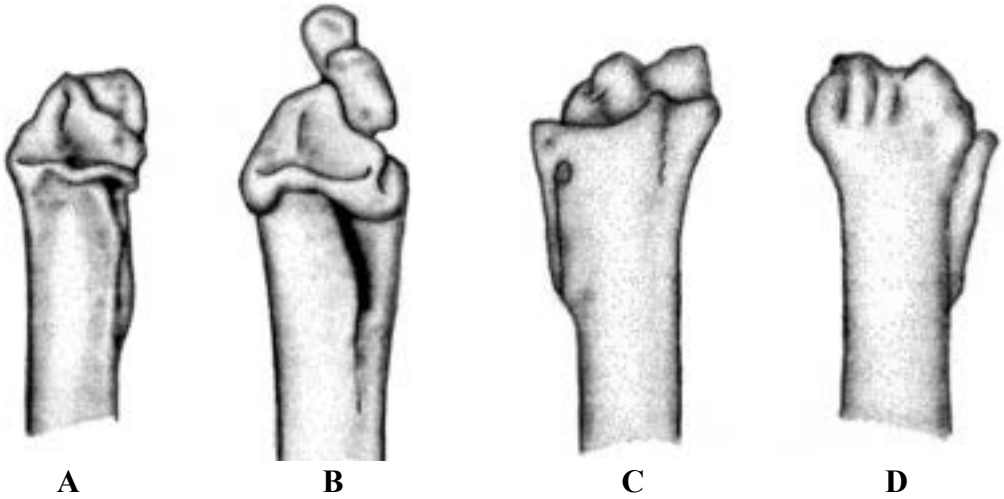


Figure 12-8. Proximal end of the radius and ulna. Anterior view. **A:** *Myotis lucifugus*. **B:** *Molossus ater*. **C:** Distal end of the right radius**,** posterior view. **D:** Anterior view. *Myotis lucifugus.* David Chapman. Modified from Vaughn.

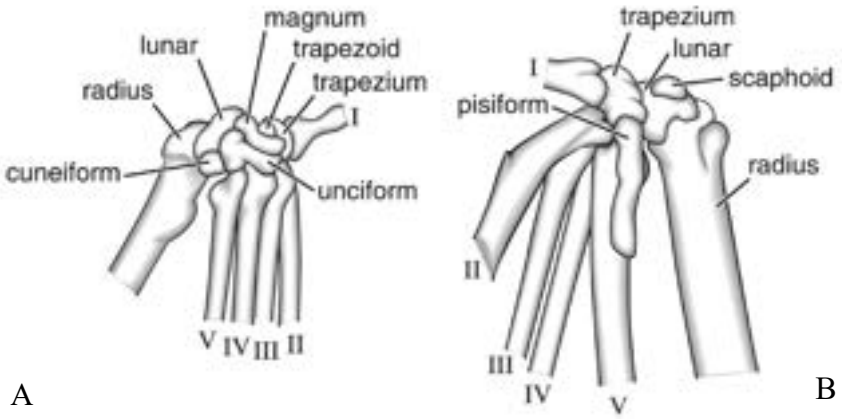


Figure 12-9. The distal end of the radius articulates with the lunar and cuneiform of the wrist. Movement is limited to one plane (the horizontal plane) when the forelimb is extended laterally at the wrist, carpometacarpal, and elbow joint. **A:** Right carpus. Lateral view. *Myotis lucifugus*. **B:** Right carpus. Medial view. *Lasiurus cinereus*. David Chapman. Modified from Vaughn, 1970.

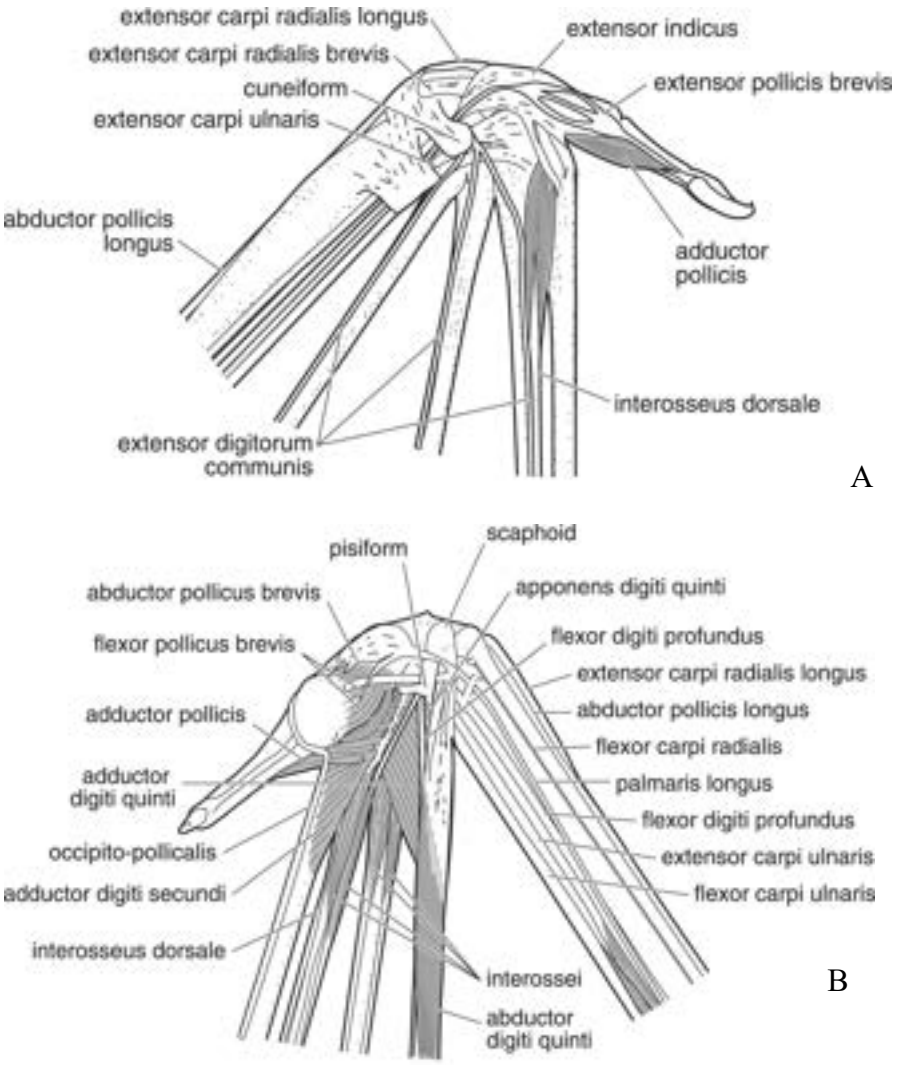


Figure 12-10. Dissection showing the muscles of the carpus. **A:** Medial view. **B:** Lateral view. *Eumops perotis*. David Chapman. Modified from Vaughn, 1970.

The smallest appendage projecting from the wrist is the thumb. The thumb is the first digit and ends in a tiny, sharp claw (see Figure 12-11). Bats use their thumbs for climbing, roosting, and manipulating insects when feeding, so injuries to the thumb may significantly decrease a bat's chances of survival in the wild. The wing is actually a modified hand with elongated fingers. The metacarpals extend from the wrist to the phalanges (Figure 12-11).

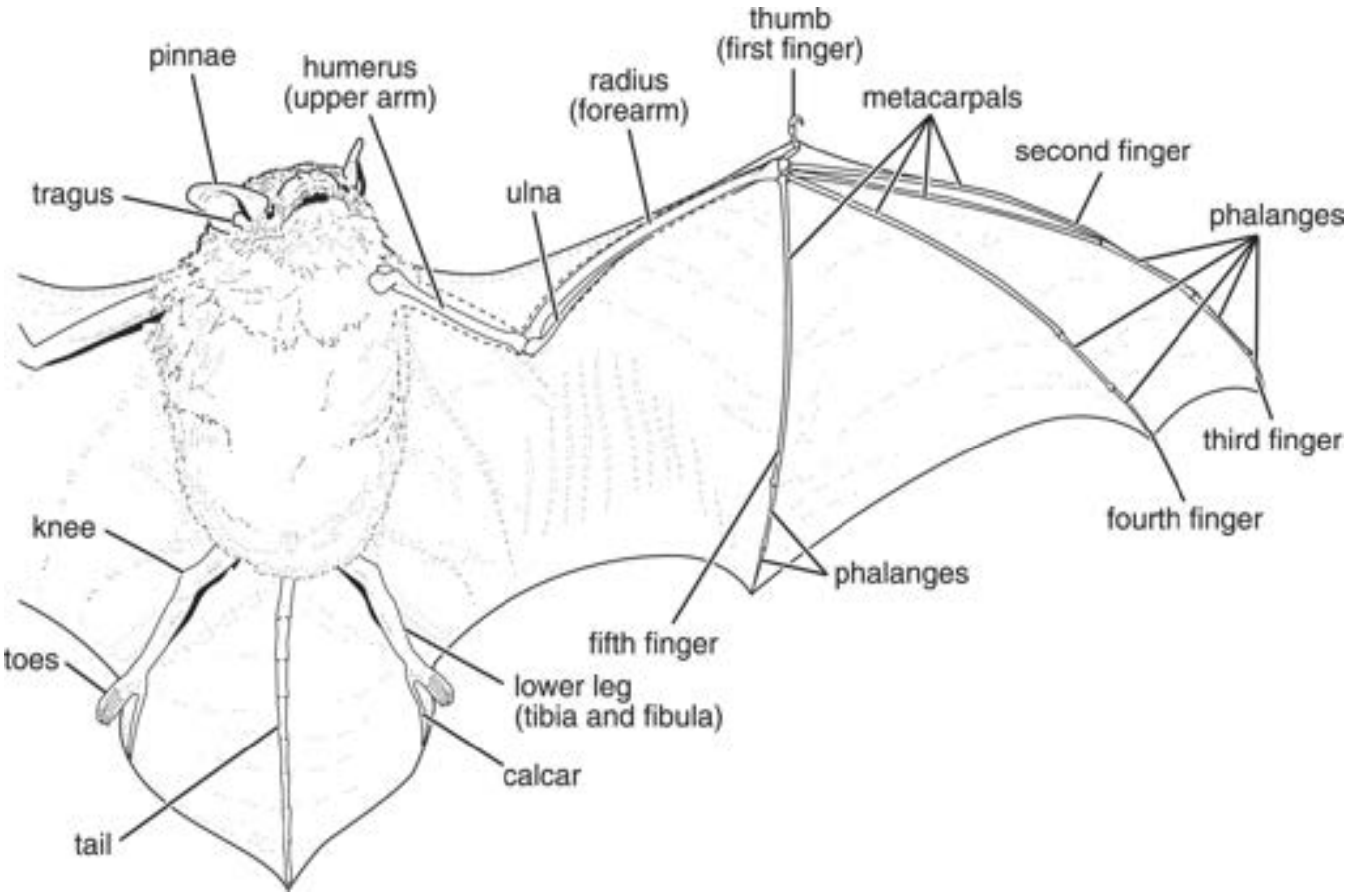


Figure 12-11. Skeletal components of the wing and other anatomical structures. Ventral view. David Chapman. Modified from Hill and Smith, 1984.

The second digit or index finger is composed of one long metacarpal and one or two phalanges. The third, fourth, and fifth fingers also have an elongated metacarpal. The third finger has three phalanges, while the fourth and fifth fingers have two phalanges. The finger joints of an adult bat are round and knobby, while those of juveniles are still cartilaginous and more elongated. The fingers and the bones of the arm provide the structural support for the wings, which begin on the sides of the body and extend from the hind limbs to the forearms, creating triangular sections of membrane between the fingers. Bats have four distinct flight membranes, including the propatagium, the dactylopatagium, (also called the chiropatagium), the plagiopatagium, and the uropatagium (Figure 12-12).

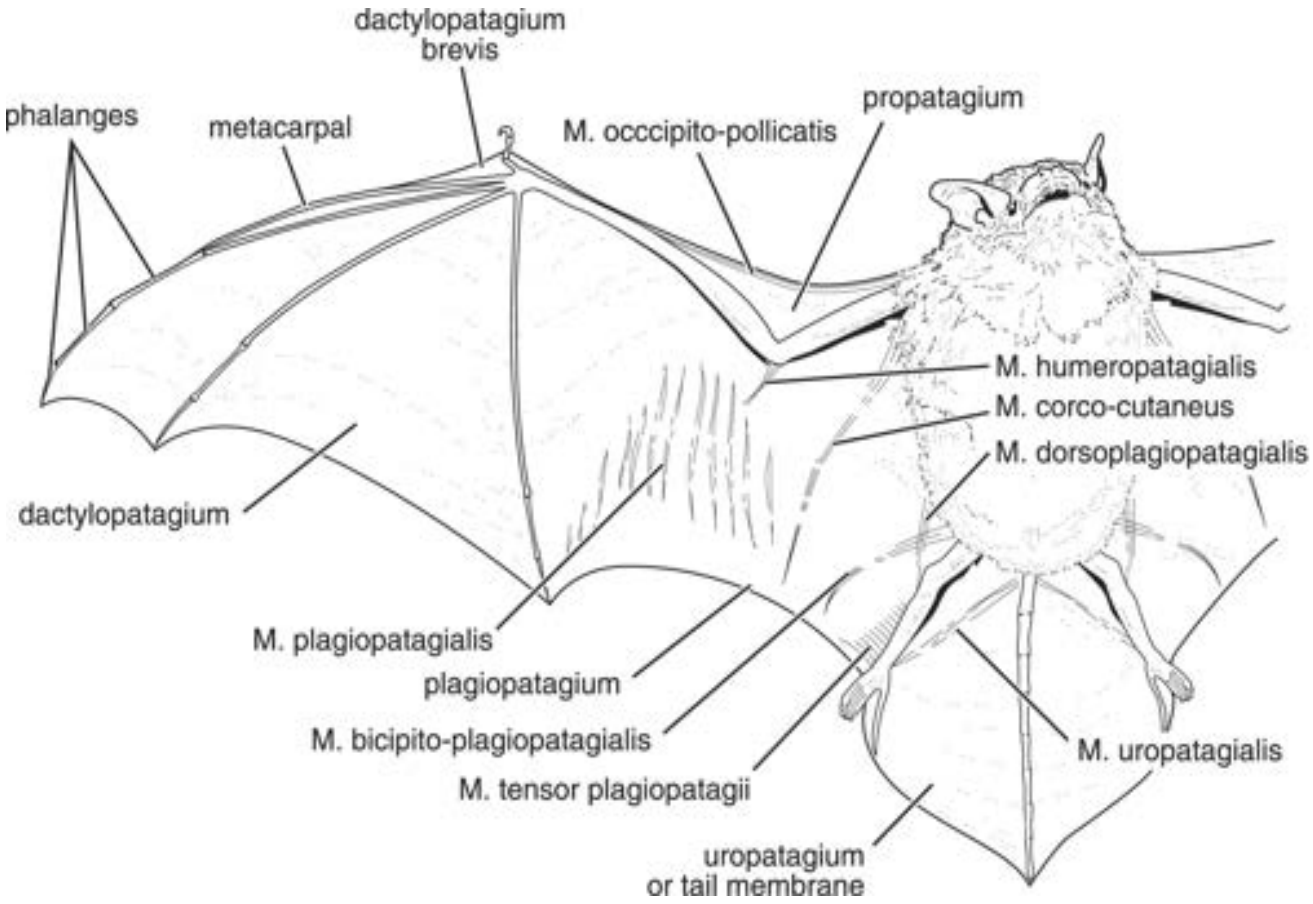


Figure 12-12. Bats have four distinct flight membranes including the propatagium, the dactylopatagium, the plagiopatagium, and the uropatagium. Ventral view. David Chapman. Modified from Hill and Smith, 1984.

The propatagium attaches at the shoulder and extends along the arm to the thumb. The contractions of a muscle along the leading edge of the membrane controls the degree of curvature of the wing during flight. The dactylopatagium is the section of the membrane that extends between the fingers. The small section of this membrane that extends between the thumb and the second finger is called the dactylopatagium brevis (Figure 12-12). The dactylopatagium brevis and the propatagium form the leading edge of the wing. The plagiopatagium is the membrane that extends from the fifth finger to the sides of the body. Flexion of the fingers and body control the curvature of the dactylopatagium and plagiopatagium during flight. The uropatagium is actually a tail membrane that is attached to the ankles or feet and encloses all, or part, of the tail. Bats use their tail membrane to assist in flight, to help them scoop up insects, and, in some species, as a pouch to catch young during parturition. The flight membranes are composed of an upper and lower layer of skin with elastic tissue, nerves, muscle fibers, and blood vessels sandwiched between the two layers.

Bats take off by first releasing their grip from the roost. Some open their wings and flap several times before letting go, while others use roosts high above the ground that allow a lengthy drop, enabling them to gain enough speed for flight. Flight requires both an upward force or lift and a forward force or thrust. Lift allows the bats to overcome the force of gravity and remain in the air; thrust moves bats forward through the air. Lift is created when air flows more quickly over the upper surface of the wing than it does under the lower surface. Thrust is generated by the dactylopatagium (portion of the wing membrane located between the fingers). At first, the wings are extended above the level of the bat's body and slightly backwards. Then they move down and forward in a down stroke. The bat then returns its arms and wrists so that the wings partially fold during the upstroke, where they are once again extended above the bat's body and slightly backwards. This series of movements is called a wing-beat cycle. Bats fly by using a series of wing-beat cycles.

The keel is much reduced in bats from that seen in birds (see Figure 12-13). Large flight muscles in the upper arms and chest provide the power needed for flight. Three pairs of chest muscles provide the power for the down stroke movement (Figure 12-14A), and several smaller muscles on the back provide the power for the upstroke (Figure 12-14B).

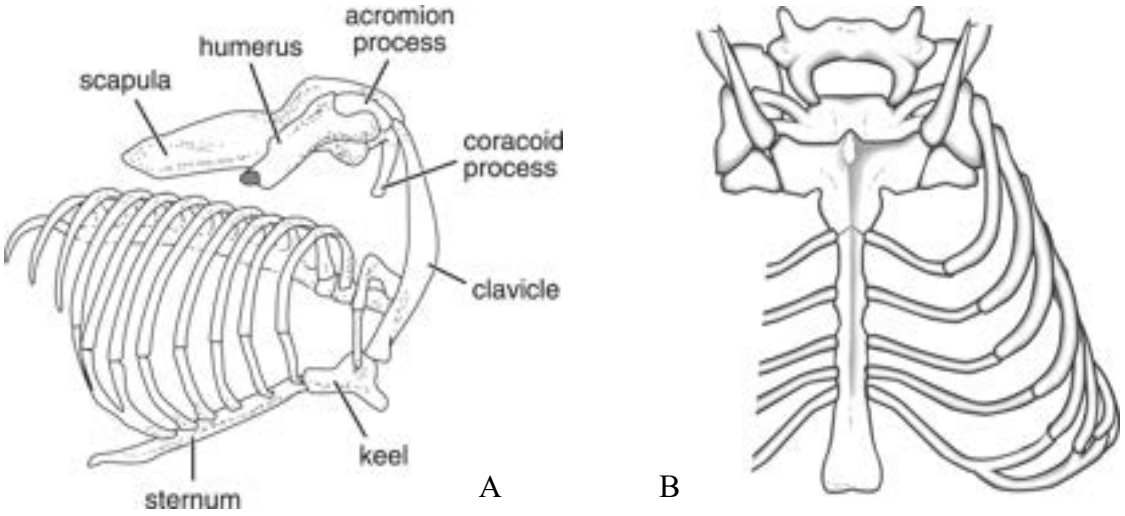


Figure 12-13. A: The keel is much reduced in bats compared to that seen in birds. Lateral view. **B:** Sternum and ribcage. Ventral view. *Myotis yumanensis*. David Chapman. Modified from Hill and Smith, 1984, and Vaughn, 1970.

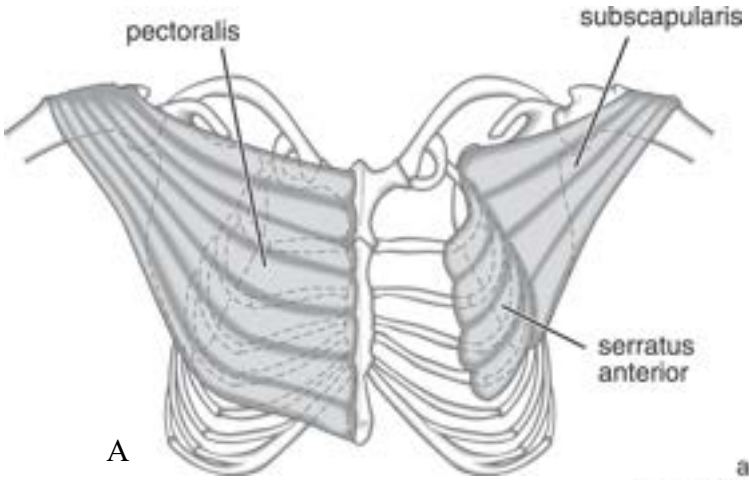
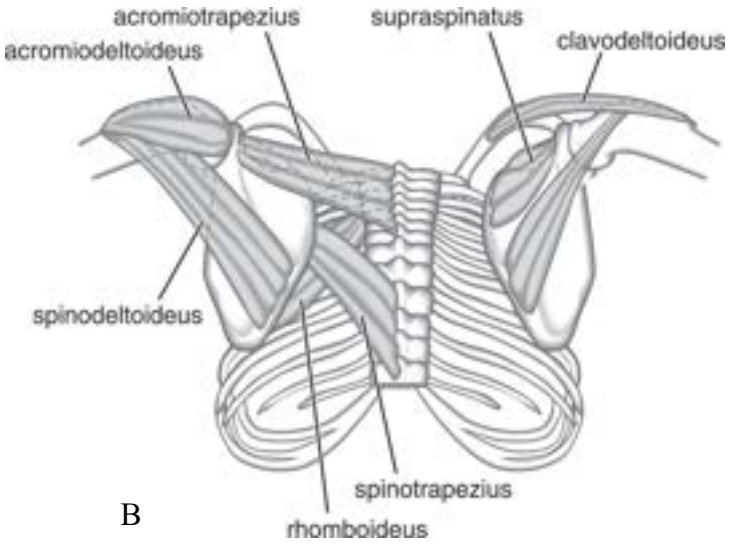


Figure 12-14. A: Ventral view of three pairs of muscles (on the chest and upper arm) that provide the power for the down stroke (power stroke) movement of flight. Superficial muscles shown on the left side; deep muscles shown on the right. David Chapman. Modified from Hill and Smith, 1984.



12-14. B: Dorsal view of several smaller muscles on the back that provide power for the upstroke (recovery stroke) movement of flight. Superficial muscles shown on the left side; deep muscles down on the right. David Chapman. Modified from Hill and Smith, 1984.

Membrane Tears

The thin wing membranes are in fact quite pliable and more resistant to tearing and puncturing than one might expect. Between the two layers of skin are many muscle fibers, nerves, and numerous blood vessels. These vessels transport oxygen and nutrients to the flight muscles and help to cool a bat as it flies by allowing the dissipation of heat through the thin wing membranes. Shunts, special modifications of the blood vessels, allow bats to regulate the amount of blood circulating through flight membranes. This feature is of great importance in thermoregulation. Bats can reduce or even cut off the circulation to parts of the wings. Altering the flow of blood over different surfaces of the wing provides a mechanism for controlling the degree of heat loss across the membranes. The vascular network is visible to the naked eye when a light source is held behind the wing.

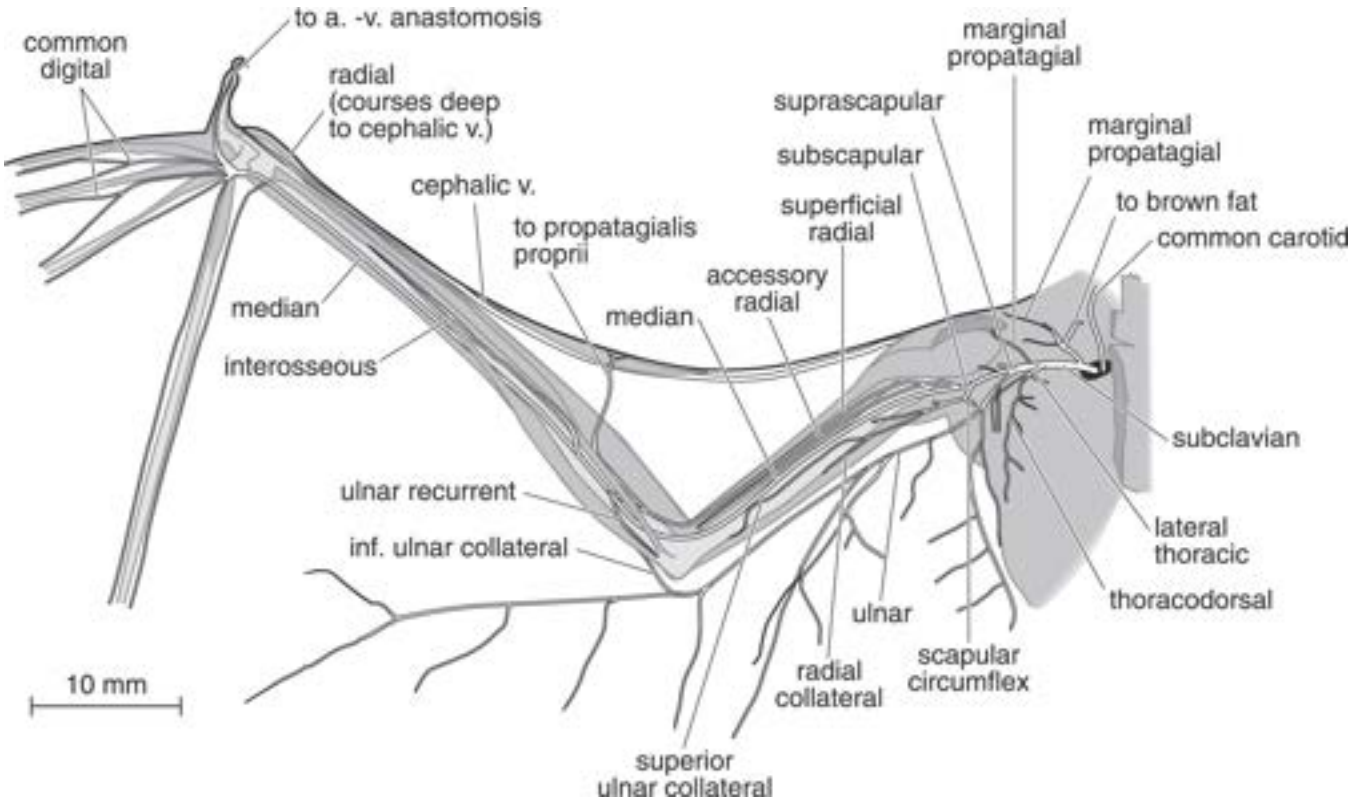


Figure 12-15. Cephalic vein and arterial distribution of the lower cervical region, superficial later thoracic wall, forelimb, and associated patagium. *Myotis myotis.* David Chapman. Modified from Kallen, 1977.

Membrane tears can result from contact with thorns or other sharp objects. The area surrounding the tear should initially be rinsed with Betadine® solution or 10% solution of Nolvasan®. Place a few drops of the antiseptic onto the torn portion of the membrane using an eyedropper. Don't pour liquids onto a bat directly from the bottle, unless it is a container that allows the application of one drop at a time. Use a gauze pad to dry off any excess liquid that may have dribbled onto the fur. It often takes six to eight weeks for membrane tears to heal. New, pale pink scar tissue will begin forming on the outer edges of the tear first. It may take as long as three to four weeks for new tissue generation to begin, and an additional three to four weeks for the tear to mend completely.

Larger tears, particularly those that extend all the way through the leading or trailing edge of the wing membrane (Figure 12-16), are unlikely to heal unless the tissue of the edges of the tear are reattached in a manner that is conducive to new tissue growth. It is not recommended that such tears be sutured because it causes further trauma to the tissue (including the muscle fibers).

Large tears that extend through the trailing edge of a membrane will heal on their own over time, although gluing may speed the process. Reattaching the two sides with tissue adhesive such as Gluture.® Position the skin on either side of the tear so that the tissue is perfectly aligned along the free edge and apply the first drop of adhesive there. Continue holding the skin in position until the adhesive dries, and be extremely careful not to allow the adhesive to touch gloves or skin during the procedure to prevent becoming glued to the bat's wing. Then apply one drop of adhesive at 1.0cm intervals along the entire length of the tear. The adhesive should not be applied in a continuous strand along the entire length of the tear because it will interfere with new growth. Initial tissue regeneration will begin in the sections between the drops of adhesive.

Figure 12-16. A large tear of the wing membrane that extends through the trailing edge. *E. fuscus. Photo by C. Meyers.*

It is important that large membrane tears be reattached with adhesives as soon as possible so that new skin growth allows the membrane to heal in a manner that reestablishes the appropriate shape of the wing. Because there are numerous nerves and muscle fibers in the wing membranes, bats with large tears should be given 10 to 30 minutes of continuous flight exercise each day for a week before being released. Only release such a bat if it is able to maintain flight without landing for a period of at least 10 minutes. Although bats are able to fly after wing injuries have healed, they must also exhibit the kind of excellent maneuverability exhibited by uninjured bats in order to feed appropriately and to avoid predators if they are to be released. A bat that can fly but that does not demonstrate aerobatics typical of uninjured bats is not likely to survive for an extended period of time in the wild.

Tears through the leading edge of wing membranes may be particularly harmful, as contraction of a special muscle (M. occipito-pollicalis) in the propatagium controls curvature of the wing during flight. Injuries to that section of the wing can significantly interfere with a bat's aerodynamic abilities. Such a bat would need to be kept in permanent captivity. The same applies to bats with large tears that heal, but that result in significant scarring and thickening of membrane tissue.

OPEN AND CLOSED FRACTURES

An open fracture is easily recognized because it involves a bone that has been broken and displaced, with one or sometimes multiple sections of the bone protruding through the tissue to the outside of the body. A closed fracture may be more difficult to identify even on X-rays. Crevice-dwelling bats can be radiographed while inside a roosting pouch. They do not need to be restrained when X-rayed in this manner because they will typically remain within the pouch where they feel safe. A bat may have a closed fracture of a wing bone if it does not attempt to fly or does not stay airborne after taking flight. It should be noted, however, that if a bat is unable to sustain flight it may have other problems such as a back injury.

Closed fractures of the hand and finger bones often heal within four to six weeks. These injuries usually require no treatment other than prohibiting flight during recuperation. Although open fractures of the hand and finger bones may heal within four to six weeks, they often do so with slight deformities that can negatively impact flight ability.

Both closed and open fractures to the bones of the upper arm (humerus) or forearm (radius or ulna) are likely to have more serious consequences. Although some of these fractures can be pinned, they sometimes heal with imperfections, including decreased agility, which preclude release. The closer the bone is to the torso of the bat, the more important it is aerodynamically, and the more likely it is that the bat may not regain full flight ability. If the bat is to remain in captivity permanently, tissue adhesive can be used to stabilize fractures of the arm to prevent further injury until the bone heals. The author recommends against the use of tapes or casts for stabilizing the wing injuries on insectivorous bats, as both methods may result in further injury to the bone and skin through self-mutilation.

Exposed pieces of bone in open fractures that cannot be pinned will sometimes become dry and break off on their own. However, because they may involve sharp pieces of bone that could cause injury to the bat, it is best if they are clipped off using sterile procedures and sharp surgical scissors. The bat should be anesthetized (see Anesthesia). Clean the amputation site with Nolvasan Surgical Scrub before clipping off the exposed bone. For exposed finger bones, snip the bone off as close to the wing membrane as possible. Control any bleeding by gently applying pressure. When bleeding has stopped, extend the wing and apply a small amount of tissue adhesive. Be careful not to get any of the adhesive on any other portion of the wing.

STABILIZING FRACTURES WITH TISSUE ADHESIVE

Many fractures can be successfully stabilized with tissue adhesive (Lollar, 1994), a method the author has used successfully on approximately 70 crevice bats over the past two decades. For open or closed fractures of the upper arm (humerus) or forearm (radius or ulna), gently immobilize the bat in a soft cloth on a padded surface, exposing only the injured wing. If the wound appears infected or contaminated with debris, flush area with hydrogen peroxide then sterile water and dry it with a sterile gauze pad. Although hydrogen peroxide is not very effective at killing bacteria when there is effervescence, it is useful as a cleaning agent for suppurating wounds and inflamed mucous membranes because the development of gas tends to loosen adherent deposits which might form a breeding place for microorganisms. It should be used only for the initial flushing because repeated use may inhibit new skin growth.

Unless it is a fresh break, the ends of the exposed bone are likely to appear dry and will need to be clipped off with sterile surgical scissors before the bone is realigned. Carefully realign the ends of the broken bone as closely as possible, and position the wing so that it lies naturally against the body. If the broken wing is glued in an unnatural position the bat will be uncomfortable and may further damage the wing while attempting to remove the glue. Once the bone has been repositioned, apply tissue adhesive to stabilize the fracture. Do not apply the adhesive to exposed bone, and do not apply the adhesive directly from the container. Instead, use the plastic applicators that come with tissue adhesive or pour a small amount (4 to 5 drops) on a piece of nonporous paper. For a fractured humerus (either open or closed), dip the plastic applicator into the adhesive, and then apply a few drops to the dorsal surface of the wing membrane in two places, below the elbow on the propatagium and between the torso and the humerus (Figure 12-17).

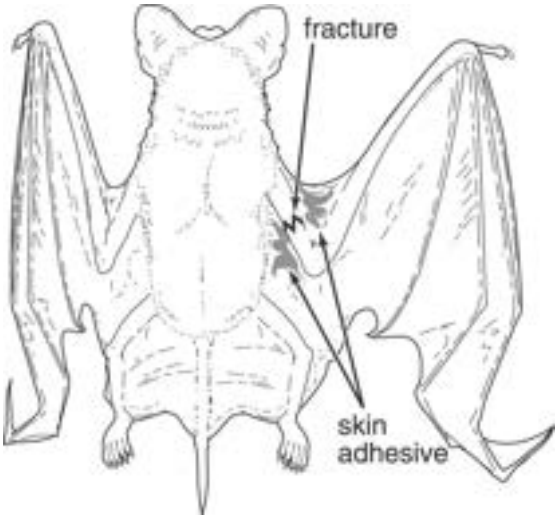


Figure 12-17. To stabilize a fractured humerus, apply a few drops of the skin adhesive to the dorsal surface of the wing membrane just anterior to the elbow, i.e., on the propatagium, and on the plagiopatagium between the torso and the humerus. *T. brasiliensis.* David Chapman.

Apply the adhesive sparingly and only on the dorsal surface of the wing. Again, be careful not to get any of the adhesive into the wound or on exposed bone. Work quickly because the adhesive dries within seconds.

Avoid contact with the adhesive to prevent gluing oneself to the bat. Then gently close the wing, pressing the forearm against the humerus and the humerus against the side of the body. **The thumb should be pointed down in its natural position**. **It is critical that the wing is folded in its natural position so that it does not cause discomfort to the bat.**

For a fractured radius, either closed or open, apply adhesive to the entire length of the dorsal side of only the outermost fingers (fingers two and three). Again, position the wing so that it lies naturally against the body. If the broken wing is glued in an unnatural position, the bat will be uncomfortable and may further damage the wing while attempting to remove the glue. After the glue is in place, gently press the outer finger against the forearm (radius) in its natural position and hold it in place for a moment until the adhesive sets (Figure 12-18).

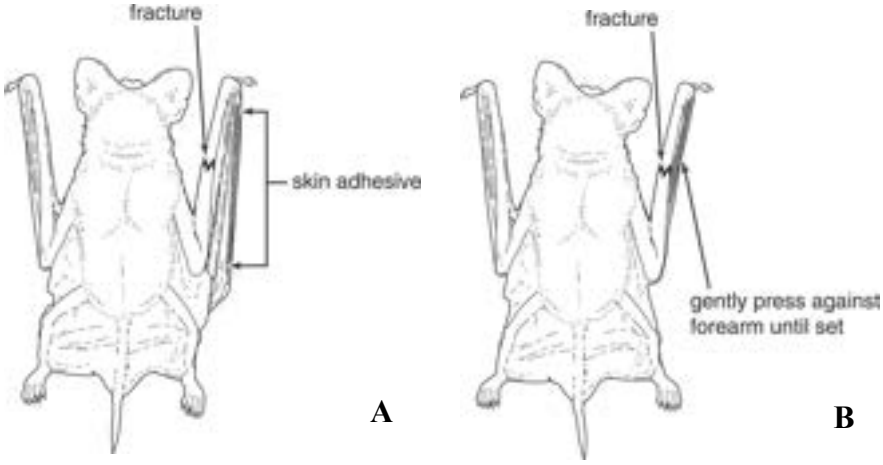
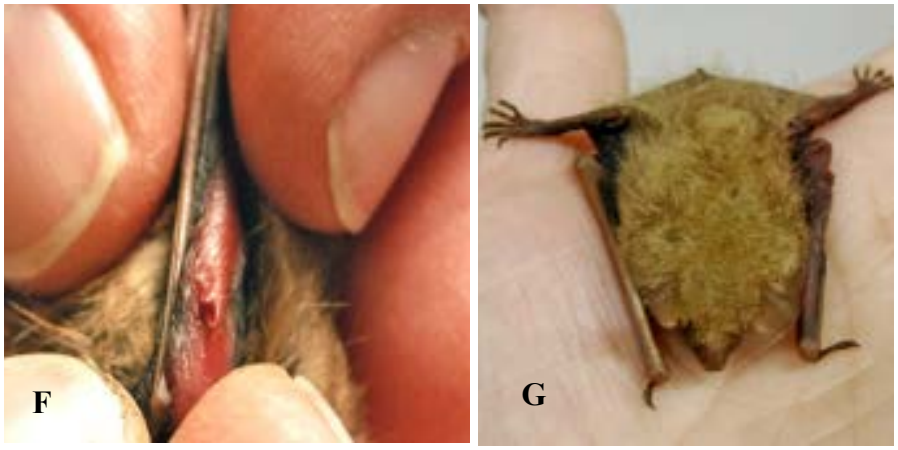


Figure 12-18. **A:** For a fractured radius, apply skin adhesive to the dorsal side of the outer fingers (i.e., fingers two and three). Skin adhesive should be applied sparingly in a thin, continuous line the entire length between the arrows. **B:** Press the outer finger against the forearm in its natural position and hold it in place for a moment until the adhesive sets. *T. brasiliensis.* David Chapman.



C: A pipistrelle with an open fracture of the radius. **D**: The fracture has been realigned and the wing is positioned to mimic the good wing, so that it lies naturally against the body. **E:** Tissue adhesive is applied to the entire length of the dorsal side of only the outermost fingers, using fingers two and three as natural splints. **F:** The fingers are held against the forearm until the glue is set. **G**: 24 hours after stabilizing the wing with adhesive. *P. subflavus. Photos by M. Singleton.*

Apply a triple antibiotic ointment twice daily. The use of tissue adhesive for stabilizing fractures as described above will prevent a bat from flapping its wing and does not require the use of bandages or slings of any kind. In fact, many bats are likely to chew incessantly at any kind of bandage, causing further damage.

To prevent further injury to the wing while the fracture heals, clip the thumb claw short on the injured wing, clip only the tip of the nail. Check the wing daily and reapply adhesive to any area where it has come loose. Old pieces of hardened adhesive should gently be lifted off with tweezers before applying more.

In about three weeks, sufficient calcification will have taken place so glue will no longer need to be reapplied. Gently remove any remaining pieces of adhesive with tweezers. X-rays can be used to monitor fracture healing, which is usually complete within four to six weeks. Do not allow the bat to attempt to fly during this time; keep it in an enclosure that is small enough to preclude flight.

Oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered to bats with open fractures. (see Medications).

REHABILITATION AFTER FRACTURED WINGS

Once an injury has healed, the bat may begin stretching the wing while roosting. This stretching is important for the re-establishment of muscle tone. The bat should be allowed a couple of days of wing stretching before being given the opportunity to fly. Again, as with any wing injury, the bat must demonstrate flight comparable to that exhibited by uninjured bats if it is intended for release.

A bat that flies well can sustain flight for several minutes and will land on the ceiling or wall of an appropriately constructed flight enclosure. Some species, such as red bats (*L. borealis*), often perform a summersault immediately prior to landing. Lasiurine bats and other bats that are not adapted to terrestrial activity are not likely to do well in captivity with wing injuries that entirely preclude flight. However, many crevice-dwelling species with permanent wing injuries will thrive in captivity. If unable to provide permanent care for non-releasable bats, a sanctuary should be contacted to take the animal.

INJURIES TO THE SHOULDER, ELBOW AND WRIST JOINTS

Because flight requires some rotation of the arms and wrists on the down stroke, bats with fractures to the shoulder, elbows, or wrist joints will have permanently impaired mobility even if they are subsequently able to fly. In addition, joint injuries have a tendency to recur. It is therefore preferable that these bats not be released. If kept in permanent captivity, the wing should be stabilized with skin adhesive as previously described for fractures of the wing bones in order to prevent further damage to the site.

Joint injuries often result in significant swelling. Swelling at the wrist and elbow joints can also be associated with infections that result from cuts, abrasions, or bites from other bats. Treat these injuries as described in Joint Swelling and Bite Wounds.

AMPUTATIONS

Amputations have been successfully performed on both crevice and tree bats, and these bats demonstrate very little loss of mobility in captive situations. Amputations are sometimes the only option in saving a bat's life from injury or infection. They are also occasionally necessary to ensure more comfort for the bat after a wing injury has stabilized, as injuries of the humerus and radius may heal in such a manner that the bat is unable to fold the fingers under the arm in a natural position. These fingers then become abraded on enclosure surfaces as the bat climbs about its enclosure, or the protruding fingers may prevent the bat from clustering with roostmates. Bats with injured, necrotic wings have been observed trying to chew off the affected area.

Amputations of the second through the fourth fingers generally have little impact on a bat's ability to maneuver in an enclosure and can often be performed so that the injury is not obvious when the wing is folded against the bat's body. Amputations at the forearm have a much more profound affect on terrestrial activity, although these bats quickly learn to use the elbow to rebalance and maneuver. Amputations that require removal of the limb above the elbow (humeral amputations) will result in significant impairment even for bats well adapted to terrestrial activity; however, the author has had several *T. brasiliensis* with such amputations that participated in mating activity for over a decade. Males actively defend established territory and harems of females against other males, and female amputees give birth and successfully raise their young with little difficulty.

In general, species that are terrestrially agile typically adapt very well to partial amputations of the wing providing they have appropriate housing modifications (see Permanent Housing, Non-Flighted Bats). Tree bats have been known to exhibit depression after amputations, and therefore must be provided with exceptional care to avoid depression and a poor quality of life. Amputations should always be performed under general anesthesia (see Anesthesia). Amputations must be carefully examined to determine the precise amputation site. It is best to perform the amputation 3 to 5mm proximal to the injury or infection site.

For amputations of the radius, locate the large vessel in the wing (Figure 12-19A). Cut through the membrane along the yellow line as indicated. After the wing has been amputated, deglove the radius by gently pulling the skin back from the amputation site (Figure 12-19B). Trim the bone back by an additional 2mm to 3mm. Control any bleeding by gently applying pressure with a sterile gauze pad at the amputation site. Slip the skin back over the trimmed bone and close it with one to two absorbable sutures, size 5-0 to 6-0 (Figure 12-19B). Tie the suture securely and trim off the excess.

Remove the bat from anesthesia and hold it with the head lower than the rest of the body. This helps to wake the bat, so be sure to hold the bat securely. Pour a small pool of tissue adhesive onto a clean, non-absorbable surface. Then, hold the wing securely between your thumb and forefinger and dip the amputation site into the glue (Figure 12-19C). Be sure to keep the bat's head lower than the rest of the body and keep the bat securely in this position until the glue dries. After the glue has dried, dip the wing into the glue a second time (Figure 12-19D). A second application of glue will provide a protective layer and help to pad the limb as the bat climbs on enclosure surfaces.

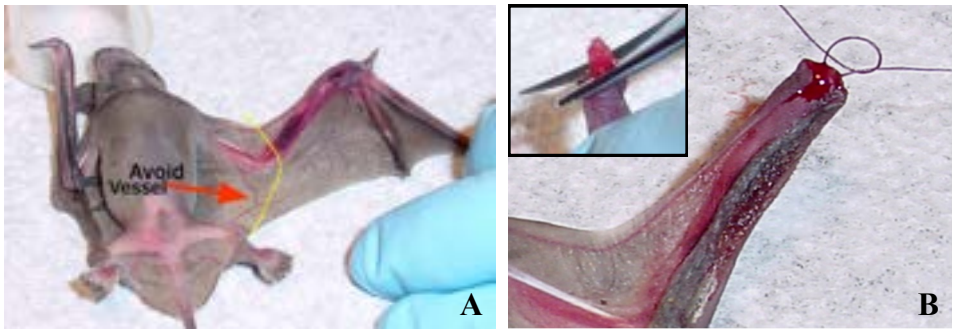
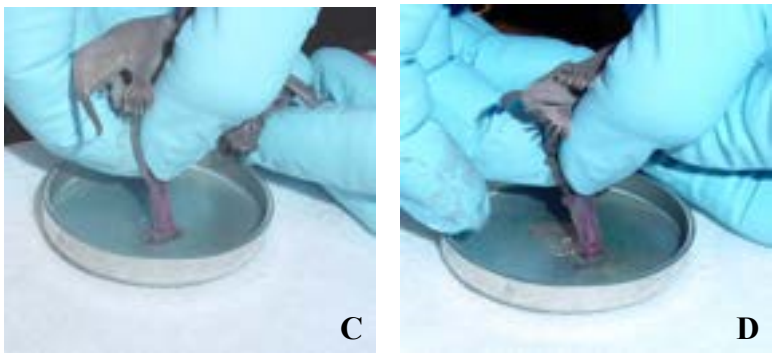


Figure 12-19. A: The bat is anesthetized and the amputation site is located.

B: The amputation site is degloved and a suture is used to close the site. *T. brasiliensis. Photo by C. Myers.*



C: The bat is removed from anesthesia and held upside down while the amputation site is dipped into a small pool of tissue adhesive.

D: The first layer of adhesive is allowed to dry, and the site is again dipped into the adhesive to create a second layer, which will help pad the injury as it heals. *T. brasiliensis. Photos by C. Myers.*

For amputations of the humerus, carefully examine the wing to determine the precise amputation site. Locate the large vessel in the wing membrane indicated by the red circle and arrow (Figure12-20A). Cut through the membrane along the yellow line. After the wing has been amputated, deglove the humerus by gently pulling the skin back from the amputation site and trim the bone back by an additional 2mm to 3mm (Figure 12-20B). Apply gentle pressure with a sterile gauze pad to control any bleeding. Slip the skin back over the trimmed bone and close with one to two absorbable sutures, size 5-0 to 6-0 (Figure 12-20C). Tie the suture securely and trim off the excess.

Remove the bat from anesthesia and hold it with the head lower than the rest of the body. (This helps to wake the bat.) Flush the amputation site with a 10% Novalsan® solution and then apply either an antibiotic ointment or Manuka Honey topically.

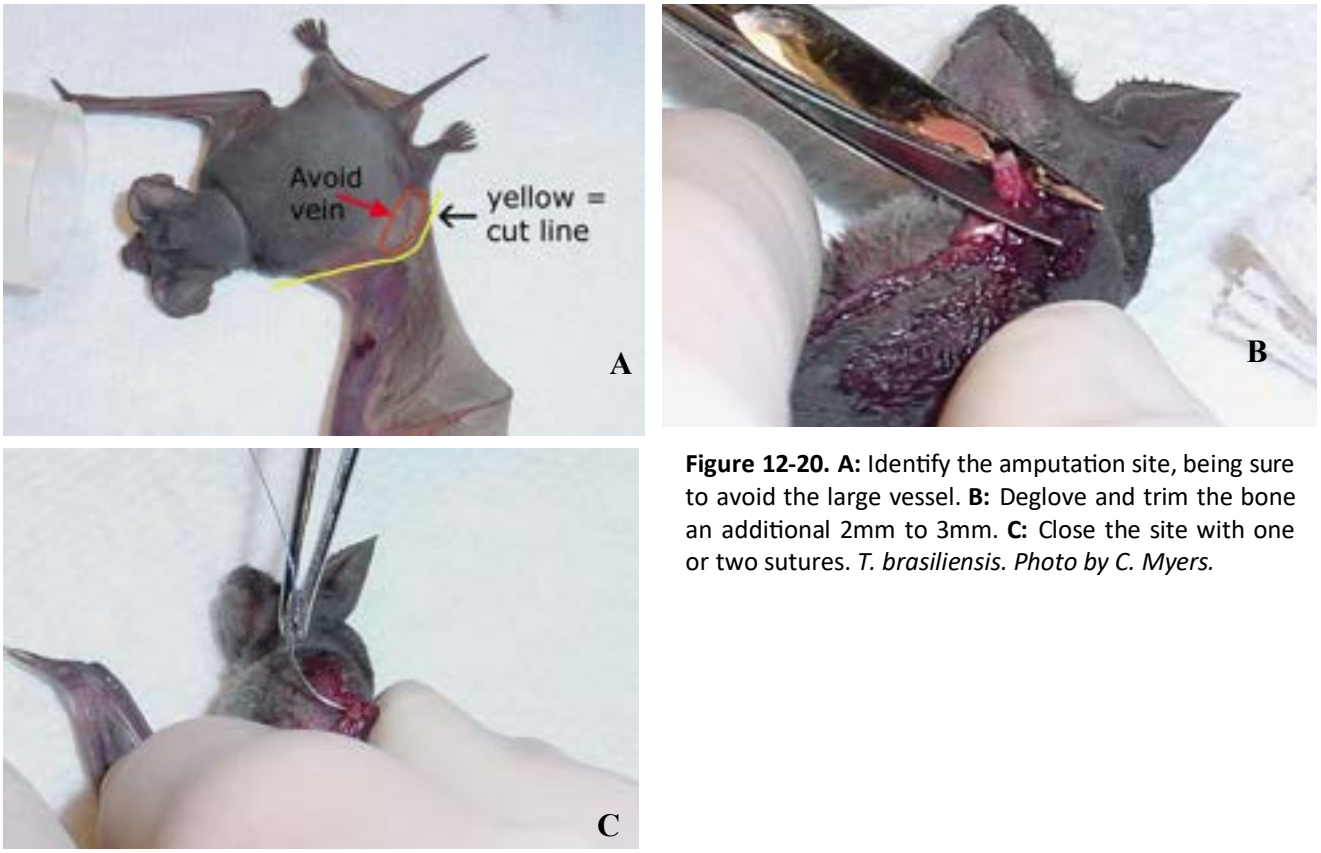


Figure 12-20. A: Identify the amputation site, being sure to avoid the large vessel. **B:** Deglove and trim the bone an additional 2mm to 3mm. **C:** Close the site with one or two sutures. *T. brasiliensis. Photo by C. Myers.*

Amputations require the oral administration of Veraflox® and Clavamox® for 14 days. Give Buprenex or Meta-cam® for pain. Wounds from amputations are generally healed within two to three weeks.

Back Injuries

The last cervical and the first thoracic vertebrae of bats generally fit tightly together, restricting movement. Species of Myotis have 11 thoracic, 5 lumbar, 4 sacral, and 10 caudal vertebrae. The thoracics fit tightly together and form a rigid structure (Figure 12-21). The lumbars are more robust and have thicker intervertebral discs that permit more movement between vertebrae. The thickest disc is found between the last lumbar and the first sacral vertebrae (the four sacral vertebrae are fused together to form the sacrum). This articulation is much more flexible than those between successive lumbar vertebrae. The transverse processes of the sacral vertebrae form a continuous lateral mass that is fused to the ilium (part of the pelvic girdle). Caudal vertebrae are thin and elongated.

Bats also have modified cervical vertebrae that allow them to arch their heads backwards when roosting. The tibia and fibula of the lower leg articulate with the tarsals, tiny bones of the foot (ankle), collectively referred to as the tarsus.

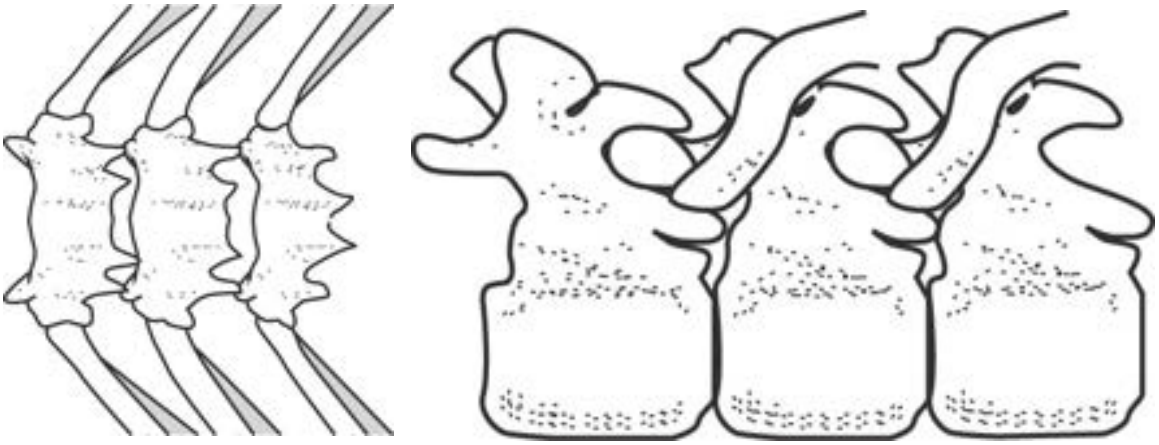


Figure 12-21: Dorsal view of thoracic vertebrae 4, 5, and 6. *Myotis lucifugus*. David Chapman. Modified from Vaughn, 1970.

Clinical signs of back injury may include partial or total loss of movement in the legs, incontinence, and sustained erection. The legs may appear limp, the bat dragging them behind its body when attempting to crawl. These animals sometimes lay tilted to one side, have a rapid, shallow respiration, and a stiff torso (Lollar, 1994). Signs of respiratory distress may also result from other causes including blunt force trauma and pneumonia (see Blunt-Force Trauma and Respiratory Disorders). In only a very small percentage of cases involving crevice-dwelling species have such injuries healed on their own. Some back injuries can be successfully treated with dexamethasone injections given twice a day until significant improvement is observed, usually five to 10 days (see Medications). Medication should not be stopped abruptly, but rather tapered off.

Signs of improvement will include response to a pin prick on the foot, such as blinking of the eyes, flinching, or voluntary movement of the toes, feet, or legs. A bat that does not show any response to a pin prick on the foot, or any other sign of improvement at the end of one week should be euthanized. Because partial paralysis is also one of the clinical signs often observed in rabid bats, use extreme caution when deciding whether or not to treat animals exhibiting these clinical signs (see Rabies).

For those animals that will be kept in permanent captivity, there are a number of things to keep in mind. First of all, bats with back injuries will not be able to hang in the typical head down position, and although a bat with a broken leg may be able to do so, this will put undue stress on the uninjured leg. For this reason, bats with either leg or back injuries should be provided with roosting pouches that allow them to roost in a horizontal (rather than an head down) position. The pouch should be placed on a padded floor of the enclosure.

Allow the bat to roost on a soft pad (such as a chamois cloth) placed inside the roosting pouch to absorb urine while the injury heals. The pad should be checked two to three times daily, and replaced as soon as any dampness is detected. It will also be necessary to keep the claws on the toes clipped short so that they don't get caught in enclosure materials, resulting in further injury. Clip the claws on the foot of the injured leg, although the nails on both feet should be clipped for bats with back injuries.

In the few cases where back injuries are known to have healed, recovery took at least six to eight weeks (Lollar, 1994). A nutritious diet is particularly essential during the recovery period.

Back and leg injuries will always inhibit a bat's ability to groom properly, because bats normally hang from one foot and groom by combing the toes on the other foot through the fur of their head and body. Bats are meticulous groomers and their general condition will quickly deteriorate if not kept clean. It is therefore essential to clean and brush the fur twice daily with an interdental brush until the animal begins grooming on its own again.

Bats also keep the inside of their ears clean with the claws of their toes. Bats with back and leg injuries will be unable to do this, and waxy buildup may occur. Wax buildup will need to be carefully removed using magnification.

Note: Mealworms should never be left in enclosures with severely debilitated bats or with bats that have sustained back injuries or other injuries that seriously impede terrestrial movement as such bats can be overcome and eaten by mealworms.

Leg Injuries

The femur or upper leg bone of a bat is attached at the hip in a manner that is reversed from that found in other mammals. There is a 180° rotation of the hind legs so that the knees point backward as the bat roosts, and the feet are rotated 180° from the usual mammalian position (so that they, too, point backwards). This posture facilitates a head-down suspension.

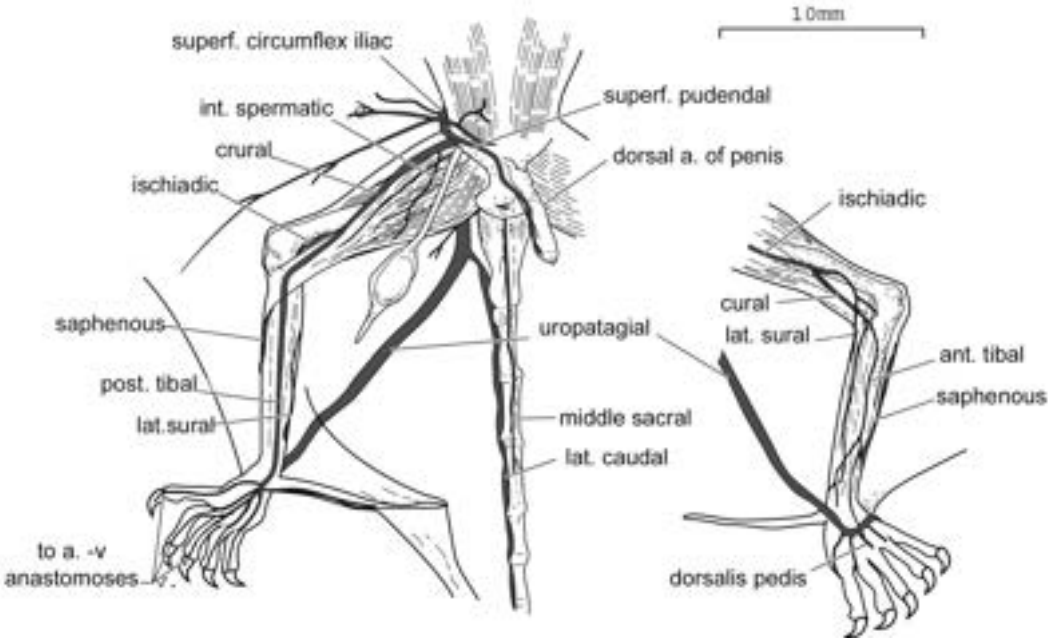


Figure 12-22: Arterial distribution of the hind limb, associated superficial ventral body wall, tail, and adjacent patagium. Also shown is uropatagial, lateral caudal, and superficial pudendal venous distribution. *Myotis myotis*. Left: ventral view. Right: dorsal view. David Chapman. Modified from Vaughn, 1977.

Injuries resulting from blunt-force trauma often include more serious back and leg injuries. A bat with a broken leg may drag the limb behind it as it crawls about, and the leg may appear stiff or swollen. These injuries frequently result when bats roost in door jambs of buildings and are crushed when the doors are closed. Injuries also occur in captivity if caretakers are not careful to note the position of the bat before closing enclosure doors. Bats in captivity may also suffer from leg or back injuries due to inappropriate caging or careless handling. A broken leg may mend on its own if the animal is housed appropriately and fed a nutritious diet.

Fractures of the femur have been pinned with some success, and a fabric tape splint proved successful in healing the leg of a wild big brown orphan, who flew well enough to be later released. The membrane was surgically sliced, allowing the gauze to wrap around and stabilize a fractured femur (Figure 12-23). As the bat grew, the tape was periodically replaced to avoid affecting normal bone development. After the fracture healed, the tape was removed to allow the membrane to regenerate.

Figure 12-23. Big brown pup with a fractured femur. *E. fuscus. Photo by L. Sturges*.

BIRTH ANOMALIES

The author has encountered five newborn orphaned free-tailed pups over the past eight years that were born with legs tucked up as if they were sitting in a "legs crossed" position (Figure 12-25A). In humans, this condition can occur when an infant is born breech. The legs maintain this position for several weeks. Bathing, massaging, and stretching the legs helps the leg muscles to relax. In severe cases, braces may be necessary to help the legs return to their normal position.

Two of these pups died within the first week of care. The legs of two of the remaining three pups returned to normal after a period of two to four weeks. During this time, warm compresses were applied to the legs with small gauze pads, and the legs were then gently manipulated with slow stretching exercises. One pup did not respond to this therapy, so a brace was fashioned from a rubber catheter.

A small section of catheter was cut using the span between the pups legs as a guide in determining a comfortable length. The catheter section was sliced down the entire length so foam could be inserted (Figure 12-25B). The section of foam measured several millimeters longer and wider than the length of catheter. Once inserted into the section, the brace resembled a double-ended matchstick (Figure 12-25C).

Small scissors were used to create holes in the protruding ends of the foam. These holes were large enough to enclose the pup's ankles without interfering with circulation, but small enough so they did not easily slip off the pup's feet. Forceps were inserted into the holes of the foam to open and guide the foam anklets over the pup's feet.

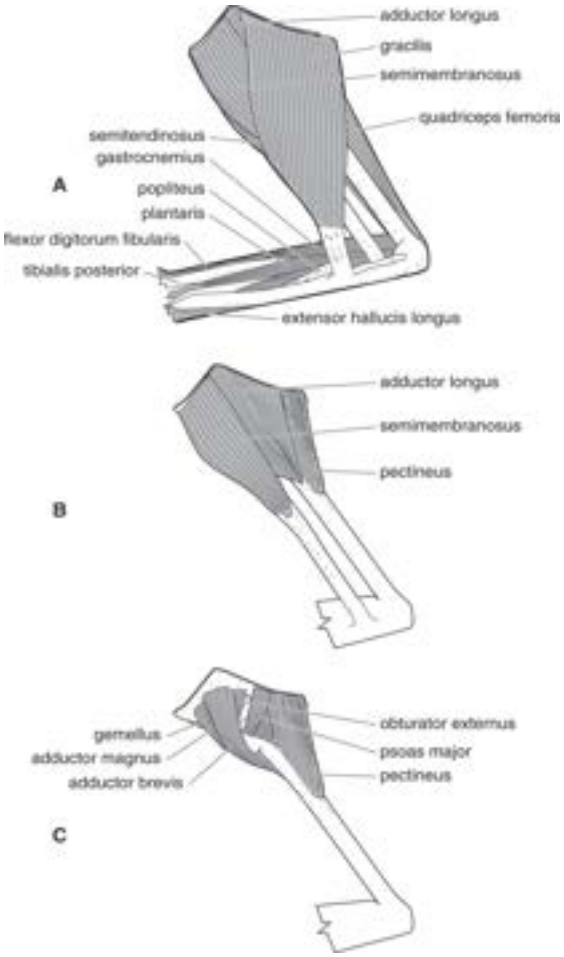


Figure 12-24.: Muscles of the hind limb. **A:** Medial view. **B and C:** Progressively deeper muscles. *Eumops perotis*. David Chapman. Modified from Vaughn, 1970.

The pup wore this brace for a period of four weeks. During this time, warm compresses were applied to the legs with small gauze pads, and the legs were gently manipulated with slow stretching exercises. Within six weeks the pup was able to use her legs to groom normally as well as hang in a head down position. Although her legs remained weak, at five years of age she gave birth to and successfully raised a healthy pup. This bat died at age seven. Gross necropsy revealed an undersized heart.

Figure 12-25. A: The pup's legs were frozen in a "legs-crossed' position. **B and C:** A small brace was made from a section of rubber catheter and soft foam. *T. brasiliensis. Bat World facility. Photo by A. Lollar.*

KNEE INJURIES

Knee injuries can result from blunt-force trauma, bites from other bats, and sometimes when bats jostle for position inside roosts. Swelling is common with such injuries. Clip the claws on the foot of the injured knee to prevent further injury. Clavamox® should be administered orally for a period of 14 to 21 days (see Medications).

JOINT SWELLING

Although joint swelling is common in association with fractures, infections may result from cuts, abrasions, and burns, as well as bites from other bats. Invasion of a joint by bacteria can take place through penetrating wounds, from contiguous sites of infection in bone or soft tissue, or from the blood stream.

Bacterial infection was suspected in a case observed by the author involving the sudden onset of severe swelling in one wrist joint of a Brazilian free-tailed bat (*T. brasiliensis*). In this instance, shifting (migratory) joint swelling was observed as swelling diminished in the wrist but was subsequently observed in one knee. Clinical signs of bacterial induced infection include swollen joints which cause the animal severe pain when palpated. This condition has been successfully treated in *T. brasiliensis* and *E. fuscus* with Doxycycline (see Medications).

Foot and Toe Injuries

The tibia and fibula of the lower leg articulate with the bones of the foot (Figure 12-26A-E). There are five toes on each foot, and each toe has a recurved claw. Tendons in the leg and feet are arranged so that the suspended weight of a hanging bat causes the toes and claws to grip firmly to the roost even while the animal is asleep (Figure 12-26F).

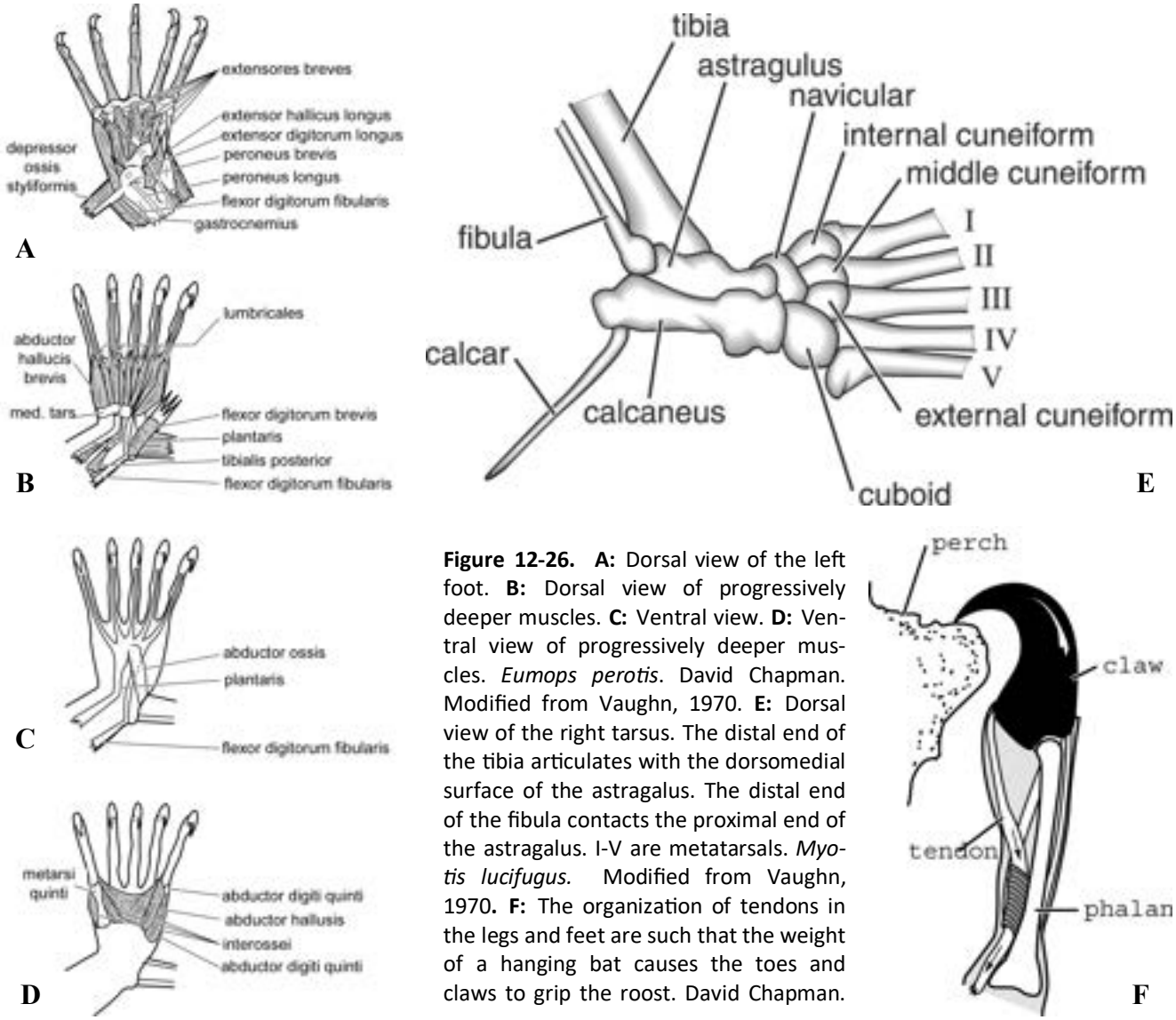


Figure 12-26. **A:** Dorsal view of the left foot. **B:** Dorsal view of progressively deeper muscles. **C:** Ventral view. **D:** Ventral view of progressively deeper muscles. *Eumops perotis*. David Chapman. Modified from Vaughn, 1970. **E:** Dorsal view of the right tarsus. The distal end of the tibia articulates with the dorsomedial surface of the astragalus. The distal end of the fibula contacts the proximal end of the astragalus. I-V are metatarsals. *Myotis lucifugus.* Modified from Vaughn, 1970**. F:** The organization of tendons in the legs and feet are such that the weight of a hanging bat causes the toes and claws to grip the roost. David Chapman.

Bats use their feet and toes to roost, to groom, and even to manipulate food. The calcar, a cartilaginous spur that articulates with the heel of the foot, helps to support the tail membrane, thereby contributing to flight capability. Injuries to the toes or feet can significantly decrease the likelihood of survival in the wild. Unfortunately, many foot and toe injuries are incurred in captivity. Inappropriate caging is most often the cause of such injuries, although some result when toes are closed in enclosure doors. It is essential to not house bats in wire cages or glass containers. The caging surface must allow the bat to move safely and easily from one place to another. If forced to move around inside of a glass or unscreened plastic container, bats are likely to develop toe deformities as well as wrist injuries.

Superficial scrapes on the feet or toes will heal well if properly treated. Such injuries do not interfere significantly with the bat's roosting or grooming abilities but should be treated before the animal is released to prevent subsequent infection.

To treat superficial scrapes on toes and feet, flush the affected area initially with sterile water and apply a small dab of triple antibiotic ointment to the site with a cotton swab. Apply antibiotic twice daily thereafter. These injuries will heal quite well within a couple of weeks.

Unfortunately, many of the foot injuries that occur in the wild are likely to be permanently incapacitating to a bat. These injuries typically result when a bat finds its way into a building or a garage and is caught in a closed door. There are many tiny bones and muscles in a bat's foot, and such incidents typically can result in crushed bones that will not heal properly.

Although enclosure modifications may allow the bat to survive in captivity, roosting ability will be greatly impeded. Such a bat will need to be groomed daily with an interdental brush. Because the quality of life of an individual with this type of injury is questionable, euthanasia should be considered for crushed bone injuries of the foot.

The prognosis for toe injuries, however, is much better. Although bats have five toes on each foot, they have been known to survive in the wild when missing one or two toes. Significant toe injuries sustained in the wild are usually accompanied by substantial foot injury. These fractures result in serious roosting and grooming deficiencies, making release, and in some cases, even permanent captivity, poor alternatives to euthanasia. If a caretaker chooses to keep such a bat in captivity, it should be thoroughly brushed twice daily for the remainder of its life. Failure to keep the bat clean and well groomed is likely to result in hair loss and subsequent physical deterioration. Again, because bats clean the inside of their ears with the claws of their toes, any injury that prevents this action can result in a waxy buildup that will need to be removed.

Blunt Force Trauma

Figure 12-27. Big brown bat with suspected head trauma resulting in ruptured blood vessels in the eyes. This bat survived with supportive care and was later released. *E. fuscus. Photo by L. Sturges*.

Many cases of blunt-force trauma are the result of human intervention when bats are found flying inside of a home or building. Frightened homeowners frequently attempt to catch or simply kill the animal by throwing or swinging objects at it. A bat that is hit with an object may suffer serious injury and require several weeks of supportive care.

Both external and internal injuries may result from blunt-force trauma. Even if there are no observable external injuries, the animal may well suffer some degree of internal damage, depending upon the force and location of the blow. Bats are delicate animals with tiny bones and they are easily injured. They are also likely to suffer from shock as a result of such incidents (see Shock). Gently palpate the chest area with the fingertips and listen for a crackling sound. This is an indication that a lung has been punctured and air has escaped and filled the thoracic cavity (see Respiratory Disorders). Ataxia, lying to one side, dragging or favoring one or both legs, abdominal swelling and hematomas are also signs of blunt force trauma.

Bleeding from the mouth is most commonly the result of tooth damage but may be a sign of internal injury. Carefully check the inside of the mouth for fragments of broken teeth. Gently run a cotton swab across the bat's chin so that it will open its mouth, allowing the caretaker to do a cursory check. If broken teeth are apparent, cut the cotton end off the swab and place the cardboard shaft in an unaffected area of the mouth so that it is between the bat's teeth, allowing fragments to be removed with forceps or fine-tipped tweezers. Head trauma may result in a subconjunctival hemorrhage (bleeding underneath the conjunctiva). The conjunctiva contains many small, fragile blood vessels that are easily ruptured or broken. When this happens, blood leaks into the space between the conjunctiva and sclera (Figure 12-27).

Administer Metacam® for pain and inflammation (see Medications). Wing fractures should be stabilized (see Wing Injuries). Check the legs, feet, and toes for swelling or inability to grasp (see Back and Leg Injuries and Foot and Toe Injuries). Flush external wounds initially with a few drops of hydrogen peroxide, then sterile water. Deep lacerations will need to be sutured. Use sterile Ethicon™ absorbable surgical sutures, 5-0 (1.0 metric), PDS. (Bats will need to be anesthetized for this procedure—see Anesthesia.) Apply a triple antibiotic ointment (just enough to cover the injury) to superficial wounds after they have been flushed with peroxide and sterile water. Treat wounds twice daily thereafter until completely healed. Bats with either deep lacerations or superficial scrapes that become infected should be given Clavamox® orally twice a day for 14 to 21 days (see Medications).

Bats suffering from blunt-force trauma should be observed carefully during the first few days of treatment. Those suffering from respiratory damage may hang on the door, or on an enclosure wall close to the door where they are receiving more air. Crevice-dwelling bats that have experienced severe bruising or rib fractures will also cling by their feet and thumbs out in the open on the ceiling or sides of an enclosure, sometimes with their backs in a hunched position. These bats should be left alone to roost in the open as they prefer, and should be handled as little as possible. As injuries heal, the bat will resume its normal roosting behavior, usually within two weeks. Signs of internal injury may not always be obvious. Several hours after a blow has been inflicted, abdominal swelling with a concurrent loss of appetite, or rectal bleeding may develop, a possible indication of a ruptured spleen or other abdominal injury. Bats exhibiting these signs generally will not survive and should be humanely euthanized. Victims of blunt-force trauma that have not experienced serious internal injury may require as much as six to eight weeks to recover completely.

Punctured Lung

A bat with a visible injury in its chest area and exhibiting signs of respiratory distress may have a punctured lung. Once any bleeding from the wound has been stopped, gently feel the chest with the fingertips. If a lung has been punctured and escaping air has entered the body wall, it will make a sound similar to the crackling of cellophane when palpated, and the bat's body may fill with air (Figure 12-28).

The excess air in the thoracic cavity exerts a pressure on the lung, impairing inflation. In larger mammals, the punctured lung will sometimes re-inflate after the air is withdrawn. Normally, air is evacuated by inserting a needle or placing a chest tube into the thoracic cavity. Air will then flow back into the lung as a result of the pressure differential between the outside air pressure and that inside the lung. Punctured lungs sometimes re-inflate without intervention when punctures seal up on their own. Owing to the small size of bats, the latter is the preferred option because of the likelihood of causing further damage when attempting to withdraw air from the thoracic cavity. Bats with punctured lungs should be housed in enclosures that do not allow flight, handled as little as possible, and treated with oral Clavamox® twice a day for 10 days (see Medications).

Figure 12-28. A: A free-tail orphaned with a punctured lung. When air escapes through a wound and outside of the body wall, beneath the skin, the bat's body can puff up two to three times its normal size. **B:** Air is gently evacuated using a 25 gauge hypodermic needle. Depending on the severity, it may be necessary to evacuate air from several areas of the body. **C:** Oxygen is administered. **D:** Two days later. **E:** Three days later the skin has returned to its normal elasticity. *T. brasiliensis. Photos by L. Schlenker.*

Bite Wounds

Animal bites frequently result in infection. Bats that have been attacked by animals, including other bats, should be examined carefully. Check the head and torso for external scrapes, scratches, or punctures. These wounds may not be immediately obvious beneath the bat's fur. Bites from other bats sometimes appear as small wounds on the arms, legs, face, or tail. Oftentimes these bites result in abscesses (Figure 12-29A). They may also result in swelling at the joints.

Administer Metacam® for pain (see Medications). Bite wounds should be flushed with an antiseptic such as Chlor-a-Flush, followed by a topical application of a triple antibiotic ointment or Manuka honey (Figure 12-29B). One of these topicals should be repeated twice a day thereafter until healed. A bite wound that has abscessed should be lanced with a sterile 27 to 29 gauge, 1/2'' needle. Purulent material should be absorbed with a sterile gauze pad. The wound can then be treated with an antiseptic and antibiotic ointment as described above.

Bats with bite wounds should be vaccinated against rabies. Oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered to bats with infected bitw wounds (see Medications).

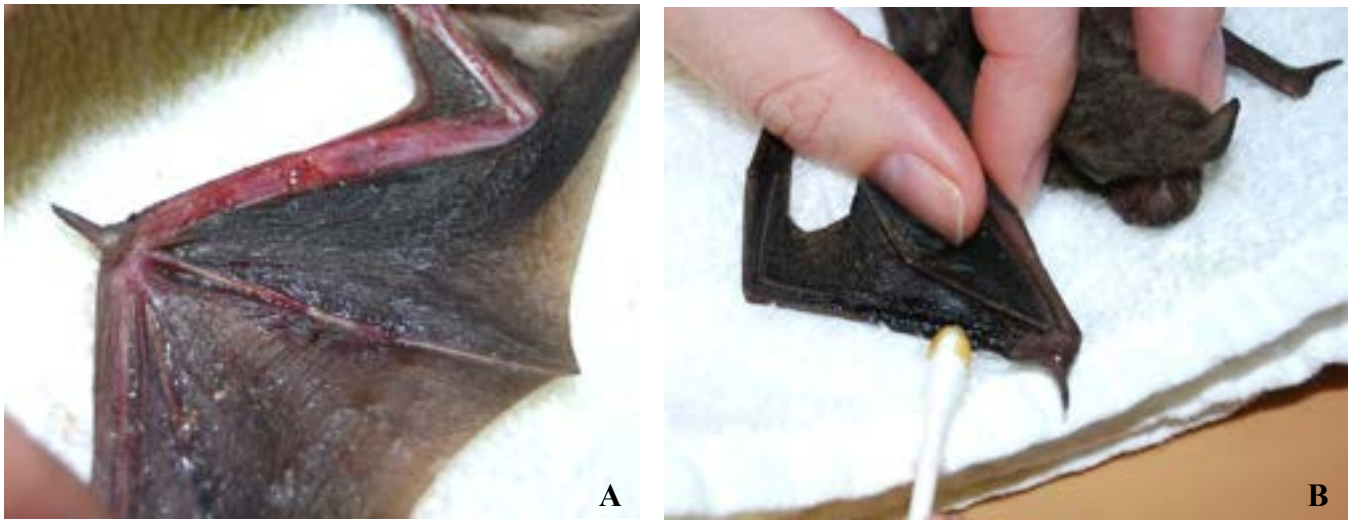


Figure 12-29. A: The mating behavior of free-tailed bats often results in severe bite wounds during territorial disputes. These bites become infected and often result in death. **B:** Bite wound being treated with a topical application of Manuka honey.

Adhesive Contaminants

Bats occasionally become stuck in or contaminated with fly paper, roofing tar, oil, paint, caulk or similar substances (Figure 12-30). Bats frequently ingest these substances in attempts to groom them from their bodies and may die from poisoning even after the substance has been removed. A bat covered with contaminants can be stressed and physically unstable; do not bathe or administer injectable medications until the bat appears alert and responsive.

Figure 12-30. A little brown bat just removed from a glue board which had been placed outside. *M. lucifugus. Photo by D. Wilkins.*

It is important to keep the bat warm before, during, and after the contaminant has been removed. First remove contaminants and debris from the nose, mouth, and eyes. Use magnification to gently remove substances from the nostrils. Gauze or a cotton swab can be used to remove debris from the mouth. Clean the eyes with a soft cloth.

Use vegetable or coconut oil and cotton swabs to detach bats from fly paper or sticky traps and remove any pieces of glue adhered to the fur and skin. Use surgical or manicure scissors to remove debris and adhesive from a bat's body by carefully clipping the fur, using caution to avoid nicking the skin.

The bat should then be bathed (see Bathing and Grooming). Be careful not to get water in the bat's mouth or nose. If necessary, the bat can be held under a gentle stream (trickle) of warm water to speed the bathing process. Several washes will be needed to completely remove the oil and remaining glue from the fur and wing membranes. The oil must be completely removed as bats will ingest substances that remains on their coats when groom. Ingesting excess oil will lead to diarrhea with subsequent dehydration and death. Additionally, bats with dirty or oily coats are unable to regulate their temperature, which can also be fatal.

The bat should be thoroughly rinsed and dried after each washing and allowed to rest between washings. Be sure to keep the bat's head in an upright position, and do not get the bat's face close to the running water, as water may accidentally fill the bats mouth or nose, causing it to aspirate. Use a mild detergent (such as Dawn® dishwashing liquid). After bathing, the bat should be wrapped in a soft cloth, dried thoroughly, and kept free from drafts.

After the bat is bathed and dried, administer 0.05ml of activated charcoal solution orally. Then feed the bat as much of the soft food mixture as it will consume (see Feeding Adult Bats). Encourage the bat to eat by gently placing small amounts of food in its mouth. Wait for the bat to swallow before offering another bite. (Food will help to absorb oil or adhesive that may be in the digestive tract.) After feeding, administer 0.05 ml of Pepto-Bismol® (Bismuth subsalicylate) orally.

After the bat is bathed and appears responsive, it should be rehydrated with an electrolyte solution as described in Dehydration and Fluid Replacement Therapy. Do not give injections to a bat that appears "shocky" or otherwise unstable (see Shock). Note: Because bats frequently ingest substances clinging to their fur as they groom, bats that have been stuck in adhesives sometimes die from poisoning or intestinal blockage even after the contaminant has been removed from the fur.

Heat Exhaustion/Heat Stroke

As previously discussed, a bat's body temperature can vary significantly, dependent in part on the ambient temperature. Despite bats typically requiring warm temperatures and high humidity levels, and that excess heat can be eliminated to some extent by radiation from the highly vascularized flight membranes, it is possible for colonial bats to experience the effects of heat stroke when roosting in small, tight areas with little or no ventilation during periods of extreme temperatures.

Figure 12-31 A. Petechial hemorrhages on the wing membrane is one of several signs of heat stroke. B. Vaginal bleeding of a bat with heat stroke. T. *brasiliensis. Bat World facility. Photo by A. Lollar.*

In August of 1995, the author found a small group of Brazilian free-tailed bats (*T. brasiliensis*) roosting on a screen behind a piece of plywood being used to board up a window in a vacant building. The bats had been trapped between the plywood and an inner window that had been closed. A pile of bats lay at the bottom of the window below those roosting on the screen. When the window was opened, a tremendous wave of heat escaped. All the bats were collected, put in transport carriers, and placed in front of the vehicle's air conditioner vents (set to high), where they remained during the five-minute trip back to the Bat World facility.

Of the 31 bats retrieved, only ten females and two males were alive. All of the bats were prostrate, with rapid shallow respiration and dazed expressions. Many were bleeding from the nostrils and had petechial hemorrhages on the wings (Figure 12-31A), legs, and tail membrane. One male had dried blood around the rectum, and four of the females had vaginal bleeding (Figure 12-31B). All twelve bats were injected with a room temperature (not warmed) electrolyte solution. One of the four females died. The nasal and vaginal bleeding in the others stopped completely within three to four hours. Hemorrhages in the wings and legs of the remaining 11 bats began to dissipate within two days. Necrotic tissue developed at the site of one hemorrhage on the tip of the tail of one female. All 11 bats recovered over the following two-week period.

Although many bat species are known to tolerate, even require, fairly high temperatures (particularly in maternity colonies), ventilation is critical to preventing heat stroke. Since the incident in 1995, the author has encountered several other instances of heat exhaustion in insectivorous bats both through personal experience and through communication with caretakers who left bats inside carriers that were placed in parked cars. During a heat wave in 1997, between 80 and 100 free-tailed bats (*T. brasiliensis*) at Bat World's wild sanctuary succumbed to heat exhaustion. Although windows provided some air flow, ventilation was increased in the building by use of fans aimed at the rafters. Sheets of plastic mesh was also secured to rafters to give the bats additional space to roost directly in the breeze of the fans. Within hours, hundreds of bats moved onto the netting, laying spread-eagle over the breeze of the fans. This netting is still utilized during hot temperatures, by pups as well as adult bats (Figure 12-32).

Treatment for Heat Exhaustion/Heat Stroke

Immediately move the bat into a cooler environment, such as the stream of cool air from an air conditioner so it can cool down gradually (a too rapid cool down can result in death). Keep the animal as calm as possible as any exertion will result in increased oxygen requirement. Inject 1.0 to 2.0 electrolyte solution soon as possible. The solution should be room temperature (not warmed). Administer oxygen for a period of 15 minutes. If a large number of bats suffering from heat stroke are received at the same time, they will need to be placed inside an oxygen chamber (see Oxygen Therapy).

A soft food mixture containing baby food banana (to help replace lost potassium) can be offered to a bat within six to eight hours of administration of the first injection of electrolytes if the bat has responded to treatment by becoming alert and aware. The soft food diet should be offered two to three times a day for the next two to four days, then feedings reduced to twice a day.

Figure 12-32. Free-tail mothers and pups taking advantage of a breeze during hot weather by laying on netting positioned above a nearby fan. (*T. brasiliensis*). *Photo by A. Lollar.*

Frostbite

Frostbite is characterized by the freezing of tissue. Wrists, elbows, thumbs, ears, and feet are most likely to be affected. Mild cases involve only the epidermis and are characterized by redness or hard white patches on the skin, swelling, and/or a waxy appearance. In more severe cases, there may also be the formation of blisters filled with a clear or milky fluid, or blood-filled blisters that turn black and slough off over a matter of weeks (Figure 12-33). The most severe cases of frostbite involve the epidermis, dermis, subcutaneous tissue, and deeper structures such as muscle, nerve, and bone. If the blood supply to the area is affected, the tissue will die, requiring amputation. Bats with frostbite may also be suffering from hypothermia. If this is the case, the bat must be treated for hypothermia first.

Treatment for Hypothermia

Clinical signs of hypothermia can include poor coordination, rigid muscles, slow respiration, violent shivering in waves (pauses and then begins again) and curling into fetal position. Handle the bat very gently if it exhibits signs of hypothermia. Rehydrate with a warmed electrolyte solution. Make sure the bat is dry, then wrap the bat in a warmed cloth, leaving only the muzzle protruding. A cloth can be quickly warmed in a microwave for 10 to 15 seconds (check against your wrist to ensure the cloth is not too hot). Alternately, an exam glove filled with warm water can also be used to warm the bat. Replace the cloth or glove with a warmed one as soon as it begins to cool. Offer warm fluids such as sugar water or Progenix Recovery every fifteen minutes. Frostbite injuries should be treated as soon as the bat appears alert and responsive.

Treatment for Frostbite

Do not massage, rub, or apply dry heat directly to frostbitten areas as this can further damage the tissue. Instead, apply warm compresses to affected areas as often as the bat will tolerate for the first 24 hours post exposure, taking care not to rupture any blisters. If skin or blisters have ruptured, gently disinfect topically with a 10% Nolvasan® solution and pat dry with a sterile gauze pad. Oral administrations of Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered to bats with tissue damage from frostbite (see Medications). Keep affected tissue clean and dry during the recovery period, which may take several weeks. Be meticulous in keeping enclosures clean throughout the treatment period.

Figure 12-33. A: A big brown bat with blood-filled blisters from frostbite. *E. fuscus. Photo by D. Kinamon.* **B:** A little brown bat with deep tissue damage from frostbite. *M. lucifugus. Photo by D. Kinamon.* **C:** A little brown bat with healed injuries from frostbite involving the tips of the ears and the wings. *M. lucifugus. Photo by A. Lollar.*

Insect Stings and Spider Bites

Bats can be stung by spiders or stinging insects. Clinical signs of insect stings can include prostration and a large area of localized swelling. The fur on the top of the head and around the neck may stand erect, creating a "lion's-mane" appearance. Clinical signs of allergic reactions to insect bites may include disorientation, respiratory distress, seizures, and collapse. The bat may crawl repeatedly in a circular motion as if slowly chasing its tail.

Allergic reactions require immediate subcutaneous injections of epinephrine and dexamethasone (see Medications). Because secondary infections can result from such stings, antibiotics must be administered, as well as pain medication. For the first few days, it may be necessary to feed the bat a soft food mixture, as it is likely to experience a loss of appetite. Some of these animals may only accept a small amount of food at each feeding. Appetite should improve within three to four days. Denosyl or milk thistle should be administered to bats suspected of sustaining insect stings as the venom can result in liver damage.

FIRE ANTS

Fire ants (genus *Solenopsis*) found throughout parts of the southern United States bite and sting (Arnett, 1993). As many as several hundred ants will cover a debilitated animal, biting and stinging it repeatedly. They are responsible for the death of many young and incapacitated animals. Fire ants can completely cover a grounded bat within seconds. Ants should be brushed from the bat's body as quickly as possible. Euthanasia may have to be considered when a bat has received ant bites on more than 50% of its body. Keep in mind that a bat covered with fire ants may well have an injury or illness that caused it to be grounded in the first place.

Apply Chlor-a-flush and then Manuka honey topically to the affected area. Rehydrate with an electrolyte solution (see Dehydration and Fluid Replacement Therapy) and administer dexamethasone. Oral administrations of Denosyl, Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered (see Medications). Encourage the bat to eat by gently placing small amounts of soft food in its mouth. Wait for the bat to swallow before offering another bite. Bats that do not improve within 24 hours should be humanely euthanized.

WASP AND BEE STINGS

Wasp and bee stings can occur when bats roost behind window shutters, trees, or anywhere near the nests or hives of stinging insects. Yellow jackets are particularly aggressive wasps. Stings frequently occur to bats' heads and cause the area to puff up significantly. The fur may stand on end, giving the appearance of a lion's mane (Figure 12-33). Other clinical signs of stings can include panting, wincing, mouth breathing or anorexia.

If a stinger is present, do not push or squeeze it as this may cause more venom to be injected. Instead, gently scrape the stinger out with the edge of a fingernail file or similar object. Lance the region around the bite with a 20-to-25-gauge hypodermic needle to expel excess fluid. Apply Chlor-a-flush and then Manuka honey topically to the affected area. Rehydrate with an electrolyte solution (see Dehydration and Fluid Replacement Therapy) and administer dexamethasone.

Figure 12-34. Red bat suffering from a yellow-jacket sting. *L. borealis. Photo by D. Kinamon.*

Oral administrations of Denosyl, Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered (see Medications). Encourage the bat to eat by gently placing small amounts of soft food in its mouth. Wait for the bat to swallow before offering another bite. Bats that do not improve within 48 hours should be humanely euthanized.

SPIDER BITES

Spider bites sometimes occur on bats roosting in buildings. Several species of spiders, including the brown recluse, have bites that can result in necrotic wounds. Spider bites often occur on the head, back or forearms. A large puffy area at the site of the bite is often the first visible sign. Bites on the head usually include swelling of both ears. Prostration, rapid respiration and anorexia can also occur. As swelling subsides, a centralized wound surrounded by hard necrotic tissue (known as the bull's-eye) may become visible on bats that have been bitten by brown recluse spiders (Figure 12-34).

Lance the area around the bite with a 20-to-25-gauge hypodermic needle to expel infected fluid. Apply Chlor-a-Flush and then Manuka honey topically to the affected area. Rehydrate with an electrolyte solution (see Dehydration and Fluid Replacement Therapy) and administer dexamethasone. Oral administrations of Denosyl, Veraflox® and Metacam® once daily, along with oral Clavamox twice daily, for 21 days should be administered (see Medications). Encourage the bat to eat by gently placing small amounts of blended food in its mouth. Wait for the bat to swallow before offering another bite. Bats that do not improve within 48 hours should be humanely euthanized.

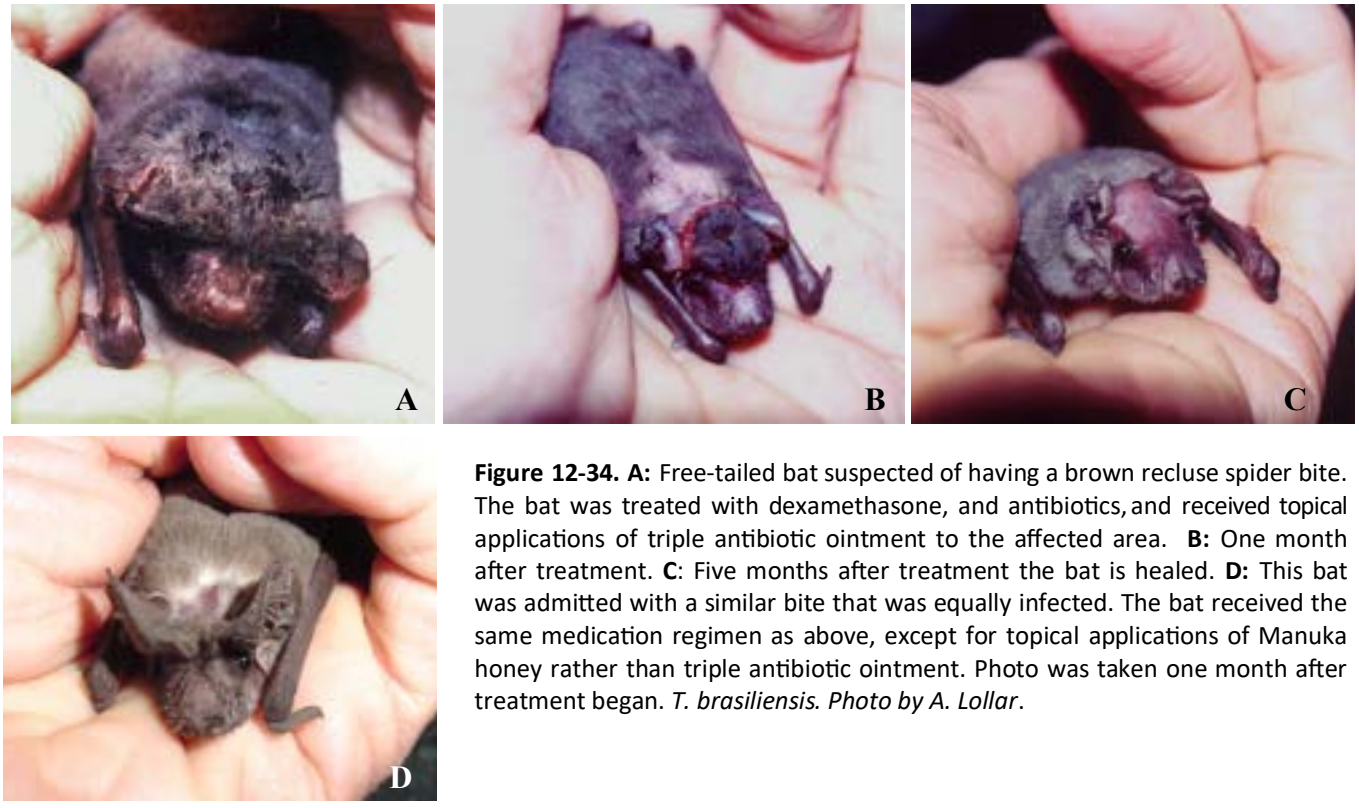


Figure 12-34. A: Free-tailed bat suspected of having a brown recluse spider bite. The bat was treated with dexamethasone, and antibiotics, and received topical applications of triple antibiotic ointment to the affected area. **B:** One month after treatment. **C**: Five months after treatment the bat is healed. **D:** This bat was admitted with a similar bite that was equally infected. The bat received the same medication regimen as above, except for topical applications of Manuka honey rather than triple antibiotic ointment. Photo was taken one month after treatment began. *T. brasiliensis. Photo by A. Lollar*.

Chapter Thirteen

Hibernation, Release and Euthanasia

Hibernation

During the winter in some parts of the world, ambient temperatures drop significantly and adequate food (i.e., insects) is not available for an extended period of time. Some species of bats simply migrate to warmer climates where food is available. Other species adapt to temperate conditions by entering hibernation, a physiological state in which metabolic activity is decreased to minimal survival levels. Many bats decrease energy demands by entering a daily state of inactivity called torpor. By allowing body temperatures to approximate the ambient temperature, they are able to decrease energy demand. Heart rates of bats in daily torpor may drop to 40-80 beats per minute, while rates as low as 10 beats per minute have been recorded in some bats during winter hibernation This is a significant decrease as heart rates of 250 to 450 beats per minute have been recorded for some bats at rest, while rates in flying bats can reach 1000 beats per minute. A little brown bat (*M. lucifugus*) has a daily energy budget of 0.89Kcal/g/day which means that a 7g little brown bat requires 6.23kcal (6230 calories) per day (Hill and Smith 1984). Because smaller mammals (such as bats) have greater surface-area-to-volume ratios than larger ones, they require more calories per gram of body weight to maintain thermal homeostasis.

Many of the bats of the family Vespertilionidae in the United States and Canada enter hibernation during winter months. Some species migrate short distances to specific hibernation sites in caves or abandoned mines where temperatures remain relatively constant. Others stay in the same location year-round when the temperatures drop. Big brown bats *(E. fuscus*), a species that commonly roost in the attics of homes, sometimes hibernate there throughout the winter months.

Some bat species hibernate in tightly packed clusters. By clustering with one another they are better able to stabilize body temperatures against potential environmental fluctuations. Other species hibernate singly or in small groups. When ambient temperatures rise in the spring, hibernating bats arouse. There is an increase in both the heart rate and the respiratory rate, and a subsequent increase in body temperature. Different species of bats arouse from hibernation states at different rates, so it will take some bats longer to warm up than others.

If awakened from hibernation, bats experience an increase in metabolic activity, using up stored fat needed to survive the remainder of the winter. Although hibernating bats may arouse during winter, each arousal leads to the expenditure of almost 30 days of body fat. Hibernating bats are therefore extremely sensitive to disturbances. In addition, because some species of bats come from multi-state regions and congregate in great numbers (as many as tens or even hundreds of thousands of individuals) at a small number of hibernation sites, disruption and disturbances of any kind can result in the loss of large numbers of bats important to the agricultural interests of farmers far from the site.

Some bat species make long migrations when colder weather arrives. The hoary bat (*L. cinereus*), the red bat (*L. borealis*), and the silver-haired bat (*L. noctivagans*) can be found as far north as Canada in the summer but are known to make long migrations to the southern United States and Mexico in the winter. Some species, such as those in the family Molossidae, are not able to tolerate cold temperatures for extended periods of time and migrate to warmer climates during cold months. In the United States, southwestern populations of Mexican free-tailed bats make long migrations to parts of Mexico where they spend the winter. A sub-species of the Brazilian free-tailed bat remains in warmer parts of the southeastern United States year-round. Although the Molossidae are not true hibernators, they are capable of entering daily torpor. See Roosting and Hibernating Patterns on page 5 for additional species information.

Artificial hibernation allows a busy rehabilitator the luxury of minimizing the time needed to care for healthy bats that must remain in captivity for several months before release. If a caretaker receives dozens of bats disturbed during hibernation, artificial hibernation allows the opportunity to maintain all of the bats for the remainder of the winter, something that might not be possible if each individual required daily care. Hibernation in captivity does not appear to be necessary for the survival of a bat. Some bat care specialists hibernate bats simply because they prefer to duplicate natural conditions when possible.

Review by Wimsatt (1969), has shown that sperm storage is one facet of the complex reproductive adaptations of bats living in temperate latitudes where a period of hibernation occurs during prolonged oestrus. Females that have mated may give birth during the winter or early spring if they are kept from entering normal hibernation. Normally, fertilized ova implant when females arouse from hibernation, but artificially warm conditions, low stress, and appropriate nutrition have resulted in out-of-season births in hibernating species. Males and females housed together under artificially warm conditions may engage in mating behavior outside normal mating periods, which may also affect seasonal cycles of mating, fertilization, implantation, and gestation.

Never attempt to hibernate a non-hibernating species; nor a bat that is sick, underweight, or injured. The animal is unlikely to survive, and even if it does, healing of bones and tissue will slow significantly if not altogether. Only a healthy bat of a species that normally hibernates should be artificially hibernated in captivity.

A bat that appears healthy but has been disturbed during hibernation is a potential candidate for artificial hibernation. (Renovation of buildings sometimes disturbs hibernating bats.) Bats should be rehydrated and fed for at least two days before being placed in artificial hibernation. If the bat does not approach the upper end of the weight range for its species, it should not be artificially hibernated (i.e., do not hibernate a thin bat, which is often the case with juveniles).

Hibernating bats require very specific temperatures and humidity levels. An artificial hibernaculum needs to duplicate these conditions as much as possible. Older refrigerators have been used successfully to hibernate bats; however, the use of modern, frost-free refrigerators is considered an unnatural and inhumane practice as the humidity levels are much too low (Barbosa, 1996).

The ambient temperature during the winter may allow caretakers to hibernate a bat in an unheated room, such as a garage. However, the temperature in this room should not drop below 40° Fahrenheit, and in some parts of the United States and Canada, temperatures in garages will drop far below freezing for extended periods of time. Many bats may not be able to survive such conditions. If this is the case in your area, unused rooms or basements that have some heat, but remain relatively cool, may provide more appropriate temperatures. Temperatures in a room used to hibernate bats should remain at least in the low to mid 40℉s. Surprisingly, some species, such as big brown bats (*E. fuscus*), have been successfully hibernated for the winter without supplemental feedings at temperatures ranging from the lower 50℉s to the mid 60°'s. In some parts of the U.S. various species of bats have different temperature preferences in the wild. Variations may even exist within the same species from one geographical area to another. However, it is not recommended that either the upper or lower temperature ranges exceed these temperatures, as they have proven optimal for hibernating bats in captivity. Do not hibernate bats at freezing temperatures. Bats undergoing artificial hibernation must also be able to maintain sufficient body temperature with minimal outlay of energy.

Once an appropriate location has been chosen, set up an enclosure with a heating pad over a section of the top or on one side of the enclosure for warmth. In the wild, many bat species arouse from hibernation if temperatures drop below a certain level and move to areas where conditions are more favorable. While a heating pad will allow a bat to move on or away from a warmer spot. Roosting pouches should be placed in numerous positions throughout the enclosure for crevice dwelling species. When possible, it is best to allow bats to hibernate in clusters of individuals as they normally do in the wild. For example, if a caretaker receives a small colony of big brown bats that were disturbed during hibernation, it would be best to hibernate them together as a group.

High humidity levels in a natural hibernaculum can result in the condensation of water droplets on bat's fur, thus making water available to the bat. In addition, relative humidity in many hibernacula approaches 90%. Bats in the wild sometimes arouse from hibernation to find water and replenish their fluids. In captivity, a small, shallow dish of water should be placed inside the enclosure and fresh water should be available to hibernating bats throughout the entire hibernation period.

We cannot perfectly duplicate natural hibernation. Because bats kept in artificial hibernation do not have access to their natural environment, the author recommends that bats be deliberately reawakened (see below) and provided with food and water periodically throughout the entire hibernation period.

Record the weight of the bat before initial hibernation and each time it is awakened and fed. The bat's initial weight should be in the upper end of the weight range for this species. The author recommends that a hibernating bat be reawakened, weighed, and fed after the first three days. If the bat appears healthy and has not experienced a significant weight loss (i.e., it is not at or below the lower end of the weight range for the species), continue to awaken and care for it once every one to six weeks thereafter throughout the normal period of hibernation (i.e., winter months).

To awaken a bat from hibernation, allow it to warm up to room temperature slowly. Do not force the animal into any kind of heated container. Instead, move the entire enclosure into a warmer room. Allow the animal to warm up slowly on its own. It will take different species of bats different periods of time to arouse, so allow the bat at least one to two hours to warm on its own before handling. Once it has warmed, weigh it, and then offer it water and food. Then return it to the enclosure (which should have remained at room temperature) for the night so it can complete the digestion process. If the bat appears well and has maintained a body weight at the upper end of the weight range for the species, it can be placed back into hibernation.

If the bat is kept out of hibernation for longer than 12 hours, it should be fed again as metabolic activity will have increased. The procedure of awakening and caring for a bat that is hibernating in captivity should be repeated once every one to six weeks throughout the hibernation period. Although many researchers have artificially hibernated bats for a matter of months without intermittent feeding, more frequent feedings allow caretakers to ensure the continued good health of each individual which will likely result in higher survival rates.

If intended for release, artificially hibernated bats should not be released until outdoor ambient temperatures have warmed sufficiently to allow an insect population. It is not necessary to hibernate bats kept in permanent captivity, even if they would normally do so in the wild. Hibernation is a method by which bats in the wild survive periods of sub-optimal temperatures and an insufficient food supply, a problem bats in captivity do not experience.

Again, artificial hibernation is a method by which a busy caretaker, who is already caring for several bats, or who receives dozens of bats disturbed during natural hibernation in the wild, can minimize his or her time. This allows a caretaker the opportunity to care for many more individuals than would be possible if each bat required daily care. In addition, artificial hibernation may also help to ensure normal timing of fertilization, implantation, or fetal development in females of reproductive age. Timing of births is important because rearing young needs to coincide with optimal temperatures and food availability in the wild. It is possible that artificial hibernation may help to ensure the survival of offspring of female bats released in the spring.

Releasing Bats to the Wild

First and foremost, bats must demonstrate perfect flight ability before being released. Bats that do not demonstrate perfect flight are not likely to survive in the wild. Bats depend on flight for feeding, avoiding predators, etc. Wing injuries will render a bat non-releasable. Tooth loss, back or leg injuries (i.e., fractures of the leg bones), and some complications associated with pregnancy will also render a bat non-releasable (see Infections of the Gums and Teeth, Back and Leg Injuries, and Caring for Pregnant and Lactating Females sections).

Releasing Hand-Raised Orphans

Questions have long been raised regarding the wisdom of releasing insectivorous bat orphans raised in captivity. Research suggests that young bats need time to acquire the skills necessary to successfully capture flying insects (Davis and Hitchcock, 1965). It is further suggested that young may learn these techniques by spending a considerable amount of time foraging with their mothers when they are young (Brigham and Brigham, 1989).

The author has recaptured several tattooed hand-raised Brazilian free-tailed (*T. brasiliensis*) bats after they were rescued as orphans ranging from a few hours to a few weeks old. These bats were subsequently hand-raised and released back to the wild after they were determined to be able to survive on their own. Microscopic examination of a fecal sample from a juvenile recaptured two days after release revealed insect parts (Lollar, 2008). Another juvenile was recaptured 11 days following release and three were recaptured three, five and seven days after release. In 2006, a tattooed adult female was found approximately 400 miles away five years after release, and in 2015, a tattooed adult female *T. brasiliensis* was found 13 years after release.

Additionally, the recapture of a hand-raised evening bat (*N. humeralis*) was reported 16 days following release (Laura Finn, pers. comm.), and the recapture of a hand-raised pallid bat (*A. pallidus*) was reported approximately seven months after release (Christine Scott, pers. comm.). Orphaned red bats (*L. borealis*) and yellow bats (*L. intermedius*) have learned to forage on their own and also exhibited predator avoidance behavior by darting into small trees when an owl flew over their flight enclosure (French, pers. comm.) Microscopic examination of feces of red bat orphans (*L. borealis*) indicates that orphans begin feeding preferentially on available prey when placed in large outdoor flight enclosures (French and Whitaker, 2000). On June 17th, 2003 an orphaned big brown pup (*E. fuscus*) weighing 2.9 grams was rescued with eight other orphaned big browns. This female was released on August 24th, 2003, and recaptured one month later on Sept. 24th, 2003. The bat was in excellent physical condition with a recorded weight of 17.0 grams (Barbosa, 2003). Most significant, however, involved a report of a small colony of seven-year-old big brown bats (*E. fuscus*) which had remained in captivity since infancy. These bats had never been exposed to live prey but were fully flighted. At age seven, the bats were moved into an outdoor flight enclosure, and a bucket light trap containing live flighted insects was emptied into their enclosure. Although the bats were provided with their normal ration of mealworms, they began to prey on the insects the very same night, as evidenced by insect wing parts on the flight enclosure floor the next morning. The following evening insects were again introduced into the flight area, and the next morning the flight enclosure floor was again littered in insect wings. A number of these wings were subsequently identified as belonging to the following families:12 *Arcttidae* wings; 25 *Nocturidae* wings; 5 *Nymphalidae* wings; 1 *Torticidae* wing; and 5 *Saturnidae* wings. Four unknown wings were also found. These bats remained in the outdoor flight enclosure for approximately one month where they continued to feed on flying insects and were eventually released into a maternity colony of *E. fuscus* (Barbosa, 2005). These reports demonstrate beyond doubt that hand-raised pups can survive after release, even though they did not have any opportunity to spend a considerable amount of time foraging with their mothers beforehand.

Supplemental feedings of mealworms or the soft food diet is recommended for orphaned bats while in a pre-release flight enclosure. Milk formula appropriate for the species may also be offered to these bats. Juvenile bats must maintain appropriate weights before being released. Additionally, these bats must exhibit significant flight abilities before release to successfully forage and avoid predators in the wild.

Releasing Adult Bats

Bats that have been in captivity for more than a few days should be given daily flight exercise before being released. As a rule of thumb, the bat should be given one night of flight exercise in a flight enclosure for every day in captivity. Alternately, a bat can be exercised in a room, with careful monitoring. The bat should be given 10 to 20 minutes of flight exercise per day in captivity. Wait at least 10 minutes after feeding before flight exercise.

Hold the bat in your hand over your head while inside a flight enclosure or a room that is closed off from other rooms. Release your fingers so that the bat is not confined in your grip, but merely sitting in the palm of your hand. The bat will typically stretch its wings once or twice before taking flight. If the bat has sufficiently recovered from injuries and has a proper flight area, it will generally attempt to take flight. Bats must be able to sustain flight for 5 to 10 minutes and must land and roost appropriately on the ceiling or upper portion of the enclosure. A bat that seems to fly well but continually lands on the floor is not ready for release.

Bats have a strong affinity for day and night roosting sites, as well as established feeding grounds. It is always best when possible to release a rehabilitated bat in the general area from which it originated, and even back into its original colony if this information is available. Solitary bats, of course, such as red bats (*L. borealis*), may simply be released in the area from which they came. When this information is not available, attempt to release in areas that provide known roosting and feeding requirements for the species. For example, red bats *(L. borealis*) roost in tree foliage, particularly along fence rows surrounding agricultural crops. These bats should not be released in bat houses or other structures used by crevice-dwelling species. Big brown bats (*E. fuscus*), on the other hand, are crevice-dwellers and need to be released in areas with known colonies of this species where natural (or man-made) crevices exist. When the location of roosts or colonies of the species is not known, bats (including solitary tree bats) should simply be released in areas that provide appropriate habitat for the species.

On numerous occasions the author has witnessed wild free-tail bats (*T. brasiliensis*) coming to investigate other bats being released, including red bats (*L. borealis)*. The bats often swoop by in very close proximity to a bat being held overhead for release. During one instance, two dozen *T. brasiliensis* had been rescued from a building and overwintered together in a flight enclosure. The bats were released the following spring. They were released in small groups of two to four, held overhead in the hand. As each small group was set free, they began to circle back, swooping close to the next group of bats being held overhead. The number of bats circling in the air continued to increase as more bats were set free. This behavior continued until there were no bats left to release.

Always release bats at nightfall (never at dusk when predators can easily locate the bat) and always take a spotlight along for hand releases to retrieve the bat if necessary. **Always hold your hand over your head to release the bat**. Use a ladder, if necessary, to provide bats at least a 7’ to 8’ drop. Use the flashlight to make sure the bat remained airborne and flew away safely.

Never release a bat by placing it on a tree trunk or the side of a building as it may be eaten by predators before it is able to fly away. Female tree bats with pups are the only exception to this rule. However, they should also not be placed on the trunk of a tree. Instead, carefully placed them on the branches of a tree (with a clear drop below) in the early afternoon and at least 10 feet off the ground. There should be several branches with foliage surrounding the mother and her pups to help conceal them from possible predators. Do not hang the mother from a single branch. It is best to place her in a forked branch within a clump of leaves so she has better support and is somewhat hidden from view. If not disturbed before being placed in the tree, she will hang quietly with the pups until dark. Females that become stressed during this move will fly off and may not return for the young. Although the female may hang the pups in the tree after dark and then fly off to feed, she may return for one or more of the pups before dawn. The tree must be checked again in the early morning to determine if any pups were abandoned. A red bat will frequently abandon one or more of the young; these pups must be retrieved and hand-raised.

Euthanasia

Euthanasia is defined as the act of inducing humane death. Ideally, the method used to administer painless death to an animal should cause minimal stress throughout the procedure. It should result in rapid unconsciousness, followed by cardiac or respiratory arrest, and ultimately, loss of brain function. The current preferred methods of euthanasia for insectivorous bats are by inhalant anesthetics such as isoflurane and halothane.

UNACCEPTABLE METHODS

Carbon dioxide gas is often used in specially designed chambers to euthanize small laboratory animals. In mammals of similar size to insectivorous bats, such as mice, carbon dioxide has rapid depressant and anesthetic effects and is considered conditionally humane. However, insectivorous bats have a high tolerance to carbon dioxide. When 25 pallid bats (*A. pallidus*) were euthanized at Texas A&M University, a research assistant noted gasping, and contortions in each of the bats for a period of one to three minutes. When suffocation was thought to be achieved, each bat was placed into a plastic zip-lock bag and placed into a refrigerator to await tissue sample collection to test for rabies. A small number of these bats remained in a semi-conscious state after being placed into plastic bags and then awoke while being necropsied (at which time their necks were broken) (M. Singleton, pers. comm.). Two species (*T. brasiliensis* and *L. borealis*) suspected of rabies were euthanized with a specially designed $C0_2$ chamber by the author in 1998. Similar distress was noted in both species. (These bats were removed from the $C0_2$ chamber and euthanized instead with isoflurane.) The author, therefore, considers $C0_2$ an unacceptable method of euthanasia for insectivorous bats.

T-61, Ketamine, Telazol, and Diazepam are not acceptable means of euthanasia for insectivorous bats. T-61 is a non-barbiturate, non-narcotic, injectable used for euthanasia. Although it may be available to animal caretakers in Canada, it is no longer commercially available in the United States. It provides a combination of general-anesthetic, curariform, and local-anesthetic actions. The AVMA Panel on Anesthesia recommends that, if the drug is used at all, it should be administered only intravenously as there is some question as to the absorption and onset of action when administered by other routes. Because curariform causes paralysis, including that of the respiratory system, an animal could be conscious and aware as it suffocates. The author, therefore, considered it unacceptable as a means of euthanasia.

Ketaset®/PromAce is a combination of Ketamine hydrochloride and Acepromazine, a general anesthetic and a tranquilizer. Although it has been injected subcutaneously to euthanize bats, it is known to induce an excitability phase characterized by tremors and vocalization preceding loss of consciousness. The author, therefore, considers it unacceptable as a means of euthanasia in bats.

Freezing was recommended as a method to euthanize torpid bats for many years (Barnard, pers. comm). The AVMA lists the rapid freezing of conscious animals as inhumane but does not address torpid animals. Although bats enter a state of torpor when subjected to cold temperatures, they may awaken to full consciousness in an attempt to find a warmer location as their body temperature approaches lethal level. The author, therefore, considers it unacceptable as a means of euthanasia in bats.

ACCEPTABLE METHODS

Halothane and Isoflurane are the preferred inhalants and recommended by the author for euthanizing bats. Both chemicals produce a moderately rapid anesthetic effect followed by death when used in high enough doses (concentrations) or with prolonged exposure.

Insert a cotton ball into the plastic casing used as packaging for a 6ml syringe and then pour 5.0ml of Halothane or Isoflurane onto the cotton ball. If the bat is calm, it can be placed in a roosting pouch, soft cloth or held in hand. Place the open end of the plastic casing near or the bat's head. Do not shove the bat's head into

the casing so far that it panics, but rather hold the casing just above its head (see Anesthesia section) until the anesthetic effect is obvious. It should take less than a minute for the bat to succumb and it should exhibit no signs of distress during this process. Once the bat is unconscious, completely cover its head with the casing, and place the bat into a small airtight container, in a quiet location, for one to two hours. Use a neonatal stethoscope to insure the heartbeat has stopped.

Bats that are difficult to handle should be put in a roosting pouch or dark cloth and placed in a small plastic container with a tight-fitting lid (Figure 13-1). Place the plastic casing with the cotton ball (which has been saturated with the inhalant) into the container and close the lid. The plastic casing should not be placed directly in front of the bat's face. Although the bat will fall asleep quickly, wait for one to two hours before checking for a heartbeat with a neonatal stethoscope.

Figure 13-1. A euthanasia box. Crevice bats are placed inside the pouch and tree bats are placed on top of the pouch. Cotton inside the plastic casing is saturated with isoflurane and the lid is then closed. *Bat World facility. Photo by A. Lollar.*

An injectable method of euthanasia may be preferred to euthanize bats that are suffering from respiratory distress. The preferred injectable medications are Acepromazine and Butorphanol Tartrate (0.008ml/g of body weight) mixed with Xylazine (0.01ml/g of body weight). The solution should be warmed before injecting. Mix 0.05ml Acepromazine with 0.05ml Butorphanol Tartrate and 9.8ml of an electrolyte solution. Administer 0.08ml SQ. Put the bat in a roosting pouch or in the folds of a soft cloth. Wait 20 minutes before administering 0.1 ml Xylazine. Alternately, sodium pentobarbital (euthanasia solution) can be administered intraperitoneally after the bats is sedated.

Bats are usually anesthetized within minutes; however, the bat should be left undisturbed and safely contained in a quite, dark location for several hours. Ensure death has occurred by checking for respiration and heartbeat.

Products

Aluminum Tubing
Outwater Plastics
Phone : 1-800-631-8375

Automotive Expansion Plugs
Available at automotive supply stores.
Pioneer, Inc. Part # EPC-178-88-10

Bat Hut
www.batworld.org

Boston Rounds
U.S. Plastic Corporation: 800-809-4217

Breeze and similar enclosures
amazon.com

Calsorb™
Chris's Squirrels and More

Calcium Carbonate Powder
www.hilife-vitamins.com

Cetacaine® Topical Anesthetic Gel
www.shopmedvet.com:
Item # rxceta-gel

Chlor-a-Flush
http://www.shopmedvet.com/product/335/rxc

CHX Gel
Available at veterinary supply stores

Cube Enclosures
Amazon.com

Cranberry Juice Powder (organic)
Amazon.com

Ecogen™ Magnetic Bin
Available at office supply stores

Econo-Heaters
http://econo-heater-warehouse.com
888-877-4522

Eye Shadow Applicators (foam nursing tips). Sally Beauty, Item # SBS-

EZ-Up Canopy Pop-up Tent
Amazon.com

Flax oil (cold pressed)
Available in the refrigerated section of health food stores

Gluture® (tissue adhesive)
Abbot Animal Health
www.abbott.com

Hair dryer (travel)
http://www.hdryers.com/travel-size-hair-dryers.htm

Head Loop
Amazon.com
800-355-2137

Hide-a-Squirrel
www.upco.com, item # 10573

Humidity Chamber (pvc cooler strips).
www.pvcstrip.com/about-doors-

Interdental Brushes
Available at drug stores in the dental hygiene section.

Laminated Polyester
www.mytarp.com/vinyl-tarps-13-oz-20x30.aspx. 404-551-4347

Lumite (BioQuip) Caging
310-667-8800

Magnaturals (enrichment, roosts, and dishes). Pet-Tech. 800-854-7387

Magnetic sheeting material
(cave roost) www.custom-

Manuka honey
www.manukahoney.com

Mesh Fabric (Phifertex®)
www.glfi.comvinylbook_phifertex.htm

Milk Thistle (liquid, no alcohol)
Available at health food stores

Missing Link® (equine or feline)
www.missinglinkproducts.com

Neodymium Magnets
www.emovendo.net/magnets/rings/
304-257-1193

Nitrile Gloves and Finger Cots
Available through medical supply stores and amazon.com.

Nolvadent
www.petrx.com: 888-889-1814

Oravet® Plaque Prevention Gel
http://www.oravet.us.merial.com/vets/product_home.html

O-ring Syringes
Chris's Squirrels and More
877-717-7748

Oxyfresh dental additive
amazon.com

Polypropylene mesh (1/6)
Product # OV-7100

PVC Plastic Lumber
Available at lumber yards

Progenix Recovery
Amazon.com

PVC Wire-coated Mesh
CE Shepherd Company
713-924-4300

Roosting Pouches (pattern)
batworld.org

Spirulina Powder
amazon.com

Stainless Steel Binding
M-D Building Products. 800-654-8454

Vionate® Powder
Chris's Squirrels and More

Zoomesh (1/8")
www.pwrconcepts.com. 800-334-5330

Metric Conversions

VOLUME

Multiply milliliters (ml) by 0.03 to find fluid ounces (fl oz).*
Multiply liters (L) by 2.113 to find pints (pt).
Multiply liters (L) by 1.057 to find quarts (qt).
Multiply liters (L) by 0.264 to find gallons (gal).

1 liter = 2.113 pints
1.057 quarts
0.264 gallons

Multiply teaspoons (tsp) by 5 to find milliliters (ml).*
Multiply tablespoons (tbsp) by 15 to find milliliters (ml).*
Multiply fluid ounces (fl oz) by 30 to find milliliters (ml).*
Multiply cups (c) by 0.24 to find liters (L).*
Multiply pints (pt) by 0.473 to find liters (L).
Multiply quarts (qt) by 0.946 to find liters (L).
Multiply gallons (gal) by 3.785 to find liters (L).

1 drop = 0.05 milliliters
1 teaspoon = 5 milliliters
1 tablespoon = 15 milliliters
1 fluid ounce = 30 milliliters
1 cup = 0.24 liters
1 pint = 0.473 liters
1 quart = 0.946 liters
1 gallon = 3.785 liters
1 tablespoon = 3 teaspoons
1/4 cup = 4 tablespoons
1 pint = 2 cups
1 quart = 4 cups
1 quart = 2 pints
1 gallon = 4 quarts

Note: cc is an abbreviation for cubic centimeter (cm3). It is a unit of volume in the CGS metric measurement system. 1cc is essentially equivalent to 1ml (milliliter).

LENGTH

Multiply millimeters (mm) by 0.04 to find inches (in).*
Multiply centimeters (cm) by 0.394 to find inches (in).
Multiply meters (m) by 3.281 to find feet (ft).
Multiply meters (m) by 1.093 to find yards (yd).
Multiply kilometers (km) by 0.621 to find miles (mi).

1 millimeter (mm) = 0.04 inches (in)
1 centimeter (cm) = 0.394 inches (in)
1 meter (m) = 3.281 feet (ft) =1.093 yards (yd)
1 kilometer (km) = .621 miles (mi)

Multiply inches (in) by 2.54 to find centimeters (cm).
Multiply feet (ft) by 30.48 to find centimeters (cm).
Multiply yards (yd) by 0.914 to find meters (m).
Multiply miles (mi) by 1.609 to find kilometers (km).

1 inch (in) = 2.43 centimeters (cm)
1 foot (ft) = 30.48 centimeters (cm)
1 yard (yd) = 9.14 meters (m)
1 mile (mi) = 1.609 kilometers (km)

MASS/WEIGHT

Multiply grams (g) by 0.035 to find ounces (oz).
Multiply kilograms (kg) by 2.205 to find pounds (lb).

1 gram (g) = 0.035 ounces (oz)
1 kilogram (kg) = 2.205 pounds (lb)

Multiply ounces (oz) by 28.35 to find grams (g).
Multiply pounds (lb) by 0.454 to find kilograms (kg).

1 pound (lb) = 16 ounces (oz)

TEMPERATURE

Multiply degrees Celsius (C) by 9/5 and add 32 to find degrees Fahrenheit (F).
Subtract 32 from degrees Fahrenheit (F) and multiply the difference by 5/9 to find degrees Celsius (C).

* Approximations

References

Adams, R. A., and S. C. Pedersen (2000). *Ontogeny, Functional Ecology, and Evolution of Bats*. Cambridge University Press

Aguilar-Setie´, A., Campos, Y., Cruz, E., Kretschmer, R., Brochier, B., and P. Pastoret. (2002). *Vaccination of vampire bats using recombinant vaccinia-rabies virus.* Journal of Wildlife Diseases, 38(3), pp. 539–544. Wildlife Disease Association 2002

Airola, P. (1974). *How To Get Well*. Health Plus. Phoenix, Arizona

Allen, A. A. (1921). Banding Bats. *Journal of Mammalogy* 2: 53-57

Allen, K. L., Hutchinson, G., and P.C. Molan,. (2000) The potential for using honey to treat wounds infected with MRSA and VRE. First World Wound Healing Congress, Melbourne, Australia

American Veterinary Medical Association (2007). *Report of the AVMA Panel on Euthanasia*. Journal of the American Veterinary Medical Association. 202:229-249

Anthony, E. L. P. (1988). *Age determination in bats.* In T. H. Kunz (ed.), *Ecological and Behavioral Methods for the Study of Bats.* Smithsonian Institution Press. Washington, D. C.

Arnett, R. H. (1993). *American Insects: A Handbook of the Insects of America North of Mexico*. The Sandhill Crane Press, Inc. Gainesville, Florida

Arroyo-Cabrales, J., Hollander R.R., and J. Knox Jones, Jr. (1987). *Choeronycteris mexicana. Mammalian Species,* No. 291. The American Society of Mammalogists. New York

Australian Bird and Bat Banding Scheme. (2007). *Why Band Birds and Bats?* Retrieved August 26, 2008, from http://www.environment.gov.au/biodiversity/science/abbbs/whyband.html

Baer, G. M. (1975). Rabies in nonhematophagous bats. *The Natural History of Rabies*. Academic Press. New York

Baer, G. M., and G. L. Bales (1967). Experimental rabies infection in the Mexican free-tail bat. *Journal of Infectious Diseases*. 117:82

Baker, G. B., Lumsden, L.F., Dettmann, E.B., Schedvin, N.K., Schulz, M., Watkins, D., and L. Jansen. (2001). *The Effect of Forearm Bands on Insectivorous Bats (Mircrochiroptera) in Australia. Wildlife Research* 28: 229-237

Balcombe, J. P. (1990). Vocal recognition of pups by mother Mexican free-tailed bats, *Tadarida brasiliensis mexicana. Animal Behavior*. 39:960-966

Balcombe, J. P., and G. F. McCracken (1992). *Vocal recognition in Mexican free-tailed bats: do pups recognize mothers? Animal Behavior*. 43:79-87

Balcombe, J. (2006). *Pleasurable Kingdom*. Macmillan Press. New York

Barbosa, P. (1996). Hibernating Bats: Not in My Refrigerator? *Chiropteran Care*. 2:3

Barbosa, P. (2003). Release and Recapture of a Juvenile Big Brown Bat, *International Bat Rehabilitation Association*. 1:1

Barbosa, P. (2005). Instinctive Hunting Behavior in a Captive Colony of Female Big Brown Bats. *International Bat Rehabilitation Association.* 1:3

Barclay, M. R., and D. W. Thomas (1979). Copulation call of *Myotis lucifugus*: A discrete situation-specific communication signal. *Journal of Mammalogy*. 60:632-634

Barnard, S. (1995). *Bats in Captivity*. Wild Ones Animal Books. Springville, California

Bassett, J. E., and E. H. Studier (1988). Methods for determining water balance in bats. In T. H. Kunz (ed.), *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press. Washington, D. C.

Beer, J. R. (1955). Survival and Movements of Banded Big Brown Bats. *Journal of Mammalogy* 36: 242-248

Bell, J. F., Hadlow, W.J., and W. L. Jellison (1955). Chiropteran rabies in Montana. *Public Health Reports*. 70(10):991

Bell, J. F., Hadlow, W.J., and W. L. Jellison (1957). A survey of chiropteran rabies in western Montana. *Public Health Reports.* 72(1):16

Best, T. L., Kiser, W.M., and P. W. Freeman (1996). *Eumops perotis, Mammalian Species*, No. 534. The American Society of Mammalogists. New York

Bill, R. (1993). *Pharmacology For Veterinary Technicians*. American Veterinary Publications, Inc. Goleta, California

Biourge, V., Pion, P., Lewis, J., Morris, J.G., and Q. R. Rogers (1993). Spontaneous occurrence of hepatic lipidosis in a group of laboratory cats. *Journal of Veterinary Internal Medicine*. 7(3):194-197

Bohn, K1,2, B. French3, C. Schwartz,2, M. Smotherman,2, G. Pollak1. (2009). Versatility and Stereotypy of Free-Tailed Bat Songs. 1 Department of Biology, Texas A&M University, College Station, Texas, United States of America, 2 Section of Neurobiology, University of Texas at Austin, Austin, Texas, United States of America, 3 Bat Conservation International, Austin, Texas, United States of America

Bonaccorso, F.J. and N. Smythe (1972). Punch-Marking Bats: An Alternative to Banding. *Journal of Mammalogy* 53: 389-390. Department of Biology, Texas A&M University, College Station, Texas, United States of America, Section of Neurobiology, University of Texas at Austin, Austin, Texas, United States of America, 3 Bat Conservation International, Austin, Texas, United States of America

Boss, J. (1999). Olfaction and the use of chemical signals in bats. *Acta Chiropterologica*. 1(1):31-45

Braaksma, S. (1973). Some details about the occurrence of bats in summer and winter-resorts in the Netherlands and about the risks caused by wood preservation activities in buildings. *Periodical of Biology*. 75:125-128

Bowden J.J., Schoeb, T.R., Lindsey, J.R., and D.M. McDonal (1994). Dexamethasone and oxytetracycline reverse the potentiation of neurogenic inflammation in airways of rats with Mycoplasma pulmonis infection. Am. J. Respir. *Critical Care Medicine*, Vol 150, No. 5, 1391-1401;Cardiovascular Research Institute and Department of Anatomy, UCSF

Bradbury, J. W. (1977). Social organization and communication. *Biology of Bats*. Academic Press, New York, 3:1-72

Bradbury, J. W. (1977). Lek mating behavior in the hammer-headed bat (*Hypsignathus monstrosus). Zeitschrift furTierpsychologie*. 45:225-255

Bradbury, J. W., and L. H. Emmons. (1974). Social organization of some Trinidad bats. *Emballonuridae. Zeitschrift fur Tierpsychologie* 36:137-183

Brass, D. A. (1994). *Rabies in Bats: Natural History and Public Health Implications*. Livia Press. Ridgefield, Connecticut

Brass, D. A. (1996). Human rabies of insectivorous bat origin, 1994-1995. *NSS News*. 54(9):42-246

Brigham, R. M., and A. C. Brigham. (1989). Evidence for association between a mother bat and its young during and after foraging. *The American Midland Naturalist*. 121:205-207

Constantine, D. G. (1967). Bat rabies in the southwestern United States. *Public Health Reports*. 82(10):867

Constantine, D. G. (1988). Health precautions for bat researchers. In T. H. Kunz (ed.), *Ecological and Behavioral Methods for the Study of Bats.* Smithsonian Institution Press. Washington, D. C.

Czaplewski, N. J. (1983). *Idionycteris phyllotis, Mammalian Species*, No. 208. *The American Society of Mammalogists*. New York

Davis, R. B., Herreid II, C. F. and H.L., Short (1962). Mexican free-tailed bats in Texas. *Ecological Monographs*. 32, 311-346

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

Davis, W. H., and H. B. Hitchcock (1995). A new longevity record for the bat *Myotis lucifugus. Bat Research News*. 36(1):6

De Fanis, E. and G. Jones (1995). The role of odour in the discrimination of conspecifics by pipistrelle bats. *Animal Behavior*. 49:835-839

Dunne, L. J. (1990). *Nutrition Almanac*. McGraw-Hill Publishing Company. New York

Eisenberg, J. F. (1989). *Mammals of the Neotropics*. The University of Chicago Press. Chicago, Illinois

Eisentraut, M. 1934. Markierungsversuche bei Fledermausen. Zeitsch. Morph. okol. Tiere 28: 553-560

Emmons, L. H. (1990). *Neotropical Rainforest Mammals: A Field Guide*. The University of Chicago Press. Chicago, Illinois

Engler, C. H. (1943). Carnivorous activities of big brown and pallid bat. *Journal of Mammalogy*. 24:96-97

Fenton, M. B. (1992). *Bats.* Facts on File. New York

Fenton, M. B., and M. R. Barclay (1980). *Myotis lucifugus, Mammalian Species*, No. 142. The American Society of Mammalogists. New York

Finn, L. (1996). Release of hand-raised pups. *Chiropteran Care*. 2(3)

Finke, M.D. (2002). Gut loading to enhance the nutrient content of insects as food for reptiles: A mathematical approach. *Zoo Biology*. 22(2,). 147-162

Fitch, J. H., and K. A. Shump, Jr. (1979). *Myotis keenii, Mammalian Species*, No. 121. The American Society of Mammalogists. New York

Fitch, J. H., Shump, K.A., Jr, and A. U. Shump (1981). *Myotis velifer, Mammalian Species*, No. 149. The American Society of Mammalogists. New York

French, B. S., and A. Lollar (1998). Observations of the reproductive behavior of captive Mexican free-tailed bats (*Tadarida brasiliensis). The Southwestern Naturalis*t. 43(4)

French, B., and A. Lollar (1998). Communication among Mexican free-tailed bats. Bats. 18(2)

Fujita, M. S., and T. H. Kunz (1984). *Pipistrellus subflavus. Mammalian Species*, No. 228. The American Society of Mammalogists. New York

Gelfand, D., and G. McCracken (1986). Individual variation in the isolation calls of Mexican free-tailed bat pups (*Tadarida brasiliensis mexicana). Animal Behavior*. 34:1078-1086

Gerell, R., and K. Lundberg (1985). *Social organization in the bat Pipistrellus pipistrellus. Behavioral Ecology Sociobiology* 16:177-184

Gershoff, S. N. (1972). Nutrient requirements of the cat. *Nutrient Requirements of Laboratory Animals*. National Academy of Sciences. Washington, D.C.

Griffin, D. R. 1934. Marking bats. *Journal of Mammalogy* 15:202-207

Griffin, D. R. 1936. Bat Banding. *Journal of Mammalogy*. 17: 235-239

Greenhall, A. M. (1976). Care in Captivity. Biology of Bats in the New World family Phyllostomatidae. Pp. 89—131. Special Publication: Museum of Texas tech University, Lubbock, TX

Gustin, M., and G. McCracken (1987). Scent recognition between females and pups in the bat *Tadarida brasiliensis mexicana. Animal Behavior.* 35:13-19

Haagsma, J. (1989). Rabies en vleermuizen: hoe te handelen? *Ned. Tijdschr. Geneeskd*. 133(11):550. (Rabies in Bats: How should it be treated?)

Harvey, J., Altenbach, J.S., and T. L. Best (1999). *Bats of the United States*. Arkansas Game and Fish Commission, Arkansas

Hermanson, J. W., and T. J. O'Shea (1983). *Antrozous pallidus, Mammalian Species*, No. 213. The American Society of Mammalogists. New York

Herreid, II, C. F., Davis, R.B., and H. L. Short. (1960). Injuries Due to Bat Banding. *Journal of Mammalogy* 41:398-400

Hitchcock, H. B. (1957). The Use of Bird Bands on Bats. *Journal of Mammalogy* 38:402-405

Iwamoto, Y., Nakamura, R., Folkers K., and R. Morrison (1975) Study of periodontal disease and coenzyme Q10. *Research Communications in Chemical Pathology & Pharmacology* ;11:265-71

Jacobs, S. K. (1998). *Healers of the Wild*. Coyote Moon Press. Denver, Colorado

Jones, C. (1977). *Plecotus rafinesquii, Mammalian Species*, No. 69. The American Society of Mammalogists. New York

Jones, C., and R. W. Manning (1989). *Myotis austroriparius, Mammalian Species*, No. 332. The American Society of Mammalogists. New York

Jones, Jr. J. K., Armstrong, D.M., and J. R. Choate (1985). *Guide to Mammals of the Plains States*. University of Nebraska Press. Lincoln, Nebraska

Kallen, F. C. (1960). Plasma and blood volumes in the little brown bat. *American Journal of Physiology*. 198:999-1005

Kallen, F. C. (1977). The cardiovascular systems of bats: Structure and function. In W. A. Wimsatt (ed.), *Biology of Bats*, Vol. III. Academic Press. New York

Kaplan, M. M. (1969). Epidemiology of rabies. *Nature*. 221(5179):421

Kelly, A., Goodwin, S., Grogan, A., and F. Mathews. (2008). Post-release survival of hand-reared pipistrelle bats (*Pipistrellus spp). Animal Welfare* 17: 375-382

Kiser, M. (1995). *Eumops underwoodi, Mammalian Species*, No. 516. The American Society of Mammalogists. New York

Khajuria, H. (1972). Courtship and mating in *Rhinopoma hardwickei hardwickei* (Chiroptera: Rhinopomatidae). *Mammalia.* 36:307-309

Kleiman, D. G., and P. A. Racey. (1969). Observations on noctule bats (*Nyctalus noctula*) breeding in captivity. Proceedings of the First International Bat Conference, Czechoslavakia, Hluboka n. Vltavou, 1968. 10:65-78

Klug, Brandon J., Turmelle, Amy S., Ellison, James A., Baerwald, Erin F., Barclay, and M.R. Robert (2011). Rabies Prevalence in Migratory Tree-Bats in Alberta and the Influence of Roosting Ecology and Sampling Method on Reported Prevalence of Rabies in Bats. J Wildl Dis, 47: 64-77

Krutzsch, P. H., and S. E. Sulkin (1958). The laboratory care of the Mexican free-tailed bat. *Journal of Mammalogy*. 39 (2):262-265

Kumirai, A., and J. Knox-Jones, Jr. (1990). *Nyctinomops femorosaccus, Mammalian Species*, No. 349. The American Society of Mammalogists. New York

Kunz, T. H. (1982). *Lasionycteris noctivagans, Mammalian Species*, No. 172. The American Society of Mammalogists. New York

Kunz, T. H., and R. A. Martin (1982). *Plecotus townsendii, Mammalian Species*, No. 175. The American Society of Mammalogists. New York

Kunz, T. H., and K. A. Nagy. (1988). Methods of energy budget analysis. In T. H. Kunz (ed.) *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press. Washington, D. C.

Kunz, T. H., Oftedal, O.T., Robson, S.K., Kretzmann, M.B., and C. Kirk (1995). Changes in milk composition during lactation in three species of insectivorous bats. *Journal of Mammalogy*. 164:543-551

Kunz, T. H., Whitaker, Jr. J.O., and M. D. Wadanoli (1995). Dietary energetics of the insectivorous Mexican free-tailed bat (*Tadarida brasiliensis*) during pregnancy and early lactation. *Oecologia*. 101:407-415

Kunz, T. H., and S. Parsons. (2009) Methods of and Devices for Marking Bats. In T. H. Kunz (ed.) *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press. Washington, D. C.

Kurta, A., and R. H. Baker (1990). *Eptesicus fuscus, Mammalian Species*, No. 356. The American Society of Mammalogists. New York

Kurta, A., and G. C. Lehr (1995). *Lasiurus ega, Mammalian Species*, No. 515. The American Society of Mammalogists. New York

Kwiecinski, G. G., Chen, T.C., and M. F. Holick (1998). Calcium Homeostasis in Bats Revisited: What is the Role of Vitamin D. Paper presented at the 11th International Bat Research Conference. August. *Pirenopolis* (GO), Brazil

Lawrence, B. D., and J. A. Simmons. (1982). Echolocation in bats: The external ear and perception of the vertical positions of targers. *Science* 218:481-483

Lianson, J. A. (1993). Hepatic Lipid Accumulation in a Captive Raccoon. Wildlife Rehabilitation: A Perpetual Learning Process. Proceedings of the 1993 International Wildlife Rehabilitation Council Conference. IWRC. Suisun City, California. 66-70

Lollar, A. (1994). Rehabilitation and Captive Care for the Mexican Free-tailed Bat. *Bat World Sanctuary.* Texas

Lollar, A. (1995). Notes on the mating behavior of captive colony of Tadarida brasiliensis. *Bat Research News*. 36(1):1

Lollar, A. (2000). Notes on the behavior of a building-dwelling colony of Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) in Mineral Wells, Texas. *Bat Research News*. 41(1)

Lollar, A. and B. French. (2002). *Captive Care and Medical Reference for the Rehabilitation of Insectivorous Bats*. Bat World Sanctuary. Texas

Lollar, A. (2007). *Diagnostic and Treatment Update for the for the Rehabilitation of Insectivorous Bats*. Bat World Sanctuary. Texas

Lollar, A. (2008). Rescuing the Orphans. *Bat World News*. 14:2

Long, R. F. (1996). Bats for insect biocontrol in agriculture. *The IPM Practitioner*. 18(9):619-626

Loughry, W., and G. McCracken (1991). Factors influencing female-pup scent recognition in Mexican free-tailed bats. *Journal of Mammalogy.* 72(3):624-626

Manning, R. W., and J. Knox-Jones, Jr. (1989). *Myotis evotis, Mammalian Species*, No. 329. The American Society of Mammalogists. New York

Maynard, L. A. and J. K. Loosli (1969). *Animal Nutrition*. McGraw-Hill. New York

McCracken, G. F. (1984). Communal nursing in Mexican free-tailed bat maternity colonies. *Science*. 223:1090-1091

McCracken, G.F. and G. S. Wilkinson. 1988. Allozyme Techniques and Kinship Assessment in Bats. In T. Kunz (ed.), *Ecological and Behavioral Methods for the Study of Bats* pp 141-156. Washington D.C.: Smithsonian Institution Press

McCracken, G. F. (1993). Locational memory and female-pup reunions in Mexican free-tailed bat Maternity Colonies*. Animal Behavior*. 45:811-813

McCracken, G., and M. Gustin (1991). Nursing behavior in Mexican free-tailed bat maternity colonies. *Ethology.* 89:305-32

McDonald, D. (2001). Angiogenesis and Remodeling of Airway Vasculature in Chronic Inflammation. *American Journal of Respiratory and Critical Care Medicine.* Vol 164, S39-S45; Cardiovascular Research Institute and Department of Anatomy, UCSF

Milner, J., Jones, C., and J. Knox-Jones, Jr. (1990). *Myctinomops macrotis, Mammalian Species*, No. 351. *The American Society of Mammalogists.* New York

Miller, L. A., and H. J. Degn. (1981). The acoustic behavior of four species of vespertilionid bats studied in the field. *Journal of Comparative Physiology*. 142:67-74

Moore, G. J., and G. H. Raymond (1970). Prolonged incubation period of rabies in a naturally infected insectivorous bat, Eptesicus fuscus (Beavois). *Journal of Wildlife Diseases*. 6:167

Moore, T. (1970). The biochemistry of vitamin A in the general system. In R. A. Morton (ed*.), Fat-Soluble Vitamins*. *Pergamon*. Oxford

Muller, B., Glosmann, M., Peichl, L., Knop, GC., Hagemann, C., and J. Ammermuller. (2009). Bat Eyes have Ultraviolet-sensitive Cone Photoreceptors. PLoS One 4(7)

Nagorsen, D. W., and R. M. Brigham (1993). *Bats of British Columbia*. UBC Press, University of British Columbia. Vancouver, British Columbia

Nelson, J. E. (1964). Vocal communication in Australian flying foxes (*Pteropodidae; Megachiroptera). Zeitschrift fur Tierpsychologie.* 27:857-870

Neuweiler, G. (2000). *The Biology of Bats*. Oxford University Press

Nowak, R. M. (1994). *Walker's Bats of the World*. The Johns Hopkins University Press. Baltimore

O'Farrell, M. J., and E. H. Studier (1980). *Myotis thysanodes, Mammalian Species*, No. 137. The American Society of Mammalogists. New York

Orr, R. T. (1954). Natural history of the pallid bat, *Antrozous pallidus* (LeConte). Proc California Acad. Sci. 28:165-246

Perper, R. J., and S. Kepner (1985). The Complete Medical Guide to Cats. The New American Library of Canada Limited. Scarborough, Ontario

Pettigrew, J. D. (1986). Flying primates? Megabats have the advanced pathway from eye to midbrain. *Science.* 231:1304-1306

Phillips, C., Jones, Jr. J.K., and F. J. Radovsky (1969). *Macronyssid* mites in oral mucosa of long-nosed bats: occurrence and associated pathology. *Science.* 165:1368-1369

Pierson, E. D., and G. M. Fellers (1993). Injuries to *Plecotus townsendii* from lipped wing bands. *Bat Research News*. 34 (4):89-91

Porter, F. L. (1979). Social behavior in the leaf-nosed bat, *Carollia perspicillata*. I. Social organization. *Zeitschrift fur Tierspychologie. 49:*406-417

Price, J. L., and Everard, C.O.R., (1977). Rabies virus and antibody in bats in Grenada and Trinidad. Journal *of Wildlife Diseases*. 13:131

Podlutsky, A.J., Khritankov, A.M., Ovodov, N.D., and S.N. Austad. (2005). A new field record for bat longevity. Journals *of Gerontology Series A: Biological Sciences and Medical Sciences*.(11):1366-8

Racey, P. A. (1974). The reproductive cycle in male noctule bats, *Nyctalus noctula. Journal of Reproduction and Fertility*. 41:169-182

Riedesel, M. L. (1977). Blood physiology. In W. A. Wimsatt (ed.), *Biology of Bats*, Vol. III. Academic Press. New York

Roer, H., and W. Egsback. (1969). Uber die Balz der Wasserfledermaus (*Myotis daubentoni*) (Chiroptera) in Winterquartier. Proceedings of the First International Bat Conference, Lynx (Praha) 10:85-91

Schmidly, D. J. (1991). *The Bats of Texas. Texas* A & M University Press. College Station, Texas

Schmidt, U., Hessel, K., and A. Weisemann (1998). On some unexpected abilities of the visual system in *Phyllostomid* bats. *Bat Research News*. 39(3):81-82

Schowalter, D. B. (1980). Characteristics of bat rabies in Alberta. *Canadian Journal of Comparison Medicine.* 44:70

Schwartz, C. W. and E. R. Schwartz (1981). *The Wild Mammals of Missouri.* University of Missouri Press and Missouri Department of Conservation. Columbia, Missouri

Sherman, H. B. (1930). Notes on the foods of some Florida bats. *Journal of Mammalogy*

Shump, K. A., and A. U. Shrump (1982). *Lasiurus borealis, Mammalian Species*, No. 183. The American Society of Mammalogists. New York

Shump, K. A. and A. U. Shump (1982). *Lasiurus cinereus, Mammalian* Species No. 185. The American Society of Mammalogists. New York

Simpson, M. R. (1993). *Myotis californicus, Mammalian Species*, No. 428. The American Society of Mammalogists. New York

Stebbing, R. E. (1987). *The Bat Worker's Manual*. Interpretive Services Branch, Nature Conservancy Council. Northminster House. Peterborough. U. K.

Stebbings, R. E. (1988*). Conservation of European Bats*. Christopher Helm Ltd. Imperial House. Bromley, Kent, U. K.

Stebbings, R., and L. Thurston (1988). Bad news from the belfry. *BBC Wildlife.* Sep:492-494

Sullivan, T. D., Grimes, J.E., Eads, R.B., Menzies, G. C., and J. V. Irons (1954). Recovery of rabies virus from colonial bats in Texas. *Public Health Reports*. 69(8):766

Suthers, R. A., (1970). The ear and audition. In W. A. Wimsatt (ed.), *Biology of Bats*, Vol. I. Academic Press. New York

Thomson, C. E. (1982). *Myotis sodalis. Mammalian Species*, No. 163. The American Society of Mammalogists. New York

Trimarchi, C. (1978). Rabies in insectivorous temperate-zone bats. *Bat Research News*. 19(1):7

Trimarchi, C. (1996). *Wild Today, Wild Tomorrow*. Proceedings 1996 International Wildlife Rehabilitation Council Conference. Niagara Falls, New York

Turmelle, A.S., Allen, L.C., French, B.A., Jackson, F.R., Kunz, T.H., McCracken, G.F., and C.E. Rupprecht. (2010). Response to vaccination with a commercial inactivated rabies vaccine in a captive colony of Brazilian free-tailed bats (*Tadarida brasiliensis*). Journal of Zoo and Wildlife Medicine

Tuttle, M. D. (1976). Population ecology of the gray bat (*Myotis grisescens*): Philopatry, timing and patterns of movement, weight loss during migration, and seasonal adaptive strategies. Occasional Papers of the Museum of Natural History, The University of Kansas. Lawrence, Kansas

Tuttle, M. D. *Rabies in Perspective* (2018) Retrieved from https://www.merlintuttle.org/resources-2/rabies-in-perspective/

Von Helversen, O., and D. Von Helversen. (1994). The advertisement song of the lesser noctule bat (*Nyctalus leisleri*). *Polia Zoologica*. 43:331-338

Vaughan, T. A. (1970). The muscular system. In W. A. Wimsatt (ed.), *Biology of Bats*, Vol. I. Academic Press. New York

Walker, S. (1996). Anorexia in captive *E. fuscus*: Two case histories. *The Journal of Wildlife Rehabilitation*. 19(2):3-9

Warner, R. M. (1982). *Myotis auriculus, Mammalian Species*, No. 191. The American Society of Mammalogists.. New York

Warner, R. M., and N. J. Czaplewski (1984). *Myotis volans, Mammalian Species*, No. 224. The American Society of Mammalogists. New York

Watkins, L. C. (1972). *Nycticeius humeralis, Mammalian Species*, No. 23. The American Society of Mammalogists. New York

Watkins, L. C. (1977). *Euderma maculatum, Mammalian Species*, No. 77. The American Society of Mammalogists. New York

Webster, W. D., Knox-Jones, J. Jr., and R. J. Baker (1980*). Lasiurus intermedius. Mammalian Species*, No. 132. The American Society of Mammalogists. New York

Whitaker, J. O. Jr. (1993). The Big Brown Bat, Friend of the Farmer. The 23rd Annual North American Symposium on Bat Research. October13-16. Gainesville, Florida

Whitaker, J. O. Jr. (1995). Food of the big brown bat, Eptesicus fuscus, from maternity colonies in Indiana and Illinois. *American Midland Naturalist*. 134:346-360

Whitaker, J. O. Jr., Neefus, C., and T. H. Kunz (1996). Dietary variation in the Mexican free-tailed bat (*Tadarida brasiliensis mexicana). Journal of Mammalogy*. 77:716-724.

Wickler, W., and U. Seibt. (1976). Field studies on the African fruit bat *Epomophorus wahlbergi* (Sundevall), with special reference to male calling. Zeitschrift fur Tierpsychology. 40:345-376

Wilkins, K. T. (1989). *Tadarida brasiliensis. Mammalian Species*, No. 331. The American Society of Mammalogists. New York

Wilkins, K. T. (1987). *Lasiurus seminolus. Mammalian Species*, No. 280. The American Society of Mammalogists. New York

Wilkinson, G. S. (1995). Information transfer in bats. Symposia of the Zoological Society of London Symposia. 67:345-360

Wilson, D. E. (1988). Maintaining bats for captive studies. In T. H. Kunz (ed.) *Ecological and Behavioral Methods for the Study of Bats*

Wimsatt, W. (1969). Some interrelationships of reproduction in hibernation in mammals. Symposia of the society of experimental biology 23:511

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